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# Waveforms and Sonic Boom Perception and Response (WSPR): Low-Boom Community Response Program Pilot Test Design, Execution, and Analysis

*Juliet A. Page*  
*Wyle, Arlington, Virginia*

*Kathleen K. Hodgdon*  
*The Pennsylvania State University, University Park, Pennsylvania*

*Peg Krecker*  
*Tetra Tech, Inc., Madison, Wisconsin*

*Robbie Cowart*  
*Gulfstream Aerospace Corporation, Savannah, Georgia*

*Chris Hobbs and Clif Wilmer*  
*Wyle, Arlington, Virginia*

*Carrie Koenig and Theresa Holmes*  
*Tetra Tech, Inc., Madison, Wisconsin*

*Trent Gaugler, Durland L. Shumway, James L. Rosenberger, and Daisy Philips*  
*The Pennsylvania State University, University Park, Pennsylvania*

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*Trent Gaugler, Durland L. Shumway, James L. Rosenberger, and Daisy Philips*  
*The Pennsylvania State University, University Park, Pennsylvania*

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Alexandra Loubeau, NASA Technical Monitor  
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# Executive Summary

The Waveforms and Sonic boom Perception and Response (WSPR) Program was designed to test and demonstrate the applicability and effectiveness of techniques to gather data relating human subjective response to multiple low-amplitude sonic booms. It was in essence a practice session for future wider scale testing on naïve communities, using a purpose built low-boom demonstrator aircraft. The project team was led by Wyle and includes experienced researchers at The Pennsylvania State University (PSU), Tetra Tech, and Gulfstream Aerospace Corp.

The low-boom community response pilot experiment was conducted in California in November 2011. The WSPR team acquired sufficient data to assess and evaluate the effectiveness of the various physical and psychological data gathering techniques and analysis methods. WSPR obtained sufficient information to prepare an OMB application for future experiments to gather low-boom general public community response data.

## *Experimental Design and Execution*

The WSPR experiment involved exposing subjects living in the Edwards Air Force Base (EAFB) Housing area to 2 weeks of low-amplitude sonic booms while recording their responses via structured surveys. A NASA F-18 was flown using a low-boom dive maneuver in order to create sonic boom N-waves with varying intensities ranging from a few tenths of a psf to approximately 1 psf. EAFB is a heavy flight activity intensive base with frequent supersonic operations so the test area is also exposed to non-WSPR sonic boom events, and the community residents are considered non-naïve and are acclimated to sonic booms. A schedule of sonic boom exposure was designed covering a DNL range from 10 to 37 dB and a CDNL range from 42 to 58 dB (Table 1). The experiment also provided for subject response to multiple sonic booms while providing continuity with prior impulsive noise social response studies (Table 1).

The low-boom design was constructed from combinations of Low (L, 0.13 psf), Medium (M, 0.33 psf) and High (H, 0.53 psf) sonic booms with paired days of similar daily exposure and differing numbers of booms, and similar numbers of booms but differing daily exposures. This noise exposure design balanced DNL exposure across test days, the number of Low, Medium, and High booms across the full design, the separation of booms between AM and PM flight sequences, and the distribution of booms among the sequences. It also provided flexibility for day-of-flight modifications by substituting daily flight operations depending on weather conditions or other factors. Additionally, the design allowed for the intentional creation of larger “full scale” (~1 psf) sonic booms in the event that there were no non-WSPR created sonic booms.

The data from the low-boom field test provides a measure of the acceptance of low booms in an acclimated community. It also allows a comparison with the findings of previous studies, several of which are summarized in CHABA, 1996. To address these two objectives, the noise design included the full range of low-boom levels, distributed between Low, Medium, and High booms, to provide the opportunity to assess low-boom impact. Additional higher-level booms were included to deliberately raise the DNL so as to ensure comparison with the findings from previous studies.

**Table 1. WSPR Pre-Flight Experimental Design Exposure and Comparison with Prior Studies**

WSPR Experimental Design					
Booms	Daily DNL (dB)	CDNL (dB)	Source	Team	Approx. CDNL (dB)
5L	10	42	Low Boom	WSPR NASA, 2011 EAFB	42 - 58
8L	12	44	Sonic Boom	Borsky 1965, OK City	54 - 64
2L,3M	23	49	Sonic Boom	Fields et al., 1994 Nellis AFB	38 - 56
5L, 3M	24	49	Artillery	Schomer 1981, Ft. Bragg	58 - 70
4L,3M,1H	28	51	Gunfire	Sweden Rylander Lundquist, 1996	41 - 68
5M, 3H	31	55	Artillery	Schomer 1985, Fort Lewis	51 - 65
8M	28	53			
4L,5M,3H	32	55			
1M,9H	36	57			
12H	37	58			

Social surveys were designed for WSPR to collect subjective response to sonic booms. Subjective data was collected before, during, and after the test period to support analysis and assess methods of data collection. Survey instruments consisted of a baseline survey, a single event survey, and a daily summary survey. Baseline surveys were administered via telephone interviews. Three modes of administration were utilized for both the single event and daily summary surveys: paper/pen, web-based, and Mobile (Apple) device. Following PSU and NASA IRB review and approval, subject recruitment was coordinated closely with Edwards AFB personnel and conducted during the months of July, August, and September 2011. Subjects were randomized (to the maximum extent possible) to the three modes of survey administration.

The WSPR low-boom noise design survey included a question on strength of annoyance, followed by questions on the strength of perception of five additional variables that contribute to the annoyance response. The WSPR surveys relied on an 11-point (0 to 10) scale (“not at all” to “extremely”). The questions gathered data on six dimensions of subjective response to noise, focusing on reactions that are most appropriate for impulsive noise events. These six dimensions include:

- Annoyance,
- Loudness,
- Interference,
- Startle,
- Vibration, and
- Rattle.

The wording of questions, response scale, and the order in which the reactions are solicited follow guidelines for social measurement recommended by The International Commission on the Biological Effects of Noise (ICBEN) (Fields et al., 2001). These guidelines bolster comparability across social surveys assessing human response to noise, and the recommended wording and response formats have been examined by ICBEN to maximize reliability and validity.

The baseline survey was administered to study participants in order to confirm eligibility, collect socioeconomic and household characteristics, reactions to prior sonic boom exposure, and attitudes about noise and ability to adapt to noise. During the experimental timeframe, subjects were instructed to complete a single event survey as soon as possible after hearing a sonic boom. The single event survey contained 10 questions to collect reactions to sonic booms using the six dimensions indicated above, plus additional characteristics of the boom event such as time and subject location (indoors or outdoors, at home or away from home). The Daily Summary was completed at the end of each day and was designed to collect the daily annoyance, the number of sonic booms heard during the day (including zero), and other factors relating to the subjects’ time at home and noise exposure levels.

The WSPR experiment was conducted from November 4 – 21, 2011. During the course of the experiment, EAFB and China Lake supersonic training operations created non-WSPR sonic booms in the subject area resulting in the as-flown noise exposures shown in Table 2. Note in particular the 18 non-WSPR booms on Test Day 8, and the resultant 67.3 dB CDNL exposure.

**Table 2. WSPR As-Flown DNL and CDNL Exposures**

Test Day	Boom List	CDNL (dB)	DNL (dB)	PLDN (dB)	Booms/Day
10	4L,1M	41.0	16.5	28.0	5
9	5L,3M	43.4	19.0	34.0	8
5	4M	47.5	19.1	34.9	4
4	3M, 4H,4HR,1F	55.7	30.5	46.0	12
3	4L,4M,4H,1F	55.6	34.9	49.4	13
1 Train	1L, 1H, 1HR,1F	55.3	38.3	52.5	4
2	4L,2M,2H,1F	56.2	39.1	52.5	9
6	3L, 6M, 2H, 2HR,1F	59.3	39.5	54.3	14
7	4L,1M,4H,1HR,4F	59.5	41.7	55.6	14
8	3L, 8M, 2H,1HR,13F	67.3	51.5	65.6	27

### *Overview of WSPR Findings*

For the WSPR data, the CDNL metric best explained the variation in the percent highly annoyed response, with a correlation coefficient ( $R^2$ ) of 0.8911. It was the best metric in this study for correlation with the Percent Highly Annoyed (%HA) annoyance response ratings (response categories 8, 9, and 10) when compared to PLDN ( $R^2 = 0.8329$ ) and DNL ( $R^2 = 0.7984$ ).

On the WSPR baseline survey the respondents indicated that they tended to find the booms quite loud and startling, experienced vibration and rattle to a lesser extent, and tended to not experience a great deal of disruption and hindrance of conversations due to booms. We found that in response to baseline survey questions about adaptation to noise, 95 percent of respondents moderately or strongly agreed with the statements “I believe that with time most people adapt to noise” and “I believe that with time I can adapt to noise.” Most respondents (60 percent) moderately or strongly agreed that they can “adapt to even the loudest noise” while a sizeable proportion (25 percent) moderately disagreed.

The WSPR data included assessments of single events during the day as well as a cumulative daily summary assessment of annoyance and categorical variables including loudness, interference, startle, vibration, and rattle. A correlation of respondent ratings of categorical attributes with their concurrent annoyance ratings showed that the strongest dependence was on interference for both the single event and daily summary ratings. For the daily summary ratings, interference was followed by loudness, vibration, and rattle in that order in strength of the dependence between variables. For the single event rating, interference was followed by startle, loudness, vibration, and rattle in that order in strength of the dependence between variables. Startle was not evaluated on the daily summary ratings as it is a single event response, rather than a response that is reported for a daily average.

In addition to the planned low-amplitude sonic booms, there were 21 non-WSPR booms produced by EAFB operations. These events were recorded and have been included in the cumulative noise exposure during the WSPR test period. The CHABA report noted that the high-energy impulsive noise assessment procedure is primarily based on five studies (CHABA, 1996). Two were sonic boom studies – Oklahoma City reported by Borsky (1965), and NASA reported by Fields et al. (1994). Three were blast noise assessment studies – Ft. Bragg reported by Schomer (1981), Ft. Lewis reported by Schomer (1985), and Sweden reported by Rylander and Lundquist (1996). Figure 1 presents the CHABA (1996) datasets in addition to the WSPR data, expressed in terms of the percent highly annoyed as a function of the yearly averaged metric C-weighted Day-Night Level (CDNL). The annoyance ratings for WSPR are significantly lower than was observed in Fields (1994) or Rylander and Lundquist (1996) but are consistent with the data from the other researchers. The WSPR team used noise measurements obtained during the same period as the social surveys, while some of the prior studies relied on measurements from different time periods or from predicted levels.

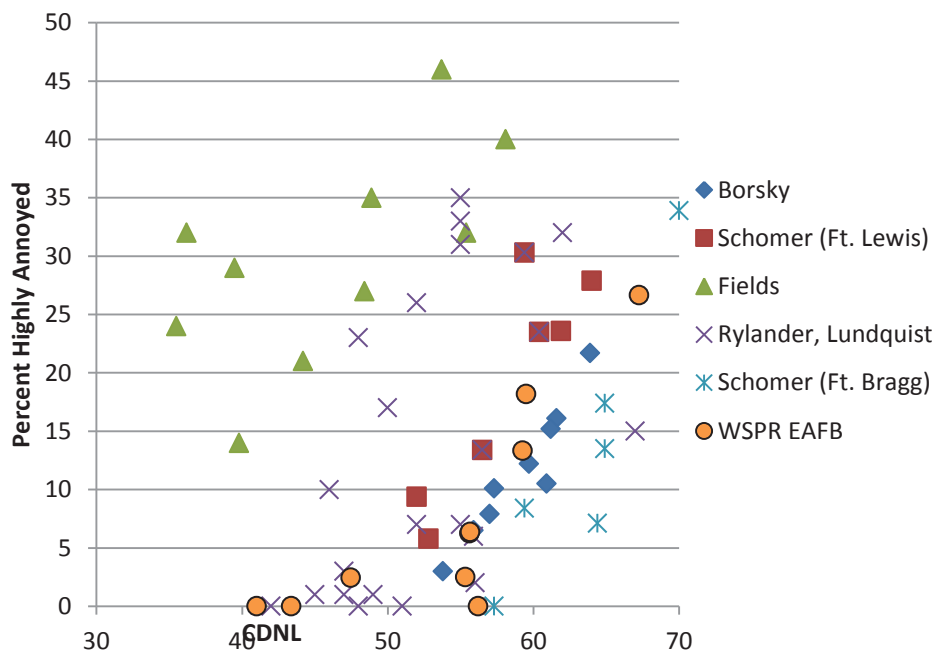


Figure 1. Comparison of WSPR measured exposures to related field studies (Source: CHABA, 1996).



# Introduction

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This final report documents the Waveforms and Sonic boom Perception and Response (WSPR) Program. It is intended to be an archive of the experimental design, execution, analysis and results, and includes the rationale behind all aspects of the project. The report body contains the key features of the WSPR experiment while the appendices include voluminous detail for the permanent record.

## 1.1 Background

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The NASA-sponsored and Wyle-led Low-Boom Community Response Pilot Program team conducted this research effort. This project investigated the noise impact of supersonic flight for future commercial aircraft over land. NASA is working to identify future innovations in aviation technology that will contribute to the advancement of the United States aerospace industry. There is great interest in the prospect of building a commercial supersonic aircraft. In order for such a plane to reach its full potential it would need to be capable of flying at supersonic speeds over land, which at present is not permitted by FAA regulation in commercial airspace.

The data gained from this research effort will be used to provide information and guidance to decision makers responsible for assessing noise impacts and mitigation strategies and for the advancement of aviation technology in the future. This research intends to further provide information about the probable effects of aircraft noise and low-level sonic booms on people. The focus of this research is the acceptability of low-level sonic boom noise, with the premise that the variables influencing acceptability are stimulus factors, situational factors, and psychosocial factors.

The survey instruments developed and tested during this program include:

1. Baseline survey to determine participant-specific variables and attitudes, such as duration of residence at EAFB, attitudes towards noise, demographics, etc.
2. Field test single event survey to obtain the participant's response to each sonic boom event that the respondent hears.
3. Daily summary survey to obtain the participant's response to the noise environment over the course of each day.
4. Post-test survey, where participants were interviewed and asked to provide open-ended opinion and feedback to enable researchers to assess the ease of using the subjects' assigned response method (i.e., paper/pencil, web based, smart phone). These questions provide data to assist in interpreting the results of the dose-response models.

## 1.2 Test Objectives and Experimental Design

---

The primary objective of the WSPR experiment was to gather data relating the impact of exposure to multiple low-amplitude sonic booms to the subjective response of community residents. The test was performed at EAFB, a non-naïve community, over ~2.5 weeks from November 4–18, 2011, using recruited subjects who resided in Base Housing.

Specific goals of the project were to demonstrate the effectiveness of the experimental methodology including:

- Noise exposure design;
- Survey methods;
- Data acquired;
- Analysis methods;
- IRB approval;
- OMB application preparation; and
- Identification of strategies and address issues to minimize transient and adaptation effects associated with introduction of a new noise source into a community.

### ***1.3 Program Execution and Data Acquired***

Data acquired during the WSPR experiment falls into three areas:

- Acoustic data capturing the noise exposure from 110 sonic booms;
- Meteorological data in the Base Housing Community area; and
- Subjective response data from 52 recruited subjects.

One of the intents of the WSPR experiment was to gather data from multiple modes of survey application. As suggested by NASA in the procurement for this project, future regional American testing of human subjective response to low-amplitude sonic booms with a purpose built low-boom demonstrator vehicle will be needed to gather the required scientific evidence to guide the regulatory process. This suggests that larger scale experimentation must be conducted, for which one must naturally consider the cost implications of reaching broader communities with significantly increased subject participation.

The classic pencil and paper survey administration is reliable and does not require sophisticated technology; however, the logistics of distribution, collection, and cataloging responses comes with a resource burden. Survey administration via alternate modes, such as the internet or smart phones, is gaining popularity and has the advantage of central data collection. Web and smart phone applications can also be programmed in such a way as to increase subject response compliance.

Questionnaires were designed to be comparable across three modes of data collection – paper/pencil, Web, and Apple device (iPhone, iPod Touch, and iPad).

## 1.4 Test Schedule

The experiment was conducted from November 4–18, 2011. Key WSPR activities that were carried out in preparation of, during, and after the experiment are itemized in Table 3.

**Table 3. Key WSPR Activities**

Dates	Activity
Fall 2010	Subject Recruitment preparation
23 May 2011	PSU IRB Approval
09 June 2011	NASA IRB Approval
June 2011	Initiation of Subject Recruitment
20-23 September 2011	Field-Kit <sup>1</sup> Demonstration @ NASA Dryden
Fall 2011	SNOOPI <sup>2</sup> Installation @ EAFB
30 August – 01 September 2011	Pre-Test with NASA Dryden Volunteers
30 September 2011	Closed Subject Recruitment
11-13 October 2011	Apple Device Installation with WSPR Subjects @ EAFB
04-18 November 2011	WSPR Flight Testing
02-12 December 2011	Post Test Subject Interviews

<sup>1</sup> Sonic Boom Field-Kits are described in Section 3.1.

<sup>2</sup> Supersonic Notification Of OverPressure Instrumentation (SNOOPI) is NASA Sonic Boom monitoring instrumentation, requested GFE for this project.

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# Test Objectives and Experimental Design

The WSPR experimental design included both subjective and objective elements. The noise exposure was optimized both to meet expected future low-boom cumulative exposure [Rachami, 2009 and 2010] while spanning existing impulsive noise datasets. Practical considerations for achieving the low-amplitude sonic booms using the F-18 low-boom dive maneuver [Haering et. al., 2006 and 2008] while avoiding placement of focused booms on populated areas while accounting for atmospheric day-of-flight variability needed to be included in the design. These factors are explained in Section 2.1. Subjective instrumentation [surveys] were developed and are presented in Section 2.2. A series of incremental design update meetings and formalized institutional review board approvals are presented in Section 2.3. Plans for subject recruitment and outreach, a significant portion of the WSPR efforts, are itemized in Section 2.4.

## 2.1 Noise Exposure Design

The experimental design was developed with the cumulative daily noise exposure as the primary controlling variable. The daily noise exposure summarizes the single event exposures for that day. The goal was to identify a range of daily exposures and replicate them within the design. Other variables were examined during the process to optimize the daily exposure design. These variables include consideration of future operational flight patterns, identifying optimal spacing of events and realistic limitations with respect to weather, flight constraints, and cost limitations.

### 2.1.1 Level and Number of Booms

The team identified three target noise levels for the design. These levels are .13 psf, .33 psf, and .53 psf for the Low, Medium, and High ranges respectively. The levels are based on the data that was obtained in the NASA 2006 field test of human response to low-intensity sonic booms [Sullivan et al., 2010] as indicated in Figure 2. The sonic boom overpressures and corresponding loudness levels for the design include atmospheric losses modeled by incorporation of a Taylor shock structure [Taylor, 1910]. The daily noise dose is the cumulative amount of sonic boom noise that the respondent is exposed to each day. The targeted levels of .13 psf, .33 psf, and .53 psf defined the range of the low-boom levels. The WSPR test design also included booms in the .73 (Higher) and above .93 (Full) range to afford ready comparison to prior research.

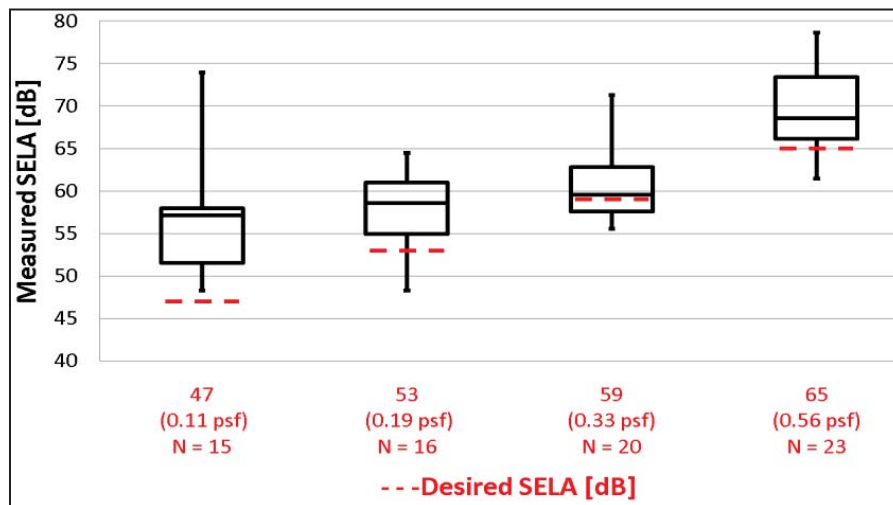


Figure 2. Average levels obtained in NASA LaRC 2006 design.

The noise dose flight schedule was developed in such a way that it could be modified daily to afford evenly distributed noise doses across the possible range. The level and number of booms represented in the design were modified using the following boom constraints.

- Boom Targets: Lo ~ .13 psf, Med ~ .33 psf, Hi ~ .53 psf;
- Target goal of 5 distinct DNL levels (allows for 1 repeat day of each target); and
- Target goal to maintain a design that repeats each distinct DNL on 2 test days.

The initial pre-flight planning considered a maximum of 10 booms daily. During one of the technical interchange meetings with NASA sponsors, this limit was relaxed to 12 in order to potentially obtain additional single event sonic boom data points. Additional revisions during the field test resulted in the daily boom limit being raised again to 14 booms per day in an attempt to maintain the balance of the cumulative daily noise exposure design while also balancing the numbers of Low, Medium, and High booms presented to the subjects.

### 2.1.2 Daily Noise Design

The design included 22 WSPR test flights flown on 10 test days over a 15-day period. The flight sequences were all within the time period from sunrise to sunset. The spacing of the booms was designed to work within the framework of one or two flights per test sequence. The noise design varied the spacing of the booms and used the full-time window as much as possible, with realistic limits on flight constraints.

The team anticipated that there would be some booms during the 2-week test period that were not part of the WSPR design. The WSPR team included a few flight sequences that produced full booms with target levels that were defined as Higher at ~ .73 psf and Highest at ~ .98 psf.

The design was optimized for spacing across the DNL levels that were possible using different boom combinations. The design details included the day of the week, the test day, the time of day that the flight sequence was scheduled, the number of booms per flight sequence, the level of the booms in each flight sequence, the total of booms per day, the total flights per day, and the associated metric level for the different boom combinations. The metrics that were included for planning were the PLDN, CDNL, and DNL. Tables 4 and 5 itemize the design at the time of the WSPR Flight-Test Review Meeting at NASA Dryden on October 5, 2011.

**Table 4. Itemized Daily Noise Design (a)**

Week Day	AM (Time)	PM (Time)	Noise Metric	Daily Noise Dose	Booms/Day	Approx. Match DNL
Fri	(10-11)	(4-5)	Full	1L,6M,4H	6	1-4-7
Train/1	6//1	8//2	DNL(PL)	51	3	
	Full .98	1L, 1M, 1H	CDNL	58		
		5M, 3H	DNL	37	DNL	37
Mon	(11-12)	(2-3)		5L, 3M	8	2-10
2	4//1	4//1	DNL(PL)	39	2	
	4L	1L,3M	CDNL	49		
			DNL	24	DNL	24
Tues	(7-8)	(2-3)		4L,5M,3H	12	
3	8//2	4//1	DNL(PL)	47	3	
	4L,2M, 2H	3M, 1H	CDNL	55		
			DNL	32	DNL	32
Wed	(10-11)	(5-6)		12H	12	4-7
4	4//1	8//2	DNL(PL)	51	3	
	4H	8H	CDNL	58		
			DNL	37	DNL	37
Thurs	(7-8)	(1-2)		8M	8	5-8
5	4//1	4//1	DNL(PL)	43	2	
	4M	4M	CDNL	53		
			DNL	28	DNL	28

☀ Day with all Hi, Med or Lo

Time of day

Actual # booms & levels

Total booms // flight

**Table 5. Itemized Daily Noise Design (b)**

Week Day	AM (Time)	PM (Time)	Noise Metric	Daily Noise Dose	Booms/Day	Approx. Match DNL
Mon	(8-9)	Respite		8L	8	6-9
6	8//2		DNL(PL)	26	2	
	8L		CDNL	44		
			DNL	12		12
Tues	(10-11)	(3-4)		1M,9H	10	4-7
7	5//1	5//1	DNL(PL)	50	2	
	5H	1M,4H	CDNL	57		
			DNL	36	DNL	36
Wed	(7-8)	(1-2)		4L,3M, 1H	8	5-8
8	4//1	4//1	DNL(PL)	43	2	
	4L	3M, 1H	CDNL	51		
			DNL	28	DNL	28
Thurs	(8-9)	Respite		5L	5	6-9
9	5//1		DNL(PL)	24	1	
	5L		CDNL	42		
			DNL	10	DNL	10
Fri	(9-10)	Respite		2L,3M	5	2--10
10	5//1		DNL(PL)	38	1	
	2L,3M		CDNL	49		
			DNL	23	DNL	23

☀ Day with all Hi, Med or Lo

Total booms// flight

Time of day

Actual # booms & levels

### 2.1.3 Daily Noise Exposure

The noise dose per day was based on the cumulative daily noise exposure response as represented by the daily DNL, PLDN, and CDNL. These measures provided the primary comparison between experimental test days in the field. Noise dose spreadsheets were populated to evaluate multiple variations of combinations of booms, so that the cumulative noise dose was still balanced between test days and across the overall experimental design. See Table 6 for an example calculation of metrics for 4 Low, 3 Medium, and 1 High boom levels.

**Table 6. Calculation of Metrics for Sample Boom Combination of 4 Low, 3 Medium, 1 High**

	Single Event Metric - Basic - No Turbulence									Enter Number of Events
	PL	CSEL	ASEL	ZSEL	LLzf	LLZd	PNL	MaxPsf	MinPsf	
Low	66	84	52	97	81	81	74	0.13	-0.13	4
Medium	83	93	68	105	92	92	91	0.33	-0.33	3
High	90	97	76	109	98	98	98	0.53	-0.53	1
	PLDN	CDNL	DNL	ZDNL	Sum LLZf	Sum LLZd	DNL(PNL)			
<b>Cumulative Metric Value</b>	<b>42.7</b>	<b>51.4</b>	<b>28.3</b>	<b>63.5</b>	<b>51.2</b>	<b>51.2</b>	<b>50.7</b>			

The metrics calculated include PLDN, CDNL, DNL, ZDNL, Sum LLZf, SumLLZd, and DNL(PNL). The metrics were computed daily during the WSPR flights to permit an adaptive schedule in response to actual WSPR and non-WSPR booms.

## **2.1.4 Items Balanced in the Design**

The final noise exposure design attempted to balance DNL exposure across test days, the number of Low, Medium, and High low-booms across the design, the separation of booms between morning and afternoon flight sequences, and the distribution of booms among the sequences. Consideration was given to operational flight constraints, recording instrumentation constraints, and anticipated participant response compliance. The design included the creation of larger “full scale” (~1 psf) sonic booms to ensure a full range of noise exposure, creating booms of a “Higher” and “Full” level. It included flexibility for day-of-flight modifications via substitution of daily flight operations depending on weather conditions or other factors in an attempt to maintain the balance of the design. There were 21 unanticipated non-WSPR created sonic booms that affected the balance of number and level of booms in the design.

## **2.1.5 Other Considerations**

The WSPR design allowed for variation on a daily basis based on weather and instrumentation parameters. The field test goal was to meet the target Daily Noise Dose (e.g., 19 DNL) by achieving the designated boom combinations (e.g., 2L, 1M) using random spacing between booms in a given time period using one or two aircraft per flight sequence. However, the day and time of the boom, the boom order and the boom spacing was permitted to change on a daily basis due to operational and environmental considerations. The planned time periods were distributed throughout the day and over the 2-week period; however, during experimental execution they were permitted to vary based on situational and weather conditions. For instance, if weather dictated that low booms were not possible that day, a different day without low booms in the design could be substituted. Likewise, if the weather was optimal for placement of low booms and the flight sequence included low booms in the order, the flight-test director could decide to place the low booms first to maximize the ideal weather conditions. The flight-test director was also given flexibility to vary the spacing between the booms, provided that the spacing remained random.

## **2.1.6 Subject Orientation to Low-Amplitude Sonic Booms**

EAFB residents are well accustomed to and tolerant of sonic booms and researchers were concerned that they may not hear (or may not recognize as sonic booms) the quieter, low-amplitude sonic booms. To mitigate the risk of widespread non-response on the event surveys during the experimental test period, we planned an orientation exercise that would expose subjects to the full range of low-amplitude booms. As part of this exercise, subjects were instructed that the booms they would hear during this period were, indeed, sonic booms and of the type they might hear (and should report in surveys) in the ensuing weeks. The orientation included exposure to the full range of low-amplitude booms.

## **2.2 *Flight Operations/Boom Placement Design and Planning***

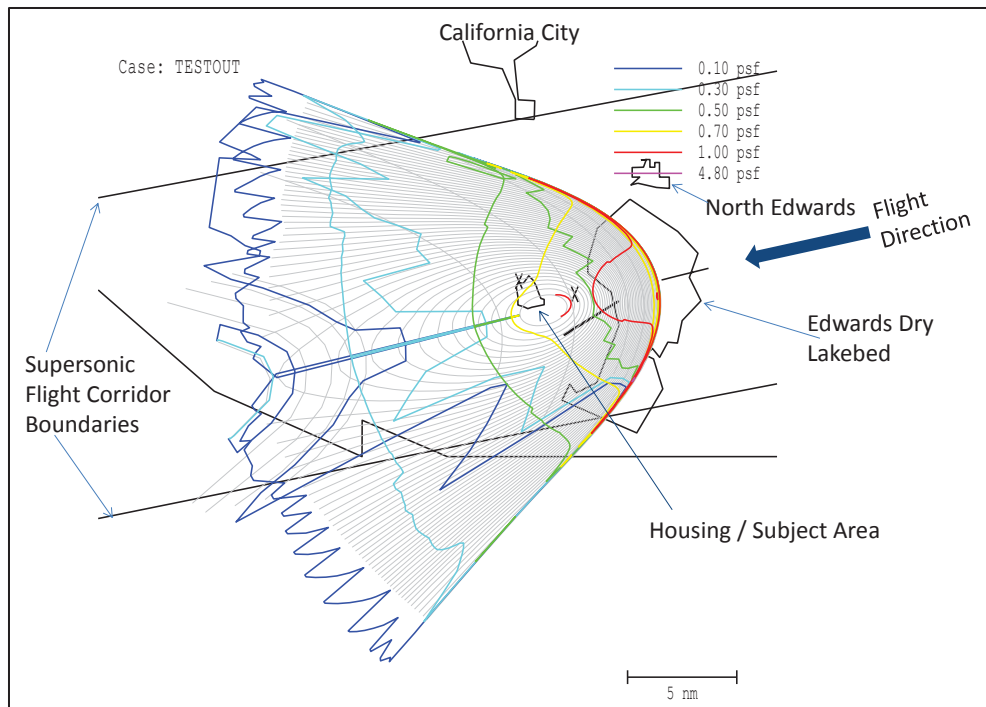
Flight operations were dependent on the weather conditions. A GPS-sonde launched nearby provided current atmospheric parameters (temperature, wind speed, and direction) covering the flight altitudes for the low-boom dive maneuvers. The balloon launch releases were scheduled to occur about 2 hours before each scheduled F-18 takeoff in order to obtain and utilize the local atmospheric data for pre-flight planning and computation of the aircraft low-boom dive maneuver waypoints. This weather information was used to adjust the F-18 waypoints in order to provide the desired amplitude sonic boom on the EAFB base housing community and avoid placing unavoidable focused booms on populated areas. A set of operational way points for desired booms under typical fall weather conditions were examined in order to gain experience with way point computation. Throughout the process care was taken to ensure compliance with airspace requirements. Adjustment of the way points on a day-to-day basis was provided by NASA personnel for the WSPR experiment. The following sections illustrate a likely range of low-boom footprints possible and document the typical waveforms considered in the WSPR experimental design process.



## 2.2.1 Boom Placement Design Process

The process for designing the boom placements relies on PCBoom [Page, Plotkin, Wilmer, 2010] for propagation and prediction of ground boom footprints. PCBoom analysis was conducted using an F-18 N-wave source characteristics model. For this project, existing as-flown low-boom dive maneuver trajectories obtained from NASA from the House VIBES<sup>3</sup> Project of vibro-acoustic response of buildings due to sonic boom exposure [Klos and Buehrle, 2007 and Klos, 2008] were utilized. These demonstrated that the maneuver can generate the desired boom level and ensures the aircraft performance capabilities are being met. An adjustment is made through way point translation in order to place the boom at the desired psf level on the community. The trajectory is run through a NASA performance code, which accounts for desired weather conditions and adjusts Mach number and other critical trajectory input parameters to PCBoom. This adjusted trajectory is then modeled using the PCBoom suite of programs to generate the focused sonic boom footprint, an example of which is provided in Figure 3. The trajectory is then translated to expose the community to a desired overpressure while avoiding placement of focused or higher amplitude sonic booms on the neighboring populated areas. During flight-testing days, use of measured data for adjustment between booms was possible. WSPR used the following target low-boom amplitudes (psf) in the experimental design<sup>4</sup>:

- 0.15 psf,
- 0.35 psf,
- 0.55 psf,
- 0.75 psf, and
- 1.00 psf.



**Figure 3. Example PCBoom footprint contours from an F-18 low-boom dive maneuver.**

<sup>3</sup> Variable Intensity Boom Effect on Structures (VIBES).

<sup>4</sup> Footprint and overpressure amplitude estimates shown in this section do not include atmospheric loss effects, however the WSPR design did account for atmospheric losses (Taylor Shock structure).

### 2.2.2 Footprint Elements of the F-18 Low-Boom Dive Maneuver

The footprint elements of the low-boom dive maneuver may be linked to the acceleration and deceleration segments of the trajectory (Figure 4). The acceleration footprint and resultant boom signature (pressure time history) are provided in Figures 5 and 6, while the deceleration footprint and boom signature are provided in Figures 7 and 8.

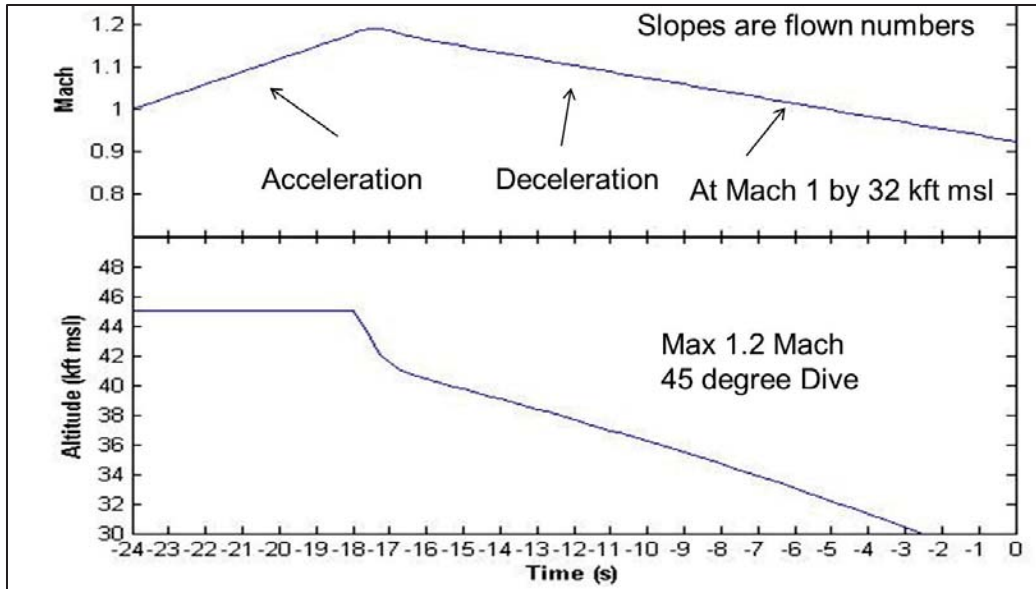


Figure 4. Example F-18 low-boom dive maneuver trajectory.

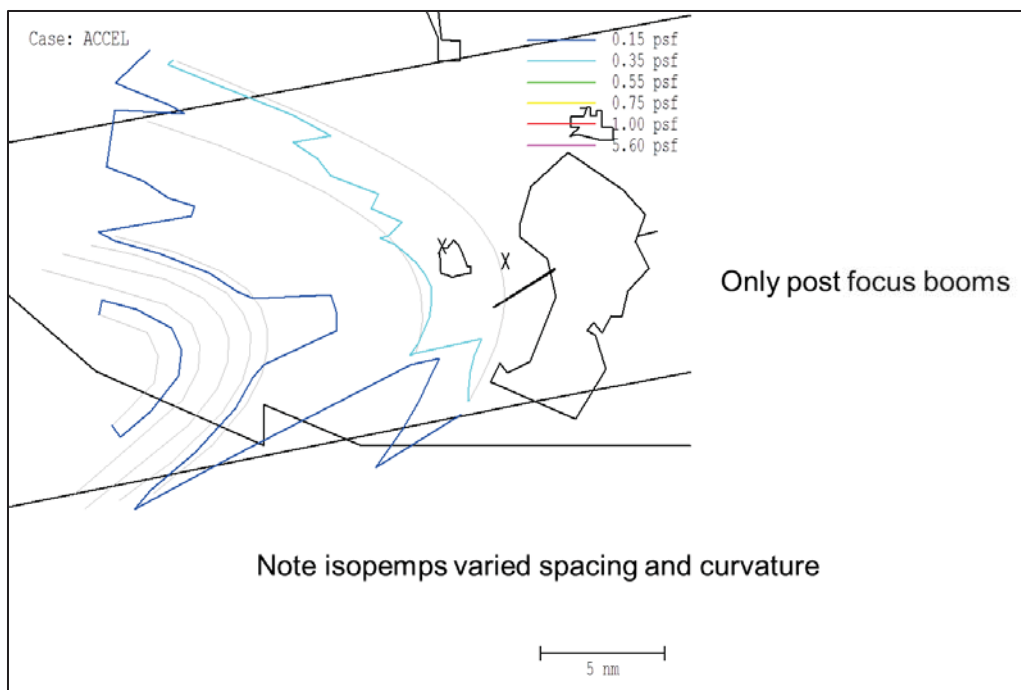
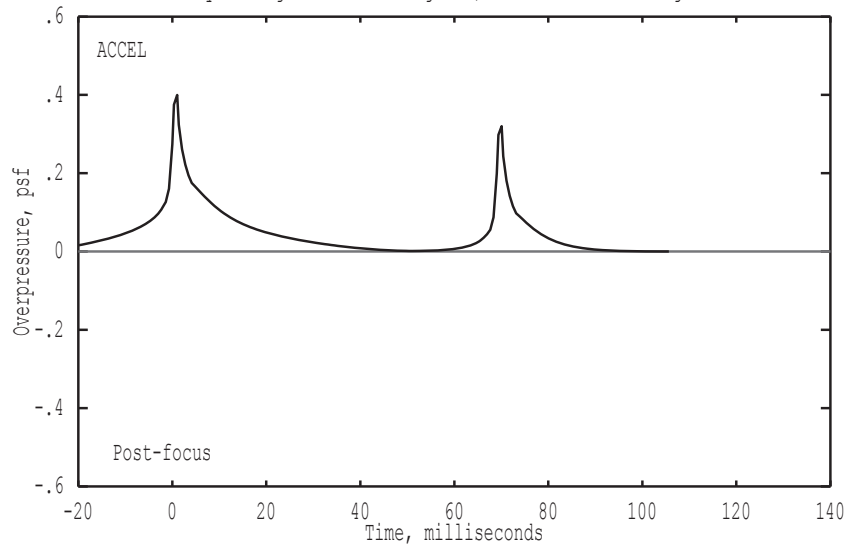
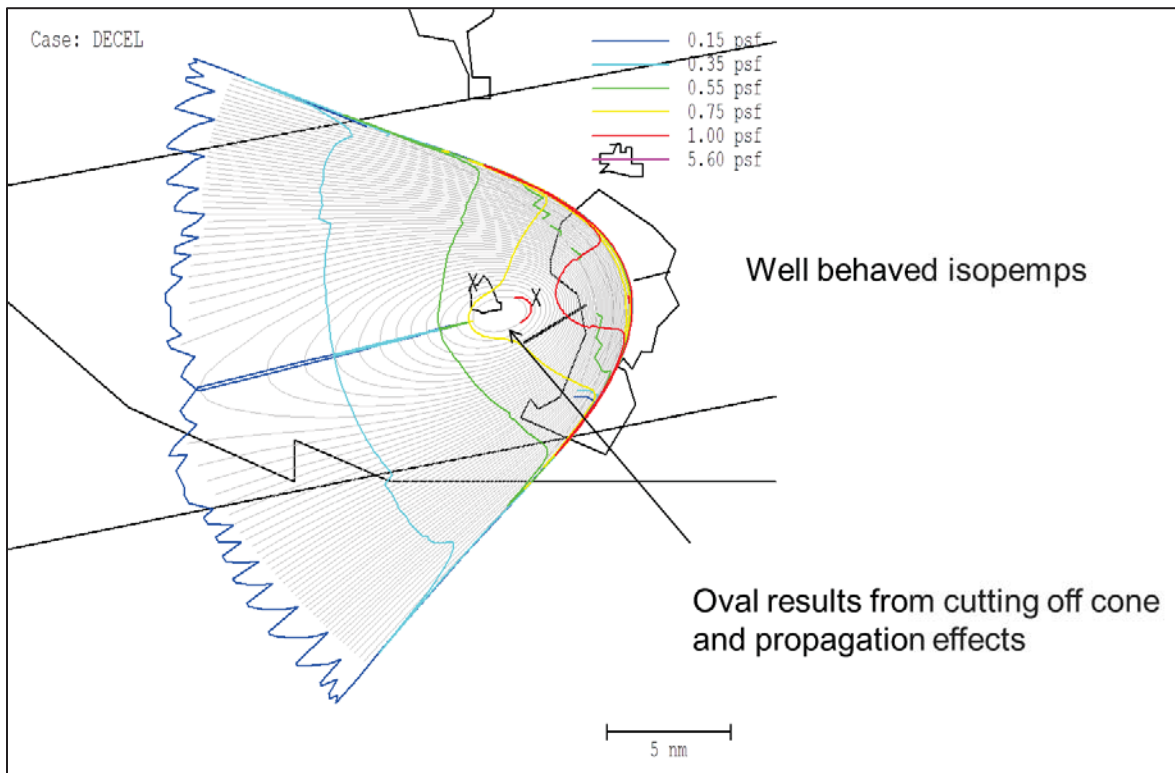


Figure 5. Sonic boom footprint from the acceleration portion of the trajectory.

Tac = 6.500 sec, Phi = -50.00 deg, Xac = 62.88 -21.59 43.21 kft, M= 1.19  
 Pmax, Pmin = 0.40, 0.00 psf, Tg = 80.131 sec, Xg, Yg = 2.04, -2.08 kft  
 Lpk = 119.6 dB, Lflt = 97.0 dB, CSEL = 91.1 dB, ASEL = 75.4 dB, Loud = 91.1 PLdB  
 Ray coming from 107.8 degrees, elevation 23.2 degrees

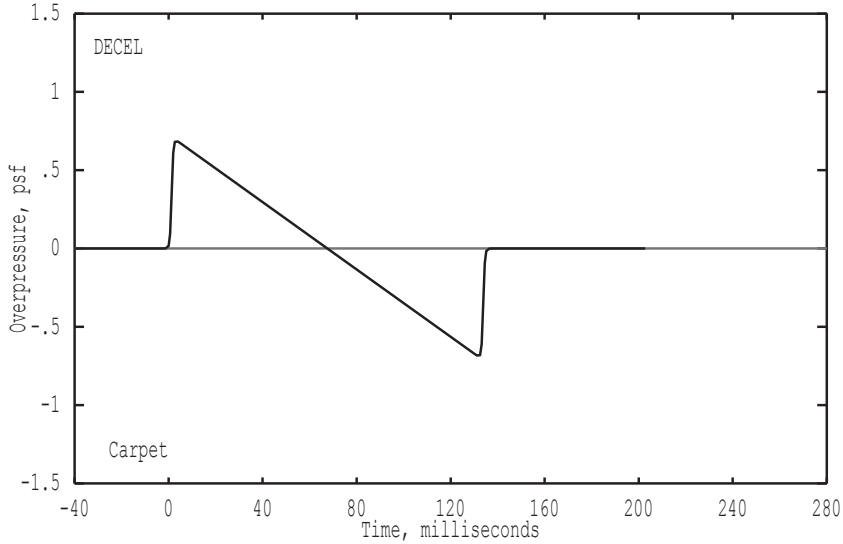


**Figure 6. Sonic boom signature from the acceleration portion of the trajectory.**



**Figure 7. Sonic boom footprint from the deceleration portion of the trajectory.**

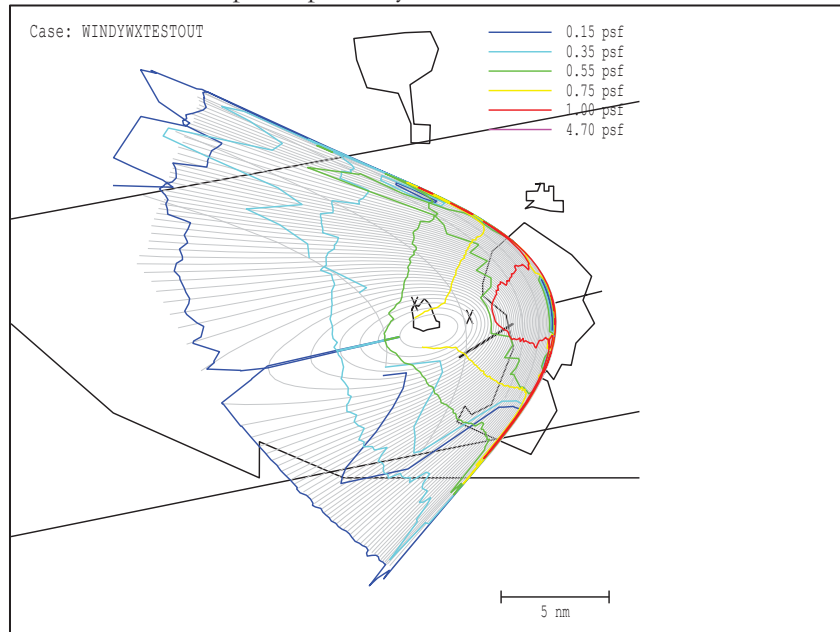
Tac = 19.250 sec, Phi = -105.00 deg, Xac = 55.06 -23.54 31.97 kft, M= 1.01  
Pmax, Pmin = 0.68, -0.68 psf, Tg = 65.138 sec, Xg, Yg = 17.13, -25.41 kft  
Lpk = 124.3 dB, Lflt = 111.0 dB, CSEL = 99.8 dB, ASEL = 79.1 dB, Loud = 96.6 PLdB  
Ray coming from 87.2 degrees, elevation 29.1 degrees



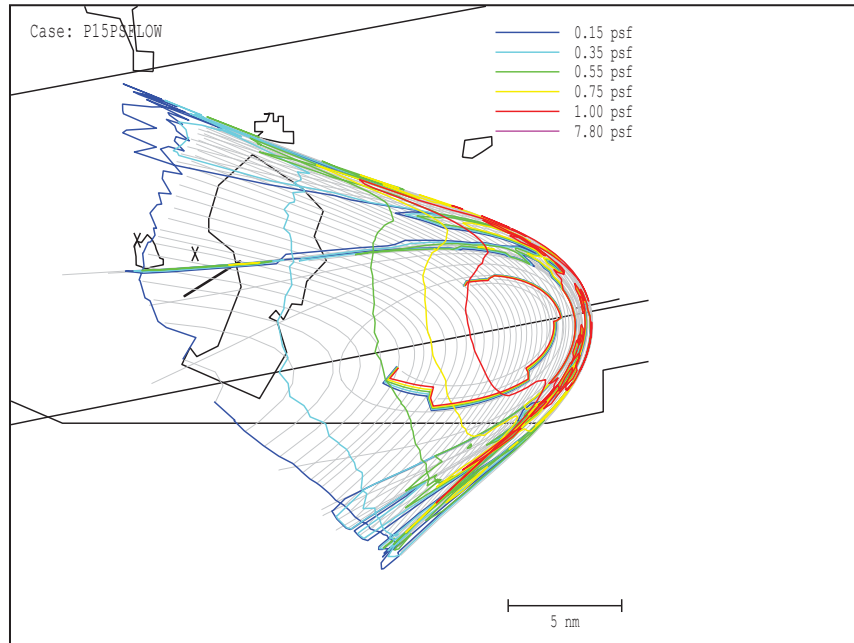
**Figure 8. Sonic boom signature from the deceleration portion of the trajectory.**

### 2.2.3 Trajectory and Atmospheric Variations

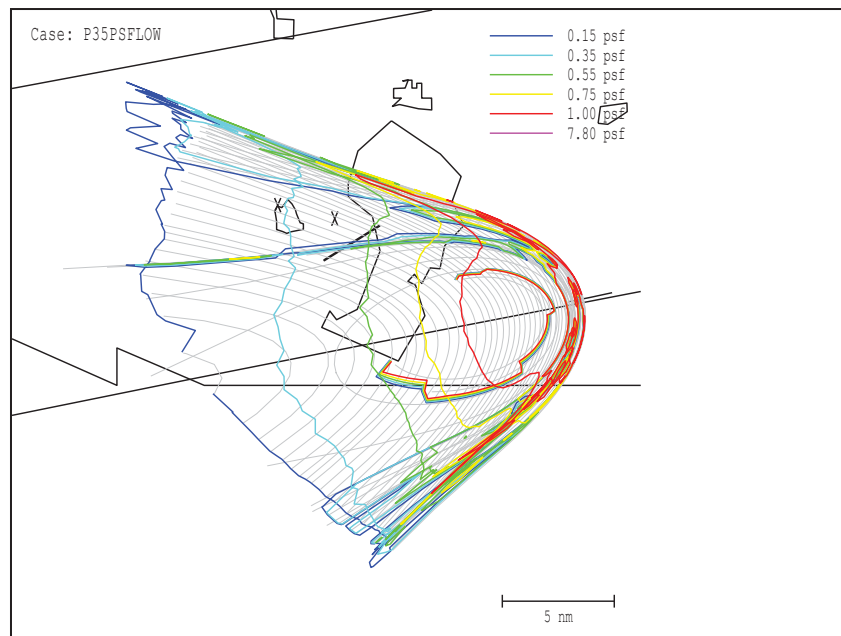
A NASA-provided aircraft performance code was used to adjust the trajectory presented in section 2.2.2 to account for different atmospheric parameters, including winds. One predicted PCBoom sonic boom footprint is provided in Figure 9. Examples of additional as-flown F-18 low-boom dive trajectories with the waypoint adjustment process applied to provide different overpressures on the EAFB community housing area are provided in Figures 10 through 13 for target overpressures of 0.15, 0.35, 0.55, and 0.75 psf respectively.



**Figure 9. F-18 low-boom dive footprint with winds.**



**Figure 10. F-18 low-boom dive footprint for 0.15 psf target on the EAFB community.**



**Figure 11. F-18 low-boom dive footprint for 0.35 psf target on the EAFB community.**

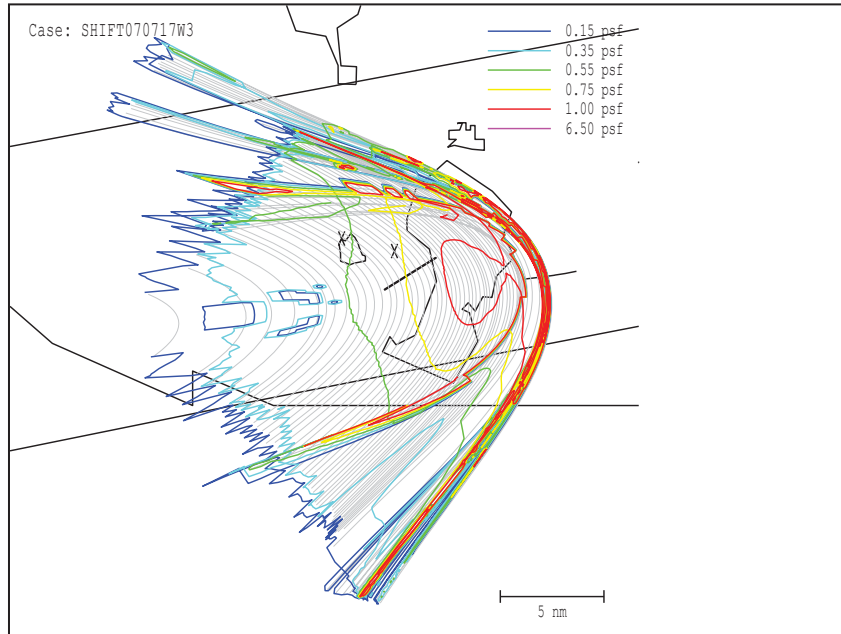


Figure 12. F-18 low-boom dive footprint for 0.55 psf target on the EAFB community (different weather).

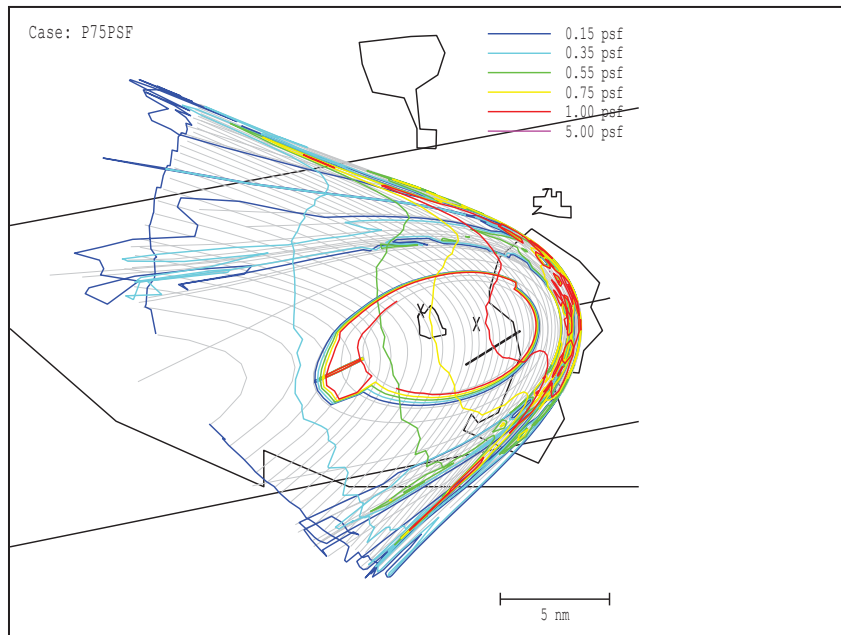


Figure 13. F-18 low-boom dive footprint for 0.75 psf target on the EAFB community.

## 2.3 Subjective Instrumentation Design and Implementation

### 2.3.1 Single Event Survey

Study participants were asked to report their reactions to sonic booms using two survey forms each day. The single event survey form was to be completed each time a sonic boom was heard. This form includes 10 questions that

collected data on subjective response to noise as well as characteristics of the individual boom event. Specifically, the form gathered the following:

- Subjective response to noise
  - Annoyance
  - Loudness
  - Interference with activity
  - Startle
  - Vibration
  - Rattle
- Characteristics of the sonic boom event
  - Date and time the sonic boom was noticed
  - Individual's location at the time of the boom (indoors or outdoors and at home or not at home)

Subjective response was measured using the 11-point (0 to 10) scale with anchored end points “not at all” and “extremely”. Appendix A-1 provides a copy of the single event survey form. The version included in Appendix A-1a was designed for administration by paper/pencil, A-1b is the web presentation, and A-1c is the Apple device application.

### **2.3.2 Daily Summary Survey**

The daily summary form contained 13 questions, including the date and an item where individuals reported additional observations. Fewer subjective response dimensions were assessed than on the single boom form—only annoyance, loudness, vibration, and rattle – but annoyance was asked twice to utilize two response formats. Individuals rated their annoyance using 11-point (0 to 10) verbally anchored scale as well as a 5-point fully-labeled verbal scale to support comparisons of the WSPR data with subjective response data gathered by Fidell & Associates. The response categories for the fully-labeled scale were displayed vertically next to the question text: “not at all”, “slightly”, “moderately”, “very”, and “extremely”. In addition to the subjective response dimensions listed above, the daily summary form collected:

- The portion of the day the participant was home for at least one hour,
- The number of sonic booms heard during the day (including zero),
- Whether most windows in the home were closed or open most of the day, and
- Whether there were any noises that might have been a sonic boom, but they were not sure and, if so, what the noise sounded like.

A complete listing of the daily summary survey may be found in Appendix A-2. In addition to reporting their reaction to each sonic boom they noticed, study participants were asked to complete a survey once each day about all the sonic booms they heard throughout the day. It was requested that this form be completed every day of the experimental test period (Monday through Sunday), even if the participant did not notice any sonic booms on a particular day or was not at home that day. Appendix A-2a lists the paper version of the daily summary form, Appendix A-2b lists the web presentation, and Appendix A-2c lists the Apple application.

### **2.3.3 Baseline Survey**

A baseline survey was developed to obtain measures of noise annoyance and sensitivity to noise before the subjects were exposed to the noise associated with low-amplitude sonic booms. The wording and response structure of these questions matched the single boom and daily summary surveys, providing a comparison for reactions to low-booms during the test period. The Baseline survey was structured to obtain characteristics of subjects and their environment that were expected to be covariates in the statistical analysis of the event survey data. Since these characteristics were fixed, at least for the two-week duration of the WSPR study, it was most efficient to gather these data prior to the experimental test period, using a single mode of survey administration.



The questionnaire for the baseline survey is provided in Appendix A-3. Briefly, the survey covered the following areas:

- Confirm eligibility and instruct participants on the next steps
  - Confirm street address and continued residence on the base
  - Inform individuals regarding the method they will be using to complete event surveys (Web, Apple device, paper/pencil) if this was not done during interim outreach activities
- Collect social and demographic characteristics
  - Age, gender, education
  - Household size, presence of young children in household
  - Duration of residence on base
- Reactions to noise prior to low-boom exposure
  - Attitudes about noise and ability to adapt to noise
  - Annoyance with common neighborhood noises (barking dogs, cars or trucks, other aircraft noise)
  - Annoyance with sonic booms
  - Other subjective reactions to sonic booms (loudness, interference with conversations inside [outside] the home, startle, vibration, and rattle)
  - Comparison of noise at EAFB with immediate prior residence

The baseline survey was administered via telephone interview for all WSPR subjects.

### 2.3.4 Modes of Survey Administration

The single event and daily summary surveys were designed to be administered using three modes – paper, web, and with an application compatible with Apple mobile devices (iPad, iPhone, or iPod Touch). A WSPR objective was to develop and evaluate data collection methods for assessing subjective response to sonic booms that would be cost effective and yield high quality data for a possible, future study with a naïve community. Examples of a portion of the single event survey may be found in Figure 14 for the paper form, Figure 15 for the web single event form, and Figure 16 for the iPod Touch app single event screen shots.

National Aeronautics and Space Administration

**Single Boom Response Form**

ID: \_\_\_\_\_

E1 Date of the sonic boom:    \_\_\_\_ / \_\_\_\_  
  MM    DD

E2 Time of the sonic boom:       \_\_\_\_ : \_\_\_\_  
  (Enter time in military time)

E3 When the sonic boom occurred, were you ... (select one)

Indoors at home                                Outdoors at home

Indoors somewhere else                        Outdoors somewhere else

(select one for each)	Not at all	0	1	2	3	4	5	6	7	8	9	Extremely
E4 How much did the sonic boom <b>bother, disturb, or annoy</b> you? .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
E5 How <b>loud</b> was the sonic boom? .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
E6 How much did the sonic boom <b>interfere</b> with your activity? .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
E7 How much did the sonic boom <b>startle you or make you jump</b> ? .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(select one for each)	None	0	1	2	3	4	5	6	7	8	9	A great deal
E8 Vibration is a motion. The motion may be seen or felt. How much <b>vibration</b> from the sonic boom did you see or feel in your home? .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
E9 Rattle is a type of noise that can occur when objects move due to a vibration. How much <b>rattle</b> from the sonic boom did you experience in your home? .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

E10 Please enter any additional comments.

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**Figure 14. Single events survey (paper form).**



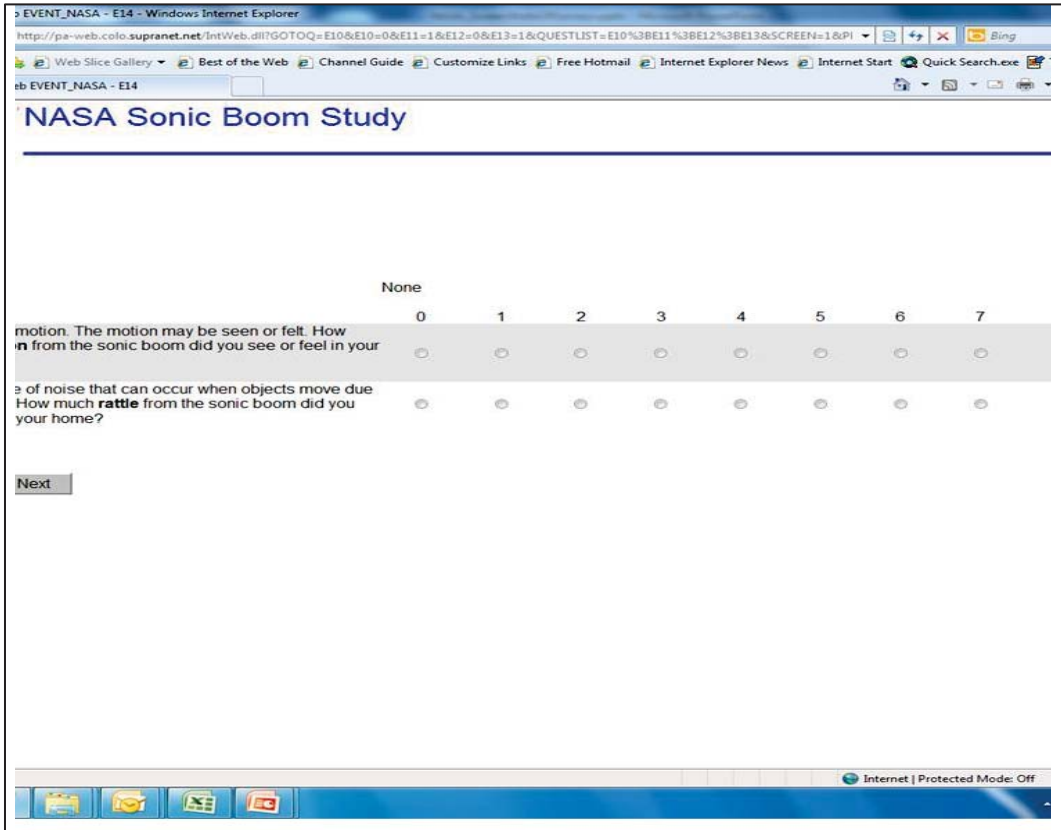


Figure 15. Single event survey (web form).

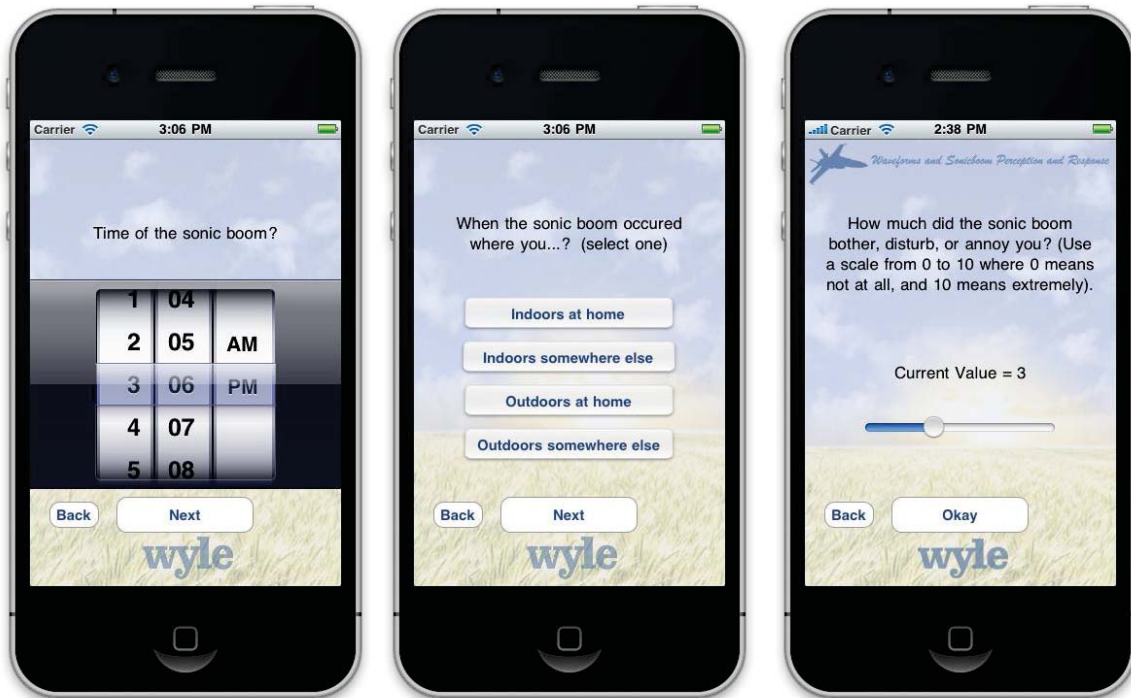


Figure 16. Single event survey (Apple application screen shots).

Complete copies of the paper surveys and screen shots of the Web and Apple surveys may be found in Appendix A.

## 2.4 Experimental Review

A series of reviews with NASA and other established review boards were conducted during the development of the WSPR experimental design. These were structured to ensure all the project objectives were met, that sufficiently detailed experimental test plans were developed, and that safety needs were met. Human subjective testing necessitated Institutional Review Board oversight for the WSPR project. A protocol was established between the Penn State IRB and the NASA IRB for this project. Further details are contained in Section 2.4.2 and the full listing of the IRB application and approvals may be found in Appendix B. In preparation for future naïve community testing and gathering of subjective response data to low-amplitude sonic booms, we also developed an expected future test protocol based on WSPR (see Section 6.3) and prepared a federal Office of Management and Budget (OMB) Application (see Section 2.4.3 and Appendix B-4).

### 2.4.1 NASA Technical Reviews

A sequence of Experimental Reviews was held with NASA researchers during the course of the WSPR project. Table 7 itemizes the review meeting purposes, dates, and locations. Each review included a comprehensive update of all elements of the project design, analysis, and planning. All meetings ended with a wrap-up and NASA feedback and out brief session with clear action items and task assignments. During the course of the WSPR program, weekly and monthly telecon and net meetings were held with team members and NASA sponsors in order to ensure a robust experimental design and analyses process and a successful outcome.

**Table 7. WSPR Experimental Review Schedule**

Meeting	Date	Purpose	Location
Technical Interchange Meeting 1	9 Sep 2010	Preliminary Experimental Design	NetMeeting
Technical Interchange Meeting 2	27 Jan 2011	Design Review / IRB / Recruitment / Instrumentation / Logistics	NASA LaRC
Year 1 Annual Review	23 Jun 2011	Program Review / Experimental Update	NASA LaRC
Detailed Experimental Review	29 Jun 2011	Survey Instrumentation / Boom Placement / Flight Logistics / Instrumentation / Recruitment	NetMeeting
Pre-Test Review	27 Sep 2011	Findings from Apple Pre-Test and Field-Kit Pre-Test	NetMeeting
Flight Test Coordination Meeting	5 Oct 2011	Final Pre-Experimental Detailed Review of Experimental Plans / Logistics / Instrumentation / Recruitment	NASA DFRC
Technical Interchange Meeting 4	15 Dec 2011	Post-Test Preliminary Experimental Review / Lessons learned	NetMeeting
Technical Interchange Meeting 5	3 May 2012	Preliminary Experimental Results	NASA LaRC
TIM 6		Boom Analysis Task Review	NetMeeting
Final Oral Reviews	30 Nov 2012	Final Program Review	NASA LaRC

### 2.4.2 Experiment Review (IRB)

The Pennsylvania State University was responsible for preparing the Institutional Review Board (IRB) application on behalf of the WSPR team and ensuring compliance with the requirements of the PSU IRB. Penn State was also

responsible for submitting the required IRB associated information for NASA IRB review. All team members likely to contact subjects, or publish data or work that used data gathered as part of this experiment complied with both the PSU and NASA IRB training requirements.

### **2.4.3 OMB Application**

The Paperwork Reduction Act (PRA) of 1995 requires that the United States Federal Office of Management and Budget (OMB) approve each collection of information by a federal agency before it can be implemented. The information requested is intended to ensure that agencies employ effective survey and statistical methodologies that are appropriate for the type of information that is to be collected.

The OMB process was investigated and related information identified to contribute to the OMB application. The application for the Low-Boom Community Response Program includes detailed information related to the methods used to gather the data and survey information. For proposed research designs, the OMB application includes the documentation related to statistical collection procedures and methods, and statistical information presentation and dissemination. This information includes the methods of obtaining the response data and how that data is analyzed. One of the WSPR goals was to gather sufficient data regarding subjective instrumentation to prepare an OMB application. The full text of a draft OMB application for a potential future naïve community low-amplitude sonic boom test may be found in Appendix B.

## **2.5 Subject Recruitment**

The WSPR team recruited over 100 residents of EAFB to participate in the study during the experimental test period. Subjects were requested to complete brief surveys each time they noticed a sonic boom as well as a summary at the end of each day. To be eligible, subjects had to live on EAFB during the experimental test period, be at least 18 years of age, and usually be at home during daytime, weekday hours. Rules for defining usual daytime/weekday hours were developed during the recruitment phase and are discussed in more detail below. The recruitment effort was designed to identify subjects for the WSPR team as well as a parallel research protocol led by Fidell and Associates.

This section describes the recruitment approach, methods used to contact subjects, and contingency plans that were implemented to reach the target number of subjects. The timeline of activities that were performed, the recruitment screening questionnaire, and the incentives offered to subjects who agreed to participate in the study are also outlined.

### **2.5.1 Approach and Needs**

Due to EAFB requirements, the WSPR team was not permitted to contact residents directly to invite them to participate in the research or to ascertain their eligibility. Instead, residents were encouraged to volunteer to participate and they were contacted only after they expressed interest. All direct communication (letters, emails, posted announcements) was issued by EAFB personnel. An approach was developed that was consistent with these requirements. A Subject Recruitment Plan was submitted for review and approval by both NASA and EAFB. The plan included the following steps:

- Coordinating with EAFB personnel to raise awareness about the study and encourage individuals to volunteer.
- Using multiple channels of communication to maximize coverage and periodically repeat communications or broadcasts over the recruitment period.
- Outlining the basic eligibility requirements on general communications and providing contact information (telephone, email, and website) for the survey coordinator to obtain more information.
- Conducting more detailed screening of volunteers via a telephone interview or self-administered web survey to determine eligibility and assign to a mode of survey administration.
- Developing a contingency plan and further outreach initiatives if 100 residents did not volunteer by the beginning of August 2011.

## 2.5.2 Communication Methods

Communication with EAFB residents involved the use of print and social media as well as email and hard-copy letters to residents. Announcements were posted on the websites of EAFB and NASA Dryden Flight Research Center (DFRC) and were broadcast on the Edwards’ Facebook page and Twitter feed. A news article about the study was published in the weekly base newspaper, Desert Wings, and the team requested an “information box” (advertisement) appear weekly thereafter. An email letter about the study was sent to the all-base distribution list and hard-copy letters were mailed to all base residents. NASA DFRC staff posted announcements on many locations throughout the base and met with organizers of social clubs (e.g., spouse’s auxiliary organization).

In addition, the research team attempted to “snowball” the sample by asking recruited subjects to encourage eligible friends or neighbors to register. After residents completed the screening questionnaire – and the vast majority completed the screener on-line – the team sent an acknowledgment email message. The message thanked individuals for their interest, explained when they would be contacted for the next phase of the study, and indicated that the research program was still seeking volunteers. Recipients were asked to encourage friends or neighbors to contact research program staff or complete the on-line registration survey to determine their eligibility. These “thank you/snowball” emails were sent to individuals starting July 8 – the earliest date that EAFB allowed research program personnel to contact residents – and continued through August 2011.

Communication with base residents rolled out slowly with long intervals between follow-up notices. Neither the timing of announcements nor the channels for communication that were outlined in the approved Subject Recruitment Plan was followed. The timeline of activities, which is summarized in Table 8 below, illustrates the start-stop nature of outreach and lack of prompt follow-up on initial communications through alternate channels to ensure maximum coverage. As a result, the team was unable to recruit the target number of subjects within the expected time period (initially defined as July 31) and additional measures were necessary to identify subjects (discussed in Section 2.5.3).

**Table 8. Timeline of Subject Recruitment Communication Efforts**

Date	Outreach Activity
<b>June 22</b>	Articles posted to NASA Dryden and EAFB websites. Simultaneous postings to EAFB Facebook page and Twitter feed
<b>June 24</b>	News article published in Desert Wings (weekly base newspaper)
<b>July 1</b>	Information box in Desert Wings (published intermittently in weekly paper)
<b>July 8</b>	Thank you/snowball emails to recruited subjects began and continued through August as new recruits were identified and sent acknowledgement email
<b>July 14</b>	All-base email
<b>July 17</b>	Letters sent to all base residents by First Class mail
<b>July 25- August 9</b>	NASA Dryden staff reach out to social clubs and posting print announcements in base facilities (e.g., fitness center, stores, gathering places)
<b>August 4</b>	Re-post recruitment notice on NASA DFRC website
<b>Sept 23-27</b>	News article in Desert Wings, all-base email and electronic posts notifying residents that a \$50 VISA gift card incentive would be given to study participants

Copies of all emails, letters, and print announcements distributed to EAFB residents are provided in Appendix C.

### 2.5.3 Contingency Plans

At the end of July, only 66 EAFB residents had completed the screening instrument and met the criteria<sup>5</sup> to participate during the experimental test period. Following each of the initial communications – the first news article in late June, the all base email in mid-July – there was a burst of interest in the study and one to two dozen new subjects were identified. However, the number of individuals completing the screener increased by single digits in late July and early August.

The Subject Recruitment Plan originally submitted for approval by NASA and EAFB included numerous strategies that were not being employed systematically as well as additional steps to take if the plan failed to yield a sufficient number of subjects. These included:

- Hard-copy announcements posted or made available for distribution in heavily-visited areas, such as the gym or fitness facility, commissary, housing office.
- Announcements on EAFB command-access TV channel.
- Oral announcements at town hall meetings, orientation sessions, or other gatherings as possible and appropriate.
- Engage with new residents opportunistically – i.e., make printed announcements available at venues typically visited as residents are posted to the base, such as the housing office, orientation sessions, and enrollment in base services.

The Subject Recruitment Plan also included fallback or contingency measures, such as:

- In-person presentations by research staff from Tetra Tech, Wyle, or other members of the team with EAFB personnel, at town-hall meetings, or other community gatherings.
- Display booths (with or without research staff present) in heavily-frequented areas (e.g., entry to fitness facility or commissary).
- In-person recruitment effort by visiting residents door-to-door at their homes on base.
- In-person “show and tell” events, such as opportunities for individuals or families to see inside the cockpit of an F-18 (with cooperation from NASA DFRC).

Elements of this plan that could be implemented without the direct assistance of EAFB were executed in the last week of July and early August by NASA DFRC staff. These included posting announcements in heavily-frequented areas and reaching out to the spouses’ auxiliary and social clubs. Other elements of the plan required further review and approval by EAFB, could not be executed quickly enough, or required additional resources and still faced considerable uncertainty of success (e.g., in-person presentations at town hall meetings and door-to-door visits to homes on base).

At the end of August, 10 more eligible recruits had registered to participate in the study but the total number (76) still fell short of the minimum needed to conduct the experiment and gather sufficient subjective response data. In light of these circumstances, the WSPR team elected to offer a financial incentive to subjects. All subjects were already told that they would receive a certificate of appreciation and a patch with the study logo after completing the study. In addition, all participants would also be given a \$50 VISA gift card if they completed surveys during the experimental test period.

All permissions to offer the gift card incentive were in place by September 16, including approval by NASA and the Pennsylvania State University’s Institutional Review Board. New communications describing the incentive and the recruitment effort were published in Desert Wings, an all-base email, and website postings between September 23 and 27. In the following 7 days, 98 residents completed the screening questionnaire (86 of whom met agreed eligibility rules), and recruitment was closed on September 30, 2011.

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<sup>5</sup> While the final selection criteria were yet to be determined, at the end of July 2011, the team anticipated seeking residents who were at home 4–5 days a week (Monday through Friday) and most of the morning hours. The final selection criteria are described in Section 2.5.6.

## 2.5.4 Recruitment Screening Questionnaire

The research program team conducted screening interviews with residents of EAFB that expressed an interest in the study. All outreach communications enumerated the main requirements for participation – that is, residence on base during the study period, at least 18 years of age, and usually at home during weekday/daytime hours. A screening interview was necessary to determine eligibility for the modes of survey administration and to gather more detailed information that would help the team refine its definition of “usual” and “daytime hours”.

The research team was prepared to conduct the screening interviews by telephone using their in-house survey lab. It was also programmed as a web survey and could be self-administered by base residents interested in the study. All outreach materials listed a toll-free telephone number and email address of a project team member that residents could use to arrange a telephone or email interview. Materials also listed the URL for the Web survey. All but three residents completed the screening interview by accessing the Website.

Table 9 summarizes the information gathered in the screening interview. Question numbers cross-reference the content areas with the full questionnaire (see Appendix C-12).

**Table 9. Information Collected in the Recruitment Screening Interview**

Topic Area	Detailed Elements	Question No.
Adult status and EAFB residence	Confirm individual is 18 years of age or older and currently lives on EAFB. Living on EAFB in Fall 2011 (to the best of their knowledge)	INT2, Q2, Q9A
Informed consent	All elements of informed consent are included in the letter of invitation and repeated in the recruitment screening interview. These include: <ul style="list-style-type: none"> <li>Assurance of confidentiality and voluntary nature of participation</li> <li>Why research is being conducted, by whom, and how data will be used</li> <li>What participants will be asked to do</li> <li>Any benefits or risks associated with participating</li> <li>Informed consent text reviewed and approved by NASA and Penn State IRBs</li> </ul>	INT2 letter of invitation (Appendix C-2)
Meet requirements for being “at home” on weekdays	Participants must be at home on weekdays during daytime hours. We ask: <ul style="list-style-type: none"> <li>Number of weekdays (Monday-Friday) typically at home at least part of the day between 7:00AM and 7:00PM</li> <li>Number of hours typically at home during different parts of the day (on the weekdays when individual is at home)</li> <li>Expect time at home will be similar in Fall 2011 (to best of their knowledge)</li> </ul>	Q3A - Q7, Q8A
Meet study requirements for being “at home” on Saturdays	It may be necessary to collect data from individuals on weekends. One question asks if individuals are generally at home on Saturdays (most of the day, about half, not usually)	Q8
Eligible for web-based survey mode	Some individuals will be asked to complete brief surveys using an on-line questionnaire. Screening questions ask <ul style="list-style-type: none"> <li>Own or have access to a computer in his/her home</li> <li>Have access to the Internet from his/her home</li> <li>Willingness to use this computer to complete brief questionnaire</li> <li>We advise individuals that they will not be reimbursed for using their own computer or Internet access to participate in the study</li> </ul>	Q11 – Q13
Eligible for Apple-device application	Some individuals will be asked to use a software application that is compatible with Apple devices; specifically an iPhone, iPod Touch, and iPad. We ask: <ul style="list-style-type: none"> <li>Own an iPhone, iPod Touch, or iPad that is his/her own personal device (not provided by an employer)?</li> <li>Willingness to use this device to complete brief surveys?</li> </ul> We inform individuals that we will provide an application that will be installed on the device for this purpose We advise individuals that they will not be reimbursed for using their own mobile device to participate in the study	Q14 – Q15



**Table 10. Information Collected in the Recruitment Screening Interview (Concluded)**

Topic Area	Detailed Elements	Question No.
Eligible for SmartPhone survey mode	<p>Researchers will lend SmartPhones to some individuals for the purpose of the research study. Screening questions ask:</p> <ul style="list-style-type: none"> <li>• Willingness to participate in the study using a SmartPhone provided by the researchers</li> <li>• Willingness to use a SmartPhone that has GPS technology. The phone uses GPS to determine if the individual is “at home” or “not at home” when survey answers are submitted. The GPS will not be used to track their locations throughout the day.</li> <li>• Willingness to complete brief surveys for approximately a 3-month period</li> </ul> <p>We advise participants of the following:</p> <ul style="list-style-type: none"> <li>• Phone can be used for personal use (calls, texts, Internet) at no expense to them</li> <li>• Phone must be used to complete brief surveys over several weeks</li> <li>• Phone must be returned at the end of the research study</li> </ul>	Q16 – Q18
Hearing loss	Screening questions ask whether, to the best of their knowledge, the individuals have normal hearing. If not, we ask if they use a hearing aid	Q9, Q10
Contact information	<p>We ask for the following contact information, which is essential to conduct the next phase of the study:</p> <ul style="list-style-type: none"> <li>• First and last name</li> <li>• Street address</li> <li>• Primary telephone number</li> <li>• Alternate telephone number (not a required field)</li> <li>• Email address (not a required field)</li> </ul>	Q21A – Q21E

### 2.5.5 Recruitment Incentives

Subjects who participated in the study and completed surveys during the experimental test period received monetary and non-monetary incentives – a \$50 VISA gift card, a patch with the study logo, and a certificate of appreciation signed by David D. McBride, NASA DFRC Center Director, and by Larry J. Cliatt, II, NASA DFRC Point of Contact for the WSPR project. Base residents were informed during the recruitment phase that they would receive these incentives at the end of the study after their participation was complete. As discussed above, the monetary incentive was added late in the recruitment period. The research team agreed, and received permission, to offer a monetary incentive in mid-September and it was made available regardless of when the subject was recruited. The VISA gift card and patch with the WSPR logo are shown in Figure 17.



*Figure 17. WSPR VISA gift card and WSPR patch.*

## 2.5.6 Recruitment Selection and Outcomes

A total of 203 EAFB residents completed the screening interview and 171 of these interviewees were deemed eligible to participate during the experimental test period. Being “deemed eligible” involved meeting the minimum criteria for exposure to the low-amplitude booms that would be generated by the F-18 flights. Outreach communications specified that participants must “usually be at home during weekday/daytime hours,” but the research team and NASA needed to determine more precisely what “usually” meant. Operationally, this required quantifying the number of days and the number of hours so that the research team could apply eligibility rules consistently and, if necessary, tighten or relax the criteria to include a sufficient number of subjects.

The screening interview collected detailed information on the number of days per week individuals were usually at home as well as the number of morning, afternoon, and evening hours they were usually at home. “Morning”, “afternoon”, and “evening” were defined specifically as 7:00 a.m. to noon, noon to 5:00 p.m., and between 5:00 and 7:00 p.m. respectively. Subjects were selected at three different time points using three slightly different rules as the flow of subjects changed over time. The dates of selection and the selection rules (using Boolean to clarify) were as follows:

- August 1: “at home 4 to 5 days/week AND 4 to 5 hours in the morning”.
- August 26: “at home 3 to 5 days/week AND (3 to 5 hours in the morning OR 3 to 5 hours in the afternoon”.
- September 30: “at home 4 to 5 days/week AND 4 to 5 hours in the morning AND 4 to 5 hours in the afternoon”.

The recruitment effort supported the WSPR research team as well as a parallel study led by Fidell and Associates. A total of 55 subjects were assigned to Fidell and Associates and 60 subjects to the WSPR team. These subject counts included a handful of “extra” subjects to cover attrition.

Subjects were randomly assigned to the two teams, conditional on meeting the project-specific requirements of the Fidell study. Specifically, subjects for the Fidell study must be willing to use a SmartPhone provided by the researchers and to use this telephone to complete short surveys each time they notice a sonic boom for roughly 2–3 months. Subject contact information was delivered to Fidell and Associates in three waves – August 1, August 26, and October 7, 2011.



The flight-testing portion of the WSPR experiment was conducted from November 4–18, 2011. A substantial number of preparatory activities were conducted to reduce risk and ensure a successful experiment. This chapter describes the Pre-Test Activities (Section 3.1), the As-Flown Flight Test (Section 3.2), the Objective Data Collection (Section 3.3), and the Subjective Data Collection (Section 3.4). A discussion of the day-of-flight planning and Go/No-Go decision-making process is provided in Section 3.2.

## 3.1 Pre-Test Activities

Before conducting the actual WSPR experiment, a series of pre-test activities were conducted. These fell into two areas – Objective and Subjective Instrumentation. A sequence of field-kit tests (Section 3.1.2 – 3.1.4) were conducted by Gulfstream in Savannah, GA and at NASA DFRC to test various elements of the sonic boom recording instrumentation system and serve as a major risk mitigation activity. A subjective pre-test was conducted at NASA DFRC with employee volunteers not involved in the WSPR project. The pre-test included assessment of both the paper and Apple device forms of the subjective instrumentation. The NASA F-18 provided intentional sonic booms on August 30, 2011 for the purposes of conducting this portion of the experiment. This served several purposes – to provide an independent review of the subjective instruments (Section 3.1.6); to permit researchers to conduct a “dry-run” of the Apple installation process and to test the back end data collection protocols (Section 3.1.5).

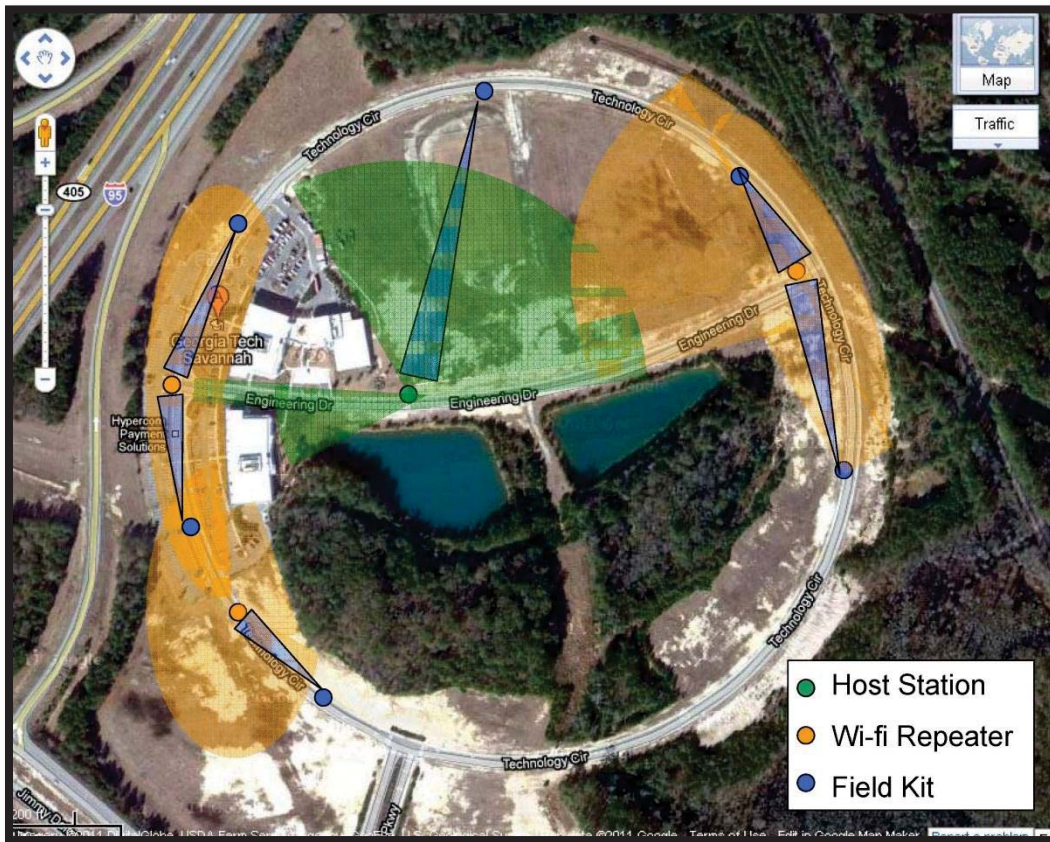
### 3.1.1 Field-Kit Test Deployment Preparations

The field-kits used in the WSPR test utilized a wireless TCP/IP network to communicate and transfer data between themselves and the host computer located at a centralized location. An initial benchmark of the range capability of this wireless network needed to be established before any testing began. The wireless network used long-range, directional antennae, and omni-directional high gain antennae. A range test was conducted on Tybee Beach near Gulfstream’s Savannah facility. Ranges of 0.7 and 0.8 miles were demonstrated for omni-directional antenna to omni-directional antenna and omni-directional to directional antenna respectively. Note this test did not benchmark bandwidth performance. Test results showed that elevated antennae and direct line of sight between antennae greatly improved reliable signal connectivity and range.

In addition to the range test, functionality of the field-kits needed to be demonstrated before a scaled test deployment would occur. This test involved one host computer, one repeater, and one field-kit. The intent of a repeater station was to merely pass information between a host computer and a field-kit node, thus extending the overall distance between the host computer and a particular field-kit. Range was not an objective of this test, therefore these components were only separated by a few hundred feet. Functionality of the user activated record function over the wireless network was tested. The acoustic data was successfully recorded and stored to a USB drive.

### 3.1.2 Georgia Tech Savannah Field-Kit Test Deployment

Gulfstream conducted risk reduction testing of the field-kits in a scenario similar to EAFB (i.e., obstructions such as buildings and trees). This task was accomplished by setting up six field-kits, three wireless repeaters, and a host computer at a satellite Georgia Tech campus near Gulfstream. The directional and omni-directional antennae were paired with the field-kits and repeaters/host respectively. The purpose of the repeaters was to extend the range between field-kit and host. Five of the six field-kits were set up to send a signal to one repeater before that signal was forwarded to the host computer. The sixth field-kit was set up to relay a signal through two repeaters before reaching the host computer. This test deployment reaffirmed the importance of line of sight between the antennae. Intermittent connectivity issues were observed with the field-kit that used two repeaters in series.



*Figure 18. Physical layout of field kit test at Georgia Tech Savannah.*

### 3.1.3 Field-Kit Testing at NASA Dryden (DFRC)

Gulfstream personnel performed a risk reduction instruction test of the field-kits at NASA DFRC from September 20-23, 2011. This served as a major risk reduction item testing the kits with actual sonic booms prior to initiation of the WSPR flights. During this visit specific locations for field-kit installations were selected in conjunction with the NASA DFRC-EAFB liaison and with EAFB personnel.

### 3.1.4 WSPR Objective Instrumentation Software and Test Preparations

Throughout the field-kit hardware development phase, improvements to the existing LabVIEW program were made. LabVIEW is the software that drives the National Instruments test equipment. The existing LabVIEW program supported manual triggering to start and stop recording acoustic data. An alpha version of an auto-trigger was developed, enabling the field-kits to record data autonomously. The auto-trigger was designed to capture acoustic data before and after a user-defined sonic boom threshold was exceeded. In addition to this, the code was updated to include a function to automatically update its geographical location using the Garmin GPS, a function to remotely reboot the field-kits from the host computer, and a function to transfer the acoustic data back to the host computer via File Transfer Protocol (FTP).

Upon further testing of the field-kits, an issue with limited bandwidth and intermittent connectivity was discovered. When using an O2 Storm router in a simultaneous Access Point/Client mode, the bandwidth and connectivity of the router was negatively impacted. By daisy-chaining two routers together and configuring one as an Access Point and the other as a Client, essentially dividing the tasks of the repeater among two routers, performance and reliability of the wireless network was greatly improved. The two configurations are illustrated below in Figure 19.

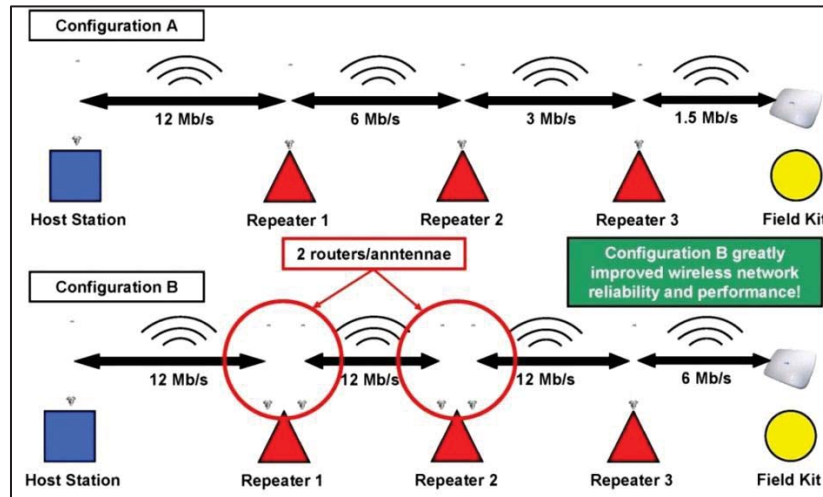


Figure 19. Evolution of wireless network configuration.

### 3.1.5 Apple Application Subjective Instrument Preparation

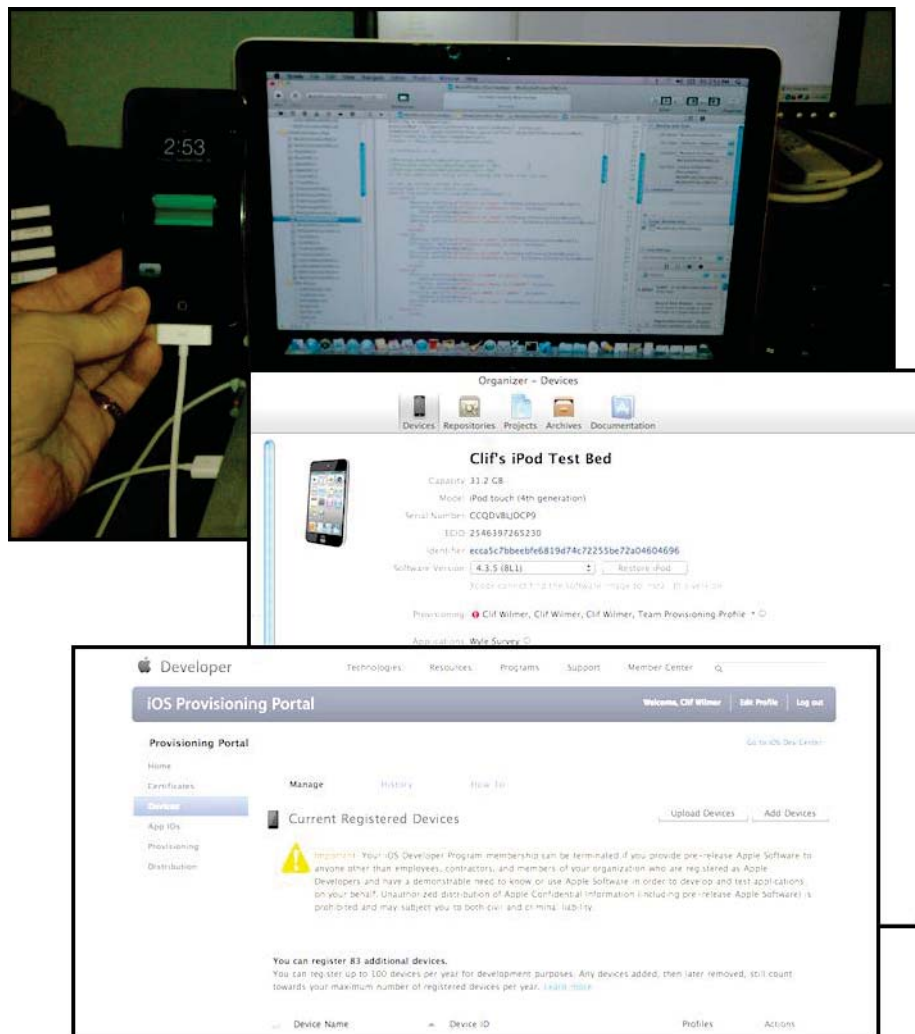
As described previously, one of the intentions of the Subjective Instrumentation pre-test was to identify possible ambiguity or sources of confusion and to also perform an assessment of the Apple application procedures. The Apple Application was developed as the third mode of Subjective survey administration. The screen layout and selection features were chosen to provide consistency across survey modes. The development included a sequence of application improvements and internal tests with WSPR team members, Wyle, and NASA volunteer employees. Prior to the NASA DFRC Pre-Test, the following was accomplished:

- Apple iOS Device Application was finished and fully functional and tested.
  - Web-based submission was fully functional and tested.
  - Email-based submission was fully functional and tested.
- Application underwent testing, both in-house at Wyle, and with WSPR team members at NASA DFRC.
- Application Server Side Back End was fully functional and tested.
- Sample subjective response data files were transmitted to Tetra Tech to ensure compatibility with web and paper response data.

Based on Wyle testing with non-WSPR volunteers, it was found that time meeting with the subject to conduct the Apple App installation requires 10 to 15 minutes, including time for a thorough application tutorial. This suggested that a time window of 30 minutes should be allotted for installations to allow for contingencies, plus additional travel time to next subject. This schedule was maintained for both the NASA DFRC pre-test and for the installations with WSPR subjects.

A Check List was created to prompt activities during the App Install and Tutorial, including words highlighting the need for the subject to double check time and date entered into the survey application to ensure that correct data is entered. A copy of the Apple Device Install Checklist may be found in Appendix D. Application installation on the NASA subjects' Apple device was accomplished using the same procedure for the WSPR experimental subjects (Figure 20) and is itemized below:

- Device is tethered to Laptop.
- Device UDID is obtained using Organizer tool.
- Device UDID is registered on Apple Developer Website.
- Device is added to Provisioning Profile.
- Provisioning Profile is downloaded and installed on Laptop.
- Program is installed on device.
- Installer checks date and time on device and provides guidance if date and time are not accurate.
- Installer walks participant through survey submission process and provides participant with a copy of application checklist.
- Device UDID copied down with associated Case ID for later use.



**Figure 20. Installation of application on Apple devices.**

Table 11 lists the equipment necessary for performing the Apple Application install on subject-provided iOS 5 devices – iPhone, iPod Touch, and iPad. Note that during the pre-test at DFRC, the Verizon AirCard cellular coverage was tested and was found to function adequately throughout the EAFB housing areas. Because a limited subject pool was assigned to the Apple survey mode, the WSPR team elected to utilize provisioning profiles and a tether cable rather than going through iTunes. This provided additional control over the application.



**Table 11. Tools Required for Apple Application Installation**

Tool	Purpose
Tethering Cable	Used to connect participant device to Laptop
MacBook Pro	Installed version of XCode is used to install application and manage portions of the device provisioning process.
Verizon AirCard	AirCard is used to ensure a reliable internet connection to the Apple Developer Website to obtain Provisioning Keys for device installation.

### 3.1.6 NASA DFRC Pre-Test of the Subjective Instruments

A pre-test of the single boom and daily summary surveys was conducted with a small sample of subjects selected from NASA DFRC volunteers. The pre-test was conducted over a 3-day period (from August 30 to September 1, 2011) and utilized all three modes of data collection that were planned for the experimental test period itself, including telephone follow-up interviews with a subset of participants from each mode to evaluate the survey instruments and data collection procedures.

Pre-test subjects were recruited with the assistance of WSPR's NASA DFRC/EAFB liaison, who circulated an announcement about the pre-test via email that explained the purpose of the pre-test eligibility requirements, and what participants would be asked to do. The NASA liaison was available to address questions and Tetra Tech staff was available for additional clarification as needed.

To be eligible, individuals had to work or be based at a location on the NASA DFRC grounds where they could hear sonic booms, and they anticipated working from that location from August 30 through September 1. Altogether 21 employees participated in the pre-test; of these, eight used the Apple-based application (seven on an iPhone and one using an iPod), five subjects completed paper forms, and eight participated using the Web survey.

Study procedures matched those planned for the experimental test period with a few exceptions. Due to the short time available, all instructions were sent by email and the paper forms were sent as attached electronic files with instructions to print multiple copies for use during the pre-test. No hard copy forms or hard copy instructions were mailed. A small number of survey questions include the text "while you were at home," which would not apply during the pre-test because sonic booms would be generated during working hours and participants were being asked to complete the forms from their work locations. Instead, participants were asked to answer these questions in terms of "while you were at work." A Wyle representative visited NASA DFRC to meet with participants who agreed to use their Apple mobile device for the pre-test. Wyle staff installed the survey application on devices, demonstrated its use, and answered questions. All installations were completed successfully.

August 30 through September 1, 2011 were selected as the pre-test field dates, with the expectation that NASA would create some sonic booms on August 31. Instructions were sent to participants via email on August 25. The instructions reminded participants of the study dates, explained the survey response tasks associated with the single-event and daily summary forms, provided mode-specific information (Web address and ID number) or attachments (paper forms). Participants were also told that some sonic booms may have a "double boom" noise (e.g., "boom-boom, boom-boom") and they should treat these as a single sonic boom, reporting them only once. Participants were contacted by telephone (August 26 and 29) to confirm receipt of the email, address any questions, and confirm their eligibility and availability on the pre-test study dates. Apple applications were installed on individuals' mobile devices on August 29 and (the morning of) August 30.

NASA sonic boom measuring equipment (SNOOPI) provided measures of actual boom times. No data were recorded on August 30 due to a facility circuit breaker malfunction. Several participants reported a boom that day at approximately 13:35. Six sonic booms were recorded on August 31, and these were the booms generated by a NASA

F-18 on behalf of WSPR. The booms were approximately 6 minutes apart, registering at 13:19, 13:26, 13:32, 13:38, 1:44, and 13:49. SNOOPI recorded one additional (non-WSPR) boom on September 1 at 11:50.

### 3.1.6.1 Completion of Survey Forms: Dryden Pre-Test

The tables below summarize completion of the single-event survey forms and the daily summary survey forms. We examine completion of the daily summary forms for all 3 days of the pre-test period; for the single boom survey forms, we focus on August 31 – the date when booms were generated specifically for the purpose of the pre-test.

As noted in Table 12, slightly more than 60 percent of all expected daily summary survey forms were submitted. A higher percent of forms were submitted by paper participants – 87 percent of all expected forms – and just over two-thirds of all Apple forms were submitted. Less than one-half of all daily summary forms that should have been submitted by Web participants were submitted. Eight of the 21 subjects submitted daily summary forms on each of the three pre-test days; one Apple participant and two Web participants did not submit any daily forms.

**Table 12. Completion of Daily Summary Survey Forms, August 30 – September 1**

Mode (N subjects)	Submitted	Expected	Response Rate
Apple (8 subjects)	16	24	67%
Paper (5 subjects)	13	15	87%
Web (8 subjects)	10	24	42%
Total (21 subjects)	39	63	62%

Note: The expected number of daily summary survey forms is number of subjects x number of days of pre-test (three). Participants were instructed to submit the daily summary each day, even if they did not notice any sonic booms and even if they were not working at their usual work location.

On August 31, 63 percent of all expected single boom survey forms were submitted. Although the overall completion rate is very similar to that for the daily summary, the distribution by mode differs. As shown in Table 13, the research team received over 70 percent of all Web forms and 60 percent of the forms they expected to receive from Apple participants. In contrast, participants using paper forms submitted just over one-half of the single boom survey forms that were expected based on the exposure to sonic booms on August 31. One Apple participant and one paper participant who were at their work locations on August 31 did not submit any single boom survey forms (not shown).

**Table 13. Completion of Single Boom Survey Forms on August 31**

Mode (N subjects)	Submitted	Expected	Response Rate
Apple (8 subjects)	25	42	60%
Paper (5 subjects)	13	24	54%
Web (8 subjects)	34	48	71%
Total (21 subjects)	72	114	63%

Note: The expected number of single-event survey forms is number of subjects x number of booms (six) with an adjustment for exposure. One Apple participant and one paper participant indicated they were not at their work location on August 31 (i.e., not exposed).

To maximize survey response, we reviewed Web data after the first day of the pre-test. All participants should have submitted a daily summary form even if no sonic booms occurred. After seeing less than full compliance with the survey instructions, we sent an email reminder to all participants on the morning of August 31 (Central time) before the pre-test generated booms occurred. The reminder clarified how and when to complete the survey forms and emphasized the importance of completing the daily summary form everyday through September 1. Telephone follow-up calls were made with selected Web participants repeatedly over the 3-day period to encourage cooperation.

It is not surprising that completion rates of the single boom forms for Web participants were higher than the other modes. The pre-test participants tended to be sitting at their desks and working at their computers when the sonic booms occurred. Completing the forms was simply a matter of opening a Web browser, or switching pages on a

browser that was already open, and clicking on a dozen or so radio buttons before returning to their work. Accessing the Apple application was similarly convenient for participants who kept their mobile phones readily at hand. In contrast, participants suggested the paper forms introduced more of an interruption – they had to stop working on their computers, locate the paper forms (and possibly clear a spot on their desks), and complete the survey form before returning to their work tasks. Alternatively, the research team discovered that the Web mode faced an additional barrier for completing the daily summary form – Participants who forgot to submit the form before shutting down the computer for the night were disinclined to re-boot the computer in order to login and complete the survey. The paper forms, on the other hand, could still be accessed easily. Nothing prevented participants from submitting the daily summary forms the following morning, but Web participants were the least inclined to do so.

### 3.1.6.2 Timeliness of Response: Dryden Pre-Test

We examined two aspects of response timeliness – how quickly single boom forms were submitted following a boom and how closely the “reported time” aligned with the time of the boom as recorded by SNOOPI. For Apple and Web surveys we compared the time the boom was reported to occur with the device time-stamp when the survey application was ready for transmission (Apple) and the time-stamp on the server when the form was submitted (Web). Paper surveys lack an independent or automated time-stamp and therefore could not be examined. With few exceptions, most surveys were completed very soon after the boom was noticed. Among Apple participants, the time difference ranged from 24 seconds to 3 minutes. Among Web participants, the difference ranged from 0 to 8 minutes. Ten single booms were reported to have occurred before the server timestamp; for example, the boom was noticed at 1332 and the timestamp was 1330. The range for these cases was 1–4 minutes.

Figure 3-4 below presents the times that subjects noticed a sonic boom and the times the sonic booms actually occurred (as recorded by SNOOPI). The chart shows data only for August 31, which is the date that sonic booms were generated on behalf of WSPR. Although responses cluster around the actual boom times in many cases, there is a substantial number of individual responses that are as likely to be reported midway between two booms as they are to align closely with a boom. Other reports that are close but not spot-on might just as easily be a report about a boom that already occurred (i.e., a delayed subjective response) as a report about a boom that has “yet to occur,” at least as recorded by SNOOPI (i.e., clock time incorrect or rounded down). This variability occurs for all of the survey modes. While there appear to be more discrepant reports for Web and Apple participants, it is difficult to attribute this pattern to mode. There were fewer paper participants and single boom completion rates were lower for the paper mode, so there are overall fewer observations to analyze.

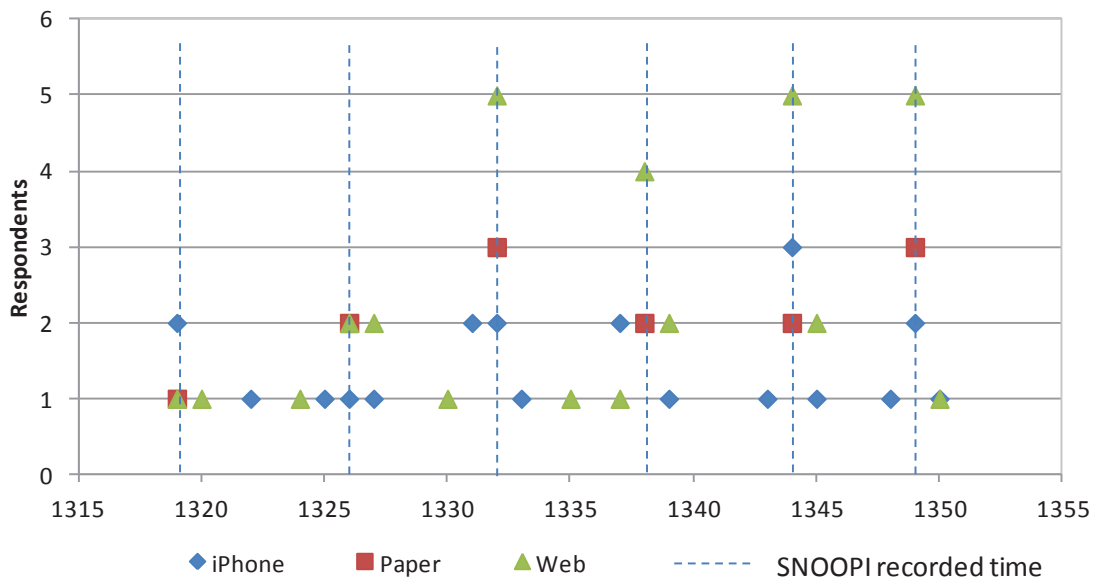


Figure 21. Reported boom times and actual boom times as recorded by SNOOPI, August 31, 2011.

### 3.1.6.3 Follow-up Interviews with Dryden Pre-Test Participants

Telephone interviews were conducted with a subset of participants after the pre-test data collection period. The interviews were conducted September 12 – 19 after the survey data had been received and reviewed. These qualitative interviews used a topic guide, or list of broadly worded questions, rather than a script that was followed verbatim by the researcher conducting the interview. The guide addressed the following issues:

- Comprehension of survey instructions,
- Functionality of the survey mode and ease of use,
- Barriers or challenges to completing the survey forms in a timely fashion, and
- Follow-up questions on specific issues or response patterns unique to a given participant.

Eleven follow-up interviews were conducted; three participants had been assigned to the Apple application (two iPhone and one iPod), four to the paper form, and four to the web survey. The main lessons learned from these interviews included the following:

- Review the data early and often to encourage completion and check for data errors; for the full-scale study paper forms should be mailed back more than the two times initially planned.
- Conduct more frequent follow-ups across all modes and/or develop tools or checklists to increase completion.
- Highlight key information and critical tasks in the instructions; do not rely solely on electronic distribution of materials even for Web or Apple participants. Electronic communications were seldom read by the pre-test participants.
- To simplify response tasks, instruct participants to complete the daily summary form every day, Monday through Sunday, regardless of whether the subject is at home or noticed any booms.
- The single boom survey task can become burdensome; study fatigue is likely to occur and completion rates may decline over time.
- The study itself – and the repetition of the survey task – may affect subjective responses to sonic booms; that is, subjects may notice the booms more or become more annoyed by the booms because activities are frequently interrupted by the survey response task. The short interval between booms (6 minutes) exacerbated annoyance with the interruption.
- The web survey will be more inconvenient and less accessible if participants are not sitting at their computers when booms occur.
- The 11-point response scale for several survey questions demanded more granularity than individuals felt they could reliably report or differentiate.

In terms of survey mode, the pre-test interviews revealed the following:

- Apple application
  - Easy to use, intuitive, and readily accessible because the device is at hand
  - In-person installation offers a useful training opportunity
  - Preferred mode by most participants if they were given a choice
  - Amenable to remote Quality Control (QC) (data were downloaded daily and available for review by the survey team) and missing or invalid data can be disallowed by the programmed instrument
- Paper
  - Survey forms are simple, straightforward, and well-designed
  - May be more accessible than the Web for individuals not working at a computer
  - Not amenable to remote quality control
  - Questions may be skipped and invalid answers cannot be prevented
  - Frequent mail-backs of completed forms should be planned for the experimental test period to strengthen QC and foster regular and timely completion



- Web
  - Quick and easy to complete if individuals are working at the computer
  - Web pages and presentation of survey questions are clear and well-designed
  - Amenable to remote QC (data were downloaded daily) and missing or invalid data can be prevented

### 3.1.7 Subject Communications and Activities Prior to the WSPR Flights

In the weeks leading up to the November 4th kick-off of the WSPR flight tests, the survey team’s communications with subjects focused on three areas – 1) arranging installation of the Apple application on personal devices for the fifteen subjects assigned to this mode, 2) preparing and distributing instructions and survey materials to subjects, and 3) re-confirming eligibility to participate. Table 14 summarizes the key activities performed in support of the subjective response surveys prior to the WSPR flights.

**Table 14. Subjective Response Survey Activity Prior to the WSPR Flights**

Date	Subjective Response Survey Support Activity
Oct 11-13	Schedule appointments for installation and demonstration of Apple application
Oct 18-20	Installation and demonstration of Apple application (in-person, on-site)
Oct 22	Study instructions sent by email to Apple and Web participants
Oct 24	Study instructions, paper survey forms, and return mail supplies sent by FedEx to all participants (back-up supplies for Apple & Web, 19 daily packets for paper participants)
Oct 31-Nov3	Telephone follow-up to confirm receipt of paper materials, address questions, and re-confirm eligibility

**Apple Application Installations.** A representative of Wyle was scheduled to be on-base October 18 – 20 to meet in-person with participants, install the Apple application, provide a demonstration, and answer questions. Appointments were arranged in advance by interviewers from Tetra Tech’s in-house telephone survey lab, with calls being placed October 11 – 13 to schedule appointments. All installations were completed successfully with 13 subjects using the application on iPhones and two subjects using the application on iPods.

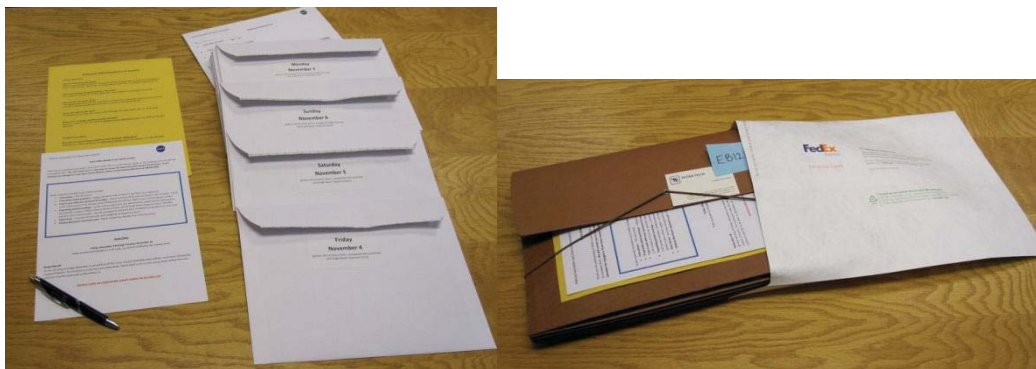
**Survey Instructions.** All subjects received hard-copy instructions on the survey response tasks, and participants using the Apple and Web modes also received instructions via email. The instructions included:

- The start and end dates of the study period.
- How the study would “kick-off” on November 4 with a loud boom followed by a series of booms.
- Description of the single-boom form and instructions to complete this form each time they noticed a boom.
- Description of the daily summary form, instructions to complete this form once at the end of each day, and the importance of completing this form every day regardless of whether they were at home or whether they noticed any booms.
- Important reminders and clarifications, such as recording a “double boom sound” (boom-boom, boom-boom) as a single boom, going about their normal activities, and clarifying that “at home” meant while in their homes, their yards, or the immediate vicinity.
- Participants were also provided with an email and toll-free number to call for assistance, and they were told they might be contacted at the end of the study for a brief interview.
- The study would continue until November 22 and we would call if the study ended earlier.

Appendix D provides copies of the hard-copy and emailed instructions and the FAQ.

**Mail Packets with Paper Survey Forms.** All participants were sent packets with paper survey forms. As shown in Figure 22 below, the packets included:

- Instructions (white paper) and FAQ (yellow paper).
- Mailing envelopes for returning completed survey forms (postage affixed, address labels, and ID codes attached).
- Daily summary forms.
- Single-boom forms.
- The subject's survey ID.
- An expanding pocket file folder holding all of the materials.
- A pen and business card of the project team member who could provide technical assistance.



*Figure 22. Paper materials shipped to all study participants.*

For participants assigned to paper, the materials were organized into 19 pre-posted envelopes – one for each day of the study, labeled and sequenced in order from November 4–22. Each day's envelope included one daily summary form (blue) and 10 single event forms (white) and that envelope served as the day's return mailer. The subject needed only to complete the forms, put them in the envelope designated for that day as shown on the label, seal and drop it in a mailbox. A tear-off tablet with extra single-boom forms was also provided. By placing survey forms in 19 pre-posted envelopes that also served as return mailers, there was no need for participants to keep track of completed forms from 1 day to the next. Instead, they began each day with that day's envelope as indicated by a large label (e.g., "Tuesday, November 8"), removed the blank single boom survey forms as needed during the day when sonic booms occurred, completed the daily summary form at the end of the day, placed all completed forms back in the envelope, removed the plastic strip on the self-adhesive envelope, and dropped it in a USPS mailbox that evening or the next morning.

Participants assigned to the Apple and Web modes were also sent a mail packet with 2 days' supply of paper forms. They were instructed to complete the paper forms and return them in the pre-posted envelopes if they encountered difficulty with Internet service or mobile coverage.

Mail packets were sent to all participants via FedEx on October 24. Follow-up calls were placed October 31 – November 3 to verify receipt of the materials and address any questions. During these telephone contacts, we also invited participants to sign-up for daily reminder messages that could be sent by email or text message to their mobile telephones. Thirty-one subjects elected to receive a reminder via one or both channels before the experimental test period began. An additional four subjects signed up for reminders after the study began.

**Re-Confirming Eligibility of Subjects.** To maximize completeness of the survey data, it was essential that study subjects, many of whom were recruited several months earlier, were still living on base. Eligibility was reconfirmed during the baseline survey interviews that were conducted September 19 – October 14, 2011 and during

contacts with subjects in the 2 weeks leading up to the experiment. The requirement that all subjects must reside on base was also emphasized in all instructions and survey materials, and subjects were asked to contact the survey coordinator by email or telephone if they were moving off base. Altogether as a result of the final contacts and instructions, five subjects were determined to be ineligible before the experimental test period began because they were moving off-base or would be away from the base during the study period due to a new assignment. Of the five subjects, one had been assigned to the Web and four to paper. Ultimately, 52 subjects completed single event and daily summary forms during the 2 weeks of the test – in addition to the five determined to be ineligible before November 4<sup>th</sup>, two persons dropped out after the test began and the research team could not retrieve data from a subject using an iPod Touch due to technical difficulty. Of the 52 subjects, 22 were assigned to Web, 16 used paper, and 14 used an Apple device.

## 3.2 As-flown Flight Test

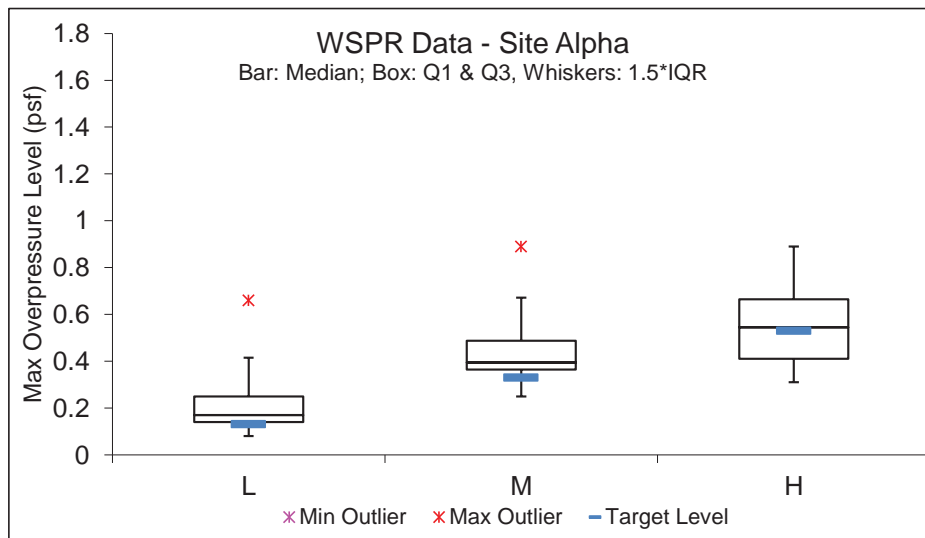
### 3.2.1 Flight-Test Overview

The WSPR test was conducted from November 4–18, 2011, and included 22 total F-18 flights (excluding the pre-test flight). Of these test-flight missions, 21 were successes and 1 was an aborted flight. There were 91 passes over the WSPR community, which resulted in 89 planned sonic booms in the residential community. Of the 89 WSPR booms, 84 were low-amplitude sonic booms and 5 were “full-sized” sonic booms. The low-amplitude booms were created by executing the low-boom dive maneuver as described in Section 2.2. The full-sized booms were generated by the F-18 flying a constant Mach number flight at a fixed altitude. Figure 23 illustrates the desired and actual sonic boom overpressures obtained during the WSPR program.

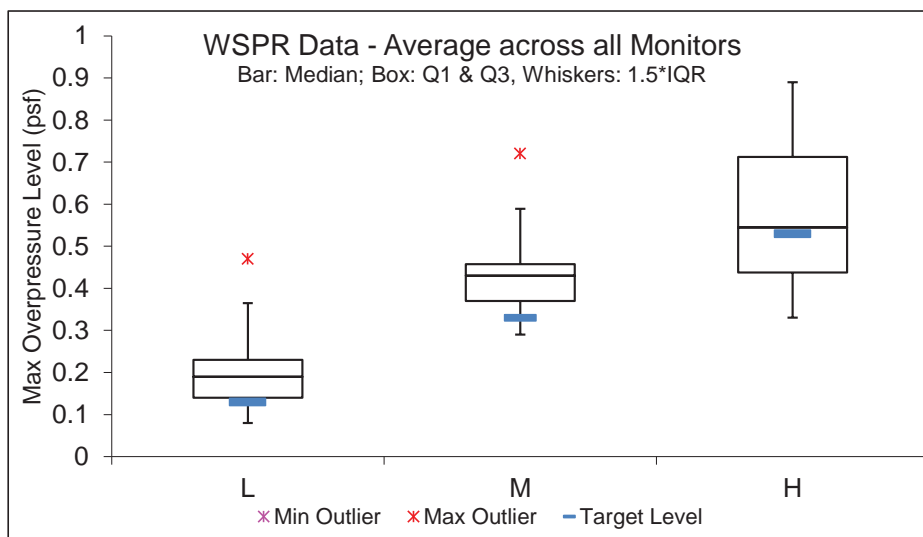
There were 21 non-WSPR booms included in the cumulative noise exposure during the WSPR test period. The number and range of booms for each test day is provided in Table 15. The booms are grouped by range, regardless of whether the source was from a WSPR or a non-WSPR flight. There were 84 booms in the low-boom range and 26 booms in the higher noise range for a total of 110 booms in the WSPR field test.

**Table 15. Number and Range of Booms per Test Day**

Range	Low	Med	High	(Non-Low) Higher	(Non-Low) Full	Non-Low- Booms /Day	Total Booms /Day
PSF Midpoint	.13 psf	.33 psf	.53 psf	.73 psf	.98+ psf		
Test Day							
1	1		1	1	1	2	4
2	4	2	2		1	1	9
3	4	4	4		1	1	13
4		3	4	4	1	5	12
5		4				0	4
6	3	6	2	2	1	3	14
7	4	1	4	1	4	5	14
8	3	8	2	1	13	14	27
9	5	3				0	8
10	4	1				0	5
<b>Total</b>	<b>28</b>	<b>32</b>	<b>19</b>	<b>9</b>	<b>22</b>	<b>31</b>	<b>110</b>



*(a) Comparison with measured data (psf) at Site Alpha.*



*(b) Comparison with Average data (psf) across all Measurement sites.*

**Figure 23.** *Desired L (.13psf), M (.33psf), and H (.53psf) and achieved WSPR sonic boom overpressures.*

### 3.2.2 Go/No-Go Conditions

A Go/No-Go decision was made by the NASA Principal Investigator prior to each day's testing and prior to each flight. This section describes the criteria established for the WSPR Go/No-Go decision.

Flights will not occur in the event of the following:

- Aircraft readiness or safety issues are not met, as determined by NASA
- Weather condition including:
  - Precipitation
  - Lightning. NASA’s rules regarding lightning safety for personnel will be followed.
  - Meteorological Front within or passing through the airspace
- Communication system failure
- Instrumentation failure
  - Failure of flight instrumentation such that position and orientation information cannot be obtained or the aircraft cannot reliably perform the low-boom dive maneuver
  - Excessive number of field-kits channels not ready
  - Failure to obtain initial (pre-flight) upper air data
  - Widespread internet or Verizon wireless outage in the EAFB housing area

### 3.2.3 Daily Flight Planning

Daily flight planning was performed by NASA. This included computation of the F-18 waypoints based on the most recent GPSsonde upper air meteorological data. Daily flight planning also included an assessment of the best flight cards to be flown depending on the atmospheric conditions. The experimental design intentionally included flexibility to allow for day of flight variations (see section 2.1.5). More detailed criteria for specific aircraft flight card selection was developed by NASA DFRC pilots and operations personnel and are not reported here.

### 3.2.4 WSPR Orientation Exercise

The WSPR orientation exercise was conducted on Friday, November 4<sup>th</sup>. The experimental test period<sup>6</sup> began on the following Monday, November 7, 2011. All subjects already had been sent survey materials and instructions for the test period, and these same materials would be used for the orientation exercise. Specifically, subjects assigned to the Web survey mode had been sent instructions on how to access the Web survey, provided with an ID number, and asked to confirm they could access the website. For subjects assigned to the Apple mode, the survey application had been installed on their personal mobile devices (iPhone, iPad, and iPod); and, individuals assigned to paper mode had been sent packets with paper survey forms and mail-back envelopes. Tetra Tech confirmed receipt of the materials by telephone or email with subjects from October 31 – November 3.

The instructions sent to subjects stated that the study would kick-off on the morning of Friday, November 4. They were told to expect a loud boom about 10:00 a.m. followed by a series of booms. The loud boom would mark the start of the study and they should begin completing the survey forms at that time, continuing until the study period ended. Subjects were also told that some sonic booms have a “double-boom” sound (e.g., “boom-boom, boom-boom”) and that they should count this as a single sonic boom, reporting it only once on the survey forms. The description of the study kick-off, including the date and approximate timing, is included in Appendix D “NASA Sonic Boom Study Instructions.”

F-18 flights were used to create the sonic booms and the pilots executed maneuvers to generate a pre-determined sequence of booms that covered the range of “high” “medium” and “low” booms as defined in the experimental test plan. This sequence was *not* communicated to subjects; they were informed only that they would hear a loud boom followed by a series of booms.

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<sup>6</sup> The first experimental flight was initially planned for the afternoon of November 4<sup>th</sup>, but was cancelled due to inclement weather.



### **3.2.5 WSPR Sonic Boom Environment during Test Execution**

Tables 16 and 17 contain comprehensive master listings of the sonic boom events (processed and analyzed) that occurred during the execution of the WSPR test. These are also included in Appendix E.



Table 16. WSPR Sonic Boom Master List

Sequence #	Primary Recorded Data				Backup / Estimated Data				WSPR F-18 boom?	Recorded On Main Array (Y)	Estimated Overpressure / Aural (psf)	Supplemental Chapel II Mic Overpressure @Array (psf)	Recorded On Main Array (Y)	WSPR F-18 boom?	Field and Processing Notes
	UTC DATE	LOCAL DATE	Recorded Local Time	Site Alpha Peak Overpressure (psf)	SNOOP UTC TIME	SNOOP LOCAL TIME	SNOOP Peak Overpressure (psf)	Estimated Local Time							
1	11/4/2011	11/4/2011	11:22:14	0.84	18:22:18	11:22:18	1.15		Y	Y		Y	Y		
2	11/4/2011	11/4/2011	11:32:36	0.21	18:32:41	11:32:41	0.24		Y	Y		Y	Y		
3	11/4/2011	11/4/2011	11:41:27	0.44	18:41:32	11:41:32	0.54		Y	Y		Y	Y		
4	11/4/2011	11/4/2011	11:48:55	1.17	18:49:00	11:49:00	0.86		Y	Y		Y	Y		
5	11/7/2011	11/7/2011	12:13:42	0.10	20:13:47	12:13:47	0.09		Y	Y		Y	Y		
6	11/7/2011	11/7/2011	12:23:58	0.11	20:24:03	12:24:03	0.12		Y	Y		Y	Y		
7	11/7/2011	11/7/2011	12:36:50	0.19	20:36:55	12:36:55	0.26		Y	Y		Y	Y		
8	11/7/2011	11/7/2011	12:56:03	0.09	20:56:08	12:56:08	0.11		Y	Y		Y	Y		
9	11/7/2011	11/7/2011			22:33:44	14:33:44	1.51		N	N		N	N		
10	11/7/2011	11/7/2011	15:18:42	0.66	23:18:48	15:18:48	0.22		Y	Y		Y	Y		
11	11/7/2011	11/7/2011	15:32:10	0.29	23:32:15	15:32:15	0.28		Y	Y		Y	Y		
12	11/7/2011	11/7/2011	15:43:47	0.38	23:43:53	15:43:53	0.44		Y	Y		Y	Y		
13	11/8/2011	11/7/2011	16:03:56	0.55	00:04:00	16:04:00	0.46		Y	Y		Y	Y		
14	11/8/2011	11/8/2011	07:30:56	0.16	15:31:01	07:31:01	0.18		Y	Y		Y	Y		
15	11/8/2011	11/8/2011	07:43:05	0.16	15:43:10	07:43:10	0.17		Y	Y		Y	Y		
16	11/8/2011	11/8/2011	07:59:35	0.49	15:59:39	07:59:39	0.58		Y	Y		Y	Y		
17	11/8/2011	11/8/2011	08:11:43	0.37	16:11:48	08:11:48	0.42		Y	Y		Y	Y		
18	11/8/2011	11/8/2011	08:22:48	0.17	16:22:44	08:22:44	0.22	0.19	Y	Y		Y	Y	SNOOP: too low, no autoflagger. Missed call, no manual trigger	
19	11/8/2011	11/8/2011	08:34:11	0.15	16:34:16	08:34:16	0.22		Y	Y		Y	Y		
20	11/8/2011	11/8/2011	08:43:18	0.39	16:43:23	08:43:23	0.41		Y	Y		Y	Y		
21	11/8/2011	11/8/2011	09:02:50	0.54	17:02:55	09:02:55	0.60		Y	Y		Y	Y		
22	11/8/2011	11/8/2011						0.35	N	N		N	N	Aural Estimation	
23	11/8/2011	11/8/2011	14:13:06	0.39	22:13:12	14:13:12	0.34		Y	Y		Y	Y		
24	11/8/2011	11/8/2011	14:23:34	0.61	22:23:38	14:23:38	0.52		Y	Y		Y	Y		
25	11/8/2011	11/8/2011	14:37:55	0.40	22:37:59	14:37:59	0.43		Y	Y		Y	Y		
26	11/8/2011	11/8/2011			22:50:35	14:50:35	0.86		N	N		N	Y	Site M (manually triggered) also recorded the boom	
27	11/9/2011	11/9/2011							Y	Y		Y	Y		
28	11/9/2011	11/9/2011	11:22:01	0.68	19:22:05	11:22:05	1.06		Y	Y		Y	Y		
29	11/9/2011	11/9/2011	11:33:57	0.47	19:34:02	11:34:02	0.50		Y	Y		Y	Y		
30	11/9/2011	11/9/2011	11:43:36	0.55	19:43:41	11:43:41	0.71		Y	Y		Y	Y		
31	11/9/2011	11/9/2011	12:04:58	0.52	20:05:02	12:05:02	0.54		Y	Y		Y	Y		
32	11/9/2011	11/9/2011	14:16:02	0.66	22:16:06	14:16:06	0.68		Y	Y		Y	Y		
33	11/9/2011	11/9/2011	14:28:22	0.47	22:28:26	14:28:26	0.50		Y	Y		Y	Y		
34	11/9/2011	11/9/2011	14:42:49	0.38	22:42:54	14:42:54	0.30		Y	Y		Y	Y		
35	11/9/2011	11/9/2011	14:58:25	0.35	22:58:29	14:58:29	0.34		Y	Y		Y	Y		
36	11/9/2011	11/9/2011	15:26:07	0.7	23:26:11	15:26:11	0.78		Y	Y		Y	Y		
37	11/9/2011	11/9/2011	15:41:11	0.66	23:41:15	15:41:15	0.73		Y	Y		Y	Y		
38	11/10/2011	11/9/2011	15:51:14	0.34	23:51:18	15:51:18	0.49		Y	Y		Y	Y		
39	11/10/2011	11/9/2011	16:11:07	0.36	00:11:11	16:11:11	0.42		Y	Y		Y	Y		
40	11/10/2011	11/10/2011	11:28:15	0.41	19:28:20	11:28:20	0.36		Y	Y		Y	Y		
41	11/10/2011	11/10/2011	11:38:44	0.35	19:38:48	11:38:48	0.33		Y	Y		Y	Y		
42	11/10/2011	11/10/2011	11:51:13	0.25	19:51:17	11:51:17	0.33		Y	Y		Y	Y		
43	11/10/2011	11/10/2011	12:09:51	0.38	20:09:55	12:09:55	0.34		Y	Y		Y	Y		
44	11/14/2011	11/14/2011	08:21:25	0.17	16:21:30	08:21:30	0.19		Y	Y		Y	Y		
45	11/14/2011	11/14/2011	08:31:34	0.36	16:31:38	08:31:38	0.37		Y	Y		Y	Y		
46	11/14/2011	11/14/2011	08:41:21	0.3	16:41:26	08:41:26	0.21		Y	Y		Y	Y		
47	11/14/2011	11/14/2011	08:54:50	0.33	16:54:55	08:54:55	0.34		Y	Y		Y	Y		
48	11/14/2011	11/14/2011	09:04:18	0.1	17:04:21	09:04:21	0.12		Y	Y		Y	Y		
49	11/14/2011	11/14/2011	09:49:22	1.65	17:49:22	09:49:22	1.85		Y	Y		Y	N	Non WSPR	
50	11/14/2011	11/14/2011	14:12:14	0.18	22:12:19	14:12:19	0.29		Y	Y		Y	Y		
51	11/14/2011	11/14/2011	14:25:56	0.53	22:26:01	14:26:01	0.35		Y	Y		Y	Y		
52	11/14/2011	11/14/2011	14:44:54	0.31	22:44:58	14:44:58	0.62		Y	Y		Y	Y		
53	11/14/2011	11/14/2011	14:53:30	0.48	22:53:35	14:53:35	0.48		Y	Y		Y	Y		
54	11/14/2011	11/14/2011	15:23:02	0.61	23:23:06	15:23:06	0.66		Y	Y		Y	Y		
55	11/14/2011	11/14/2011	15:37:45	0.4	23:37:50	15:37:50	0.38		Y	Y		Y	Y		
56	11/14/2011	11/14/2011	15:47:41	0.89	23:47:45	15:47:45	0.77		Y	Y		Y	Y		
57	11/15/2011	11/14/2011	16:07:27	0.38	00:07:32	16:07:32	0.32		Y	Y		Y	Y		

Table 17. WSPR Sonic Boom Master List

Sequence #	UTC DATE	LOCAL DATE	Site Alpha Recorded Local Time	Site Alpha Peak Overpressure (psf)	SNOOPI UTC TIME	SNOOPI LOCAL TIME	SNOOPI Recorded LOCAL TIME	SNOOPI Peak Overpressure (psf)	Estimated Local Time	Supplemental Chapel Hill Mic Overpressure @Array (psf)	Estimated Overpressure / Array (psf)	Recorded On Main Array (?)	WSPR F-13 boom?	Field and Processing Notes
57	11/15/2011	11/15/2011	10:26:52	0.35	18:26:57	10:26:57		0.30				Y	Y	
58	11/15/2011	11/15/2011	10:38:19	0.17	18:38:24	10:38:24		0.14				Y	Y	
59	11/15/2011	11/15/2011	10:47:34	0.29	18:47:39	10:47:39		0.20				Y	Y	
60	11/15/2011	11/15/2011	10:58:36	0.16	18:58:41	10:58:41		0.14				Y	Y	
61	11/15/2011	11/15/2011	11:08:24	0.14	19:08:29	11:08:29		0.17				Y	Y	
62	11/15/2011	11/15/2011	13:25:06	0.89	21:25:10	13:25:10		0.62				Y	Y	
63	11/15/2011	11/15/2011	13:33:44	0.74	21:33:48	13:33:48		0.82				Y	Y	
64	11/15/2011	11/15/2011	13:46:14	0.59	21:46:19	13:46:19		0.46				Y	Y	
65	11/15/2011	11/15/2011	13:56:19	0.42	21:56:24	13:56:24		0.59		0.46		Y	Y	No SNOOPI
66	11/15/2011	11/15/2011	14:07:07	0.31	22:07:09	14:07:09		1.19				Y	Y	
67	11/15/2011	11/15/2011	15:29:47	0.59	23:29:52	15:29:52		1.43				Y	Y	
68	11/15/2011	11/15/2011	15:36:24	1.1	23:36:29	15:36:29		1.30				Y	Y	
69	11/15/2011	11/15/2011	15:44:24	1.11	23:44:29	15:44:29		1.30				Y	Y	
70	11/15/2011	11/15/2011	15:50:21	1.08	23:50:26	15:50:26		1.35				Y	Y	
71	11/16/2011	11/16/2011	09:03:23	0.3	17:03:29	09:03:29		0.25				Y	Y	SNOOPI missed bow shock, est. from tail shock. 0.0913 (0.25?)
72	11/16/2011	11/16/2011	09:15:52	0.25	17:15:56	09:15:56		0.23				Y	Y	
73	11/16/2011	11/16/2011	09:26:03	0.2	17:26:08	09:26:08		0.17				Y	Y	
74	11/16/2011	11/16/2011	09:39:43	0.16	17:39:48	09:39:48		0.21				Y	Y	
75	11/16/2011	11/16/2011	09:51:54	0.23	17:51:59	09:51:59		0.22				Y	Y	
76	11/16/2011	11/16/2011	13:47:50	1.76	21:47:50	13:47:50		1.66				Y	N	Non-WSPR SNOOPI caught the first of two big booms at 13:47 local.
77	11/16/2011	11/16/2011	13:47:58	1.69		13:47:58			1.61			Y	N	Non-WSPR. The array auto recorded both as being 8 seconds apart.
78	11/16/2011	11/16/2011							13:48:39	2.04		Y	N	Non-WSPR. Plane-Only recorded at Golf at 2.04 psf
79	11/16/2011	11/16/2011							13:48:48	1.11		Y	N	Non-WSPR. Plane-Only recorded at Golf 1.11 psf
80	11/16/2011	11/16/2011							13:57:00		0.25	Y	N	Non-WSPR Low Boom
81	11/16/2011	11/16/2011										N	N	Heard two big booms. Assume 10 sec separation, equal amplitude
82	11/16/2011	11/16/2011							14:37:04		1.65	N	N	
83	11/16/2011	11/16/2011										N	N	Array was not set to autotrigger. Recorded at Chapel 2.
84	11/16/2011	11/16/2011										N	N	Array was not set to autotrigger. Recorded at Chapel 2.
85	11/16/2011	11/16/2011										N	N	Chapel 2 captured two big booms and the little boom
86	11/16/2011	11/16/2011								1.60		N	N	
87	11/16/2011	11/16/2011								0.28		N	N	
88	11/16/2011	11/16/2011										N	N	
89	11/16/2011	11/16/2011										N	N	
90	11/16/2011	11/16/2011	15:39:00	0.28	23:39:05	15:39:05		0.29				Y	Y	
91	11/16/2011	11/16/2011	15:53:19	0.39	23:53:24	15:53:24		0.40				Y	Y	
92	11/16/2011	11/16/2011										Y	Y	
93	11/16/2011	11/16/2011								0.43		N	N	
94	11/17/2011	11/17/2011										N	N	
95	11/17/2011	11/17/2011										N	N	
96	11/17/2011	11/17/2011	16:13:58	0.31	00:14:03	16:14:03		0.35				Y	Y	
97	11/17/2011	11/17/2011	16:23:58	0.26	00:24:03	16:24:03		0.30				Y	Y	
98	11/17/2011	11/17/2011	16:09:51	0.2	18:09:57	16:09:57		0.19				Y	Y	
99	11/17/2011	11/17/2011	16:10:24	0.17	18:10:29	16:10:29		0.17				Y	Y	
100	11/17/2011	11/17/2011	16:32:48	0.22	18:32:48	16:32:48		0.24				Y	Y	
101	11/17/2011	11/17/2011	16:49:24	0.21	18:49:29	16:49:29		0.23				Y	Y	
102	11/17/2011	11/17/2011	11:03:43	0.22	19:03:48	11:03:48		0.23				Y	Y	
103	11/17/2011	11/17/2011	11:15:05	0.1	19:15:10	11:15:10		0.09				Y	Y	
104	11/17/2011	11/17/2011	11:39:07	0.08	19:39:12	11:39:12		0.08				Y	Y	
105	11/17/2011	11/17/2011	12:06:17	0.1	20:06:22	12:06:22		0.12				Y	Y	
106	11/18/2011	11/18/2011	07:20:32	0.17	15:20:37	07:20:37		0.20				Y	Y	
107	11/18/2011	11/18/2011	07:28:16	0.12	15:28:20	07:28:20		0.11				Y	Y	
108	11/18/2011	11/18/2011	07:42:00	0.08	15:42:05	07:42:05		0.12				Y	Y	
109	11/18/2011	11/18/2011	07:50:53	0.28	15:50:58	07:50:58		0.24				Y	Y	
110	11/18/2011	11/18/2011	08:09:23	0.12	16:09:27	08:09:27		0.14				Y	Y	

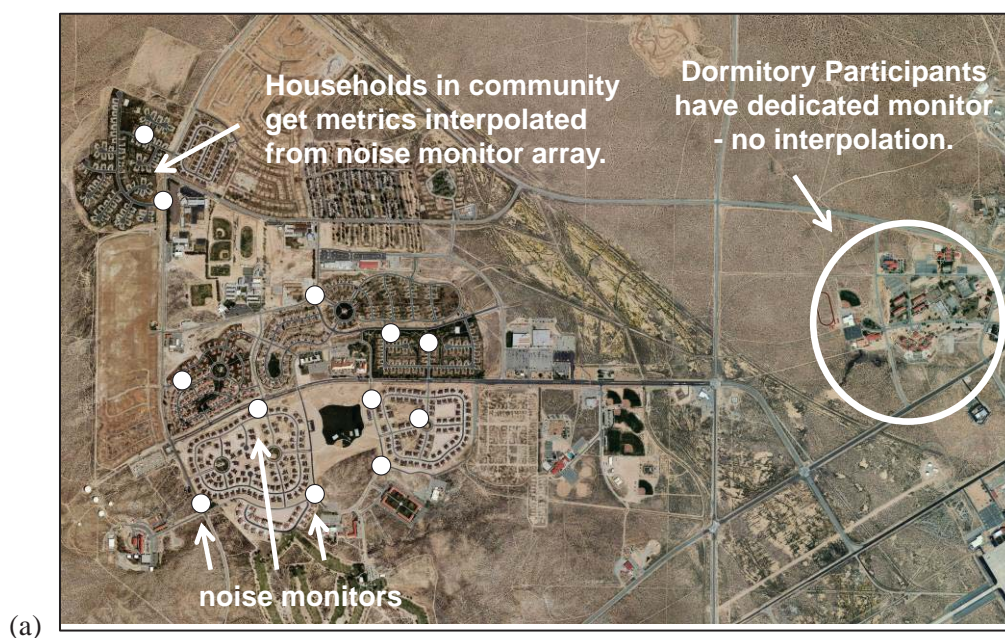


### 3.3 Objective Data Collection

#### 3.3.1 Acoustic Array and Acoustic Instrumentation

The acoustic array was spread across the main housing neighborhoods at EAFB. Figure 24 is a graphical layout of the microphone (field-kit) locations, the wireless repeater locations and the host computer relative to the EAFB housing area. The location of the field-kit nodes was determined by two main factors – location of the human subjects and performance of the wireless communication hardware. Reliable communication along the transmission path between the host computer and any particular field-kit was essential. Therefore, the location of the primary host computer was chosen due to its centralized proximity to most of the human subject locations. The wireless repeater locations were chosen based on the performance of the wireless networking hardware. Development testing of the field-kit array showed the reliability of the wireless communication was highly dependent on line of sight between any two components of the wireless network. The elevation of the broadcast antennae was also significant in the communication range between components in the wireless network. Additionally, development testing showed that the number of repeaters should not exceed three “hops” in the communication chain. Based on these constraints, the repeater locations were determined to provide field-kit deployment across the extent of the housing community while keeping the networking components within their performance capability. This resulted in spacing between networking components that varied between 0.1 miles to 0.5 miles. The distance between the main housing area and the residential apartments (or dorms) exceeded the wireless range capability of the field-kit array components, both in the range of a single wireless component and in the number of repeaters that could be deployed within that distance. As a result, a secondary host computer was directly connected to a field-kit located adjacent to the apartment parking lot and ensured reliable data acquisition at that location.

The acoustic instrumentation communicates wirelessly between the host computer and the field-kit nodes, and the wireless repeater hardware as required, depending on the path and distance between the host computer and a particular field-kit. The wireless networking utilizes TCP/IP transmitted over 2.4 GHz wireless G communication protocol. Approval to broadcast and operate over a localized wireless network was required by EAFB. The evaluation of the field-kit wireless hardware was conducted by NASA DFRC personnel. The evaluation consisted of analyzing the spectral output of the two types of wireless routers utilized for the WSPR testing (an O2storm and a GS2400, both from RadioLabs, Inc). The spectral output from the routers was examined by a spectrum analyzer and was inspected to ensure the broadcast frequency of the routers was within allowable thresholds for communication hardware of that nature.



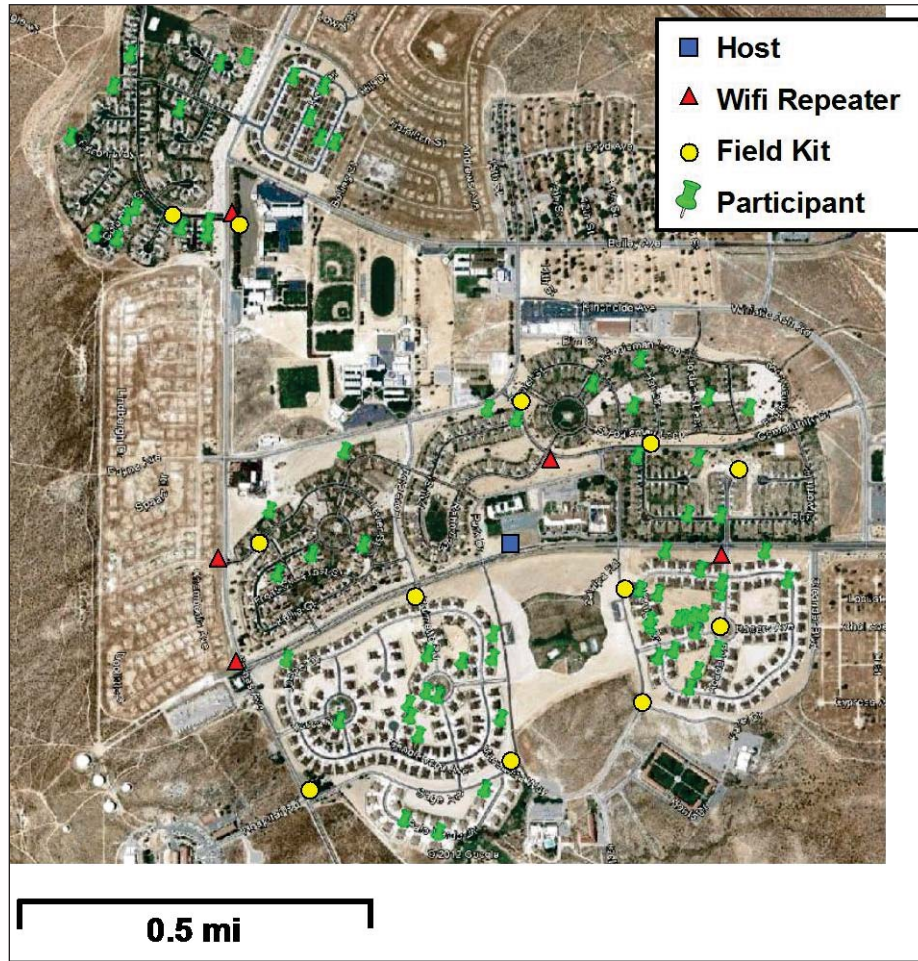


Figure 24. (a) Physical layout of microphone locations (field kit nodes), wireless repeaters, and host computers with respect to the EAFB housing community. (b) Zoom of the non-dormitory housing area.

### 3.3.2 Acoustic Instrumentation

For the WSPR test, Gulfstream utilized its digital data acquisition system consisting of networked nodes that can be deployed for extended periods of time. The Sonic Boom Unattended Data Acquisition System (SBUDAS) was purposely developed for sonic boom community noise testing.

The SBUDAS architecture is based on a host-node format. Each node was configured with two low-frequency microphones with windscreens, a preamplifier, a National Instruments CompactRIO (cRIO) with the ability to log microphone data, ground boards, and a battery. Both the microphones rested on a flat, hard surface and were about 8 inches away from each other. Both provided good signals. One of the microphones had a low-frequency adapter and one did not. The redundant microphones were deployed in order to assess potential signal differences between the channels. Post-test analysis revealed no differences between the microphone signals. With the exception of the microphones, the sonic boom monitoring equipment was packaged into an environmental enclosure (Figure 26). The nodes also had a solar panel and a wireless Ethernet bridge. The microphone orientation was such that the boom was incident to the microphone diaphragm at grazing angle. Additionally, each node was GPS time-synchronized, allowing absolute time-correlation of the recorded data to other test parameters. Each node was weather-proofed and utilized a solar panel and battery to provide continuous power permitting deployment without requiring grid power or frequent battery exchanges. The system could be monitored and controlled remotely from a host computer with communications accomplished via long-range wireless TCP/IP with nodal deployment extending across 1.5 square

miles. Outside of scheduled flights, the SBUDAS system was left in an auto-trigger mode in an effort to capture sonic booms generated by non-WSPR aircraft.

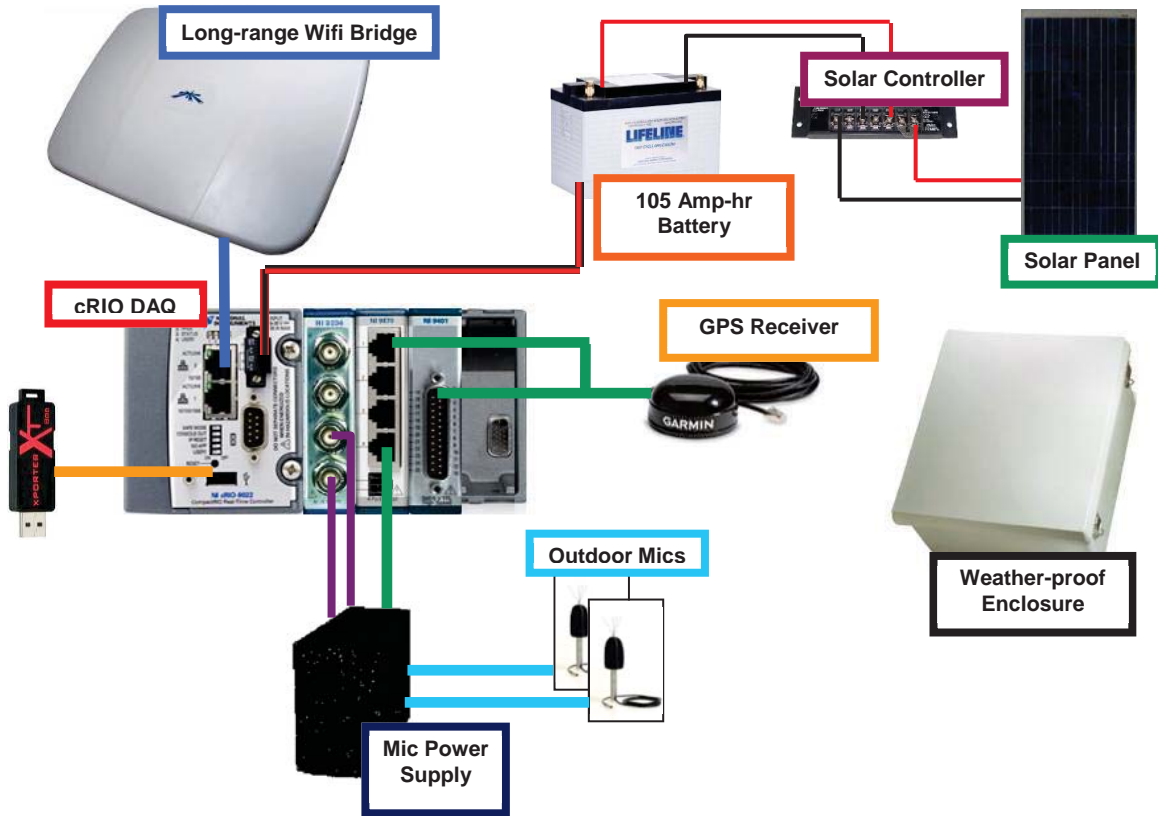


Figure 25. Configuration of SBUDAS nodes.





*Figure 26. Sonic boom field kit installation photograph.*

### **3.3.3 Meteorological Instrumentation**

NASA provided all meteorological instrumentation for the WSPR test. The metrics needed from the meteorological stations included – atmospheric pressure, temperature, relative humidity, wind speed, and direction. In the case of the weather balloons, these data are linked to altitude. All data was recorded with a time stamp relative to UTC zulu time zone to facilitate future analyses. Instrumentation was calibrated and data acquisition was conducted based on NASA procedures and protocols. Surface weather observations were conducted with a time resolution of at least 1 Hz. GPSsonde balloons were operated as close as was feasible to the EAFB housing community. Locations for the two ground based surface weather instrumentation systems were collocated with the host station as shown in Figure 25.

### **3.3.4 Aircraft and Flight Instrumentation**

NASA was responsible for providing F-18s with flight instrumentation and operational support as necessary. Established NASA flight procedures, calibration protocols, data collection, and data archival procedures were followed at the discretion of the NASA Principal Investigator.

## **3.4 Subjective Data Collection**

Social survey data were collected at three time points to support analysis of subjective response to sonic booms and assess modes of data collection. A baseline survey was conducted before the experimental test period, to obtain data on noise annoyance, and noise sensitivity before participants were exposed to the low-amplitude sonic booms. During the experimental test period, we asked individuals to report their reactions to each sonic boom they noticed as well as a summary for the day. We interviewed a subset of participants after the experimental test period to help us evaluate the data collection methods. Each of these surveys is described below. Section 3.1.6 described the pre-test of the survey questionnaires and study procedures with NASA DFRC employees. A full representation of the questionnaire content for the single event survey, the daily summary survey, and the baseline survey is described in Section 2.3 and detailed in Appendix A for all three instrumentation modes.

### 3.4.1 Baseline Survey

The baseline survey was conducted as a telephone interview from Tetra Tech’s in-house survey lab in Madison, Wisconsin. The questionnaire was programmed for administration with computer-assisted-telephone-interviewing (CATI) software. CATI surveys have several features that support data quality – the questionnaire follows the programmed skip pattern so that questions are not accidentally missed or asked out of sequence, out-of-range values can be prevented, question text can “fill” based on responses to previous questions or sample information (e.g., assigned mode). CATI software, in combination with a centralized phone lab, facilitates remote monitoring by shift supervisors and productivity reports based on call attempts, time of day, and day of week. The baseline survey is described in Section 2.3.3 and may be found in Appendix A-3. The baseline survey was conducted September 19, 2011 through October 14, 2011. All 60 subjects originally assigned to the WSPR team were interviewed.

### 3.4.2 Survey Activities Performed during Program Execution

Sixty residents of EAFB who were recruited to participate in the experimental test period were assigned to the WSPR team. As noted in Section 3.1.7, five of these subjects were determined to be ineligible before the test began because they were no longer living on base or would be away for the duration of the experiment (one had been assigned to Web and four to paper). Fifty-five subjects were eligible at the start of the experiment and 52 subjects ultimately participated by completing single event and daily summary subjective response surveys. Of the 55 subjects who started the study, two additional persons were away for a significant portion of the 2 weeks, and data for a third subject could not be retrieved from an iPod Touch. This section describes the daily activities performed by the survey team during the experimental test to track responses and summarize outcomes. The table below lists the key activities performed in support of the subjective response surveys during and after the experiment.

Date	Subjective Response Survey Support Activity
Daily (Nov 4-18)	Text/email reminders to complete the daily summaries
Daily (Nov 7-16)	Follow-up calls/emails to subjects who were not submitting survey forms
Nov 9	General check-in with all paper participants
Nov 19	Notification of study end date and appreciation event (email sent Nov 19, telephone follow-up Nov 21 and 22)
Dec 2-12	Post-test qualitative interviews with a subset of participants from each mode

### 3.4.3 Daily Subjective Data Compilation and Review

After the study kick-off on November 4, WSPR project team members leading the survey data collection conducted several activities daily to maximize the completeness and quality of the data as well as keep the full team apprised of progress.

**Survey Forms across the Three Modes of Administration Were Compiled and Reviewed.** We downloaded data from the secure Web server daily, archived the files to protect against data loss, and reviewed the number and type (single-boom/daily summary) of submissions for completeness. Data from the Apple application was processed daily by a WSPR team member leading the Apple protocol and sent to the survey coordinator for review and consolidations with the other survey data. Paper survey forms were logged as mail packets were returned. Postmark and receipt dates were tallied, contents were assessed for completeness and IDs on survey forms were compared with external labels before re-sorting, and survey responses were double-entered using a data entry program.

**Follow-Up Calls Were Made Daily with Subjects to Promote Completion of Survey Forms.**

Each afternoon, the survey support team met to review the survey submissions for the day. A tally of daily summary forms and single-boom forms, by date, mode, and individual subject was examined to identify subjects that were not regularly submitting data. A list of call priorities was prepared and assigned to a trained telephone interviewer so that calls could be completed that evening. Subjects who did not submit a daily summary form or did not submit single event forms on a high-activity day were assigned the highest priority. In addition, general check-in calls with all paper

participants were made early in the study period since their completion of survey forms could not be assessed on a daily basis.

Table 18 summarizes the number of follow-up contacts with subjects by mode. Follow-up calls were placed from November 7 (the Monday following study kick-off) through November 16 (this table does not include the general check-in calls that were placed with paper participants). Follow-up attempts were made with 71 percent of all subjects who started the study and a total of 84 contact attempts were made over the full study period. A higher percentage of contact attempts were made to participants using the Apple (39 percent) and Web (45 percent), although these modes lend themselves to near-real time review of data that prompted the follow-up activities. Paper participants could have completed their daily summary forms 1, 2, or more days later than instructed without being detected.

**Table 18. Summary of Daily Follow-Up Contacts with Subjects, by Survey Mode**

Survey Mode	Unique Subjects Contacted	Total Contacts	Percent of all contacts
Apple	15	33	39%
Paper	7	13	16%
Web	17	38	45%
Total	39	84	100%

**A Response Rate Summary was Prepared and Circulated to the WSPR Team Daily.** The survey support team computed a daily response rate overall and by mode at the end of each day and circulated a summary report to the WSPR team. The number of expected single event forms was drawn from the field team’s daily report of booms that occurred and were captured by noise monitors (i.e., WSPR and non-WSPR booms). The number of expected daily summaries was simply the number of subjects since participants were instructed to submit a daily summary every day, regardless of whether they noticed booms. A sample of the response report, which was updated daily, is shown below in Table 19.

**Table 19. Daily Survey Response Rate Report**

	Tues Nov. 15	Wed Nov. 16	Thur Nov. 17
<b>Number of eligible respondents</b>			
Paper	16	16	16
Web	24	24	24
Apple	15	15	15
TOTAL	55	55	55
<b>Number of booms occurred</b>			
	14	23	8
<b>Daily Summary Forms received**</b>			
Paper	7	0	0
Web	21	21	19
Apple	12	13	9
TOTAL	40	34	28
<b>Single Boom Forms received**</b>			
Paper	65	0	0
Web	135	249	34
Apple	79	123	18
TOTAL	279	372	52

**Reminders to Complete the Daily Summary Form Were Sent to Subjects Daily by Email or**

**Text.** During the pre-field check-in calls, the WSPR team offered subjects the option to receive a daily reminder by text message or email. This offer was repeated in follow-up calls to subjects after the experiment began. Of the 52 subjects who participated in the experiment by completing single-event and daily summary forms, 31 elected to receive daily reminders for the entire test period. Four subjects signed up for reminders after the experiment began. No one asked to stop receiving the reminders after the study started.

### **3.4.4 Post-Test Interviews with Participating Households**

The WSPR team conducted semi-structured interviews with a subset of participating households after the experimental test period. Tetra Tech researchers conducted these telephone interviews using a topic guide, or list of broadly-worded questions, that was designed to gather additional information to assess the data collection methods. The questions were not followed verbatim but rather were used to elicit participants' description of their experiences in their own words. The more conversational nature of semi-structured interviews makes it possible to pursue other, unanticipated lines of inquiry based on participants' comments.

The post-test interviews were conducted December 2–12. The time between the experimental test period (ending November 18) and the post-test interviews allowed the team to compile all of the single boom and daily summary surveys, review the data files for unusual patterns that might be pursued during the interviews, and even select particular subjects that we wanted to target for interviews (e.g., periods of non-response or late response during the study period). Altogether, 12 subjects were interviewed; of these, five had participated using the Apple application, four on the web, and three by paper.

Topics addressed during the post-test interviews included:

- Communication before and during the test period
  - Clarity of instructions
  - How and when survey materials were delivered
  - Awareness of when (and how) the test period began and ended
- Mode of data collection
  - Ease of use and accessibility
  - Technical functionality
  - Preferred mode if given a choice for another such study
- Response process
  - Use of personal logs or other tools to keep track of booms
  - How single boom forms typically completed (e.g., time lapse between boom and survey)
  - When daily summary forms were usually completed and how responses for a day of sonic booms were developed
- Importance of incentives for participating, communication with neighbors or friends during the study, helpfulness of text/email reminders, and perceived difficulty or burden of participating for extended period of time

The main themes derived from these interviews and lessons learned for application to future studies are summarized in Chapter 5.



## 4.1 Objective Data Analysis

### 4.1.1 Sonic Boom Measurements/Data Archive

A measurement data archive was prepared and delivered to NASA that included acoustical, meteorological, and flight operations schedule data. A concise description of the data in the archive is provided below. Noise exposure at all participant households and the data including locations, sonic boom event times, sonic boom signatures, and applicable objective noise metrics are also provided. The measurement data archive file contains information central to the data analysis and results of the WSPR program.

This summary begins with a list of events, including sonic booms that impacted the housing community at EAFB. The final lists of these events are also itemized in Appendix E WSPR Sonic Boom Master List. Each event identified has a sequence number to facilitate linking of events across the individual household metric files. There were 110 events identified in the records during the WSPR measurements from November 4–18, 2011. An event was classified as being a single plane’s sonic boom. The analysis of the impact of this boom accounts for the first sonic boom received from a single plane’s fly by contained in a 650 ms interval. The treatment of this recording entailed tapering the first and last 100 ms of the recording. Any post booms that affected the community were not included in the metric analysis. An additional WSPR task was funded to examine the implications of these data analysis procedures and is described in Section 4.1.6.

There were a few non-WSPR boom events that were not recorded by the array of noise monitors deployed in the community for this study. Instances where the noise monitors did not record an event can be identified by entries in the column “Estimated Overpressure/Aural (psf)” in the WSPR Sonic Boom Master List (Table 3-6). The substitution entailed identifying the field reported estimate<sup>7</sup> of the peak overpressure of an event and selecting a sequence number for a boom that was recorded by a monitor with a similar peak overpressure. In this case, all substitution metrics were taken from the alpha monitor deployed near the center of the housing community.

### 4.1.2 Participant Household Noise Exposure

Members of the EAFB community participated in this study. In order to protect their identity, they were identified with a case id associated with their address. A list of participant coordinates were provided by the EAFB GIS department. Metrics and boom levels were projected to all WSPR subjects, both for the Wyle and the Fidell and Associates teams.

The recordings at the monitors were trimmed and written to text and wav files for analysis. The wav files were tapered as mentioned above; whereas, the text files were tapered later inside the analysis program. In the data archive delivered to NASA, files were named for the time of the boom and the particular monitor. The time is the local time and date. Recordings on November 4, 2011 in Pacific Daylight Savings Time while the rest are in Pacific Standard Time. The text file names also contain the sampling rate as well as the name of the monitor from which they came. The naming convention of all the files is:

IDNNN\_csite\_MMDDYY\_HHMMSS\_SSSSSSHZ\_CHCCExt

where

- NNN is an id number coming from a particular day of the recording that was used for internal processing,

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<sup>7</sup> The EAFB on-site WSPR team consisted of personnel with experience listening to low-amplitude sonic booms. In the cases where no sonic boom events were recorded by the acoustic instrumentation, an in-field estimate of the sonic boom amplitude was made by those personnel located at the Host location. This aural estimate process was applied to four unrecorded sonic booms with sequence numbers 22, 80, 82, and 93.

- csite is the name of the monitor - alpha, bravo, charlie,...mike,
- MMDDYY is the calendar date of the recording,
- HHMMSS is the 24-hour, local clock time of the boom associated with the recording,
- SSSSSS is the sampling rate in samples/sec of the recording,
- CCC refers to the channel number of the noise monitor (there were two channels per monitor – only one channel from each monitor was used in this analysis),
- ext is either pre, txt, pos or wav depending on the file type

The recorded sonic boom signals were tapered as described above, resampled to 32,000 samples/second, and written to wav files (extension .wav) for analysis using the Moore and Glasberg [Glasberg and Moore, 2002] metric with the program TVL found on Dr. Moore's website<sup>8</sup>. The Moore and Glasberg program requires a sampling rate of 3200 samples/second. The option to include the filter representing free-field frontal incidence was activated.

Two additional text files accompany the data set. They contain the 650 ms of the monitor recording immediately before and after the text file with the boom. The preceding 650 ms files have a .pre extension. The files containing the 650 ms immediately after the text file with the boom have a .pos extension. The files with a .pre extension were used to identify the ambient levels of the exposure based metrics. These ambient levels were subtracted from the boom metrics when the A-weighted SEL metric was at least 1 dB less than the A-weighted SEL of the boom. If the ambient levels were not at least 1 dB less than the boom metric, then that particular recording was considered too contaminated to use for further analysis.

The coordinates of the 13 monitor locations are identified with their latitude and longitude with a WGS 84 reference spheroid. The fourteenth monitor location, Chapel2, refers to a central location in the community where personnel running the microphone array based their operations.

Supplemental equipment was deployed at Chapel2 during the flights executed by NASA DFRC in order to provide feedback to the control room as to what amplitude sonic boom impacted the community. This feedback allowed for necessary adjustments to subsequent passes where necessary. The NASA DFRC sonic boom monitoring system, SNOOPI, was deployed for the duration of these measurements. Peak overpressure readings from SNOOPI were used when available in instances when the array of monitors failed to capture non-WSPR booms in order to find metrics of similar booms that were recorded by the array.

### 4.1.3 Noise Metrics

As mentioned in Section 4.1.2, 650 ms sonic boom events and 650 ms ambient files were analyzed in order to obtain the acoustic metrics of the boom and the ambient. The program used for most of the analysis was ADLOUD developed at the NASA Langley Research Center (LaRC) [Shepherd and Sullivan, 1991]. The output of Dr. Moore's program analyzing the wav files is a time history of six metrics. The time history had a resolution of 1 ms, and the six metrics were values of Moore & Glasberg's metric instantaneously, using short-term averaging, and long-term averaging with units of both sones and phons. The maximum value of each of these time histories was captured with a program and incorporated in the metrics files of the noise monitors.

The A-weighted SEL based on a 650 ms duration for boom event and the ambient immediately preceding the boom were compared. If the boom event ASEL value was 1 dB or greater than the ambient, the ambient value was subtracted logarithmically. The Moore & Glasberg metrics are the maximum value of the metric in a time series; ambient levels are not subtracted because they are not exposure-based metrics. Relationships between metrics measured indoors and outdoors of a typical house in the EAFB community were established during the House VIBES II measurements conducted by NASA [Klos, 2008]. An estimate of the exposure and peak overpressure metrics inside the homes was created using a linear regression of all the microphones deployed in the house versus a microphone outside the house. These regressions were used to estimate indoor metric levels for all WSPR subject house locations. One WSPR subject was located in the EAFB dormitory, a three-story structure considerably different from the other

<sup>8</sup> <http://hearing.psychol.cam.ac.uk/Demos/demos.html>.

residential structures. Measurements were made in a room on the same floor of a similar building and were used to derive the transmission relationships between indoor and outdoor metrics. Additionally, because the dormitory area was so far away from the housing area (Figure 3-7), a single noise monitor was dedicated to measuring booms near the dormitory area. Metrics computed from this monitor were used directly for the dormitory subject and not interpolated. An inverse-distance weighting method [Shepard, 1968] was employed for estimating the metrics at the addresses in the community from the monitors. The metric  $u$  desired at an address located at position  $x$  was found using Equation 4-1.

$$u(x) = \frac{\sum_{i=0}^N w_i(x)u_i}{\sum_{j=0}^N w_j(x)}$$

(Equation 4-1)

where  $u_i$  is the metric at the  $i^{\text{th}}$  monitor and  $w$  is weighting function given by Equation 4-2:

$$w_i = \frac{1}{d(x, x_i)^p} \tag{Equation 4-2}$$

4-2)

The distance between the address location denoted by  $x$  and the monitor location is denoted as  $d(x, x_i)$ . The power parameter,  $p$ , is used to mimic the effects of turbulence on sonic boom propagation. As noted in prior SSBD measurements [Plotkin, 2005], turbulence effects were seen at one monitor, while no evidence of the effect was seen at adjacent monitors spaced 500 feet away on a linear array (Figure 27). An example of the maximum overpressure predicted on a grid laid over the housing community can be seen in Figure 28. The peaks and holes show the locations of some of the noise monitors. The monitors that recorded the “average” overpressure are difficult to identify, but the use of a power parameter of 0.5 in this figure shows how the peaks on the left side of the graphic exhibit signs of turbulent peaking are limited to the area around the monitor. While the peaks do get factored into the metrics predicted in the community as a whole, they have the most effect in the area around them. After studying various values of  $p$ , the value of 0.5 was selected to characterize the behavior seen in the field in terms of the extent of geometric influence of the turbulent peak. Table 20 contains a listing of the computed metrics.

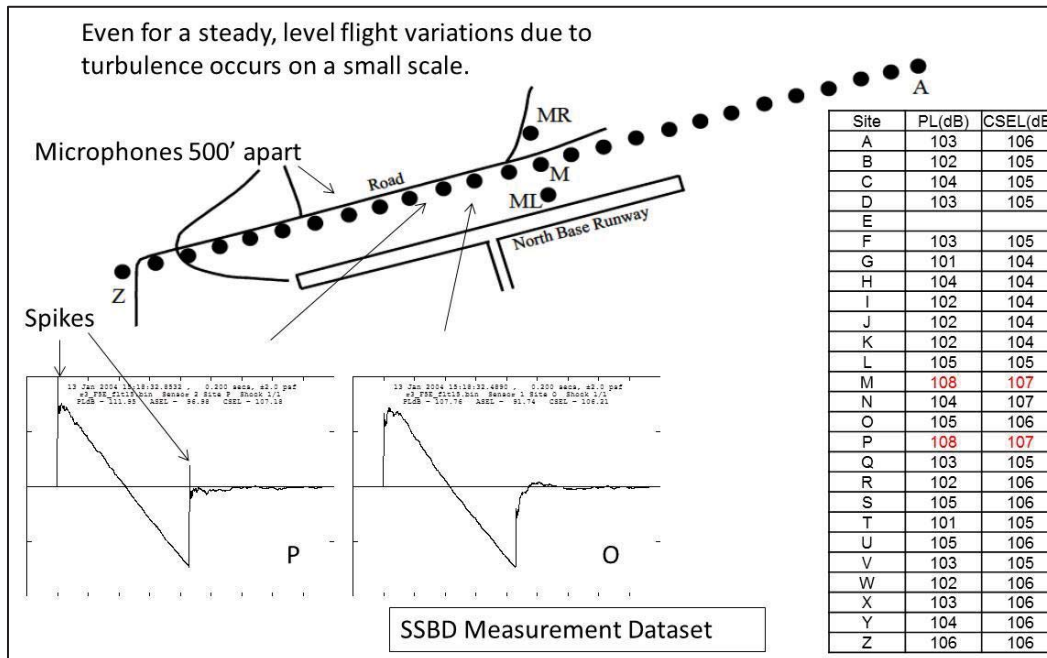


Figure 27. SSBD sonic boom turbulence measurements.

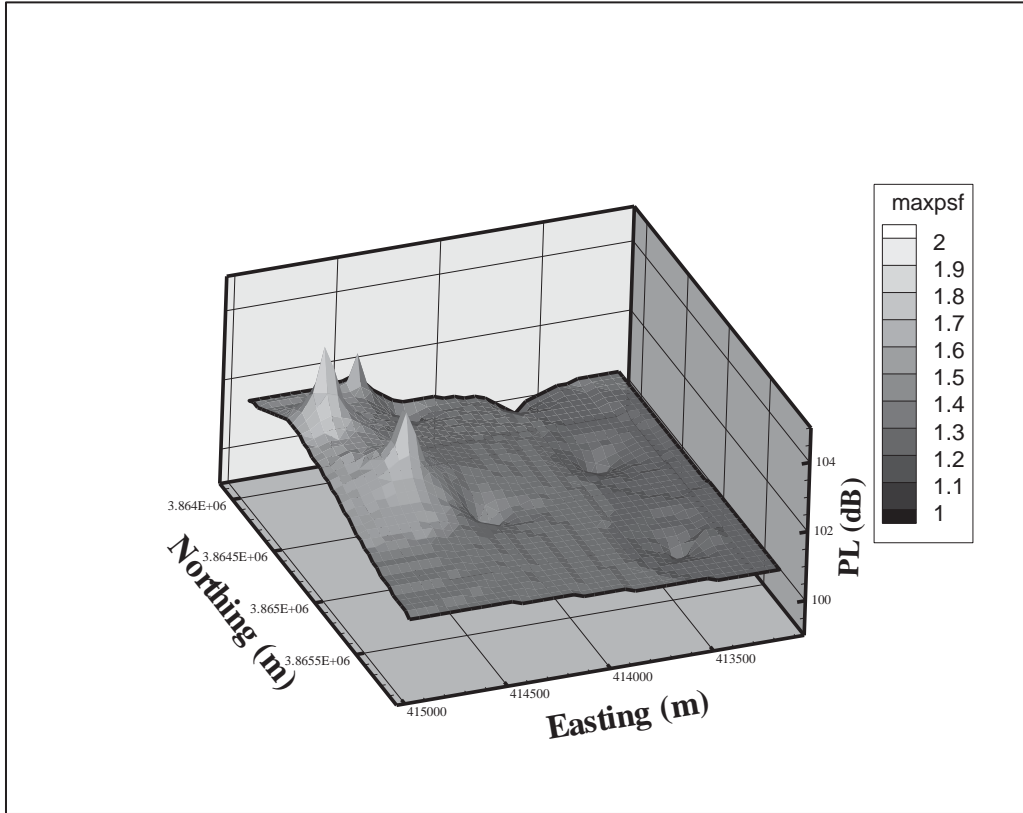


Figure 28. Peak overpressure (psf) from boom sequence 68 predicted on a grid spanning the EAFB community housing.

**Table 20. Computed Metrics**

METRIC LABEL	DESCRIPTION
<b>PL</b>	This is an estimate of Stevens Mark VII Perceived Level [Stevens, 1972] calculated using a time constant of 70 msec and averaging across the two peaks, which means 3 dB is subtracted from the 1/3 octave band levels calculated from the spectrum for the entire boom before the PL metric is calculated [Shepherd and Sullivan, 1991]. This estimate is for the outside of the participant's household or dorm room.
<b>CSEL ASEL ZSEL</b>	These are estimates of the weighted Sound Exposure Level (SEL) values (so the time constant is 1 sec and there is no averaging). These estimates are for the outside of the participant's household or dorm room.
<b>LLZf LLZd</b>	These are estimates of Zwicker loudness levels in phons, for frontal incidence and diffuse incidence, calculated using a time constant of 70 msec and averaging across the two peaks. These estimates are for the outside of the participant's household or dorm room.
<b>PNL</b>	This is an estimate of Kryter's [1959] Perceived Noise Level, calculated using a time constant of 70 msec and averaging across the two peaks. This estimate is for the outside of the participant's household or dorm room.
<b>maxpsf</b>	This is an estimate of the peak overpressure in psf outside of the participant household or dorm room.
<b>iSone iPhon</b>	These are estimates of the maximum instantaneous value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons outside the participant household or dorm room.
<b>Av1Sone Av1 Phon</b>	These are estimates of the maximum of the short term average value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons outside the participant household or dorm room.
<b>Av2Sone Av2 Phon</b>	These are estimates of the maximum of the long-term average value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons outside the participant household or dorm room.
<b>iPL iCSEL iASEL iZSEL iLLZf iLLZd iPNL imaxpsf</b>	These are estimates of the above metrics inside the household or dorm room of the participant. Interior Moore & Glasberg Time-Varying Loudness was not computed.

#### 4.1.4 Treatment of Missing Data

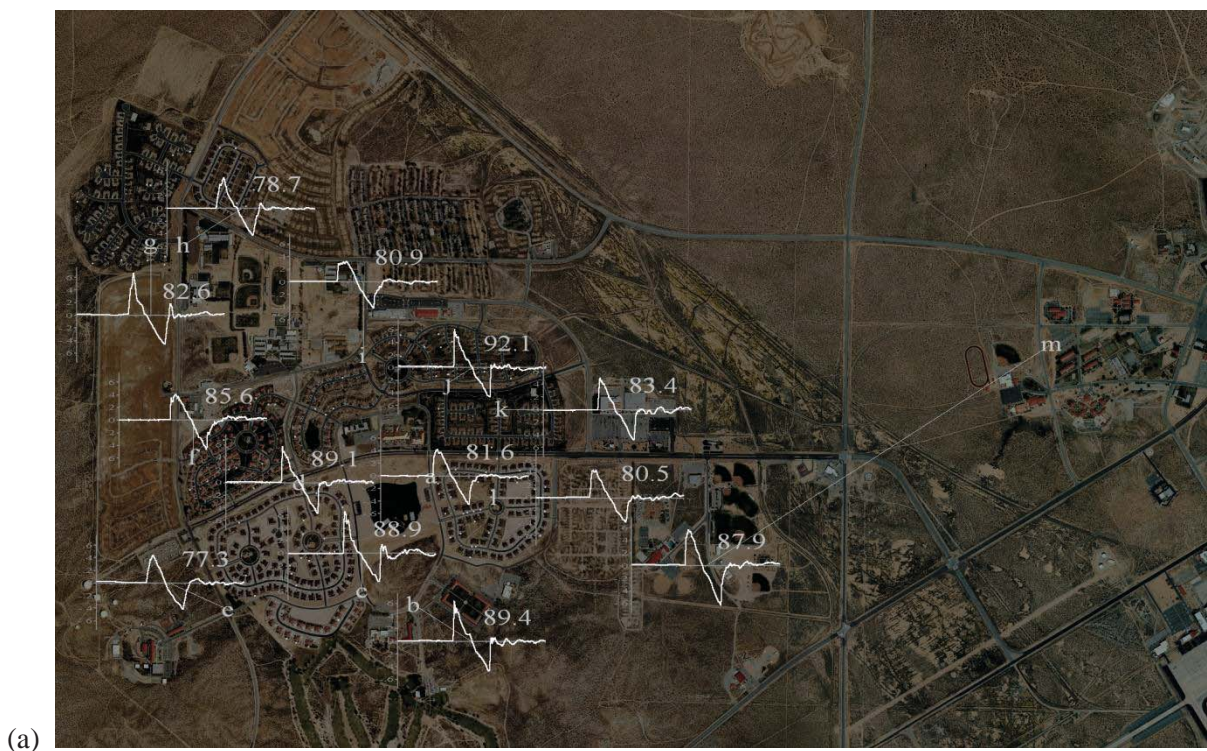
There were several instances when the monitor array did not record the sonic boom. The following pre-processing procedure was employed in conjunction with the interpolation method described above. Peak overpressures were estimated in these instances. One example of an estimate of the peak overpressure came when SNOOPI noted a 1.65 psf boom that was not recorded by the array. This was event number 81; the beginning of a shower of booms. Looking back in the boom records, it can be seen that event 76 has a similar amplitude boom; thus, the metrics of event 76 at the Alpha monitor were used by creating a proxy monitor named Estim8 to be used in the Metric Interpolation process. All booms not recorded by the array were estimated in terms of the metrics and boom times and applied to all households (Table 20).

A complete archive of the sonic boom events and itemization of which events were measured by the field-kits, SNOOPI or via Aural estimation is contained in the WSPR Sonic Boom Master List (Table 3-6). For events with missing Field-Kit data, the interpolation process relied exclusively on operational sites. For those four events where nothing was recorded by the field-kits or SNOOPI (Booms 22, 80, 82, and 93), Aural estimations were substituted. A total of 10 events were only recorded by SNOOPI and 9 of these events were adventitious USAF sonic booms.



#### 4.1.5 Interpolation Method Effectiveness

An analysis was performed to determine the effectiveness of the interpolation method used to find the loudness metrics at the participant households. Figure 29 shows an example boom measured at the monitors deployed in the EAFB housing community. Figure 29 (a) illustrates the full housing community including the dormitories to the East, while Figure 29 (b) contains a close-up of the primary housing area. Each of the white traces is a graph of the recording at one of the noise monitors. Next to it is the measure Steven's Mark VII Perceived Level (PL) for that recording. The letters attached to the signature traces refer to the name of the noise monitor – “a” is for the site Alpha noise monitor, “b” is for bravo, etc. The small x’s are participant households. Monitor Mike is the graph to the right of the figure not showing a connected letter ‘m’ because it was located to the East of the housing community in the dormitory area. That monitor played no part in the interpolation scheme, and it was used exclusively to identify the metrics of booms assigned to participants living in the dormitories. As can be seen in the figure, there is a lot of variation in waveforms shape due to turbulence. A more comprehensive collection of boom signatures across the housing area such as those displayed in Figure 29 (a) may be found in Appendix F.



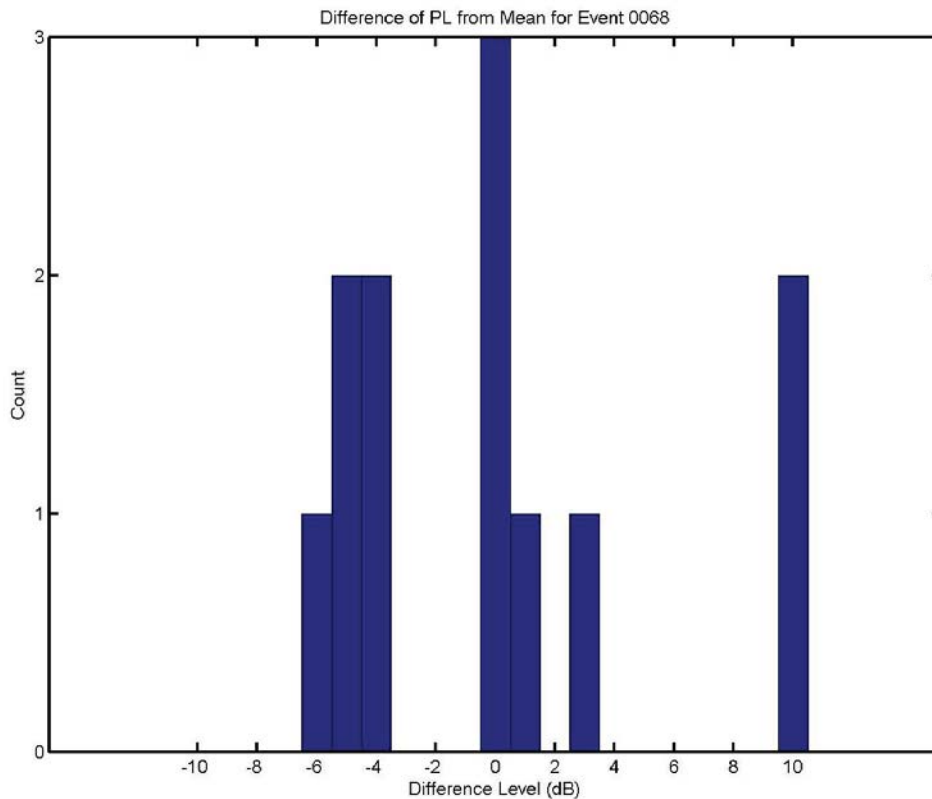


(b)

**Figure 29. Measured sonic boom signature traces (psf) and Perceived Levels (PL) at monitor locations (a) full subject area including dormitories to the east and (b) close-up of the primary housing area.**

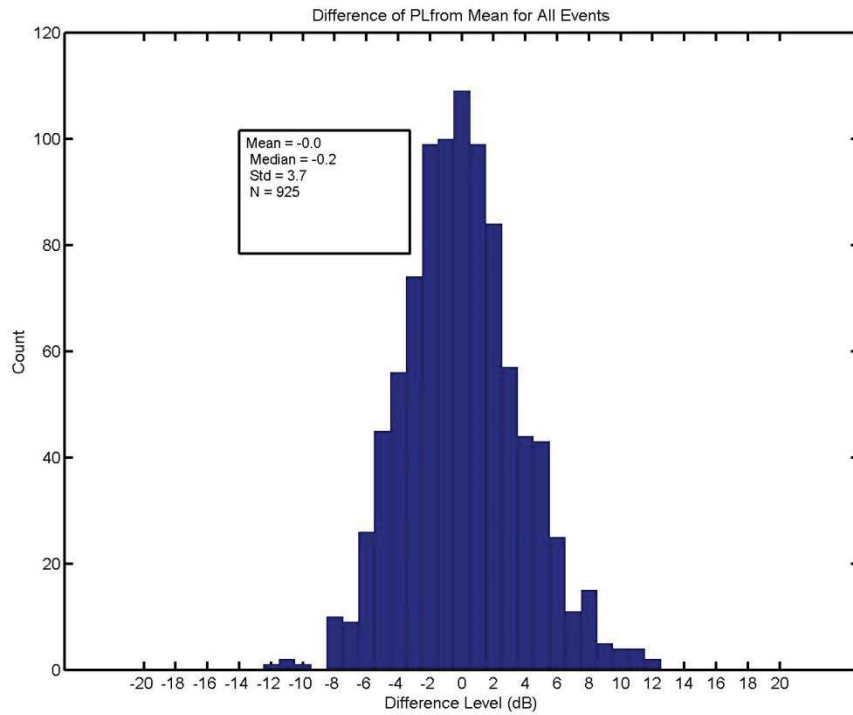
In order to say something about the effectiveness of the interpolation scheme one must first understand the confidence in the measurements. A plot of the distribution about the mean was made for the sonic boom measured data. Figure 30 shows the distribution about the mean for the PLs measured for event number 68 in the WSPR measurements. As can be seen in the figure, there are insufficient samples to make this a meaningful measure of the distribution.



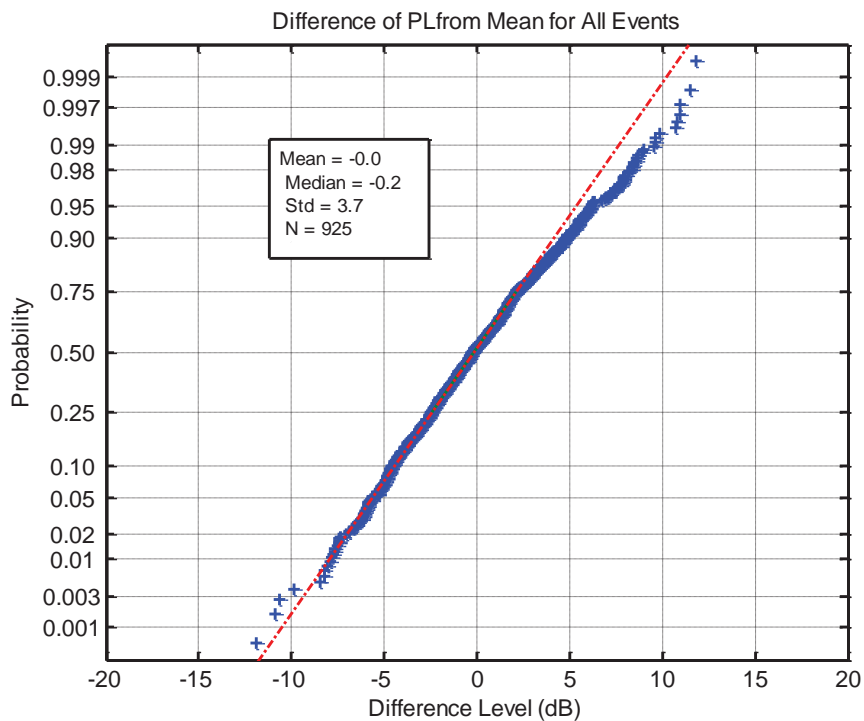


**Figure 30. Count of the binned difference level (PL) from the mean for WSPR event 68.**

If one considers the parent distribution as consisting of all the differences between measurements and their event mean, then there will be more information upon which to judge the variance of the data set. Figure 31 shows the distribution of PLs from the mean of all the events measured during WSPR. It is important to note that this distribution is for the planned WSPR flights. As the figure shows a somewhat Gaussian shape, a check for normalcy is in order. Figure 32 shows a probability plot. The dashed line represents the ideal normal trend. The data deviates from the straight line indicating a slight skewness to the left as can be seen in Figure 31. This data can be considered relatively normal and the calculation of the standard deviation is warranted. Table 21 shows the standard deviations of the other metrics. The CSEL and ZSEL show the lowest standard deviations. This is likely related to CSEL and ZSEL metrics being less affected by turbulence than the other metrics and this is because they account for more low frequency than other metrics, while turbulence is primarily a high frequency effect.



*Figure 31. Count of the binned difference level (PL) from the mean for all WSPR events.*



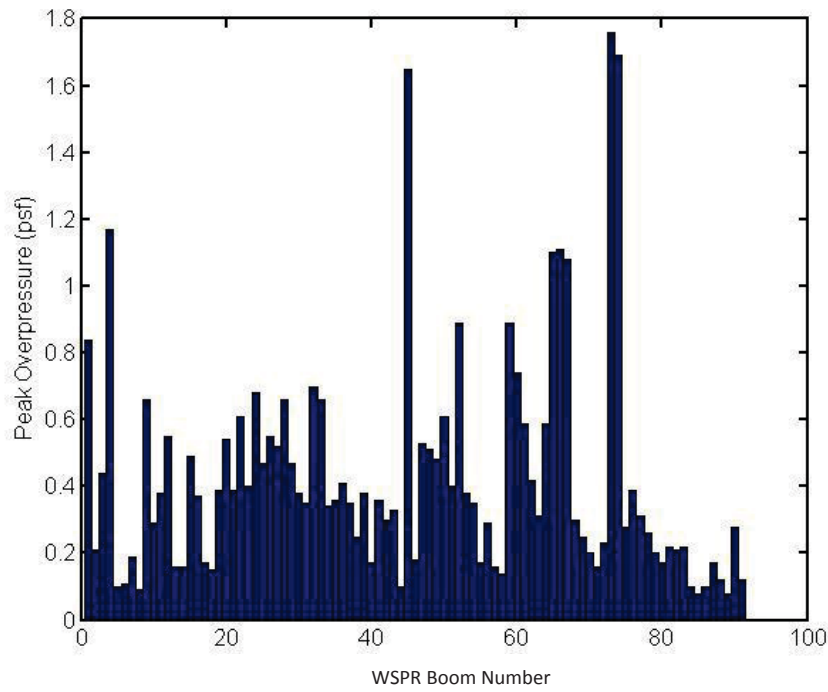
*Figure 32. Normal probability plot for all WSPR events.*

**Table 21. Standard Deviations (Measurements vs. Event Mean) for Various Metrics**

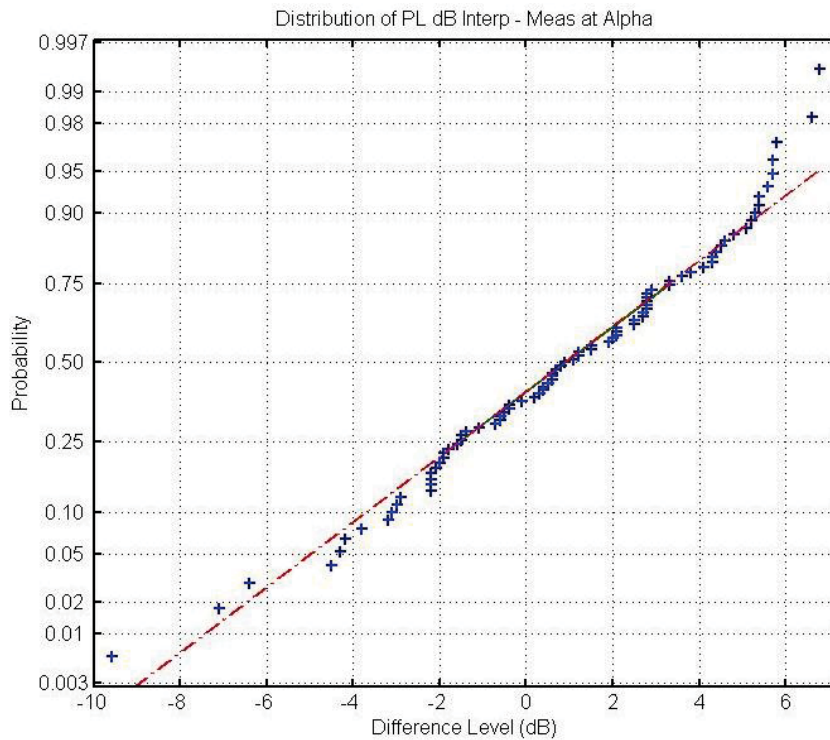
Metric	PL(dB)	CSEL (dB)	ASEL(dB)	ZSEL(dB)	LLZf(phon)	LLZd(phon)	PNL(dB)	Max PSF
<b>St. Dev.</b>	3.6	2.5	3.8	1.2	3.1	3.1	3.9	0.12

In order to gauge the confidence of the interpolated metrics, one needs to compare the interpolated value to a measurement. One way to do this that understates the accuracy of the method, is to remove one of the monitors from the computations and interpolate the metrics at its location for comparison. Because removing one of the monitors makes the array weaker in terms of its coverage, this will give a conservative estimate of the interpolation method's accuracy.

Consider the range of all the booms measured at site Alpha in terms of their peak pressures as shown in Figure 33. By virtue of the noise design, smaller booms are more frequent than bigger booms. Figure 34 shows the normal probability plot of the difference between the interpolated PL at site Alpha and the measured value. Table 22 shows the statistics for all the monitor sites when they were removed from the array and the metrics were predicted at their location. The average was nearly the same as the median. Normally, when the average and the median are not the same, nor equal to zero, a bias or outliers exist in a measurement group. That the most probable result is within 1 decibel of the actual measurement is very good agreement. The difference between the average and median is 0.2 dB and is negligible. A standard deviation of 3.2 dB using the interpolation methodology is on par with the spread of the measured data across the household area. Consider the Perceived Level – the interpolated values are, on average, less than the measured at 5 of the 12 sites. The standard deviation of all the comparisons except one is in the 3 to 4 decibel range. That the most probable estimate of the PL at any site is within 2 dB of the measured value shows that the method works. The ZSEL shows the smallest standard deviation for the decibel metrics. This again indicates that the calculation of the metric for a boom with little or no attenuation of low frequency content has less variation over an area. One can also note that the median prediction is closer to the measurement for measurement sites towards the East, closer to the aircraft trajectory, and with shorter propagation distances from the low-boom dive waypoint.



**Figure 33. Site alpha measured peak overpressures (psf).**



**Figure 34. Normal probability plot for interpolated PL minus measured level at Site Alpha.**

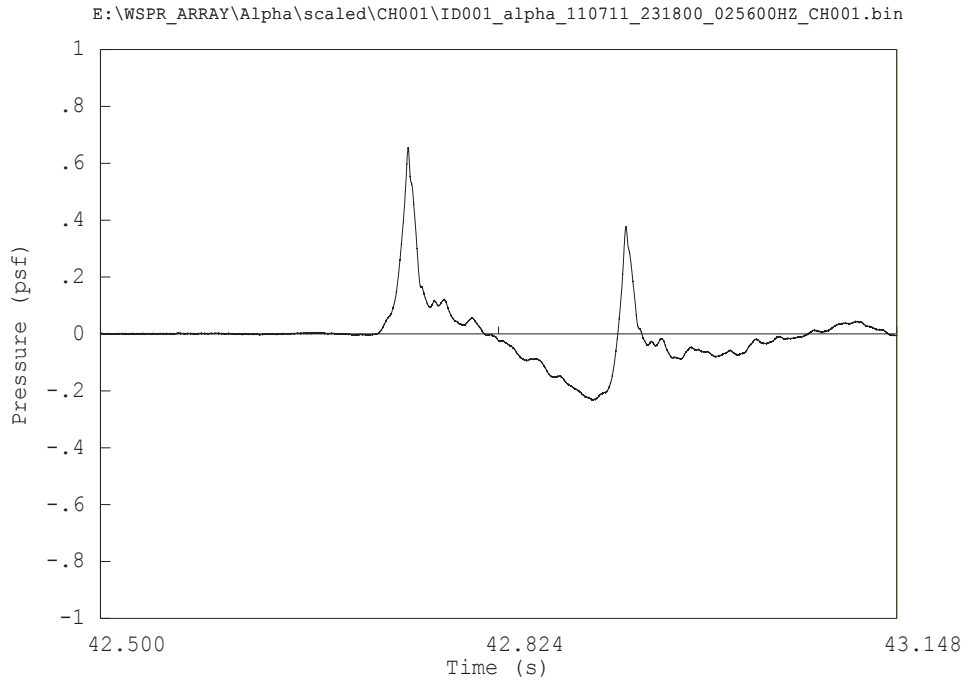
**Table 22. Interpolated Minus Measured Statistics at Monitoring Locations for Several Metrics**

Site	PL(dB)			CSEL(dB)			ASEL(dB)			ZSEL(dB)			N
Name	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	
Alpha	0.9	0.9	3.3	0.5	0.7	2.4	0.7	1	3.6	-0.2	-0.1	0.9	85
Bravo	-0.3	0.1	3.7	-0.4	-0.1	2.3	-0.5	-0.5	4.4	-0.5	-0.4	1.2	84
Charlie	-1.7	-1.7	3.2	-0.9	-0.8	2.4	-1.5	-1.8	3.5	0.1	0.1	1.2	83
Delta	-1.9	-1.6	3.8	-1.1	-0.9	2.6	-1.5	-1.1	3.9	0.1	-0.1	1.4	79
Echo	-0.7	-0.8	3.8	-0.3	0.3	2.8	-0.9	-0.8	3.8	0.1	0.3	1.5	74
Foxtrot	1.4	2.1	4.3	1.6	1.5	2.9	0.8	1.1	4.9	0.2	0.5	1.5	73
Golf	2	2.3	3.7	0.6	0.4	3.1	2.1	2.6	3.9	0.9	0.7	2.1	79
Hotel	1.2	1.2	3.5	1	1	2.7	1.2	1.4	3.7	0.7	0.6	1.3	69
India	0.8	1.1	3.5	0.6	0.8	2.6	0.9	1.3	3.7	0.4	0.5	1.3	85
Juliet	-0.8	-0.2	3.8	-0.5	-0.3	2.6	-0.7	0.1	4.1	0.1	0.1	1.2	82
Kilo	1.2	1.5	3.7	0.6	0.9	2.5	1.6	2.3	3.9	-0.1	0	1.3	77
Lima	0.3	0.8	3.6	0.3	0.5	2.7	0.5	0.9	3.8	-0.3	-0.4	1.1	86

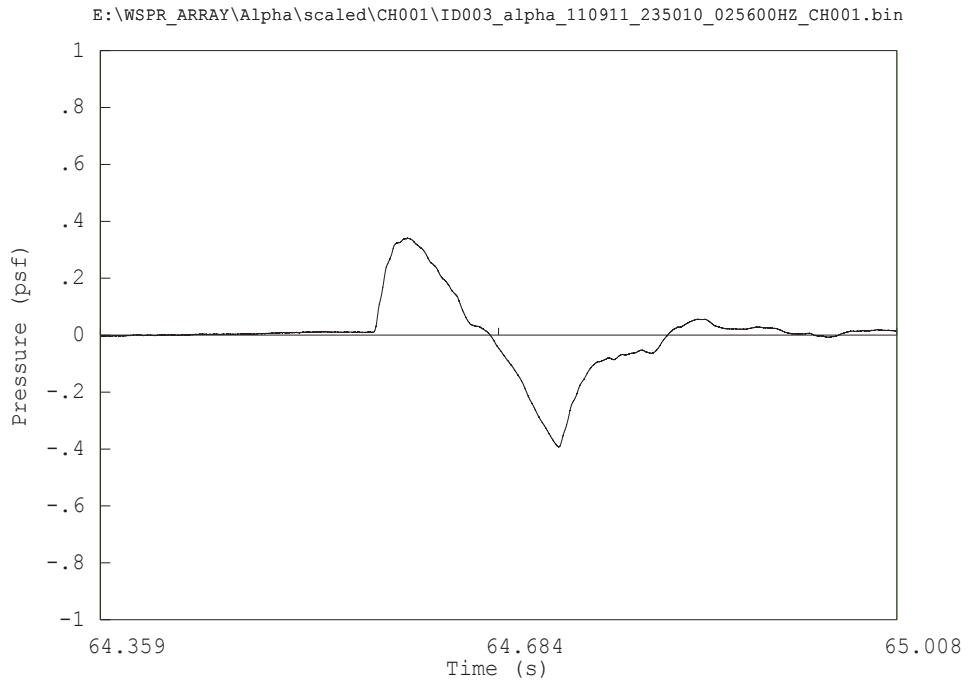
  

Site	LLZf(phons)			LLZd(phons)			PNL(dB)			MaxPSF			N
Name	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	
Alpha	0.7	1	3	0.6	0.9	3	1	0.9	3.8	0.04	0.02	0.14	85
Bravo	-0.4	-0.2	3.1	-0.4	-0.2	3.1	-0.2	-0.2	4.1	0	0	0.16	84
Charlie	-1.4	-1.6	2.9	-1.4	-1.6	2.9	-1.8	-2.1	3.6	-0.04	-0.01	0.22	83
Delta	-1.5	-1.3	3.2	-1.5	-1.3	3.2	-2	-1.5	3.8	-0.06	-0.02	0.21	79
Echo	-0.9	-1.1	3.3	-0.9	-1.1	3.3	-1	-1.1	4	0	0.02	0.22	74
Foxtrot	0.4	0.3	3.8	0.3	0.3	3.8	1	0.7	4.9	0.04	0.04	0.15	73
Golf	1.8	2	3.3	1.9	2.2	3.3	1.6	1.7	4.2	0.02	0.02	0.15	79
Hotel	1.3	1.5	3	1.3	1.4	3	1.4	1.5	3.9	0.03	0.02	0.15	69
India	0.8	1.2	3.1	0.8	1.2	3.1	0.6	0.9	3.7	0.04	0.03	0.18	85
Juliet	-0.4	0.4	3.2	-0.3	0.4	3.2	-0.9	-0.1	3.9	-0.01	0	0.21	82
Kilo	0.7	1.2	3	0.6	1	3	1.4	1.2	3.9	0	0.01	0.23	77
Lima	0.3	0.4	3	0.3	0.5	3	0.3	0.8	3.7	-0.01	0.01	0.24	86

An example where the interpolated value of PL is underestimated compared to the measured value is shown in Figure 35 and indicates that the microphone captured turbulent spiking in the signal. Turbulence spiking is a local phenomenon and explains why the interpolation method underestimated the metrics at that site. Figure 36 shows an example where the interpolated value of the PL overestimates that which was measured. The waveforms show a rounded front shock. The boom measured at the nearest monitor used in the interpolating array is depicted in Figure 37 and has a characteristic N-wave shape. The roundedness of the front shock measured at site alpha results from turbulence that is also a local phenomenon that explains the difference between the interpolated and measured values. The rounding decreases most metrics. That ZSEL is not overestimated is another indication of the imperviousness of ZSEL to turbulent effects.

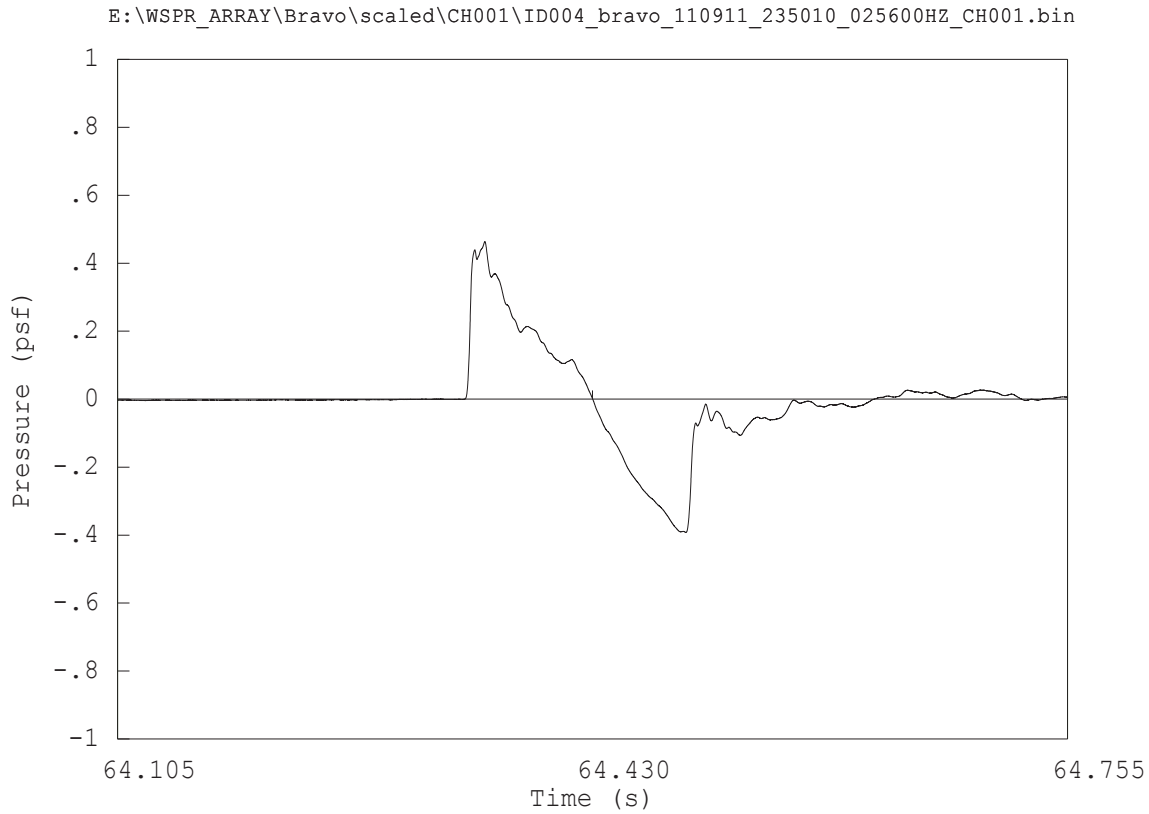


**Figure 35. Measured signature (psf) and metrics for an underestimated interpolated boom at Site Alpha.**



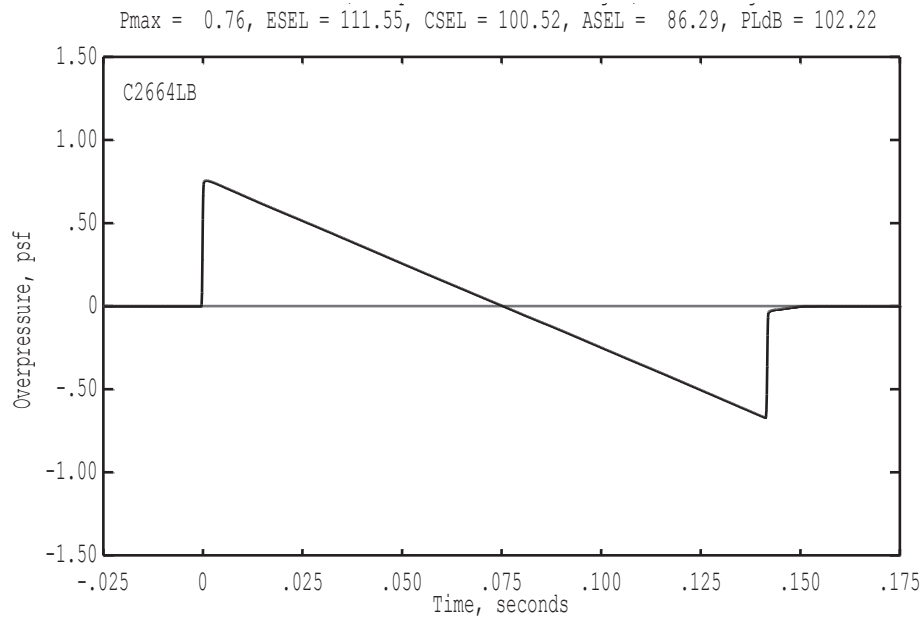
**Figure 36. Measured signature (psf) and metrics for an overestimated interpolated boom at Site Alpha.**



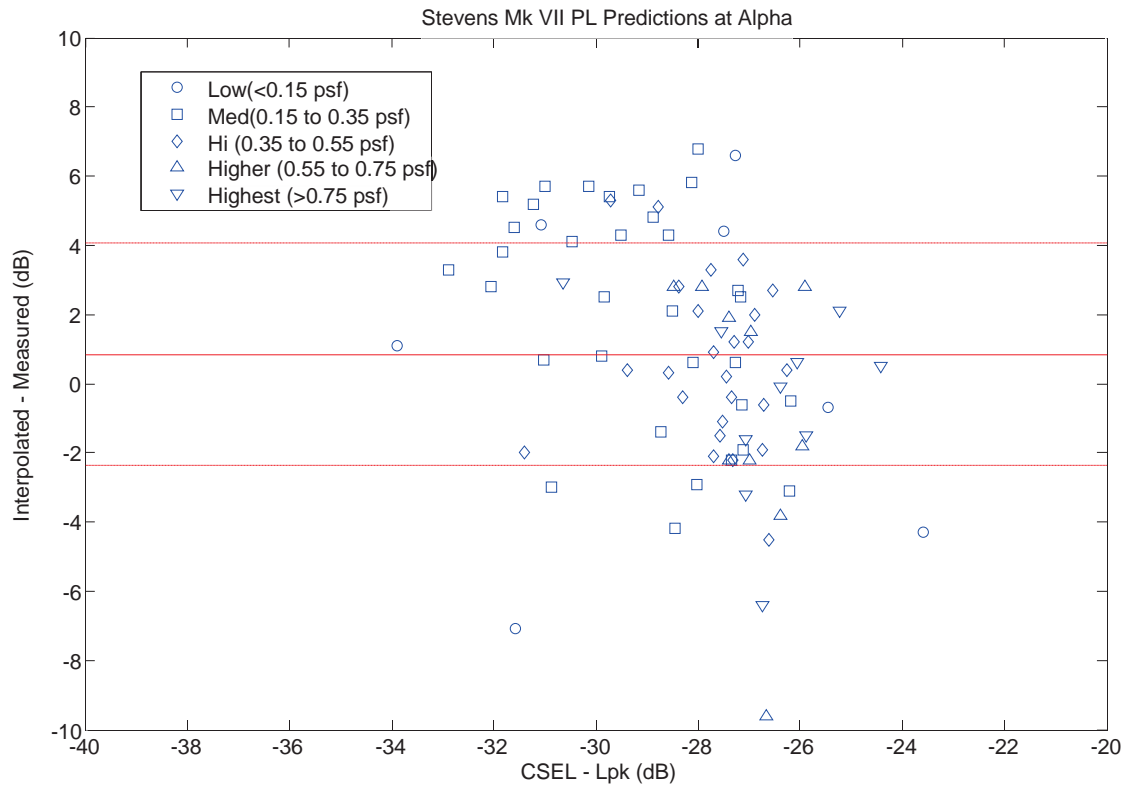


**Figure 37. Measured signature (psf) and metrics for Site Bravo – the closest monitor to Site Alpha.**

In order to gauge whether a boom has experienced turbulence, CSEL minus the level of the un-weighted peak ( $L_{pk}$ ) was computed. Consider the ideal N-wave pictured in Figure 38. The difference between the CSEL and  $L_{pk}$  is 25 dB. For the period and amplitude of the booms measured at WSPR, there could be a consistent relationship for cleaner booms (i.e., absence of turbulence). Coupled with this idea is the above discussion indicating that turbulence is the reason for the interpolation scheme not matching the measured value. While this argument will not address the case where a monitor of the array has the turbulence, it is worth investigating. Figure 39 shows the results of comparing the success of the interpolation matching the measured PL versus the difference of the CSEL and  $L_{pk}$ . Horizontal lines on the graph demark the mean and  $\pm$  one standard deviation. The majority of the comparisons within one standard deviation of the mean line up with CSEL minus  $L_{pk}$  of approximately -27 dB. Most of the outliers have a more negative value. This can be explained by turbulent spiking. If a boom has less turbulent spiking, then the  $L_{pk}$  will be greater than the  $L_{pk}$  for an ideal shaped N-wave boom; this in turn will result in the CSEL minus the  $L_{pk}$  being more negative. More research is needed to pin down a reliable method to quantify the amount of turbulence contained in a sonic boom.

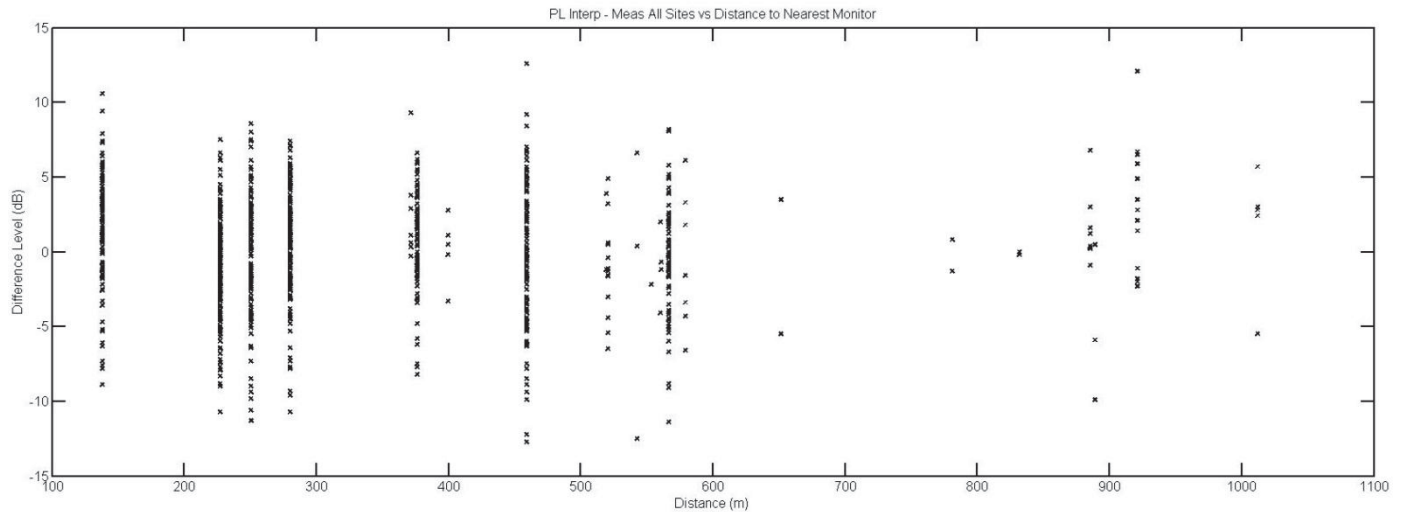


**Figure 38. Ideal N-wave.**



**Figure 39. PL interpolated minus - measured vs. CSEL – Lpeak (dB) at Site Alpha.**

Figure 4-14 shows the difference between the interpolated value at an excluded monitor and the value measured by the monitor versus distance to the nearest working monitor. Because the WSPR array had monitors drop out for some booms, the distance to the nearest working monitor varied. In conclusion, the spread of the measurements in the community was approximately 3.5 dB for the PL. Interpolating at specific sites and checking against measurements showed a similar spread but a mean difference between predictions and measurements of +/- 2 dB.

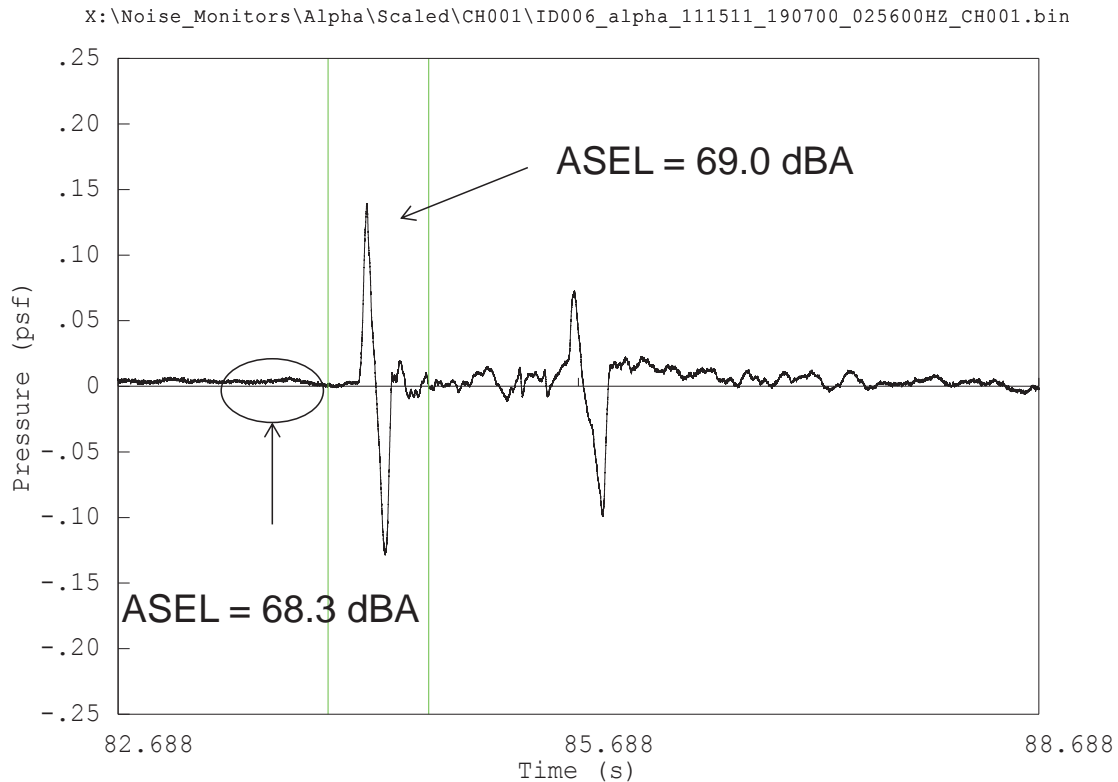


**Figure 40.** *PL interpolation minus measurement (dB) as a function of distance (m) to the nearest monitor for all sites.*

#### 4.1.6 Measured Sonic Boom Assessment – Multiple Booms, Ambients, and Metrics

The influence of ambient noise on the metrics calculated for a sonic boom is considered in this section<sup>9</sup>. In particular, the WSPR team explored the issue of how to address ambient noise when the metrics calculated for the ambient are close to those calculated for the booms. Consider the graph in Figure 41 presenting the microphone signal recorded by the field-kit at site Alpha during the WSPR measurements. The boom has a peak amplitude of 0.15 psf. The A-weighted sound exposure level (ASEL) of the boom is less than one decibel greater than that of the preceding ambient. A test of the signal to noise ratio for keeping boom metrics required that the ASEL of the boom be at least 1 dB above the ambient; thus, metrics from this boom were not used for predicting the boom’s impact at participant households.

<sup>9</sup> The Metrics included in the subjective – objective correlated database and subsequent statistical analyses presented in Section 4.2 and 4.3 were conducted using the 1 dBA signal-to-ambient background requirement. Additional examination of the treatment of ambients, metrics, and multiple booms was conducted to inform future low-boom testing on a naïve community.

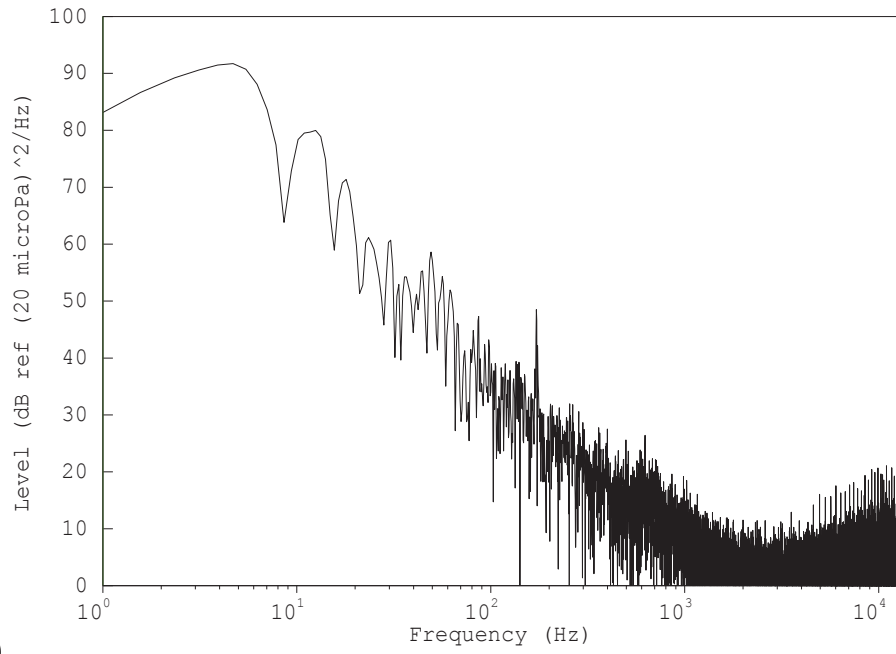


**Figure 41. Measured boom signature (psf) and computed metrics (dBA) at Site Alpha.**

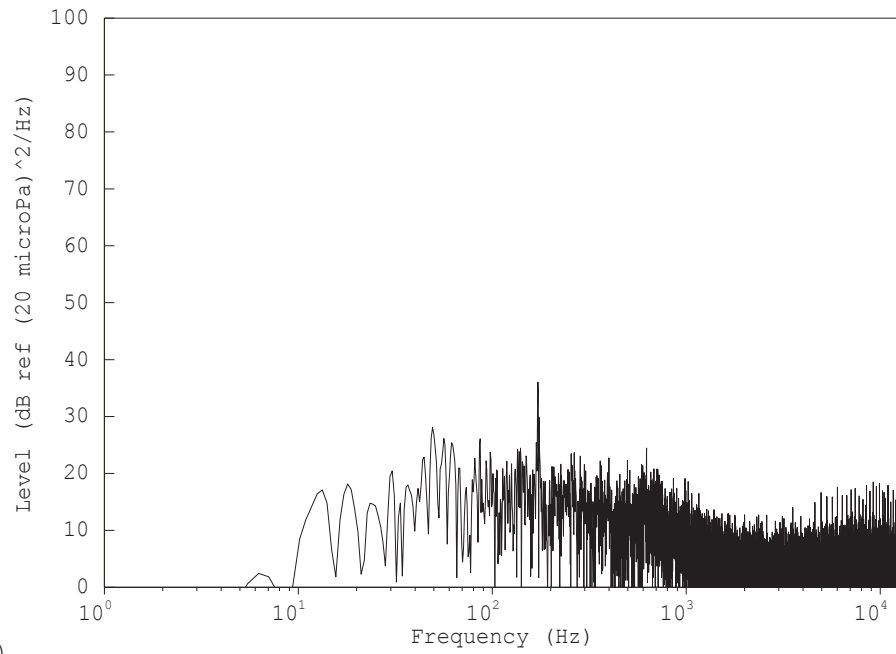
The un-weighted and A-weighted spectra of the boom and ambient are shown in Figure 42. When one considers that the measure at high frequencies is compressed, it becomes clear why the ASEL of the ambient, which has a comparable spectrum with the boom above 90 Hz, is nearly the same as the ASEL of the boom. The steepness of the boom's shocks contributes to the high-frequency content of its spectrum. The low-boom dive maneuver is executed so that the lower amplitude booms that hit the ground travel longer distances. The amplitude and steepness of a boom's shocks decrease with distance traveled. A comparison of the ASEL of the initial boom and ambient are shown in Figure 43. The dashed line has a slope of 1 for comparison. As can be seen, booms with lower A-weighted values are closer to the value of their ambient values.

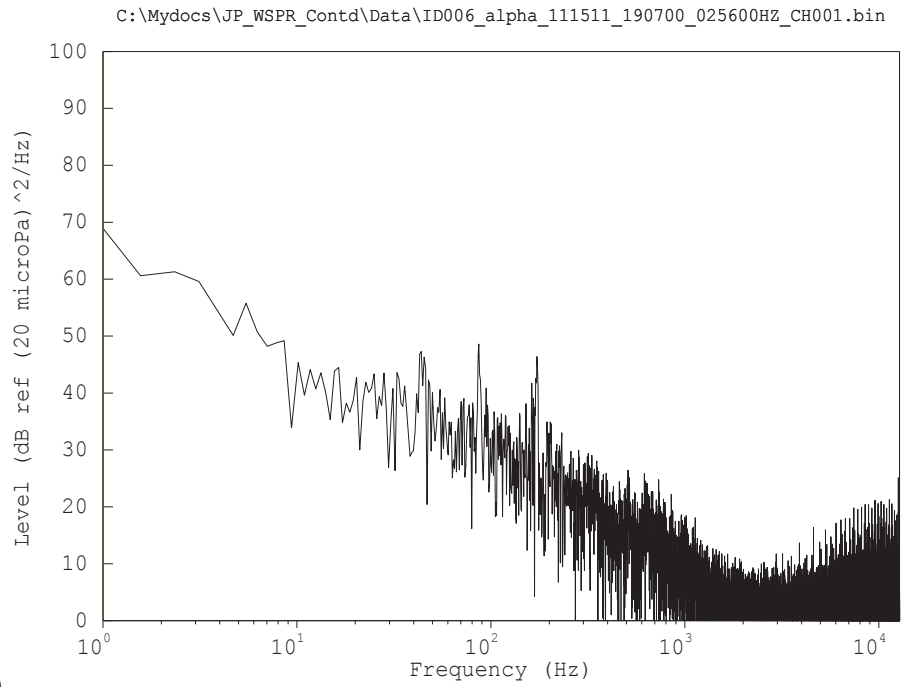
C-weighting does not affect the low-frequency portion of the spectrum as much as A-weighting. For comparison, A-weighting at 1.25 Hz is -140.59 dB while C-weighting is only -52.51 dB. As such, the C-weighted sound exposure level (CSEL) for all booms should be significantly greater than the ambient CSEL values. Figure 44 illustrates this. The lowest CSEL for a boom is more than 15 dB greater than the ambient CSEL. A similar plot of Steven's Mark VII Perceived Level for booms recorded at Alpha versus the ambient level is shown in Figure 45. The figure shows that booms with lower levels have comparable ambient levels.

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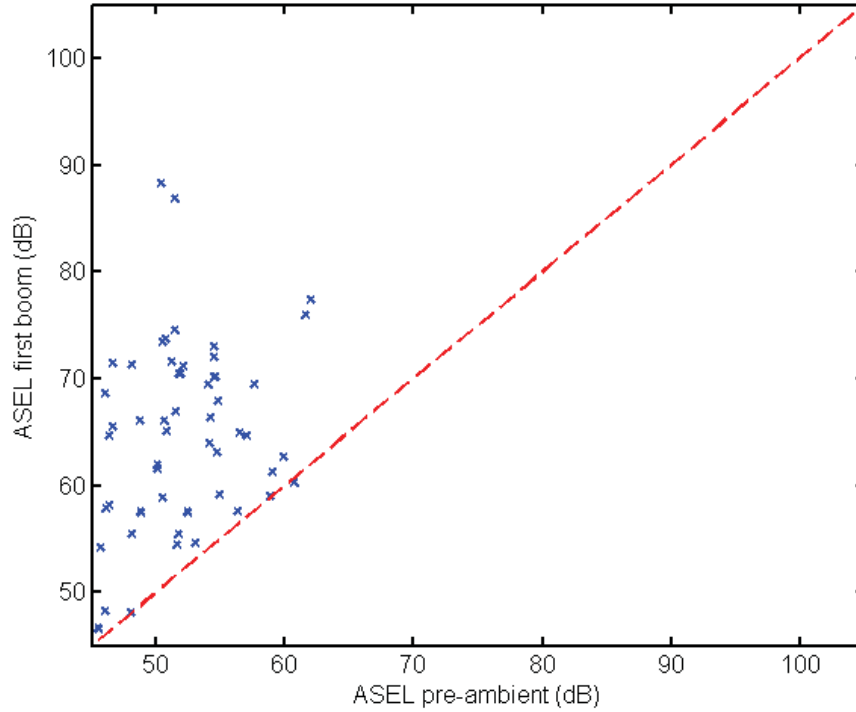


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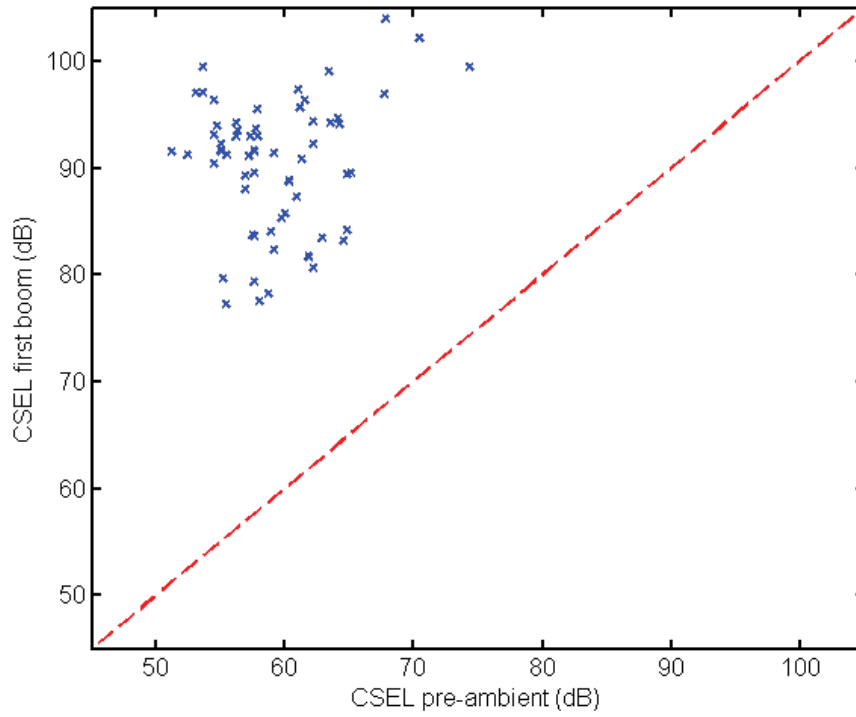


**Figure 42.** (a) Un-weighted and (b) A-weighted spectrum of the boom and (c) Un-weighted spectrum of the ambient at Site Alpha.

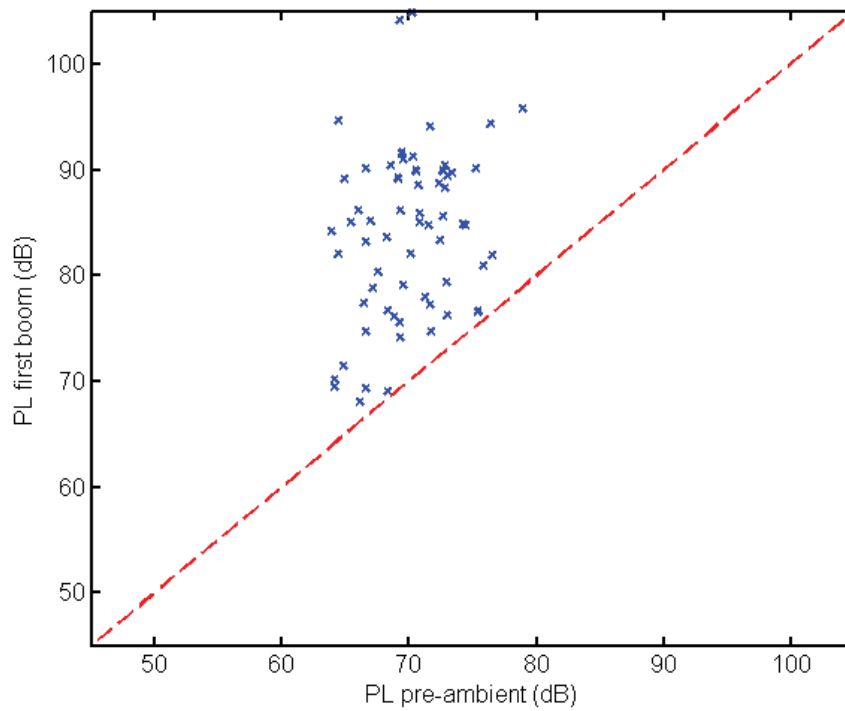


**Figure 43.** Comparison of the A-weighted level of the first sonic boom and the ambient (dBA) at Site Alpha.



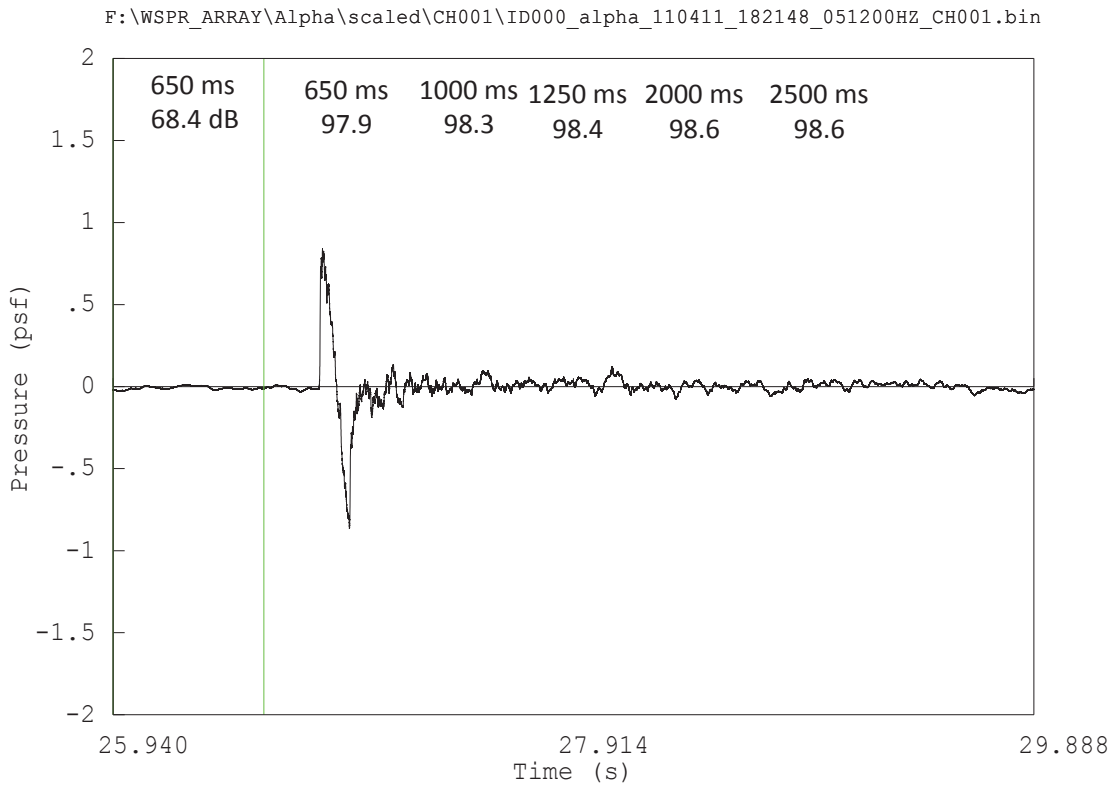


*Figure 44. Comparison of the C-weighted level of the first sonic boom and the ambient (dBC) at Site Alpha.*



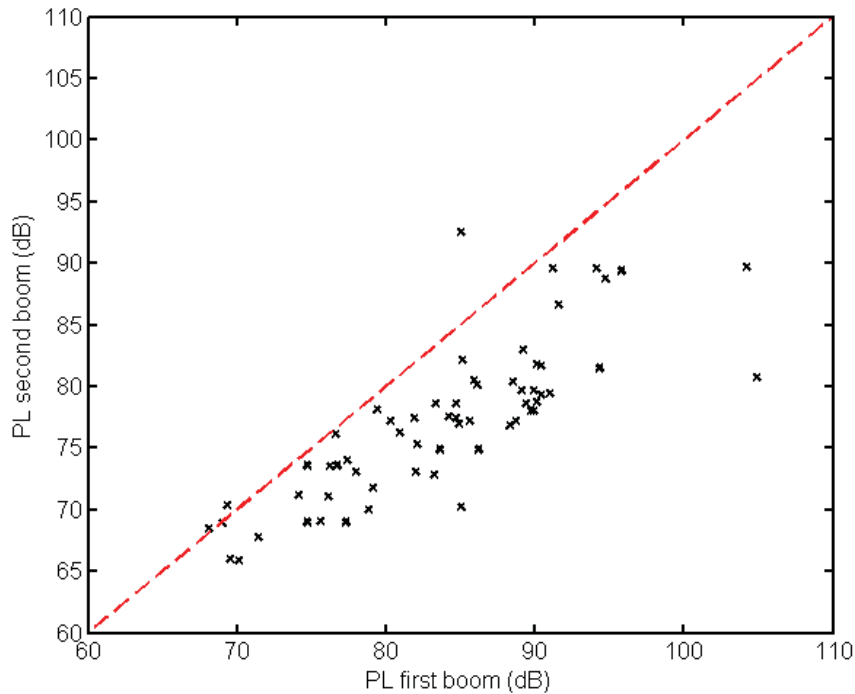
*Figure 45. Comparison of the Perceived Level of the first sonic boom and the ambient (PL) at Site Alpha.*

This analysis shows that some of the metrics calculated from low booms will exceed the ambient more readily than others. Aside from Moore & Glasberg’s metrics, the rest are based upon a single energy spectrum, thus, increasing the length of the data record used to calculate the spectrum will result in increasing levels in the spectrum until the boom and its aftermath diminish. For a perfect N-wave with zero ambient, the energy spectrum and all the metrics calculated from it will not change with record length once the N-wave is completely within the window being analyzed. Measured booms from the WSPR project include ambient noise. Increasing the record length to compute loudness metrics may result in ever-increasing levels because the ambient energy will continually add. If the energy of the boom is large enough, like the example shown in Figure 46, the ambient is so far below the boom’s energy that a metric will not change with increasing window size. This, in effect, behaves like the ideal N-wave. On the other hand, if a boom is lower in amplitude and has energy comparable to the ambient, then the only way to remove the ambient energy from the metric calculations is to subtract it from the energy spectrum before calculating the metrics. The additional problem with low-amplitude booms coming from the NASA F-18 dive maneuver is that there are two booms instead of one in most of the cases recorded for WSPR. Increasing the record length will increase the level more significantly when the window includes the second boom.



**Figure 46. Measured sonic boom (psf) at Site Alpha and computed PL for increasing record lengths.**

Consider the analysis of Steven’s Mark VII Perceived Level of the first boom compared to the second boom (Figure 47). The lower the first boom, the more significance the second boom has. More importantly, many of the second booms shown have a metric level within 10 dB of the first. From an absolute standpoint, the event’s loudness cannot be represented by analyzing just one of the booms. Review of the WSPR booms indicates that a 4-second window length will capture both booms in every instance. The potential drawback to including a 4-second window for each metric computation is that the signal might be too contaminated with ambient noise.



**Figure 47. Comparison of Perceived Level (PL) of the first and second booms.**

Subtraction of the ambient from the 650 ms sonic boom window band-by-band was also considered. The ambient is subtracted from the boom as follows – identify the boom in a 650 ms window and calculate its energy spectrum. Do the same for the 650 ms immediately preceding the boom's window. Perform a band-by-band test and determine if the sonic boom spectra is not exceeded by the ambient spectra in five or more consecutive bands. If true, subtract the energy of the ambient spectrum from the boom spectrum in those consecutive bands meeting the band-by-band test. Figure 48 shows a plot of Steven's Mark VII Perceived Level calculated from the energy spectrum of the first boom with the ambient subtracted versus the metric without the ambient subtracted. A dashed line of slope one is plotted for reference. Booms whose energy spectrum did not exceed the ambient for five consecutive bands are plotted on the abscissa. The analysis time was 650 ms. What is evident is that booms whose spectrum was not sufficiently above the ambient tended to be among the bottom third of the range measured. Only booms of lower level show the effect of subtracting the ambient as evidenced by their deviation from the dashed line. This is consistent with the observation that low booms with lower PL are only marginally larger than the ambient.

Figure 49 shows the ambient relationship plots for the other metrics based on energy spectra. Of note in Figure 49 is the absence of deviation from the dashed line of the CSEL and ZSEL. This suggests that if an event occurs before a boom so that the ambient cannot be subtracted across the whole spectrum, then the very high amplitudes of the lower frequencies of a boom will not be detracted by the ambient.

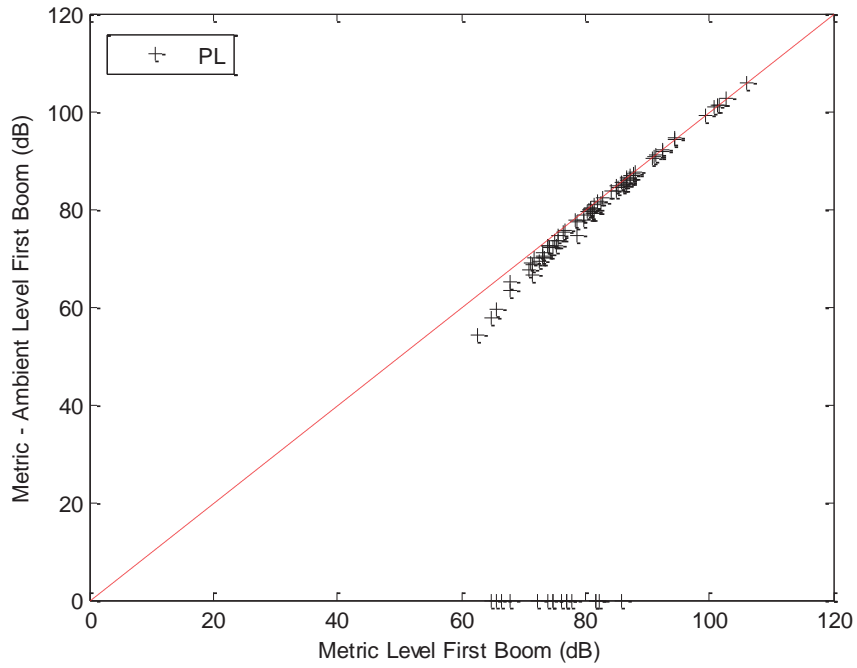


Figure 48. Comparison of PL with spectral subtraction of ambient and boom PL.

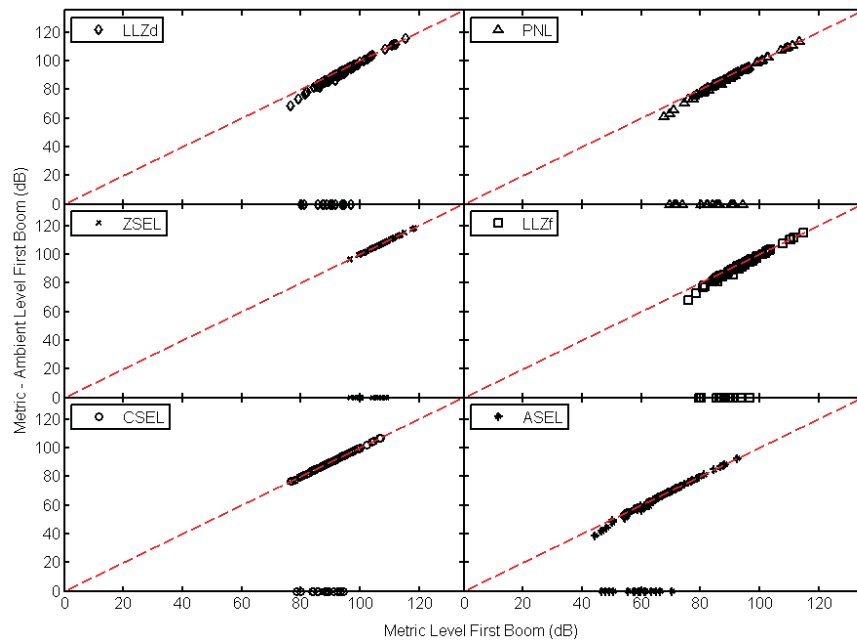
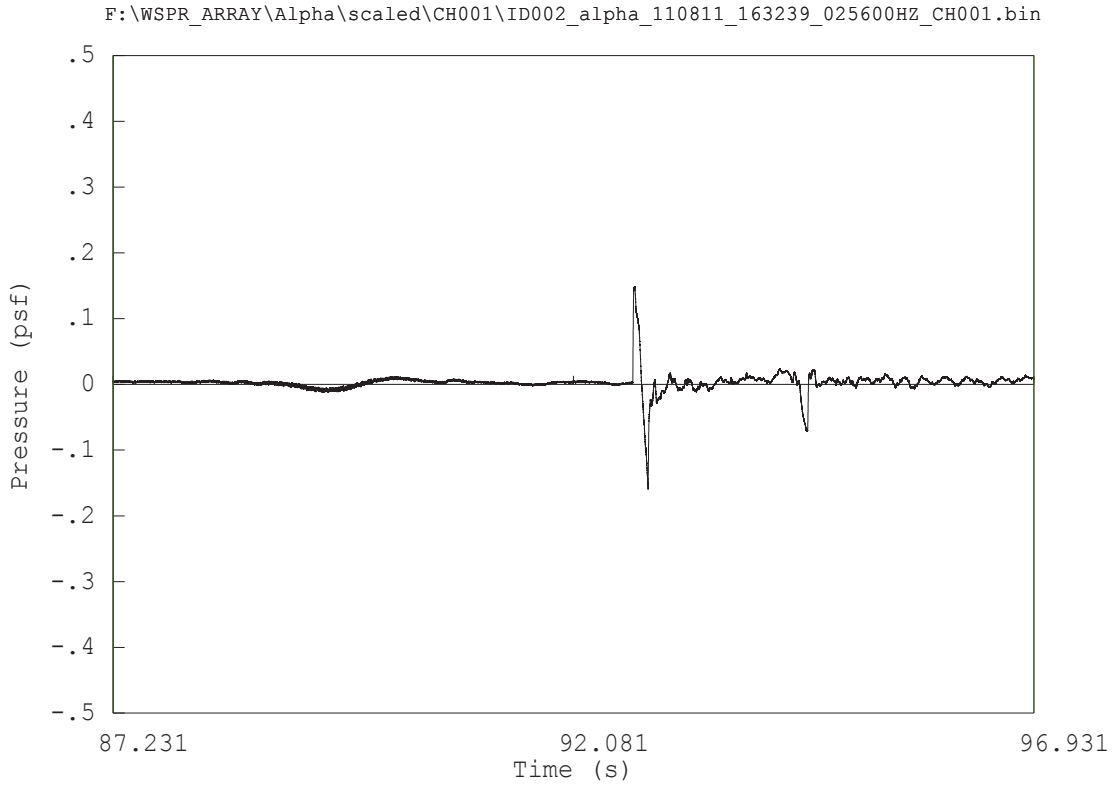
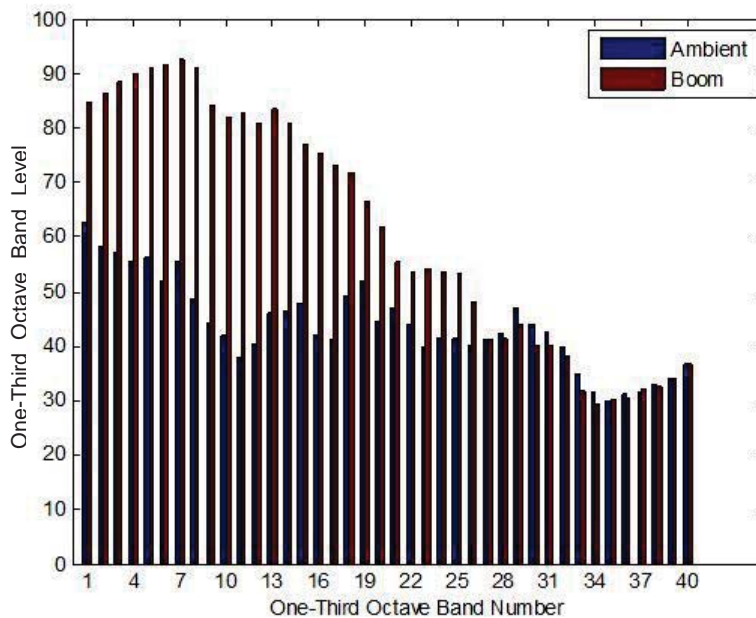


Figure 49. Comparison vs. boom metrics of spectral subtraction of ambient.

A specific example of this behavior is presented. The first boom (Figure 50) did not meet the band-by-band ambient criteria. The CSEL values for the first boom and ambient are 83.6 and 57.6 dB respectively. Figure 51 shows the two energy spectra for the boom and ambient. As can be seen, there is a period where five consecutive bands are below the ambient; thus, a spectrum without the ambient was not calculated. A car driving past the monitor caused the band-by-band criteria to not be met. The car was no longer audible just before the boom. Had the car been still making noise during the boom, its noise would have added to the spectra of the low-boom possibly allowing the band-by-band criteria to be met. Even with short duration analysis, the ambient noise levels can vary so as to exceed the boom levels.



**Figure 50. Example boom signal (psf) with CSEL ambient failure.**



**Figure 51. Energy spectrum for example boom and ambient.**

When selecting a suitable analysis window size, consideration must be given to:

- The first boom and its pre-event ambient,
- The rumble afterwards, and
- The second boom.

Also of concern, but not addressed here, is how to calculate the loudness metrics (i.e., Zwicker’s, Kryter’s, and Steven’s) for various boom event elements. The latter refers to how the energy spectrum is normalized prior to metric calculation. Prior research [Sullivan et al., 2010] provides a good argument for normalizing the energy spectrum by 70 ms. It was also argued that subtracting 3 dB from the spectrum was appropriate since the typical boom sounds like two bangs since the period of the booms is greater than the human ear’s response time. Neither of these arguments is applicable to the ambient spectrum or post-boom rumble. This point is noted but left for future research. The loudness metrics calculated in this report have consistently used 70 ms to normalize the energy spectra and correct them by subtracting 3 dB except for the following illustrative examples. Figures 52 – 54 do not have 3 dB subtracted from the energy spectrum before calculating Steven’s Mark VII PL (“PLdB” in the figures) because an existing program had to be utilized that did not correct energy spectra by 3 dB.

To see the relative magnitude of metrics from boom elements consider the example in Figure 52. The vertical lines delineate 650 ms sections of the data record with the metrics listed for each section. As can be seen, the Steven’s Mark VII Perceived Level is larger for the booms and rumble than the ambient. The ASEL for the first boom is only 1 dB larger than the other parts. The CSEL and ZSEL are clearly larger for the booms and rumble than the ambient. Figure 53 shows a nicer example. The figure emphasizes that a slight increase in the size of the boom dramatically increases the metrics relative to metrics for other parts of the boom. One last case to consider is shown in Figure 54. As a relatively large boom, the metrics are much larger for ambient and rumble. It is informative to look at the metrics for the rumble and second boom. They are small compared to the boom, but are comparable to rumble and ambient levels of other, smaller booms. This shows that one must consider the duration of a boom as well as the metrics of the parts, because if a lower amplitude boom is consequential, then the rumble after a big boom is also important.



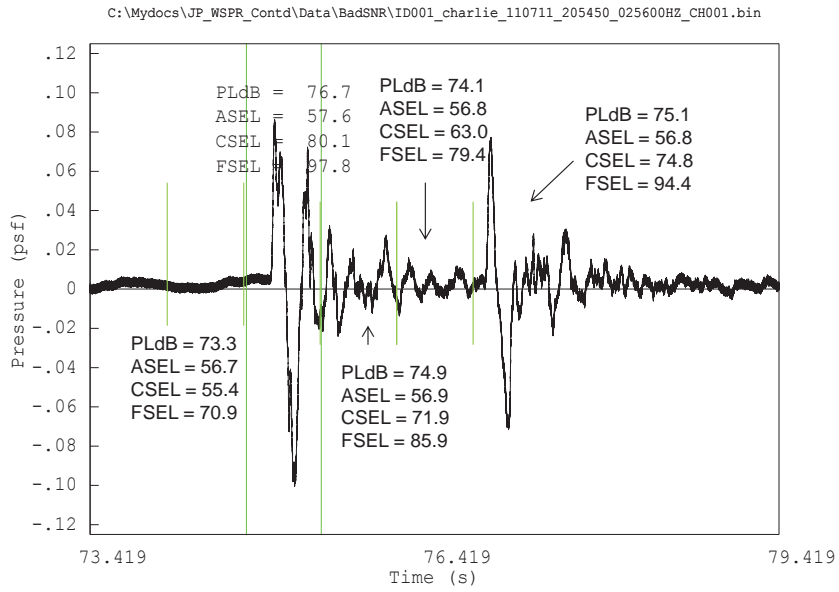


Figure 52. Example low amplitude sonic boom with commensurate rumble and ambient metrics.

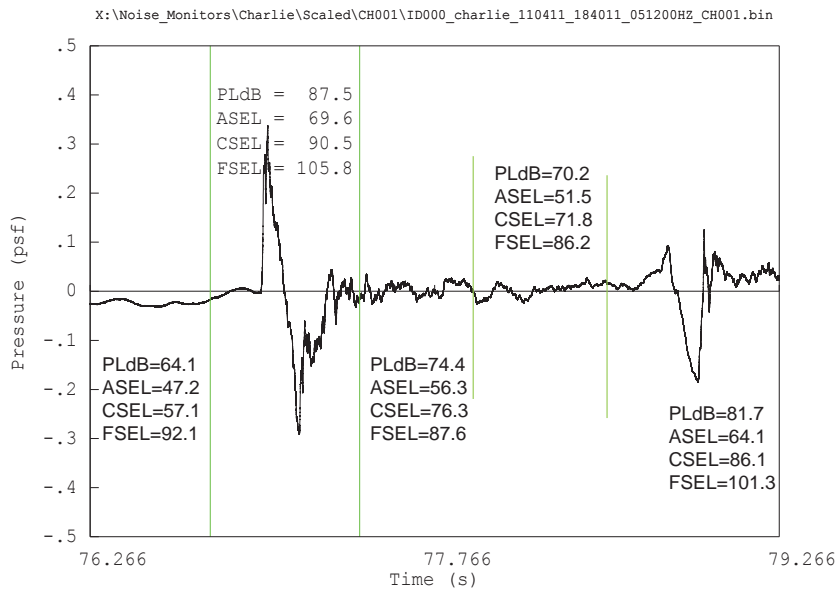
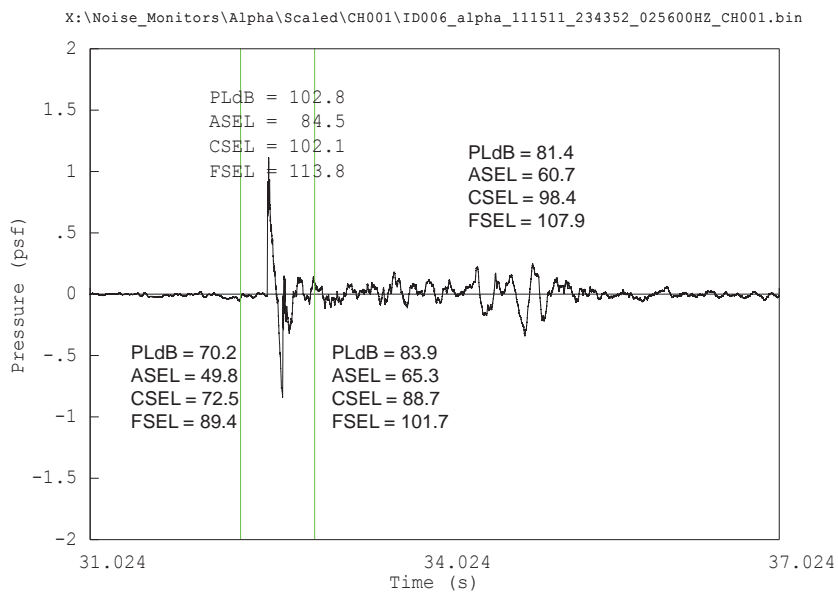


Figure 53. Example medium amplitude sonic boom with low metric levels for ambient noise.



**Figure 54. Example high amplitude sonic boom with large metrics from post-boom.**

#### **4.1.7 Automated Boom Finder (ABF) Methodology for Low-Amplitude Sonic Booms**

An Automated Boom Finder (ABF) methodology was developed for low-amplitude sonic booms such as those recorded during the WSPR experiment. This section of the report describes the ABF methodology.

ABF will search a recording for first and second sonic booms. The method it employs in finding a second sonic boom in a recording was created specifically for the second boom typically found during the low-boom dive maneuver executed by NASA DFRC’s F-18s. There were two motivations for creating the ABF – the first was to automate identification of the portion of a recording that contains a sonic boom, while the second was to combine the calculation of metrics into a single process and single output file.

Previously, sonic booms were identified visually in a recording by plotting the data in the recorded file and looking for the N-wave shape characteristic of a sonic boom. While higher amplitude booms can easily be found by employing an algorithm that uses an amplitude-based trigger to find when a recording exceeds some preset amplitude, the number of false triggers will increase as the trigger amplitude is decreased. As will be explained below, additional characteristics of the recording are examined in order to decrease the number of false triggers. Also sharp rise times are not unique to sonic booms (lightning, etc.), so analyzing frequency content versus time allows booms to be separated from other noise sources.

Initial work on the WSPR project used a modified version of a program called ADLoud [Shepherd and Sullivan, 1991] and the Moore & Glasberg loudness metrics, including the TVL program<sup>10</sup>. The ABF is set to work in two stages. The first stage identifies the location of the first and second booms in the input file employing user-input parameters and is performed in the MATLAB scripting environment. The same logic and algorithms for finding the booms are applied to both the first and second booms. The second stage involves two calls to command line programs from MATLAB.

The boom identification stage in ABF utilizes a combination of amplitude triggering directly from the input data record and from a band-pass filtered version of the data. The first employs the triggering mechanism found in NASA DFRC’s Boom Amplitude and Shape Sensor (BASS) recorder. The algorithm compares a running sum of a length of the array (msum) against a retarded sum of the same length (msumlag). If the first sum exceeds the second by a set amount (triggerdp) over a pre-defined length (triggerdwell), then a trigger is set. Figure 55 shows this logic. The first shock of a

<sup>10</sup> The time varying loudness program TVL is available at <http://hearing.psychol.cam.ac.uk/Demos/demos.html>.

boom is shown with the averaged msum time history of it along with a retarded version of it (msumlag). The time when the trigger is first set is shown by the red “x” on the boom trace. The trace msum is an average of the last msumlength points (640 in this case). The trace msumlag is retarded by 1280 samples in this case. The trace msum had to exceed msumlag by 0.1 psf (triggerdp) for triggerdwell points (256 in this case).

Figure 56 shows a sonic boom with the time trace of its 4 to 10 Hz bandpass filter. A band pass filter of 4 – 10 Hz is the typical fundamental frequency of full-scale sonic booms. This band pass filter range can be customized in the ABF program. If the trigger is set from above, then the bandpass filter is tested to determine if the absolute value of the bandpass filtered level exceeds a user-set fraction of the trigger value over the expected boom interval from the time of the trigger. By testing this filtered version of the recorded data for an exceeded level, the shape of the boom is implicitly looked for. It is not uncommon for a low-amplitude boom to have a sharper peak after the expansion than the peak of the first shock. A check within the expected boom duration before the trigger is made to determine if a peak of higher pressure than that at the trigger time exists. If it does, then the trigger time is moved to the time of that greater pressure. Figure 57- shows an example where this happened. A search of the expected boom duration before the trigger found a greater maximum value and the trigger was moved to that peak.

Figure 58 shows another example where a low-amplitude boom has a greater pressure for the peak after the expansion. A search of the expected boom duration before the trigger found an expansion indicating the first peak of the boom had already occurred. The trigger was moved to the peak in the record before the expansion. If an expansion is detected before the trigger, it is tested to determine if it has a negative pressure duration greater than one third of the expected boom time and a negative peak whose absolute magnitude exceeds half of the second peak’s pressure. If this test returns positive, the trigger point is shifted to the max value found in the expected boom time before the second peak starting at the time of the minimum pressure. That is to say, the trigger can be shifted earlier at most by the number of samples in the expected boom duration. The search for the maximum value will begin before the expansion if one is found.

For the TVL program, those portions of the data record that are identified as being sonic booms are processed as follows – both ends of the data are tapered with a Tukey window; the data is re-sampled to 32 kHz<sup>11</sup>; it is normalized so that the full scale is equivalent to a sound pressure level that is the nearest 10 dB higher than the peak of the data, the normalized data is written to a wav file for the TVL program to process with the frontal incidence filter and appropriate calibration applied.

A MATLAB command line call then sends the metrics calculated by the TVL program along with user input parameters and the data record to another command line program called GetMetrics. This program calculates the same metrics as the modified ADLoud program and writes them along with the Moore & Glasberg metrics to a text file. Some additional computations are performed by GetMetrics that were not done by the modified ADLoud, including subtraction of ambient as described in Section 4.1.6.

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<sup>11</sup> The GetMetrics program applies a Tukey window internally, and does not require data resampling.

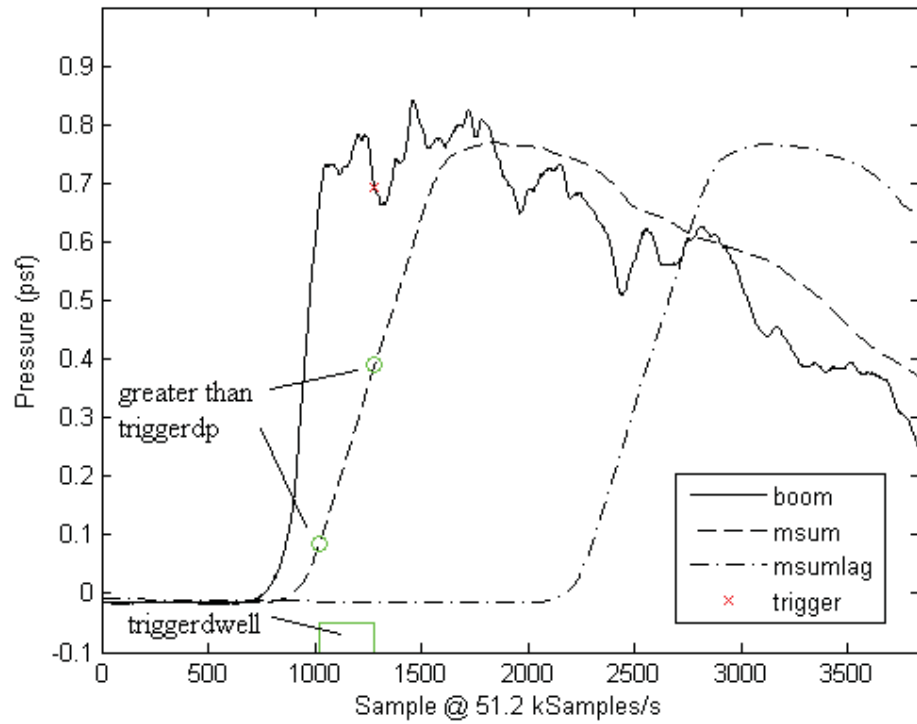


Figure 55. Time histories of the arrays in the trigger function.

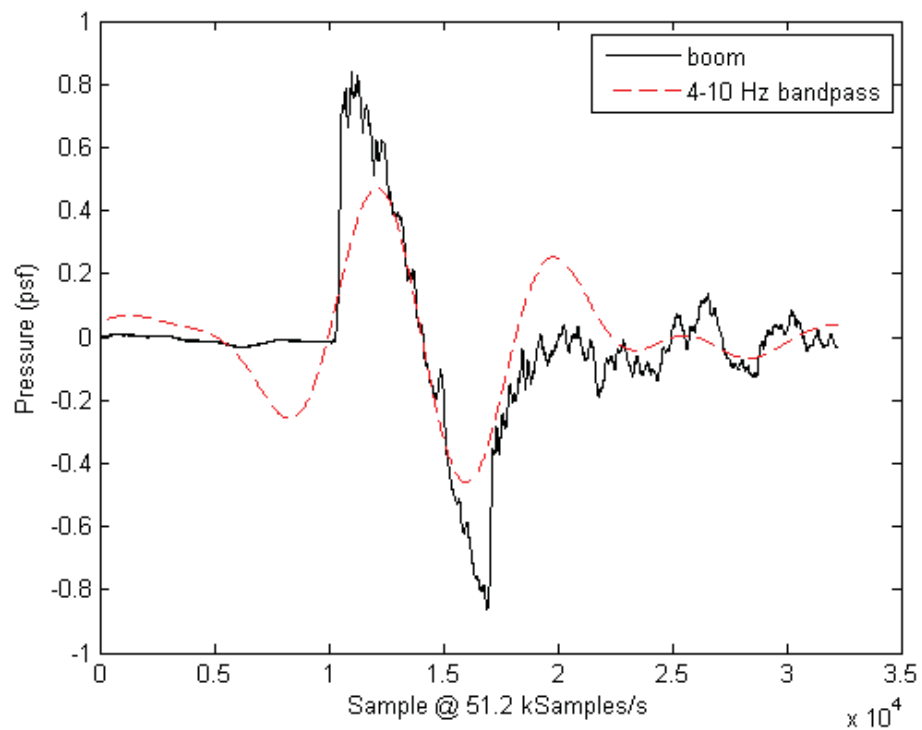
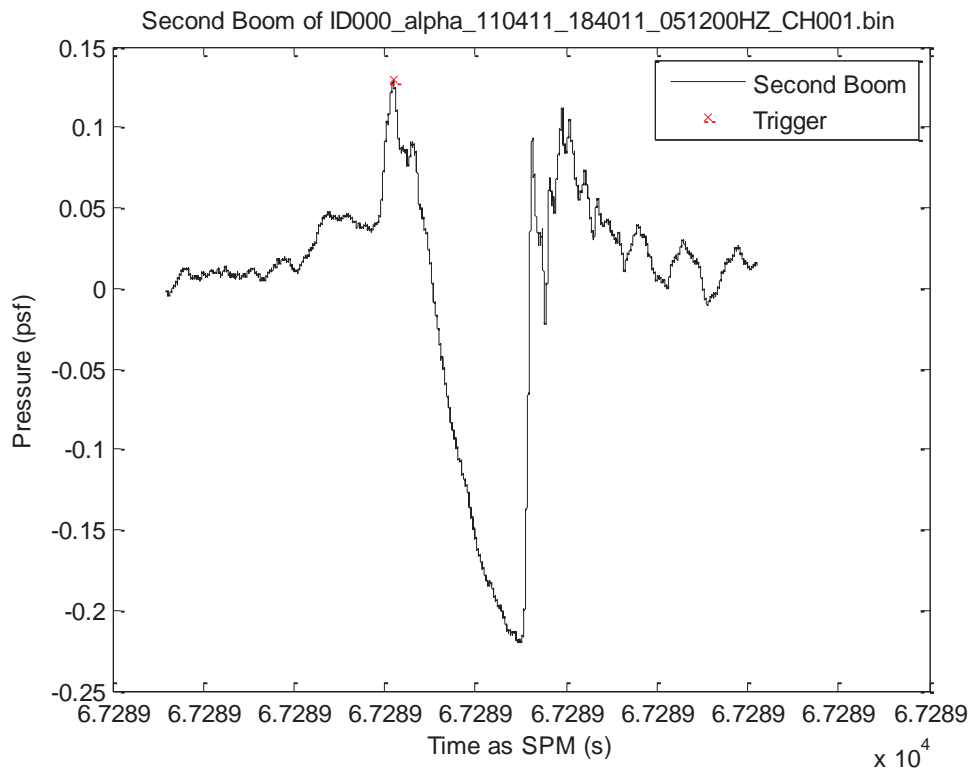
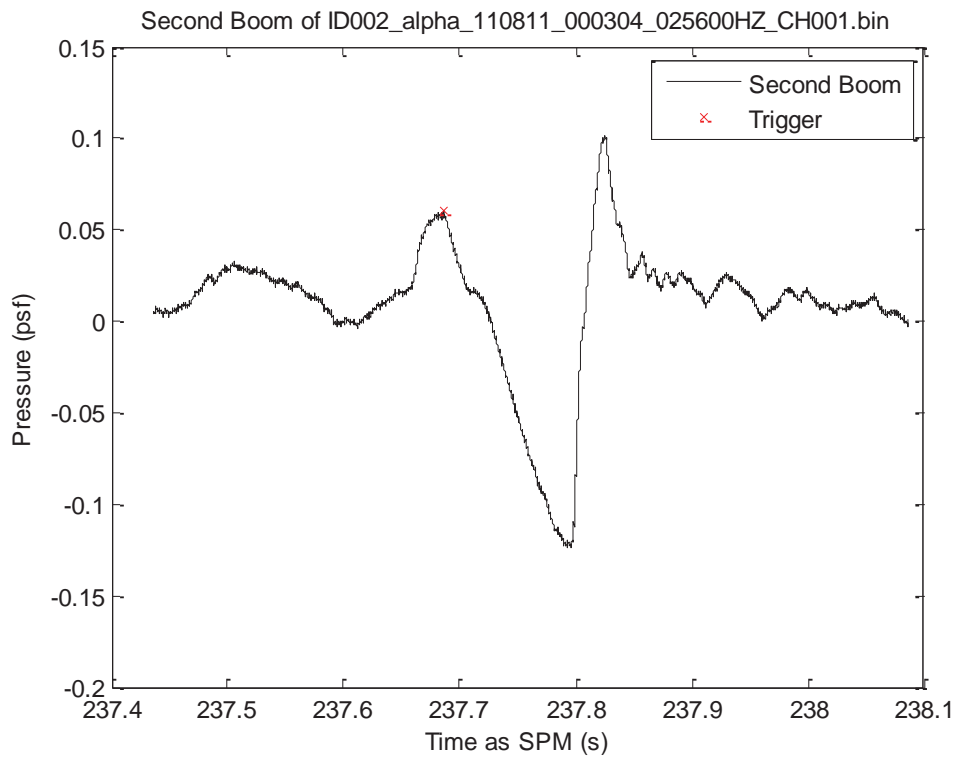


Figure 56. Graph showing boom record with its band-passed filter trace overlaid as a dashed line.



**Figure 57.** Example of the trigger point for a second boom (seconds past midnight, SPM).



**Figure 58.** Second example of a trigger point for a second boom (seconds past midnight, SPM).

## 4.2 Analysis of Survey Data Collection Procedures

Subjective survey responses were collected from 52 subjects during the experimental test period. As discussed in Sections 3.1.7 and 3.4.2, sample attrition occurred prior to the start of the test period because recruited subjects would not be on base during the 2 weeks of the test (n=4), during the study period when subjects who had told us they would be on base during the test period were not (n=2), and at the conclusion of the test due to irretrievable data (n=1). Subject recruitment and survey participation, by mode, are indicated in Table 23.

**Table 23. Subject Counts and Timing of Attrition, by Survey Mode of Administration**

Survey Mode	Recruited	Survey Participation	Timing of Attrition
<b>Apple</b>	15	14 (13 iPhone, 1 iPod)	Data not retrievable from 1 iPod
<b>Web</b>	25	22	One ineligible before study started; two dropped out after study began and did not submit surveys
<b>Paper</b>	20	16	4 ineligible before study start

This section presents results of the analysis of survey data collection procedures, including analysis of completion rates by mode and over time, the timeliness of response, and how closely reported boom times align with actual boom times.

### 4.2.1 Orientation Survey Responses

Three quarters of all single boom survey forms were submitted for orientation day, suggesting that a large proportion of subjects were “trained” to the noise associated with a low-amplitude boom.<sup>12</sup> Response rate was 100 percent among subjects using paper forms (all of the expected forms were submitted), while roughly two-thirds of Web (63 percent) and Apple (66 percent) forms were submitted. Table 24 itemizes the response rate based on the expected number of booms across the various survey modes.

**Table 24. Completion of Single Boom Forms on Orientation Day (November 4, 2011)**

Mode (N subjects)	Submitted	Expected	Response Rate
<b>Apple (14 subjects)</b>	29	44	66%
<b>Paper (16 subjects)</b>	56	56	100%
<b>Web (22 subjects)</b>	45	72	63%
<b>Total (52 subjects)</b>	130	172	76%

Note: The expected number of single boom survey forms is number of subjects x number of booms (four) with an adjustment for exposure. Individuals who reported that they were “not at home” all day, at home only after 5:00 p.m., not at home in the morning between the hours 7:00 a.m. to Noon, or heard zero booms for the day were removed from the calculation of expected number of survey forms (i.e., not exposed during the orientation exercise).

<sup>12</sup> This analysis does not adjust for the reported time of the boom. It includes surveys in which the reported time was earlier than the scheduled boom sequence as well as surveys with reported times after the orientation flights. It is possible the survey reports reflect confusion about the instruction (e.g., time the survey filled out rather than boom heard) or that individuals told to be attuned to booms of varying levels were particularly attentive and “over-reported” other noise as booms. If the discrepancies stem from individuals noting the time they completed the survey rather than the time of the sonic boom, they are unique but notable instances of not following instructions. The form clearly states “Time of sonic boom” with a place to enter the time and instructions to do so using military time. The pre-test at NASA DFRC revealed no ambiguity about this task or the instructions on this point.



Over 80 percent of all subjects submitted the daily summary form on November 4. Participation was highest among paper subjects (100 percent) and Web (77 percent), as shown in Table 25. In this analysis, the number of expected survey forms equals the number of subjects, because subjects were instructed to submit the daily summary form even if they were not at home and even if they heard zero booms that day. As a result, completion of the daily summary is a less reliable indicator of exposure to the orientation exercise. However, the high completion rate does indicate that most subjects are learning another task critical to the success of gathering subjective response data (i.e., the task of submitting the survey forms regularly and as instructed).

**Table 25. Completion of Daily Summary Forms on Orientation Day (November 4, 2011)**

Mode (N subjects)	Submitted	Expected	Response Rate
<b>Apple (14 subjects)</b>	9	14	64%
<b>Paper (16 subjects)</b>	16	16	100%
<b>Web (22 subjects)</b>	17	22	77%
<b>Total (52 subjects)</b>	42	52	81%

#### 4.2.2 Survey Completion Rates

Response rates for the daily summary surveys were high for all three modes of administration. Overall, 90 percent of all expected forms were submitted with slightly higher response by paper participants (95 percent) than Web (90 percent) or Apple (85 percent). Recall that subjects were instructed to complete the daily summary every day, regardless of whether they were at home or whether they noticed any booms, so everyone should have submitted 15 forms. Slightly more than one-half submitted all 15 daily summaries (29 of 52 subjects) and 88 percent submitted at least twelve (46 of 52 subjects) (see Table 26).

**Table 26. Completion of Daily Summary Forms, by Mode of Administration**

	Apple (14 subjects)	Paper (16 subjects)	Web (22 subjects)	Total (52 subjects)
Completed all forms	4	12	11	27
Completed 12 - 14 forms	7	3	9	19
Completed 9 - 11 forms	2	0	0	2
Completed 6 - 8 forms	0	1	1	2
Completed 3 - 5 forms	1	0	1	2
<b>Total forms submitted</b>	<b>178</b>	<b>227</b>	<b>297</b>	<b>702</b>
<b>Total forms expected (n subjects X 15 days)</b>	<b>210</b>	<b>240</b>	<b>330</b>	<b>780</b>
<b>Response Rate (submitted / expected)</b>	<b>85%</b>	<b>95%</b>	<b>90%</b>	<b>90%</b>

Response was lower for the single event survey forms, but it is more difficult to determine the correct denominator for this calculation. The total number of sonic booms during the experimental test period was 110, including WSPR and non-WSPR booms, but subjects were not necessarily exposed to all of the booms. The WSPR team used subjects' reports on the daily summaries to ascertain whether they could have been exposed to the sonic booms generated each day. Specifically, we excluded instances in which subjects reported they were not at home that day, were at home only after 5:00 p.m., or heard zero booms for the day. After these adjustments, one-half of all expected single-boom forms were submitted (Table 27). Response was highest among paper participants (58 percent) followed by Web (50 percent) and Apple (45 percent).

**Table 27. Completion Rates of Single Event Forms, by Mode of Administration**

	Apple (14 subjects)	Paper (16 subjects)	Web (22 subjects)	Total (52 subjects)
Completed all forms	0	0	0	<b>0</b>
Completed 85 - 105 forms	0	3	0	<b>3</b>
Completed 64 - 84 forms	2	4	5	<b>11</b>
Completed 42 - 63 forms	4	4	11	<b>19</b>
Completed 21 - 41 forms	5	4	5	<b>14</b>
Completed 4-20 forms	3	1	1	<b>5</b>
<b>Total forms submitted</b>	<b>556</b>	<b>882</b>	<b>1062</b>	<b>2500</b>
<b>Total forms expected*</b>	<b>1242</b>	<b>1513</b>	<b>2110</b>	<b>4865</b>
<b>Response Rate (submitted / expected)</b>	<b>45%</b>	<b>58%</b>	<b>50%</b>	<b>51%</b>

(\*) Expected number excludes cases when subject not at home all day, at home only after 5:00 p.m., or heard zero booms for the day (i.e., not exposed).

Tables 28 and 29 present an analysis of response rates for four time periods – a) November 4 (the orientation day), b) the first and second weeks of the experimental test period to assess whether respondent fatigue affected response, and c) the last 2 days of the experiment. The last 2 days were examined separately because submissions seemed to decline across all participants. The decrease in response may have resulted for several reasons – a) a very large number of sonic booms on Tuesday and Wednesday, including several full non-WSPR booms, may have contributed to respondent fatigue, b) the final 2 days included the quietest WSPR booms and subjects may, in fact, not have noticed them, and c) reports from the field suggested ambiguity in the community regarding the end date of the study. While we cannot definitively differentiate among the causes of the lower response rate on November 17 and 18, it is useful to analyze these data separately.

Completion of the daily summaries was consistently high over the study period. Response exceeded 80 percent throughout the study period and was above 90 during the bulk of the WSPR-generated booms (Table 28). Response was high for all modes of administration and for all time segments, with the exception of response on the first day by Apple and Web subjects (64 and 77 percent respectively). Both modes recovered quickly and consistently submitted about 90 percent (or more for Web) of expected forms for most of the test period. The time period reported in Table 27 includes weekends and holidays because subjects were instructed to submit daily summary forms every day from November 4–18, whether or not they were at home or noticed any sonic booms.

**Table 28. Completion of Daily Summary Forms, by Mode of Administration and Time**

	Friday, Nov 4			Nov 5-11			Nov 12-16			Nov 17-18		
	Submitted	Expected	RR	Submitted	Expected	RR	Submitted	Expected	RR	Submitted	Expected	RR
Apple	9	14	64%	85	98	87%	61	70	87%	23	28	82%
Paper	16	16	100%	110	112	98%	75	80	94%	26	32	81%
Web	17	22	77%	139	154	90%	103	110	94%	38	44	86%
Total	42	52	81%	334	364	92%	239	260	92%	87	104	84%

In contrast, completion of single event forms was consistently lower, decreased over time, and dropped substantially on the final 2 days of the study (Table 29). About three-quarters of all subjects were “trained” to low-amplitude booms as indicated by completion of survey forms on November 4. Almost 60 percent of all expected forms were submitted during Week 1 (November 7 – 10) but participation dropped to about 50 percent during the first half of Week 2

(November 14 – 16). Thirty percent of all single booms occurring on the last 2 days of the study were reported by subjects. Completion rates were consistently higher among paper participants than Web and Apple, but the pattern of decline is the same across all modes. Response among paper participants decreased sharply after the orientation day – from 100 percent to 65 percent. A perfect response rate is highly unusual – paper participants, for unexplainable reasons, may have been especially attuned to the kick-off of the study on November 4.

**Table 29. Completion of Single-Boom Forms, by Mode of Administration and Time**

	Friday, Nov 4			Nov 7-10			Nov 14-16			Nov 17-18		
	Submitted	Expected	RR	Submitted	Expected	RR	Submitted	Expected	RR	Submitted	Expected	RR
Apple	29	44	66%	227	456	50%	276	633	44%	24	109	22%
Paper	56	56	100%	348	532	65%	428	784	55%	49	141	35%
Web	45	72	63%	421	746	56%	549	1141	48%	46	151	30%
Total	130	172	76%	996	1734	57%	1253	2558	49%	119	401	30%

(\*) Subjects who reported “not at home,” at home only after 5:00 p.m., or zero booms for the day on the Daily Summary form were removed from calculation of expected number of survey forms (i.e., not exposed).

### 4.2.3 Timeliness of Response

**How Quickly Do Subjects Complete or Return Survey Forms?** We examined the elapsed time between when the boom was reported to have occurred and the time the survey form was transmitted. The length of a recall period is a factor affecting data quality and may be even more important for the current study design. Sonic booms were generated approximately 6 minutes apart; if subjects waited to record their answers to survey questions, the reactions may be less valid indicators of how people experience noise. The Apple and Web modes made it possible to compare the time the boom was reported with the time data were transmitted (timestamp on the mobile device, timestamp on Web server). The WSPR team did not have an independent measure of when participants completed paper forms that was comparable to the device timestamp of a mobile device or a Web server timestamp, and they did not ask the participants to record “current time” when completing the form.

Apple participants appeared to record their responses almost immediately upon noticing a sonic boom. Over 70 percent of all single boom forms completed by Apple participants were submitted within 1 minute of the reported boom (Table 30). The tight distribution on submission time relative to reported time reflects the ease of use of the application and the virtues of using a mobile device (often readily accessible) for collecting survey data. The survey question on the Apple app also defaulted to the current time as defined by the device itself. The default time was displayed for the subject when this question was presented on the screen and they had to accept or manually adjust the time. It is possible that subjects did not always manually adjust the time.

**Table 30. Elapsed Time between Reported Boom and Data Transmission, Apple Application Only**

	Count	Percent
Same time	175	32%
1 minute after	236	42%
2-5 minutes after	42	8%
6-30 minutes after	58	10%
31 minutes to 1 hour after	13	2%
More than 1 hour after	19	3%
Different day	13	2%

There was more variation in response time among Web participants (Table 31). Just under 40 percent of responses were submitted within 1 minute of the reported boom time and about one-half within 5 minutes. Twenty percent of responses were submitted more than 1 hour after the boom was reported to have occurred. The Web responses also revealed a fair number of instances in which the time of the survey submission was before the reported time of the boom.

Most of these were within a few minutes of submission time (i.e., 59 single boom forms submitted 1 minute earlier than the time the boom was claimed to have occurred) and probably reflect discrepancies in the subject’s personal time piece (clock, watch, or personal computer) and the time as defined by the Web server.

Greater dispersion in submission times relative to reported times for Web compared with Apple is not surprising when subjects may have been at home and engaged in other tasks – completing the survey forms on a computer likely involved more of an interruption in their activities than picking up a mobile telephone. The WSPR team also learned from the post-test interviews, however, that some respondents developed their own personal note-taking or log systems whereby they would note their reactions to the noise on a piece of paper and enter the data in survey forms later.

**Table 31. Elapsed Time between Reported Boom and Data Transmission, Web Only**

	Count	Percent
Same time	280	26%
1 minute after	112	11%
2-5 minutes after	140	13%
6-30 minutes after	150	14%
31 minutes to 1 hour after	44	4%
More than 1 hour	209	20%
Different day	16	1%
1 minute before	59	6%
2-5 minutes before	12	1%
6-30 minutes before	32	3%
31 minutes to 1 hour before	6	1%
More than 1 hour before	1	0%
Day before	1	0%

#### 4.2.4 Reported Sonic Boom Times

**How Closely Do Reported Boom Times Correspond with Actual Booms?** We compared the reported boom time with the actual time as recorded by noise monitoring equipment to identify any marked differences in reliability by mode as well as indicate how readily analyses could match subject responses with actual events. Figure 59 shows reported boom times for a 1-hour period on November 15. This date and time period were selected at random, but it is useful to note that it was Day 12 of the experimental test period and the four booms that occurred during this period were numbers 67 through 70. The subjects had already been exposed to many WSPR booms and completed numerous surveys. If response quality were to experience considerable degradation due to respondent fatigue, it would likely appear by this time.

The vertical lines indicate the actual time of the boom, as recorded by noise equipment; the X axis plots time and the Y axis is the number of respondents that reported the boom at the given time. A total of 139 data points appear in the figure, of which 119 (86 percent) report a time that was plus/minus 1 minute of the actual time of the boom. However, variability in reported times in the lower portion of the figure suggest some of the challenges of aligning subject responses to actual booms – several individually-reported times may have been a delayed report of an earlier boom or measurement error for a boom yet to occur (i.e., synchronization of individual time pieces).

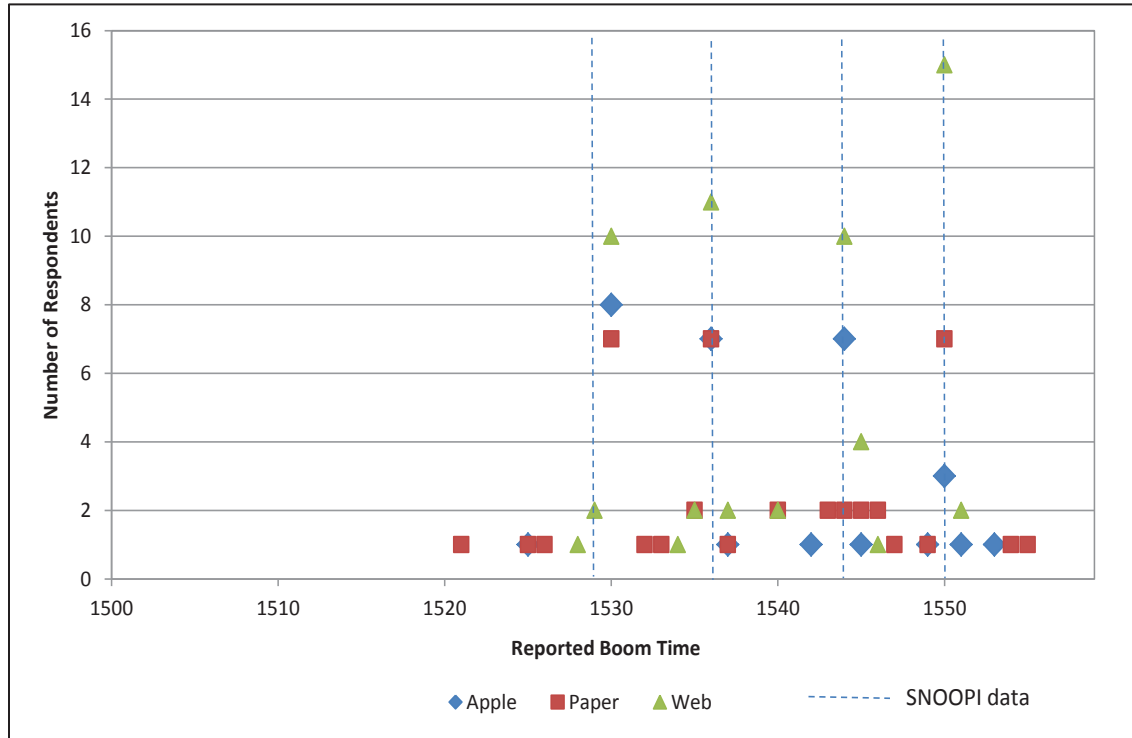


Figure 59. Reported time of boom and actual time of boom per SNOOPI, November 15, 1500 to 1600.

Table 32 suggests that boom time reported by paper participants aligned poorly with actual times compared to Apple and Web participants, at least on this particular day and time segment. Over 90 percent of the surveys submitted for this timeframe by Apple and Web participants included reported boom times that were plus/minus 1 minute of the actual boom. In contrast, 73 percent of paper participants’ surveys reported the time of the boom that was the minute of the actual boom plus or minus 1 full minute (i.e., a total time window of 3 minutes).

Table 32. Number of Booms Reported within 1 Minute of Actual Boom November 15, 15:00 to 16:00, by Mode

Mode	N booms reported	Total booms reported plus/minus one minute of actual boom	Boom reported 1528 to 1530	Boom reported 1535 to 1537	Boom reported 1543 to 1545	Boom reported 1549 to 1551
Apple	32	29	8	8	8	8
Paper	43	31	7	10	6	8
Web	64	59	13	15	14	17
<b>Total</b>	<b>139</b>	<b>119</b>	<b>28</b>	<b>33</b>	<b>28</b>	<b>30</b>

Note: Actual times of booms per noise monitors 1529, 1536, 1544, and 1550.

The WSPR team conducted a similar analysis of November 16 from 1525 to 1600. This day and time segment was selected because three low-amplitude WSPR booms were book-ended by two large non-WSPR booms. The serendipitous sequence of booms provided an opportunity to compare the precision of survey reports for full vs. low-booms, particularly when the low-booms may have been obscured by full booms that immediately preceded them in time.

Figure 60 summarizes 141 reported boom times for the November 16 time segment that included five booms. The overpressures for each of the booms are noted at the top of the vertical blue line for the corresponding actual boom time at the centrally located base station.<sup>13</sup> Of the 141 survey reports, 113 (80 percent) of reported times were within plus/minus 1 minute of the actual time. The first low boom is within the 1-minute timeframe of the first full boom so it is difficult to distill the possible effect of the full boom on the accuracy of survey reports for the low boom. Nonetheless, of the 38 surveys reporting booms between 1526 and 1629, all but two surveys reported boom times that matched the actual times (i.e., 1527 and 1528). There are fewer total survey reports within a 1-minute window of the quieter low booms occurring at 1539 and 1553, but there is clearly more variability in reported times around the quietest boom occurring at 1539.

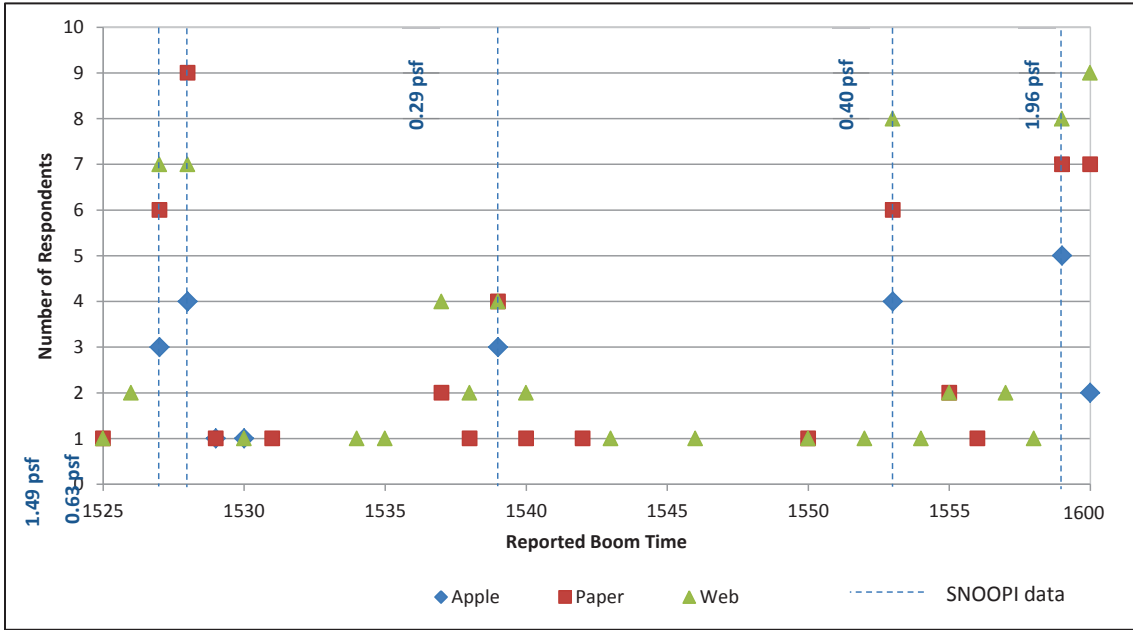


Figure 60. Reported time of boom and actual time of boom per SNOOPI, November 16, 1525 to 1600.

Table 33 summarizes the number of booms reported by mode, overall and within 1-minute time windows for the November 16 time period. Again, the Apple participants who did report booms during this time segment supplied times that most closely matched the actual times (96 percent of all Apple reports). Slightly more than 80 percent of paper and 73 percent of web participants who submitted surveys during this time segment reported accurate boom times. Across all modes, a greater number of accurate boom times occur for the loudest booms.

Table 33. Number of Booms Reported within 1 Minute of Actual Boom November 16, 15:25 to 16:00, by Mode

Mode	N booms reported	Total booms reported plus/minus one minute of actual boom	Boom reported 1527 to 1529	Boom reported 1538 to 1540	Boom reported 1552 to 1554	Boom reported 1558 to 1601
Apple	23	22	8	3	4	7
Paper	51	42	16	6	6	14
Web	67	49	14	8	10	17
<b>Total</b>	<b>141</b>	<b>113</b>	<b>38</b>	<b>17</b>	<b>20</b>	<b>38</b>

Note: Actual times of booms per noise monitors 1527, 1528, 1539, 1553, and 1559.

<sup>13</sup> Variation in arrival time of the sonic booms across the subject housing area is expected to be on the order of 5 seconds.



### 4.3 Experimental Findings

The WSPR field test was conducted over a 3-week period with 10 active test days in the study. There were 52 participants that were divided across modes. The number of people per mode in were Apple n = 15, Paper n = 16 and Web n = 22. The as-flown test schedule is provided in Figure 61.

**WSPR Flight Schedule – November 2011**

Sun	Mon	Tues	Wed	Thurs	Fri	Sat
					4 Training Day 1 1L, 1H, 1HR, 1F	5 No Flights
6 No Flights	7 Day 2 Test Starts 4L, 2M, 2H, 1F	8 Day 3 4L, 4M, 4H, 1F	9 Day 4 3M, 4H, 4HR, 1F	10 Day 5 4M	11 No Flights	12 No Flights
13 No Flights	14 Day 6 3L, 6M, 2H, 2HR,1F	15 Day 7 + AF flights 4L, 1M, 4H, 1HR, 4F	16 Day 8 + AF flights 3 L, 8 M, 2 H, 1 HR,13 F	17 Day 9 5L, 3M	18 Day 10 Test Ends 4L, 1M	

L=Low, M=Medium, H=High, HR=Higher, F=Full

*Figure 61. WSPR schedule and as flown booms per test day.*

The response instruments included baseline surveys that collected demographic and attitudinal information, Single Event Surveys that were submitted each time a participant heard a boom noise, and Daily Summary Surveys that were submitted at the end of each day. The participants were instructed to respond to each boom, or single event that they heard and to complete a daily summary of their cumulative response to the noise environment on that day. See Appendix G for the data cleaning and preparation steps that were implemented prior to statistical analysis of the WSPR data.

#### 4.3.1 Baseline Survey Analysis and Findings

The analysis described in this section identified potential outliers in the data for use in future analyses as well as exploring the applicability and effectiveness of the questions that were included in each section on the survey. The baseline survey provides insight into the respondents, which provides the potential to identify outliers in the data, affording a more complete picture of the community responses overall. A full listing of the surveys may be found in Appendix A and specific question numbers are indicated in parenthesis.

### 4.3.1.1 Identification of Respondents as Potential Outliers

#### *Section A: Respondent Attitudes*

Section A addresses general attitudes about the overall level of neighborhood noise (a4) and the respondents' perceptions of acclimation to noise in general (a6a-a6d). The respondent with caseid 2484 specified that he was an Iraq War veteran. He noted that sonic booms sound like [mortar] attacks. He gave the highest rating to the question asking how much the noise from sonic booms startles him or makes him jump. His ID was flagged to monitor as a potential outlier in his responses on future analyses. Respondents 2378 and 2398 rated their neighborhood as noisy, and are very different from the group in terms of overall perception of neighborhood noise levels. To identify potentially noise-averse people, the data was evaluated to see who the three people were that answered a6b (I believe that with time most people adapt to noise) and a6c (I believe that with time I can adapt to noise) differently from the bulk of the other respondents. Respondents 2340 and 2484 responses varied from the norm on both of these questions related to acclimation, indicating that they feel that people cannot get used to noise. Respondent 2484 was the Iraq War veteran who noted that booms sounded like mortar attacks.

#### *Section B: Noise Ratings of Neighborhood Noises*

Section B obtains ratings on actual annoyance to noise from six sources (b1a-b1f).

Respondents 2362, 2596 and 2378 (flagged in Section A for rating neighborhood as noisy) are very different from the group in terms of their annoyance to specific noises.

#### *Section C: Perception of Sonic Booms*

Section C obtains ratings on annoyance/disturbance/intrusiveness from sonic booms, measured in six distinct ways (c1-c6). Respondents 2326 and 2501 rated the loudness of booms abnormally low. Respondent 2491 rated the interference of booms with indoor conversations abnormally high.

### 4.3.1.2 Assessment of Survey Questions for Future Analyses

#### *Section A: Respondent Attitudes*

The data suggests that question a6d (I believe that with time I can get used to even the loudest noise) does not fit in the group with a6b (I believe that with time most people adapt to noise) and a6c (I believe that with time I can adapt to noise). Question a6d is measuring a construct unique from the others in this section. The data from a6b and a6c could be combined into a single variable (either by summation or averaging), and a6d used as its own variable in any predictive models that may be investigated in future analyses of the single event and daily summaries. Question a6a (I believe that people have a hard time getting used to noise) was intended as a contrast to a6b (I believe that with time most people adapt to noise) but the a6aR (the reverse-coded version of a6a) responses were not consistent. Question a6a could be considered for possible omission from future analyses.

#### *Section B: Noise Ratings of Neighborhood Noises*

Questions b1a-b1f cluster into two distinct groups – b1a-b1c, which measure noise sources that one would find in any living situation, and b1d-b1f, which measure noise from aircraft (both commercial and military) and sonic booms, which might be confined to specific areas. The b1a-b1c neighborhood noise sources group should not be split according to a reliability analysis. Variables b1d and b1f (commercial and military aircraft) exhibit a stronger relationship as a pair than when b1e (sonic booms) is included, and thus this variable would be split from the group for any future potential analyses of the event responses or daily summaries.

### Section C: Perception of Sonic Booms

Variables c1 and c4, c2 and c3, and c5 and c6 may form three subgroups of the questions in this section, (loud/startle, interference indoors/outdoors and vibration/rattle). However, a reliability analysis shows that they all belong in a single group, so they can all be combined into a single scale to measure reactions to and/or feelings about booms for inclusion in future potential analyses for follow on field tests.

#### 4.3.1.3 Summary Findings: Baseline Survey

The baseline survey was conducted with all 60 recruits, before there were any drop outs. Of those 60, 52 completed the field test. WSPR was a pilot field test, to gather information of value for future field designs. As such, the baseline survey analysis was conducted on the responses from all 60 potential respondents, to provide maximal insight and a more complete perspective of the community attitudes prior to conducting the field test. Of the 60 respondents, 39 said their neighborhood was quiet, 19 said average, and the remaining 2 described it as noisy. For questions a6b (I believe that with time most people adapt to noise) and a6c (I believe that with time I can adapt to noise) 95 percent of respondents answered either 4 or 5 (moderately or strongly agree) to these questions, indicating that they all feel that people in general, and themselves in particular, can adapt to noise given time. Respondents indicated that they can adapt to even the loudest noise (60 percent responded with 4 or 5 to a6d), but a sizeable proportion (25 percent) actually responded with a 2 (moderately disagree). Noises from street traffic, thunder, and commercial aircraft are least annoying, barking dogs and military aircraft are more annoying, and sonic booms are the most annoying. The data is displayed in the boxplot in Figure 62. The line in the center of each box represents the median of the data. The boxes represent the interquartile region; 75 percent of the data points lie below the top of each box and 25 percent of the data points lie below the bottom line. The whiskers then show the upper and lower 25 percent distributions of the data and extend to outliers in the data. The mean and median are provided in Table 34 below.

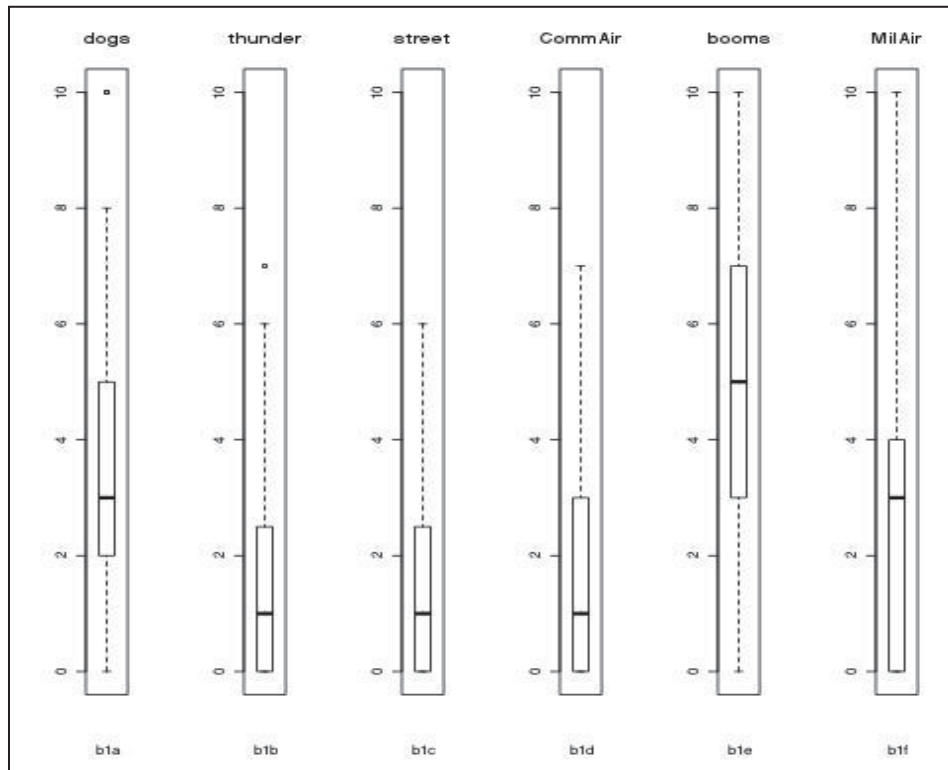


Figure 62. Side-by-side boxplots of annoyance ratings for neighborhood noise sources.

**Table 34. Mean/Median Annoyance Ratings for Six Noise Sources**

	mean	median
<b>b1a (barking dogs)</b>	3.47	3
<b>b1b (thunder)</b>	1.65	1
<b>b1c (street traffic)</b>	1.50	1
<b>b1d (commercial aircraft)</b>	1.68	1
<b>b1e (sonic booms)</b>	4.70	5
<b>b1f (military aircraft)</b>	2.55	3

Respondents tended to find the booms quite loud and startling, experienced vibration and rattle to a lesser extent, and tended to not experience a great deal of interference in conversations due to booms (Table 35).

**Table 35. Mean/Median Ratings for Six Aspects of Sonic Boom Attributes**

	mean	median
<b>c1 (loud)</b>	7.25	7
<b>c2 (inside conversations)</b>	2.38	1
<b>c3 (outside conversations)</b>	3.17	2
<b>c4 (startle/jump)</b>	6.95	7
<b>c5 (vibration)</b>	5.53	5
<b>c6 (rattle)</b>	4.88	5

The vast majority have lived at EAFB less than 3 years, with almost 42 percent of the sample living there for less than a full year at the time of the survey. The average response was 1.583 years, and the median was 1 year. When respondents were asked to compare the annoyance to noise at EAFB to that of their previous neighborhood, almost as many find EAFB less annoying as those who find it more annoying than their previous neighborhood, while almost one third find it neither more nor less annoying (Table 36). The mean and median responses to this question are 3.13 and 3, respectively. The responses are on a scale of 1 to 5, where 1 means EAFB is much more annoying and 5 means EAFB is much less annoying. Three of the five respondents who said EAFB is much more annoying than their previous neighborhood have been flagged in previous questions for abnormal observations. Their caseid numbers are 2340, 2484, and 2594.

**Table 36. Summary of Responses to Compare EAFB to Previous Neighborhood 1 Means EAFB is Much More Annoying and 5 Means EAFB is Much Less Annoying**

d2	1	2	3	4	5
<b># respondents</b>	5	17	18	5	15

The responses to question d3, which asks how many people (including the respondent) live in the respondent's household, are in Table 37. The mean and median responses to this question are 3.63 and 4 respectively.

**Table 37. Summary of Responses to How Many People Live in Respondent's Household**

d3	1	2	3	4	5	6	8
<b># respondents</b>	5	7	16	18	9	3	2

Of the 55 respondents who have two or more people in their households:

- 37 have children under the age of 6 living in their households, while the remaining 18 do not.
- Two of them are living by themselves with children, 51 have one other adult aged at least 18 living with them, and the remaining two have two other adults aged at least 18 living with them.
- 

Of the 60 respondents, eight had completed high school or obtained a GED, 20 had done some college work, gone to a technical school, or obtained a 2-year degree, 18 had earned a bachelor's degree, and the remaining 14 had obtained masters, doctoral, or professional degrees. The respondents were asked for their year of birth. The earliest was 1963 (next earliest was 1967), and the latest was 1993, so the ages ranged from 18 to 48. One respondent (number 2646) refused to answer this question. Five respondents were born in the 1960's, 22 in the 1970's, 27 in the 1980's, and five in the 1990's. The average age was 32.12 years and the median was 32 years. There are 11 males (18 percent of total) and 49 females (82 percent of total) in the baseline study. The three modes of response in the study are Apple device, web, and paper/pencil. These three modes had 15, 25, and 20 participants, respectively. There was some attrition rate from the time of the baseline survey to the start of the noise study. At the time of the noise study, apple had 15, web had 22, and paper/pencil had 16 respondents.

## **4.3.2 Single Event Analysis of Participant Responses**

### **4.3.2.1 Single Event Response Rate**

The respondents were asked to report the time that they heard each boom. The response rate is a function of accessibility of the response mode and respondent activities that may interfere with the ability to respond. The web-based response mode may be less accessible when respondents are outside their home. The data shows that 86 percent of the responses were made while participants were indoors at home. Respondents also indicated that they had their windows closed 90 percent of the time on days during the flight tests. In this environment, all three response modes afforded the respondents similar access to the survey questions and the windows closed criteria provided similar listening conditions between homes. The respondent rate of response was most likely affected by other activities that may have delayed the promptness of their response. If they were focused on other activities, there may have been greater variability in their reported time for each event. This variability created a difference between the reported time that the boom was heard and the actual time of the boom. The decision was made to accept a reported time window of  $\pm 10$  minutes from the actual time of the boom for each single event boom that was rated. This window was chosen to optimize the correct association of a given boom with the respondent's rating, while allowing for the fact that respondents were going about their daily activities while participating in the study. For the single event data, the response rate by time window was evaluated and an acceptable range of differences in times were assessed to determine which responses were "valid" responses. As the response rate time window was decreased, the range of acceptability narrowed and fewer reports were included for analysis (see Figure 63). A 20-minute window (i.e.,  $\pm 10$  min) for the difference between reported and actual time was adopted for further analysis. Reports of booms that were within the  $\pm 10$ -minute window were included in this analysis. A less restrictive analysis of  $\pm 30$  minutes was also conducted. One participant was lost by imposing both of the windows of acceptability.

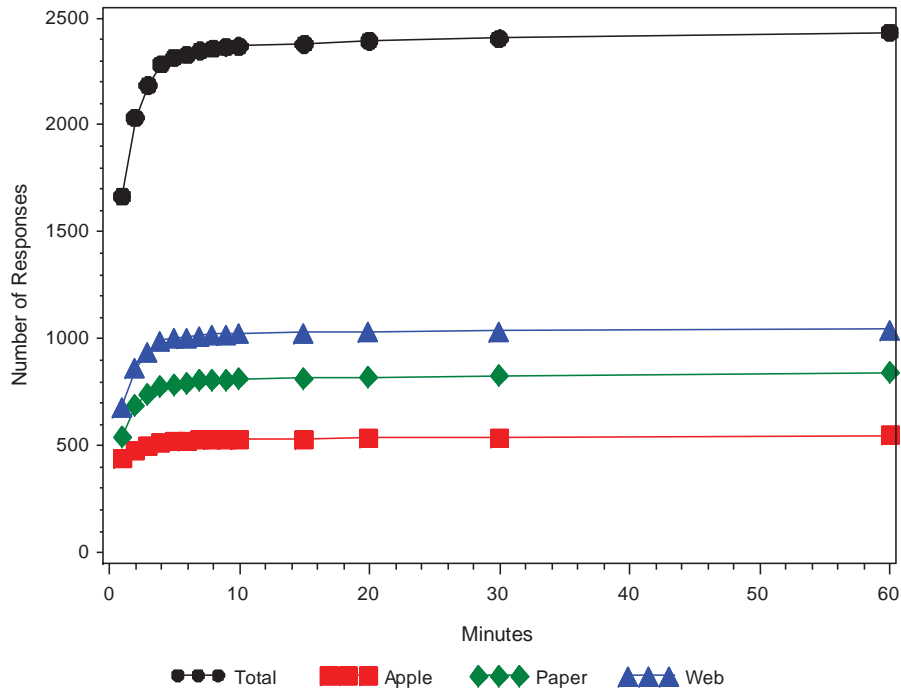


Figure 63. Response rate by time window.

#### 4.3.2.2 Correlation of Categorical Attribute Ratings with Annoyance Ratings

The daily and single event annoyance ratings were tabulated and Kendall's Tau-b categorical correlation coefficient was calculated between the annoyance ratings and the other response attributes that were evaluated on the surveys. Kendall's Tau-b reflects the strength of the dependence between the variables being compared. The WSPR data showed that interference had the largest impact on annoyance ratings for both the single event and daily summary ratings. For the single event rating, interference was followed by startle, loudness, vibration, and rattle in that order in strength of the dependence between variables. The values of the strength of the dependence are provided in Table 38. As indicated in the table, interference and startle showed a stronger dependence than loudness, vibration, or rattle on the single event annoyance response. This relationship indicates that if the boom was sufficient to interrupt or disturb an activity, or if it alarmed or startled the respondent, it had a greater effect on annoyance.



**Table 38. Kendall's Tau-b Correlation of Attributes for Single Event Annoyance Ratings**

Attribute	Tau-b	95% Lower Confid. Limit	95% Upper Confid. Limit
<b>Interference</b>	0.7626	0.7460	0.7792
<b>Startle</b>	0.6969	0.6756	0.7181
<b>Loudness</b>	0.5499	0.5258	0.5739
<b>Vibration</b>	0.4505	0.4228	0.4781
<b>Rattle</b>	0.4174	0.3886	0.4461

### 4.3.2.3 Single Event Percent Highly Annoyed and Noise Metric Correlations

The single event percent highly annoyed (HA) was correlated with a series of noise metrics to identify an objective metric that best predicts the potential for single event annoyance response. The single event data was used to evaluate the applicability of the noise metrics for the prediction of the number of individuals that were highly annoyed in response to a given noise level. The data was evaluated using polynomial regression analysis, which is a form of multiple regression in which the independent "variables" are simply  $x$  and  $x^2$ . It is applicable to efforts where the researcher would like to predict unknown values of  $Y$  (percent highly annoyed) that correspond to known values of  $X$  (noise level), as assessed by select metrics. A polynomial regression is appropriate if transformations of the data do not work to afford the use of linear regression techniques.

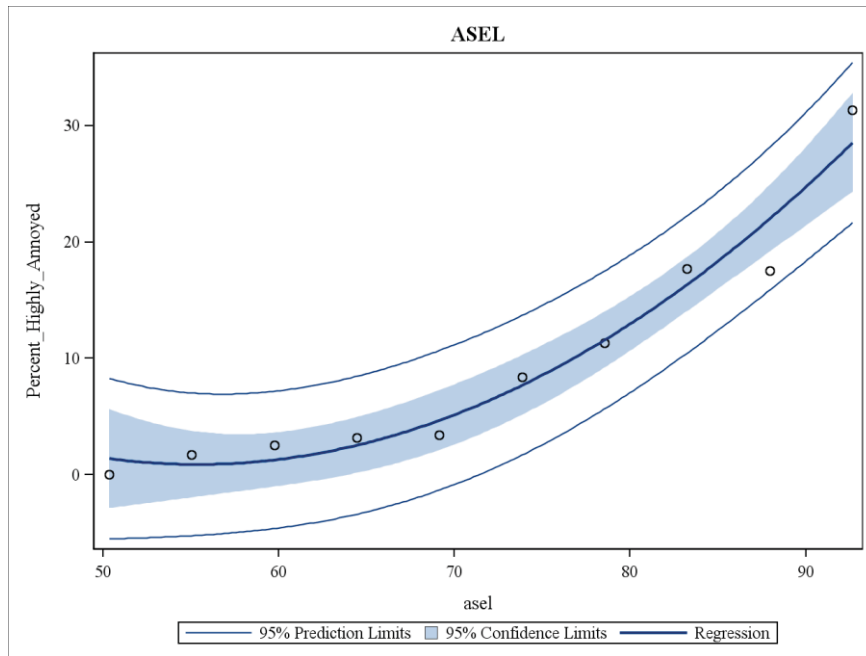
The quadratic regression approach required the definition of bins for the noise metrics because the actual response was a 1 or a 0 (highly annoyed or not highly annoyed), and we need a percent or proportion to fit the quadratic regression line. Thus one must create artificial bins to combine responses and create data points of percent HA. This means that the results of the analysis are *dependent upon choice of bin*. Choosing a different bin width would have resulted in a different regression line and a different R-Squared value. This may present a problem because, to some degree, the choice of bins was arbitrary. Between 9 and 11 bins of equal width were defined *according to the metric*. Alternatively, one could have chosen bin width based on number of responses in that bin. This would have resulted in very different choices of bins, with varying widths. There was no scientific motivation to the choice of equal length bins. If the WSPR team had some scientific reason to define the bins differently this would have been a good avenue for exploration. Because of this dependency of bin choice, *an analysis that is independent of bin is a more suitable option*. One alternative approach for this data is logistic regression. Section 4.3.5.2 applies a logistic regression analysis to the Daily Cumulative Metrics.

For each objective noise metric, a quadratic polynomial was fit. The noise data was calculated from the alpha noise monitoring station and the metrics calculated were ASEL, CSEL, ZSEL, PL, PNL, LLZF, and LLZD. The equation of best fit, the  $r^2$  and the regression curves, shown in Figures 64 – 70 for the various metrics, represent similar trends in the data. Figures 64 – 70 display the resulting data points and the quadratic regression line. Also included are the 95 percent confidence intervals for the mean (light blue region), as well as the 95 percent prediction intervals (blue lines). These regions extend well into negative values for %HA. This is a consequence of using quadratic regression – responses are not constrained to positive values. The data was binned in order to calculate the percent highly annoyed for booms with the sound level for each “bin”. This binning was done slightly differently for each of the metrics to optimize the regression curve. The regression line with the highest correlation coefficient ( $R^2$ ) is the metric that explains the most about the variation in the single event percent highly annoyed data. The  $R^2$  values are provided in Table 39 below. The PL had the highest correlation with an  $R^2 = 0.9694$ .

**Table 39. Quadratic Regression Binning and R-Squared Values for Single Event Metrics**

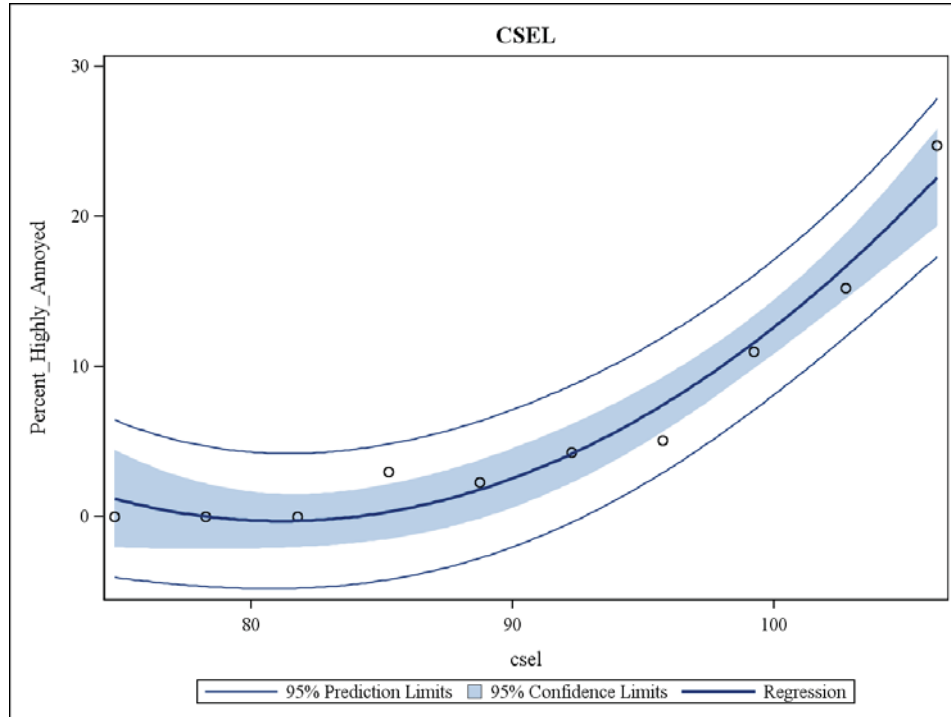
Metric	R-Squared
PL	0.9694
CSEL	0.9639
ASEL	0.9586
PNL	0.9316
LLZf	0.8804
LLZd	0.8653
ZSEL	0.8632

Metric	Minimum Value	Maximum Value	Bin Width	First Bin	Last Bin	Number of Bins
ASEL	48	95	4.7	(48, 52.7)	(90.3, 95)	10
CSEL	73	108	3.5	(73, 76.5)	(104.5, 108)	10
ZSEL	95	119	2.4	(95, 97.4)	(116.6, 119)	10
PL	63	106	4.3	(63, 67.3)	(101.7, 106)	10
PNL	69	114	4.5	(69, 73.5)	(109.5, 114)	10
LLZf	77	115	3.8	(77, 80.8)	(111.2, 115)	10
LLZd	78	115	3.7	(78,81.7)	(111.3,115)	10



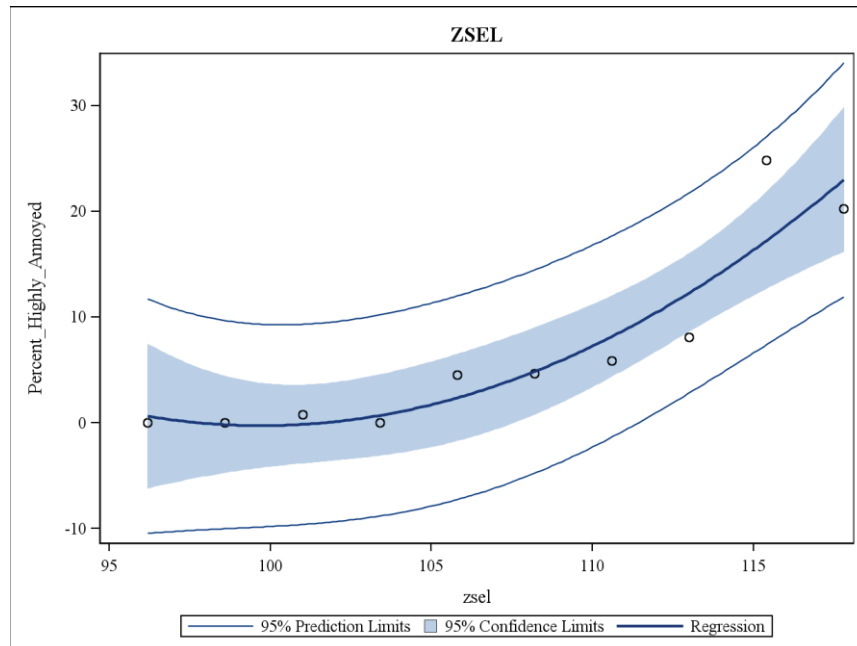
$$\%HA = 61.7 - 2.20*(ASEL) + 0.02*(ASEL)^2$$

**Figure 64. ASEL noise metrics vs. percent HA.**



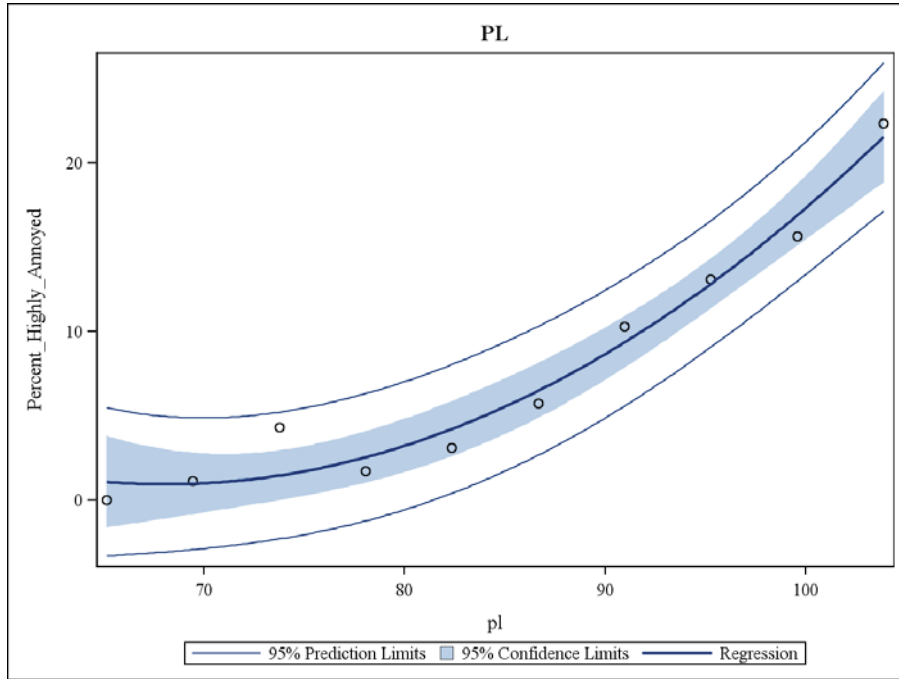
$$\%HA = 238.81 - 5.89*(CSEL) + 0.04*(CSEL)^2$$

**Figure 65. CSEL noise metrics vs. percent HA.**



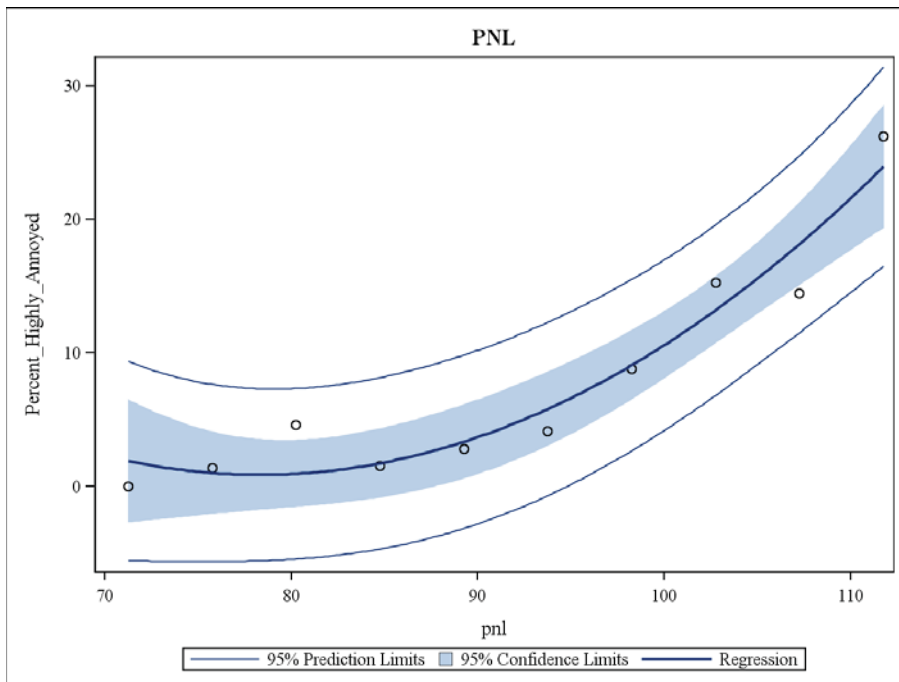
$$\%HA = 706.78 - 14.18*(ZSEL) + 0.07*(ZSEL)^2$$

**Figure 66. ZSEL noise metrics vs. percent HA.**



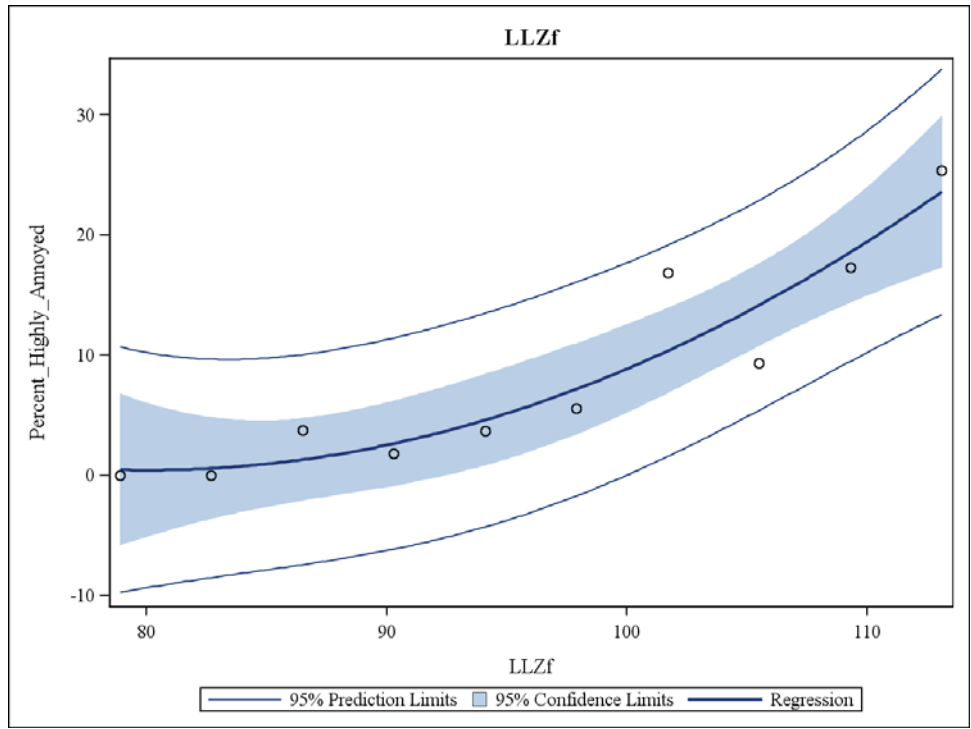
$$\%HA = 75.64 - 2.19*(PL) + 0.02*(PL)^2$$

**Figure 67. PL metrics vs. percent HA.**



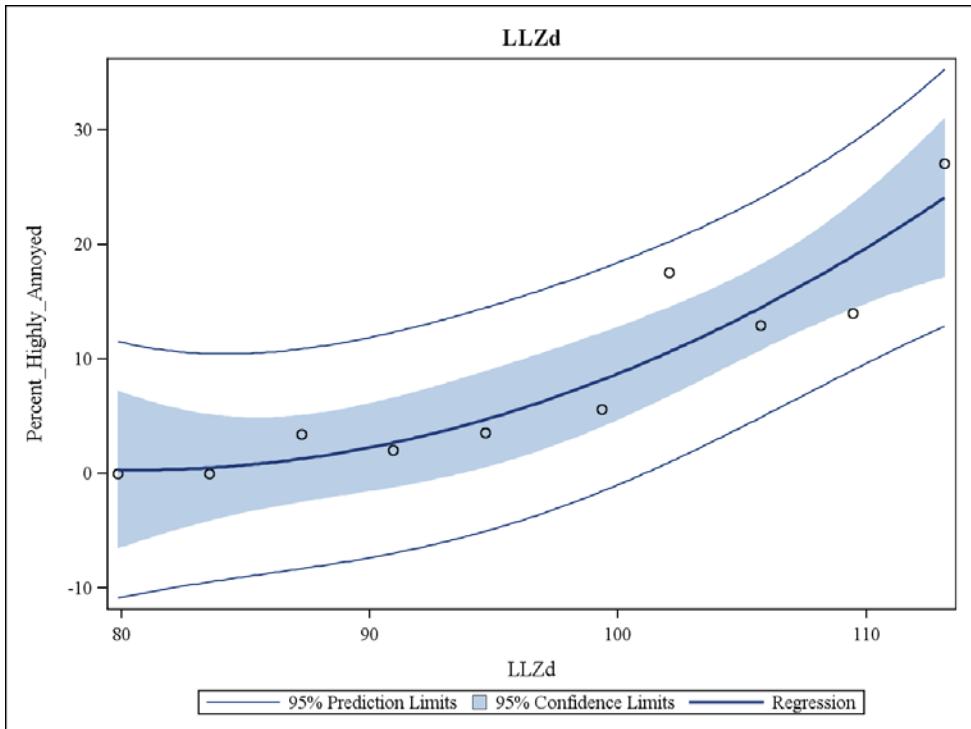
$$\%HA = 127.17 - 3.23*(PNL) + 0.02*(PNL)^2$$

**Figure 68. PNL metrics vs. percent HA.**



$$\%HA = 595.61 - 3.41*(LLZf) + 0.02*(LLZf)^2$$

**Figure 69. Zwicker loudness frontal incidence vs. percent HA.**



$$\%HA = 147.28 - 3.64*(LLZd) + 0.02*(LLZd)^2$$

**Figure 70. Zwicker loudness level diffuse vs. percent HA.**

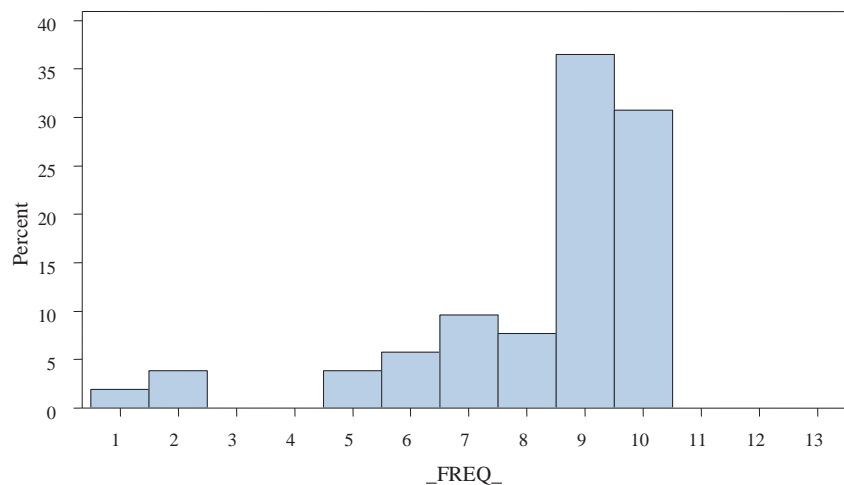
The point must be stressed that the choice of bins for the quadratic regression was more or less arbitrary and not at all scientifically motivated. In order to provide consistency with the prior body of acoustic analysis it is included here. However, even a small change in bin choice (i.e., from 8 bins to 9 bins to 11 bins), would have resulted in different regression lines. This is illustrated in Appendix I.

### 4.3.3 Daily Summary Analysis of Participant Responses

#### 4.3.3.1 Daily Response Rate and Inclusion in Annoyance Ratings

The daily summary analysis of the per person response rate is shown in Figure 71 below. For the annoyance ratings, only the 10 field test days that had flights were analyzed. To analyze only the data from flight days, the non-flight days on November 5, 6, 11, 12, and 13 were removed from the analysis data set. This afforded a distinction between daily summary reports indicating no booms heard on a flight day from daily reports indicating no booms heard on a non-flight day. This graph shows the percent of the respondents that provided reports on only 1 day of the study, up to 10 days of the study. Most of the respondents provided reports for at least half of the days. Over 65 percent responded for 9 or 10 days of the 10 day field test.

**Per-person Response Rates (Number of days reporting)**



*Figure 71. Daily summary per person response rate (number of days reporting).*

It is probable that not all participants heard all booms on all days. As such, the analysis included all days in which flights did occur and all daily summaries, even those where respondents indicated that the number of booms they heard was equal to zero for that day (num\_booms = 0). If the respondent indicated that they did not hear any booms that day, they did not complete the attribute response questions. Their response was counted in the response rate summary but they provided no contribution to the daily annoyance ratings for that day.

#### 4.3.3.2 Comparison of 11-Point Numerical vs. 5-Point Categorical Daily Annoyance Scales

The daily annoyance rating was obtained using both the 11-point numerical and 5-point categorical annoyance rating scales. Both scales were used for the daily annoyance rating only. The scales utilized were described earlier in this report. The 11-point scale was used to assess the daily rating of other perception related attributes (loudness, interference, startle, vibration, and rattle). The daily annoyance ratings are shown using the 5-point daily annoyance scale (Table 40) and the 11-point scale (Table 41) vs. a binary variable (dailyboom). The binary variable was daily boom = 0 when the respondent reported that the number of booms heard that day = 0, and daily boom = 1 when the number



of booms heard that day = > 0. In the SAS statistical analysis code, when a combination of variable values for a table is missing, the FREQ process does not include that observation in the analysis. By default, it does not include missing combinations in the output data set. The procedure displays the number of missing observations below each table.

**Table 40. 5-Point Daily Verbal Annoyance Ratings**

dailyboom	Daily Annoyance Rating						
Frequency Row Pct	N/A	1	2	3	4	5	Total
0	59 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	59
1	0 0.00	133 35.95	128 34.59	58 15.68	33 8.92	18 4.86	370
<b>Total</b>	59	133	128	58	33	18	429
<b>Frequency Missing = 2</b>							

**Table 41. 11-Point Daily Annoyance Ratings**

dailyboom	Daily Annoyance Rating												
Frequency Row Pct	N/A	0	1	2	3	4	5	6	7	8	9	10	Total
0	59 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	59
1	0 0.00	110 29.73	60 16.22	41 11.08	49 13.24	35 9.46	16 4.32	9 2.43	16 4.32	13 3.51	3 0.81	18 4.86	370
<b>Total</b>	59	110	60	41	49	35	16	9	16	13	3	18	429
<b>Frequency Missing = 2</b>													

Booms occurred on each of the days of the study, but 59 of the 429 reports recorded no booms on a given flight day. The following are possible reasons for the 59 reports from respondents, indicating that they heard no booms on a given flight day:

- The participant may not have been home when booms occurred,
- The participant heard the boom but mistook it for a different noise, or
- The participant did not hear the boom.

**Table 42. Daily Annoyance (11-Point) vs. Daily Annoyance (5-Point) Frequencies of Rating**

Daily Annoyance Rating (5 point)	Daily Annoyance Rating (11 point)												
Frequency Row Pct	N/A	0	1	2	3	4	5	6	7	8	9	10	Total
N/A	59 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	59
1	0 0.00	109 82.58	19 14.39	3 2.27	1 0.76	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	132
2	0 0.00	1 0.78	41 32.03	36 28.13	34 26.56	14 10.94	2 1.56	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	128
3	0 0.00	0 0.00	0 0.00	2 3.45	13 22.41	19 32.76	14 24.14	7 12.07	3 5.17	0 0.00	0 0.00	0 0.00	58
4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	2 6.06	0 0.00	2 6.06	13 39.39	11 33.33	2 6.06	3 9.09	33
5	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	2 11.11	1 5.56	15 83.33	18
<b>Total</b>	59	110	60	41	48	35	16	9	16	13	3	18	428
Frequency Missing = 3													

The 11-point responses were not always consistent with the 5-point categories. A “10” on the 11-point annoyance scale may have been reported as a “4” on the 5-point scale (see Table 42). This study observed some inconsistency in people’s assessment of their annoyance when asked to rate it on two different scales (Table 43).

**Table 43. Example of Inconsistency in 5-Point and 11-Point Annoyance Scales**

ID	_day	day_cat_annoy	day_annoy
2491	8	4	10
2740	10	4	10
2740	14	4	10

The responses in this study indicated that the 5-point annoyance scale was not simply a compression of the 11-point scale. Respondents were not always consistent with their daily rating of the same day on the two different scales. A comparison of the daily annoyance ratings on the 11-point numerical scale with the ratings on the 5-point categorical scale for the same day was conducted. As seen in the range of daily annoyance response (Table 44), each of the 5-point scale annoyance categories span several 11-point scale categories.

**Table 44. Range of 11-Point Daily Annoyance Responses for each 5-Point Category of Annoyance**

day_cat_annoy	mean_day_annoy	min_day_annoy	max_daily_annoy
1	1.5	0	3
2	2.5	0	5
3	4.5	2	7
4	7.3	4	10
5	9	8	10

To investigate this rating inconsistency, a comparison of the two scales of annoyance response was conducted by transforming the 0 – 10 scale (11-points) into a theoretical 5-point scale. This theoretical 5-point scale consists of five intervals with midpoints of 1.05, 3.25, 5.45, 7.65, and 9.85 for the daily annoyance values. The frequency of occurrences within each of these theoretical categories was then tallied and the tallies were compared to the actual (day\_cat\_annoy) 5-point categorical annoyance ratings (Table 45). The “daily annoyance” rating for respondents who reported hearing no booms is –6 (missing variable). This variable was defined as –5.55 for the theoretical scale.

**Table 45. Relative Frequency (%) Distribution**

**(a) Theoretical 5-point Numerical Rating Scale**

_VAR_	_MIDPT_	_OBSPCT_
day_annoy	–5.55	13.729
day_annoy	1.05	49.1841
day_annoy	3.25	19.5804
day_annoy	5.45	5.8275
day_annoy	7.65	6.7599
day_annoy	9.85	4.8951

**(b) Actual 5-point Categorical Rating Scale**

_VAR_	_MIDPT_	_OBSPCT_
day_cat_annoy	(N/A) –6	13.7529
day_cat_annoy	1	31.0023
day_cat_annoy	2	29.8368
day_cat_annoy	3	13.5198
day_cat_annoy	4	7.6923
day_cat_annoy	5	4.1958

The plot in Figure 72 compares the actual and theoretical 5-point scale distributions to illustrate the discrepancy between the two scales. The different shapes of these distributions also show that the 5-point categorical scale is not simply a compression of the 11-point scale.

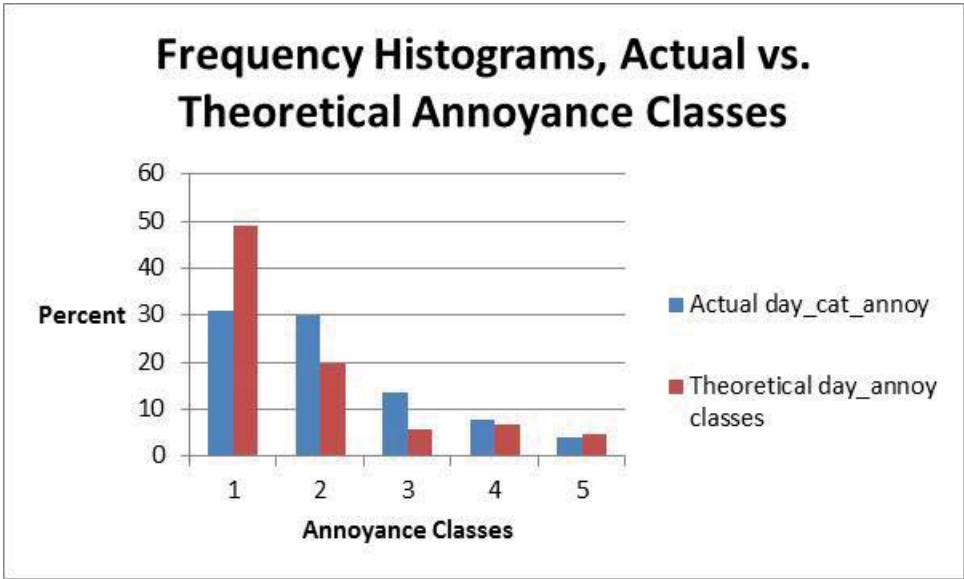


Figure 72. Frequency histograms, actual vs. theoretical daily annoyance classes.

The comparison of the 5-point and 11-point scales points to the potential for inconsistency in people’s assessment of their annoyance when asked to rate it on two different scales. The 5-point scale was included and compared to the 11-point scale based on recommendations in IC BEN to use both of these scales. For ease of administration and a more direct analysis, the experimental design was implemented to utilize just the 11-point scale for the remaining data assessment.

The histogram plot of the reported daily annoyance (Figure 73) shows that the annoyance response is not normally distributed. This was an expected trend, as the test included low-level booms and the residents in the community were acclimated to higher level booms. The (N/A) response category documents responses that indicated that no booms were heard that day (num\_booms = 0). Transformations were not able to normalize this annoyance response data. Similar non-normal distributions resulted for the ratings of the categorical attributes that contribute to annoyance.

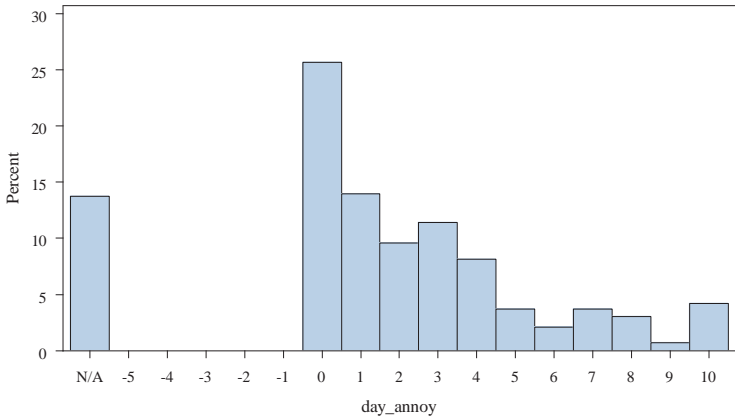


Figure 73. Histogram of daily annoyance responses, 11-point scale.

### 4.3.3.3 Daily Summary Correlation of Categorical Attributes Ratings with Annoyance Ratings

The WSPR data shows that interference had the largest dependence with annoyance for both the single event and daily summary ratings. For the daily summary ratings, interference was followed by loudness, vibration, and rattle in that order in strength of the dependence between variables. For the single event rating (Section 4.3.2), interference was followed by startle, loudness, vibration, and rattle in that order in strength of the dependence between variables. Startle was not evaluated on the daily summary ratings as it is a single event response, rather than a response that is reported for a daily average. The values of the strength of the dependence for the daily summaries are provided in Table 46.

**Table 46. Kendall's Tau-b Correlation of Attributes for Daily Summary Annoyance Ratings**

Attribute	Tau-b	95% Lower Confid. Limit	95% Upper Confid. Limit
Interference	0.7461	0.7030	0.7893
Loudness	0.6377	0.5820	0.6935
Vibration	0.4878	0.4225	0.5531
Rattle	0.4725	0.4036	0.5413

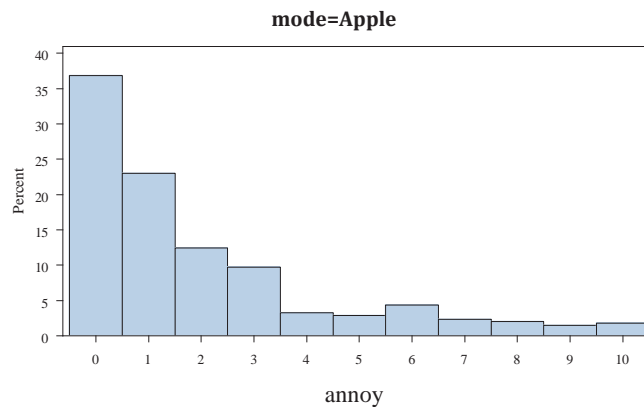
### 4.3.4 Mode Comparison and Listening Environment

One of the intents of the WSPR experiment was to gather data from multiple modes of survey application. Questionnaires were designed to be comparable across three modes of data collection – paper/pencil, web, and Apple device (iPhone, iPod Touch, and iPad). The annoyance ratings for both the single event and the daily summaries were evaluated to see if the responses differed between modes. The data showed a difference in response between paper and non-paper modes of reporting. There was no statistically significant difference between Apple and web modes.

#### 4.3.4.1 Mode Effects for Single Event Annoyance Ratings

Figures 74a through 74c show histograms for annoyance overall and for each of the modes. The plots provide a visual illustration of the mode comparisons. The trend of the data shows slight differences for paper. Figure 74d contains a boxplot that compares the basic statistics between the three modes.

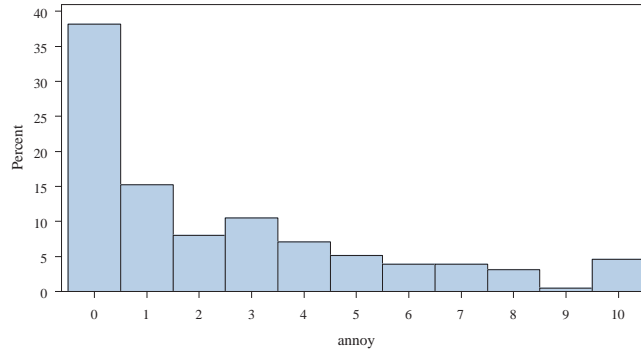
**Per Boom Annoyance by Response Mode**



(a)

### Per Boom Annoyance by Response Mode

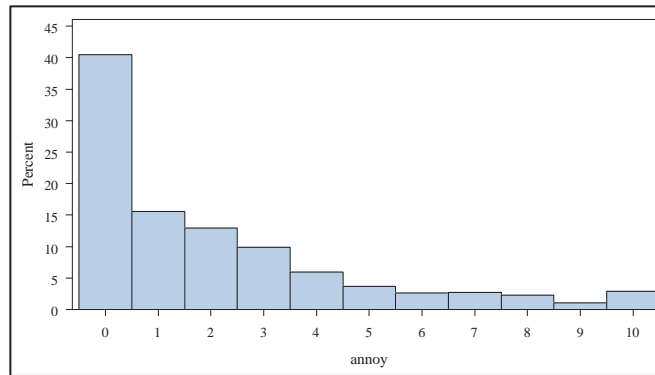
mode=Paper



(b)

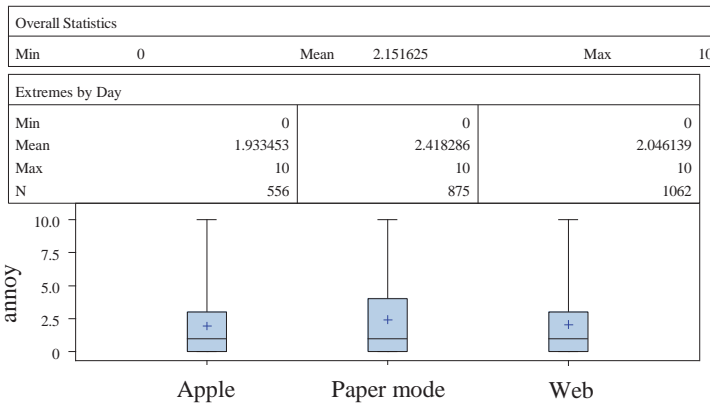
### Per Boom Annoyance by Response Mode

mode=Web



(c)

### Per Boom Annoyance by Response Mode



(d)

Figure 74. Per boom annoyance by response mode - (a) Apple, (b) Paper, (c) Web, and (d) Summary.

The boxplot in Figure 74d compares the single event per boom annoyance for the Apple, paper, and web modes. The line in the center of each box represents the median of the data, the plus mark represents the mean of the data, and the distance between the two shows the skew of the data. The boxes represent the interquartile region; 75 percent of the data points lie below the top of each box and 25 percent of the data points lie below the bottom line. The whiskers then show the upper and lower 25 percent distributions of the data, extending to the outliers in the data. The summary box shows the minimum, maximum, and mean values in each box plot. The median is not as affected by outliers as is the mean. The mean for paper is higher than the other modes. This observed difference in the trend of the data with the paper mode could be due to the influence of outliers in the data, or possibly because this mode allowed the respondent more time to reflect on their response, since the rating was not electronically time stamped. The observation was noted, but no cause and effect could be clearly identified. Additional mode analysis of the frequency of annoyance ratings by mode is provided in Tables 47 and 48.

Table 47 shows the frequency of occurrence for annoyance ratings in each numerical scale category as a function of mode. The lower value in the cell provides the row percent, that is, the frequency count as a percent of the total in that row. For ratings of 2-10, the row percentages for Apple are closer to the Web row percentages than Paper.

**Table 47. Single Event Data**

**Frequency of Single Event Annoyance Ratings by Mode**

mode	Single Event Annoyance Rating											Total
	0	1	2	3	4	5	6	7	8	9	10	
<b>Apple</b>	205 36.87	128 23.02	69 12.41	54 9.71	18 3.24	16 2.88	24 4.32	13 2.34	11 1.98	8 1.44	10 1.80	556
<b>Paper</b>	334 38.17	133 15.20	70 8.00	92 10.51	62 7.09	45 5.14	34 3.89	34 3.89	27 3.09	4 0.46	40 4.57	875
<b>Web</b>	430 40.49	165 15.54	137 12.90	105 9.89	63 5.93	39 3.67	28 2.64	29 2.73	24 2.26	11 1.04	31 2.92	1062
<b>Total</b>	969	426	276	251	143	100	86	76	62	23	81	2493

**Table 48. Statistics for Frequency of Single Event Annoyance Ratings by Mode**

Statistic	DF	Value	Prob
Chi-Square	20	63.3434	<.0001
Likelihood Ratio Chi-Square	20	64.2291	<.0001
Mantel-Haenszel Chi-Square	1	0.0080	0.9289

Sample Size = 2493

The Pearson chi-square statistic is labeled “Chi-Square”. The chi-square p-value = <.0001, which indicates a significant difference in single event annoyance ratings by mode, as presented in Table 48. The paper mode showed a difference in the annoyance response rating for single events as compared to ratings obtained by Apple smart phone or web responses.



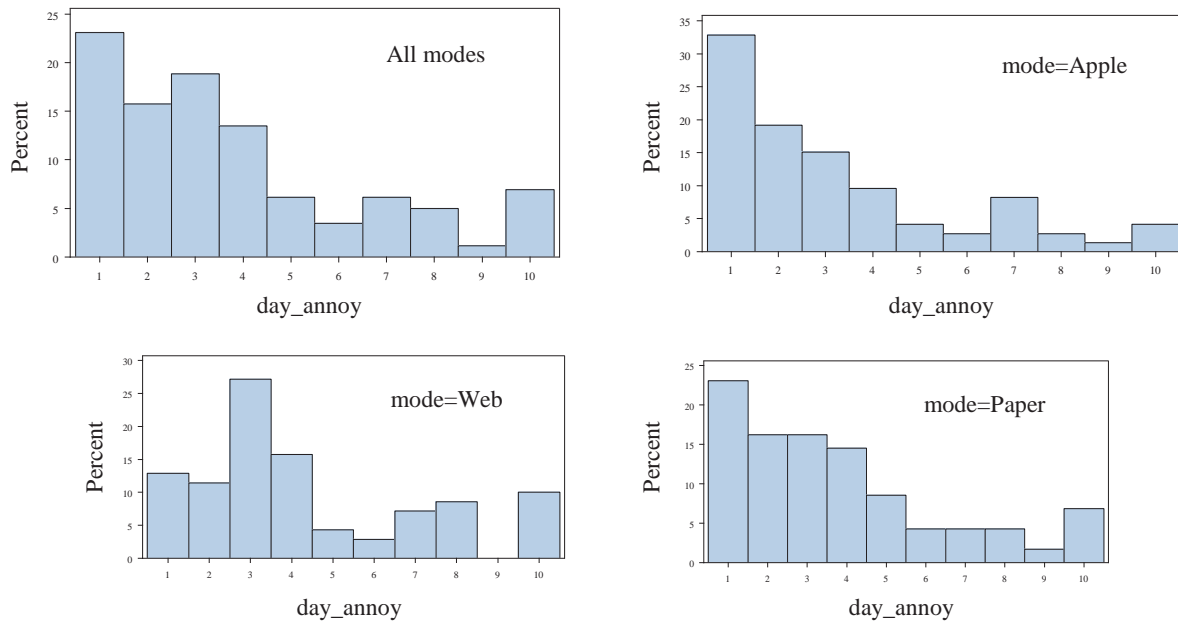
### 4.3.4.2 Mode Effects for Daily Annoyance Ratings

The daily annoyance rating was treated as a “binary” variable where if the respondent indicated a rating of 0 for the daily annoyance the variable was “No”, and if the daily annoyance rating was greater than 0, then Annoyance was “Yes”. The frequency counts for the “Yes” data were used to assess mode effects. The frequency counts are given in Table 49.

**Table 49. Daily Annoyance Ratings Frequency Counts Binary by Modes**

mode	annoyance			
Frequency Row Pct	N/A	no	yes	Total
Apple	15 13.64	22 20.00	73 66.36	110
Paper	14 10.77	46 35.38	70 53.85	130
Web	30 15.87	42 22.22	117 61.90	189
Total	59	110	260	429
Frequency Missing = 2				

Figures 75a – 75d show histograms for annoyance overall and for each of the modes, given that annoyance was “Yes”. The plots provide a visual illustration of the mode comparisons. The trend of the data follows the same slope for web and Apple, but it appears to be different for the paper mode.



**Figure 75. Percent of Response vs. Daily Annoyance Ratings – (a) All Modes, (b) Apple Respondents, (c) Web Respondents, and (d) Paper Respondents.**

A chi-squared test for independence was conducted for the daily annoyance ratings by mode (Table 50). This test evaluates whether or not there is a statistically significant difference between the variables, in this case, mode.

**Table 50. Statistics for Daily Annoyance Ratings by Mode**

Statistic	DF	Value	Prob
Chi-Square	4	10.1347	<b>0.0382</b>
Likelihood Ratio Chi-Square	4	9.8327	0.0433
Mantel-Haenszel Chi-Square	1	0.4298	0.5121

Effective Sample Size = 429  
 Frequency Missing = 2

The chi-square p-value = 0.0382, which indicates a significant difference in daily annoyance ratings by mode. To investigate the source of the significance of modes on annoyance, a “reduction chi-square analysis” was conducted. Here, a level of the categorical variable was removed and the chi-square analysis was rerun with the two remaining variables to improve the fit of the model. Since paper appeared to show a different trend in the histograms, it was the first mode selected for removal. As shown in Table 51, once the “paper” source is removed, the chi-square p-value becomes 0.7375, indicating that there is no significant difference in daily annoyance ratings between the Apple and Web modes. In other words, the Paper mode differed from the other two modes in the proportion of “yes” vs. “no” for annoyance. This shows that the significance of differences in percentages of “yes” for annoyance among the modes was due to the paper mode. When the paper mode was removed, the p-value increased from 0.0382 to 0.7375 (Table 51b).

**Table 51. Reduction Chi-Square – Paper Mode Removed**

a) Frequency of Daily Annoyance Ratings by Mode (Paper Removed)

mode	annoyance			
	N/A	no	yes	Total
Apple	15 13.64	22 20.00	73 66.36	110
Web	30 15.87	42 22.22	117 61.90	189
Total	45	64	190	299

b) Statistics for Daily Annoyance Ratings by Mode (Paper Removed)

Statistic	DF	Value	Prob
Chi-Square	2	0.6091	<b>0.7375</b>
Likelihood Ratio Chi-Square	2	0.6126	0.7362
Mantel-Haenszel Chi-Square	1	0.5641	0.4526

### 4.3.4.3 Indoors vs. Outdoors Summary Table for Single Events

The respondents were asked to indicate if they were indoors or outdoors at the time that they heard each boom. Some individuals may have responded if they were away from home, but in the immediate area (at a neighbor's). All of the responses were analyzed and are reported in the statistical results in this section. The responses were not filtered and thus include subjects not at home. The response by location is presented in the table below. Table 4-33 indicates that 86% (2126/2471) of the responses were made while participants were indoors at home.

**Table 52. Single Event Annoyance (Binary) by Participant Location**

Table of location by annoyance			
location	annoyance		
Frequency Row Pct	no	yes	Total
Indoors at Home	851 40.03	1275 59.97	2126
Indoors Away	41 33.61	81 66.39	122
Outdoors at Home	33 34.38	63 65.63	96
Outdoors Away	39 30.71	88 69.29	127
<b>Total</b>	<b>964</b>	<b>1507</b>	<b>2471</b>
Frequency Missing = 22			

**Statistics for Table of location by annoyance**

Statistic	DF	Value	Prob
Chi-Square	3	6.9687	0.0729
Likelihood Ratio Chi-Square	3	7.1265	0.0680
Mantel-Haenszel Chi-Square	1	6.4222	0.0113

Effective Sample Size = 2471

Frequency Missing = 22

### 4.3.4.4 Daily Indication of Occurrence of Windows Closed vs. Windows Open

If the respondent's windows were open, the interior noise levels might have been louder than if they were closed. This variable could have possibly affected comparisons of noise ratings. Respondents were asked to indicate on the daily summary if their windows were closed or open most of the time while they were at home during the day. In Table 53, the row labeled with a 1 indicates a response that the windows were closed most of the time, while the row labeled 2 indicates a response that the windows were open most of the time. Each cell reports the frequency and the row percent for that condition with the associated daily annoyance rating. Respondents indicated that they had their windows closed 90 percent of the time on days during the flight tests.

**Table 53. Occurrence of Windows Closed (1) vs. Windows Open (2) on Daily Response**

windows Frequency Row Pct	Daily Annoyance Rating												Total
	N/A	0	1	2	3	4	5	6	7	8	9	10	
<b>Windows Closed</b>	55 14.18	105 27.06	55 14.18	35 9.02	45 11.60	33 8.51	13 3.35	7 1.80	13 3.35	12 3.09	1 0.26	14 3.61	388
<b>Windows Open</b>	3 7.50	5 12.50	5 12.50	6 15.00	4 10.00	2 5.00	3 7.50	2 5.00	3 7.50	1 2.50	2 5.00	4 10.00	40
<b>Total</b>	58	110	60	41	49	35	16	9	16	13	3	18	428
Frequency Missing = 3													

### 4.3.5 Statistical Relationships between Exposure and Annoyance

The WSPR daily annoyance data can be analyzed two distinct ways – by computing percent highly annoyed (%HA) and relating it to the cumulative noise exposure or by relating the subjective annoyance rating (11-Point scale) directly to the daily noise exposure. The WSPR design was established to cover the full range of noise exposures and annoyance factors so that sufficient data would be gathered to facilitate analyses of %HA and noise rating. The following sections describe the statistical studies examining these relationships in more detail.

The as-flown noise exposure included 110 sonic booms and balanced DNL exposure across test days, the number of Low, Med, and High low booms across the design, the separation of booms between morning and afternoon flight sequences, and the distribution of booms among the sequences. The design allowed for the creation of larger “full scale” (~1 psf) sonic booms to ensure a full range of noise exposure, creating booms of a Higher and Full level. There were 21 un-anticipated non-WSPR created sonic booms that affected the balance of number and level of booms in the design. The number of booms per day and the cumulative metric values are given in Table 54.

**Table 54. As-Flown Sonic Booms and Cumulative Metrics re DNL Listed Quiet to Loud**

Test Day	PLDN dB	CDNL dB	DNL dB	Booms /Day	Boom List
<b>10</b>	28.01	41.01	16.54	5	<b>4L,1M</b>
<b>9</b>	33.98	43.37	19.05	8	<b>5L,3M</b>
<b>5</b>	34.91	47.47	19.08	4	<b>4M</b>
<b>4</b>	45.96	55.66	30.51	12	<b>3M, 4H,4HR,1F</b>
<b>3</b>	49.44	55.60	34.90	13	<b>4L,4M,4H,1F</b>
<b>1</b>	52.50	55.33	38.27	4	<b>1L, 1H, 1HR,1F</b>
<b>2</b>	52.47	56.21	39.09	9	<b>4L,2M,2H,1F</b>
<b>6</b>	54.32	59.25	39.49	14	<b>3L, 6M, 2H, 2HR,1F</b>
<b>7</b>	55.59	59.51	41.65	14	<b>4L,1M,4H,1HR,4F</b>
<b>8</b>	65.62	67.26	51.53	27	<b>3L, 8M, 2H,1HR,13F</b>

The WSPR test was conducted to gather sufficient data on annoyance level ratings for low-level sonic booms. Daily annoyance ratings, on an 11-point scale (annoyance ratings 0 to 10), were obtained for each day of the study in which a flight took place. An annoyance rating of 8 or higher is used to indicate someone as “Highly Annoyed” (HA).

The assessment of full sonic booms utilizes the percent Highly Annoyed (%HA) compared to noise metrics to determine noise impact. For the percent highly annoyed analysis, the annoyance rating was obtained using a binary sort, where HA = 0 for ratings of 0 to 7 and HA = 1 for ratings of 8–10. The %HA may be expressed as (8–10 HA respondents)/All Respondents for that Day). The design included the gathering of data to afford the comparison of cumulative noise metrics with both the % HA and the overall daily annoyance ratings as well as providing for a comparison of annoyance ratings for test days that are approximately matched for either level or number of booms.

#### 4.3.5.1 Using Cumulative Noise Metrics to Predict %HA: Piecewise Linear Regression

For practical applications, it is useful to identify an objective metric that best predicts the potential for an annoyance response. To address this question, the daily annoyance response was compared to the cumulative noise ratings for PLDN, CDNL, and DNL (Table 4-36). The statistical question of interest is “Which of the three metrics results in a regression line with the highest R-squared value?” Whichever metric results in the highest value of R-Squared is the metric that explains the most about the variation in the percent highly annoyed, and thus can be considered the “best” in this context. A quadratic regression line was fit using each of the three metrics, but the fit wasn’t ideal. A piecewise linear function was then fit to the data. The R-squared values for the piecewise linear regression are defined as the “proportion of variance in the response variable that is explained by the predictor variable”. In the case of this specific example, this means the proportion variation of the response in “percent highly annoyed” that is explained by the given noise metric. For linear regression, we can define the R-squared this way and compare between the metrics. A piecewise linear function is suitable for data that does not display an overall linear trend, but displays different linear trends in different ranges of the independent variables (in this case, the metrics). For this data, it seemed that the data points were very gently increasing until some threshold value was reached, and then the percent daily annoyance began to increase at a more rapid rate. This breakpoint value is often referred to as the knee or knot in the curve. Although the term often used is “percent highly annoyed”, in the regressions below the values are actually plotted in “proportion highly annoyed”. The two terms are equivalent for practical purposes, but proportions are expressed as decimals from 0 to 1, and percent is expressed as percentages from 0 percent to 100 percent. The data can be displayed as percent highly annoyed for the linear regressions. However, the logistic regressions require values between 0 and 1. A plot of the %HA and cumulative metric data points is presented in Figure 76.

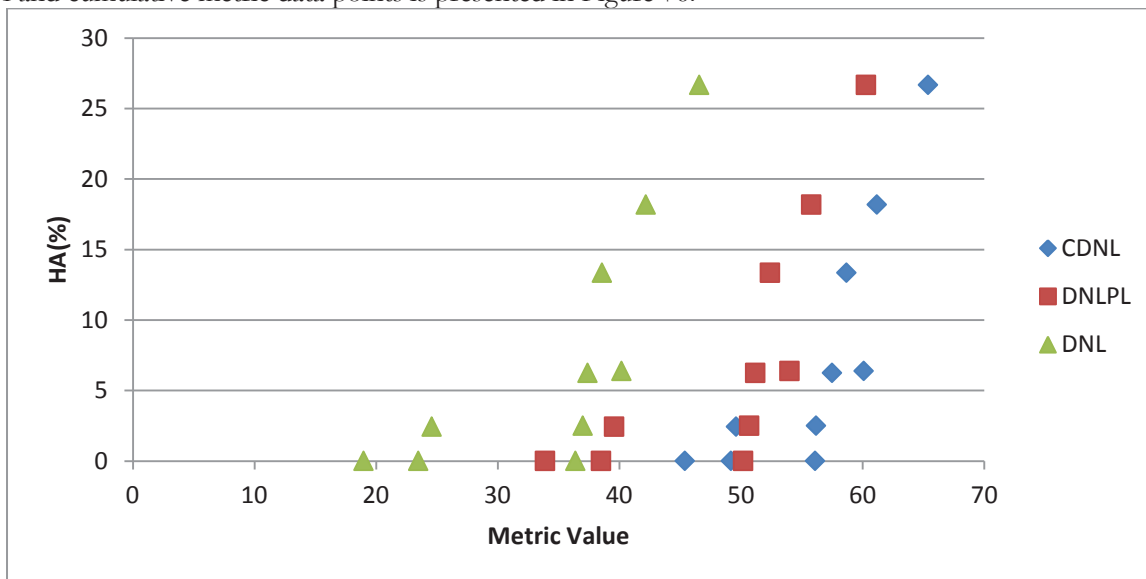


Figure 76. "Percent Highly Annoyed" versus the metrics PLDN, CDNL, and DNL from alpha noise monitor.

For each of the three metrics, linear piecewise regression was fit using one knot, or breakpoint. That is, each regression estimates three values – the location of the knot, the value of the slope to the left of the knot, and the value of the slope to the right of the knot. These piecewise regression lines seemed to fit the data very well. The R-Squared value for the regression line for each metric is in Table 55.

**Table 55. R-Squared for %HA vs. Metrics Using Piecewise Linear Regression**

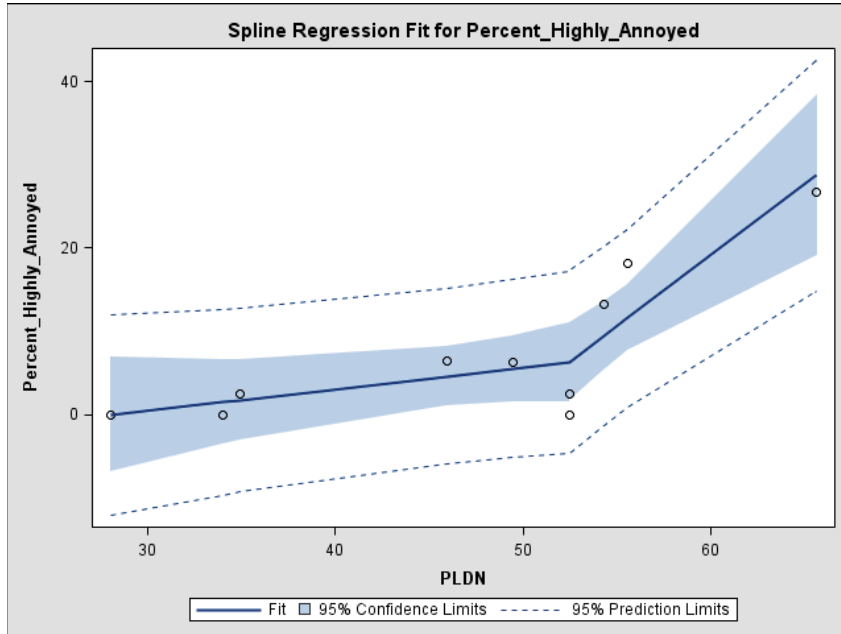
Metric	R-Squared
PLDN	0.8329
CDNL	0.8911
DNL	0.7984

The CDNL metric explains the most variation in the percent highly annoyed response, with an  $R^2 = 0.8911$ . It was the best metric in this study for correlation with the %HA annoyance response ratings. The PLDN followed closely with  $R^2 = 0.8329$  and DNL had  $R^2 = 0.7984$ . Table 56 provides the metric values of the knee and the regression equations for %HA for each metric.

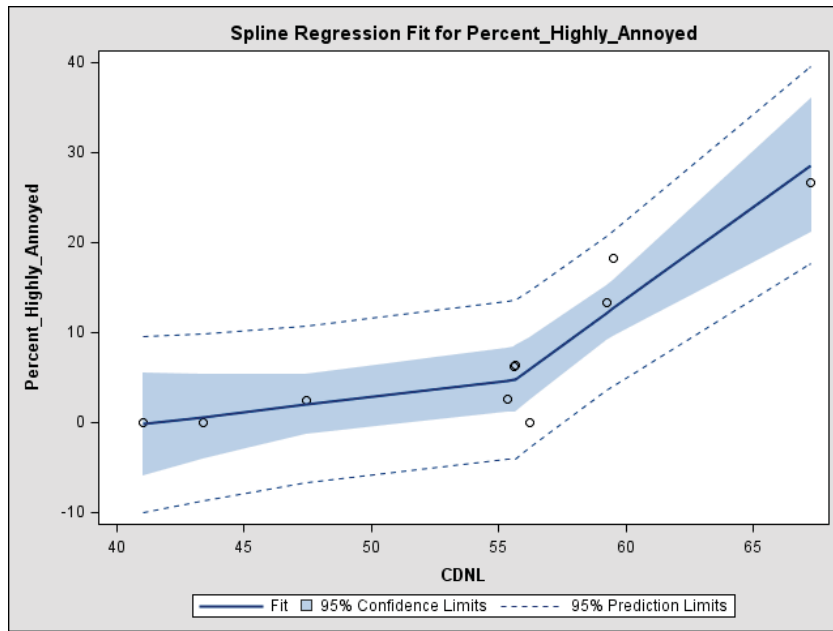
**Table 56. Percent Highly Annoyed (%HA) Regression Equations for PLDN, CDNL, and DNL**

Metric	Knee Value	Regression Equation
PLDN	< 52.47	% HA = $-7.3281820 + 0.2595982*(PLDN)$
	> 52.47	% HA = $-83.3523 + 1.7085*(PLDN)$
CDNL	< 55.66	% HA = $-14.295404 + 0.342541*(CDNL)$
	> 55.66	% HA = $-109.494 + 2.062903*(CDNL)$
DNL	< 38.27	% HA = $-3.6747571 + 0.2622964*(DNL)$
	> 38.27	% HA = $-56.7666477 + 1.6495943*(DNL)$

The piecewise linear regression plots in Figures 77 – 79 display a negative percent of people highly annoyed at the lower limit. The model seeks to explain the data, and because this data includes values that are very close to 0, the confidence limits extend into negative territory even though it's not possible to have a negative portion of people highly annoyed. The 95 percent confidence limits tell you where the true population parameter lies, with 95 percent confidence. The 95 percent prediction limits, on the other hand, tell you with 95 percent confidence in what range you would expect to see an observation from the distribution that you are considering. In terms of one specific example, consider the confidence limits for “percent highly annoyed”. For example, if the confidence limits are 2 percent and 7 percent, this means that the WSPR team is 95 percent confident that the true percent of people that were highly annoyed was between 2 and 7 percent. On the other hand, if we are considering prediction limits of 0 and 12 percent, this means that if the team were to observe another day under the same conditions, they would expect to see the percent highly annoyed to be anywhere from 0 to 12 percent. The prediction limits are wider than the confidence limits because the team was predicting individual observations in place of an overall mean. When a linear regression was fitted to the data it did not restrict the fit of the confidence intervals to include only positive values. The estimation from the regression line is valid only for the range of data where the team observed values (i.e., in the range of observed DNL, PLDN, or CDNL). Trying to make predictions or inference outside of this range requires extrapolation, and such predictions may not be trustworthy.

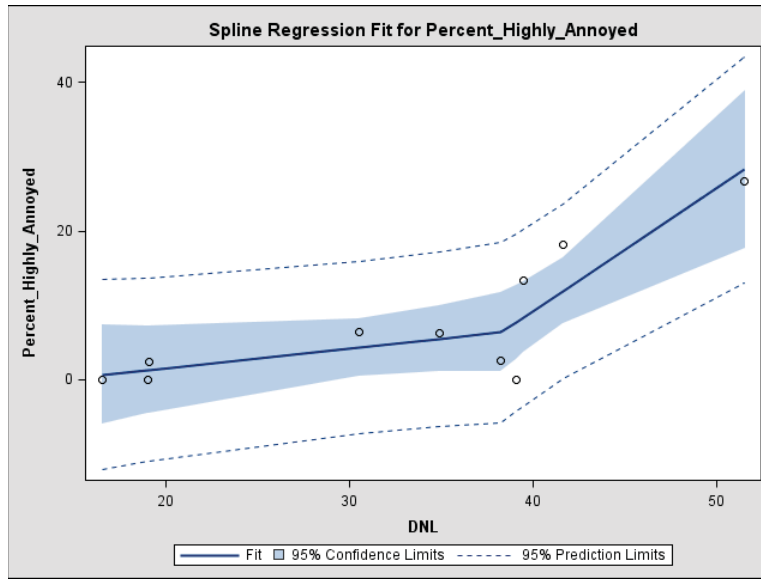


*Figure 77. Piecewise Linear Regression with PLDN.*



*Figure 78. Piecewise Linear Regression with CDNL.*





**Figure 79. Piecewise Linear Regression with DNL.**

Logistic regression fits were calculated as well. However, based on the results for the piecewise linear and the logistic regression fits, it is evident that the piecewise linear function provides more information and is more intuitive to understand, particularly since the data shows a very limited range of “percent highly annoyed” (only from 0 to 28 percent). The logistic regression analysis is described in Section 4.3.5.2.

**4.3.5.2 Logistic Regression to Predict %HA with Daily Cumulative Noise Metrics**

The daily summaries were used to evaluate the applicability of the cumulative noise metrics for the prediction of the number of individuals that would be highly annoyed in response to a given noise level averaged over the response day. This dose response relationship may facilitate the ability to predict the subjective perception of annoyance from objective noise measurements. This relationship was assessed by fitting three logistic regression models to the data – one for each of the metrics. The logistic regression was conducted to evaluate the likelihood of a participant being highly annoyed (annoyance value greater than or equal to 8).

The logistic regression analysis determined the percent of respondents that answered “Highly Annoyed” (Annoyance rating greater than or equal to eight) for a given value of a sound metric. One can rephrase this question as “For a given value of a sound metric, what is the *probability* that a respondent will indicate he or she is highly annoyed?” Also, because the sound metrics were slightly different for each respondent for each boom, we have a large number of responses all for different values of the metrics. This is the perfect situation for a logistic regression. Logistic regression models the logarithm of the odds of being highly annoyed as a function of the chosen metric. From the model fit, the research team was able to predict the probability of being HA from any value of the metric.

The logistic regression function is constrained to consider only positive values whereas the piecewise linear allows negative values (as explained in Section 4.3.6.1). The R-squared values for the piecewise linear regression are defined as the “proportion of variance in the response variable that is explained by the predictor variable”. In the case of this specific example, this means the proportion variation of the response in “percent highly annoyed” that is explained by the noise metric. For linear regression, the research team defined the R-squared this way and compared it between the metrics. For logistic regression, however, the team had an extremely different model and different modeling assumptions. The R-squared reported is in fact a pseudo-R-Squared value that is actually a measure of how much better the current model is than the null model that does not include any independent variables. In terms of equations, this pseudo-R-squared can be written as Equation 4-3.

$$R^2 = 1 - \exp\left(\frac{2\text{Log}[L(\text{model})-L(\text{null})]}{n}\right) \quad (\text{Equation 4-3})$$

Where L(model) is the likelihood of the proposed model, L(null) is the likelihood of the intercept only model, and n is the sample size. This R-squared value is clearly different from the R-Square used in linear regression. In this case, it is a measure of improvement in fit. It is also worth noting that this value cannot be 1, which is why SAS statistical analysis output also includes an adjusted R-Square value as well. This value can reach 1, as indicated in Equation 4-4.

$$R^2_{adj} = \frac{R^2}{\left[1 - \exp\left(\frac{2\text{log}L(\text{null})}{n}\right)\right]} \quad (\text{Equation 4-4})$$

The two types of models used for this data have different assumptions. For the logistic regression, the team modeled the probability of being highly annoyed. This was a good approach; however, the team only observed values of percent highly annoyed from 0 to 28, which limits the usefulness of the logistic regression. In order to fit a model that could accurately describe the behavior of the probability of being highly annoyed, the team needed observations of a higher percentage. Because of this issue, the research team fitted the piecewise linear regression, which assumes nothing about the possible range of values for percent highly annoyed. It does, however, provide an estimate of when the change in response occurred. Table 57 provides the R-squared value for each of the logistic regressions.

**Table 57. R-Squared Values for PLDN, CDNL, and DNL Using Logistic Regression**

Metric	Pseudo R-Squared
PLDN	0.0681
CDNL	0.0760
DNL	0.0651

The R-squared values in Table 57 are much lower than linear regression values. Logistic regression is very different from Least Squares regression (as is used in the linear and piecewise linear regressions), so these values are, in fact, pseudo R-squared values. The values may be compared between the three different logistic regressions, but are not meant to be compared directly with linear regression values.

The CDNL explains the most variation in the percent highly annoyed, and thus could be considered the “best” predictor of the three metrics considered. The correlation coefficients that resulted from fitting the logistic regression model are low for all three noise metrics. One of the outputs from a logistic regression analysis is an odds ratio, which expresses the increase in likelihood of being highly annoyed with every unit increase in the dependent variable. When comparing the odds ratio, a metric that ranges from 10 to 20 will have a much larger odds ratio than a metric that ranges from 10 to 100 because a one unit change in the first is much more drastic than a one unit change in the second.

The odds ratio for each metric is listed in Table 58. As explained above, the CDNL shows the best predictive capability for the likelihood of a participant being highly annoyed. For every unit increase in CDNL the odds of a person being highly annoyed increases by a factor of 1.188 based on the odds ratio point estimate. For PLDN the factor showed an increase of 1.122, and for DNL the factor increased by 1.115 for each unit increase in the metric level. The detailed logistic regression analyses for PLDN, CDNL, and DNL follow for each cumulative metric.

**Table 58. Logistic Regression Odds Ratio Point Estimate**

Cumulative Metric	Odds Ratio Point Estimate
DNL	1.115
PLDN	1.122
CDNL	1.188

The SAS statistical analysis for Maximum Likelihood Estimates and Odds Ratio Estimates using PLDN are provided in Table 59. A graphical representation of the logistic regression fit for PLDN is provided in Figure 80.

**Table 59. PLDN Maximum Likelihood and Odds Ratio Estimates**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-8.4828	1.3503	39.4625	<.0001
PLDN	1	0.1148	0.0239	23.0606	<.0001

Odds Ratio Estimates		
Effect	Point Estimate	95% Wald Confidence Limits
PLDN	1.122	1.070 1.175

The predicted event probability based on a logistic regression model using PLDN is represented by

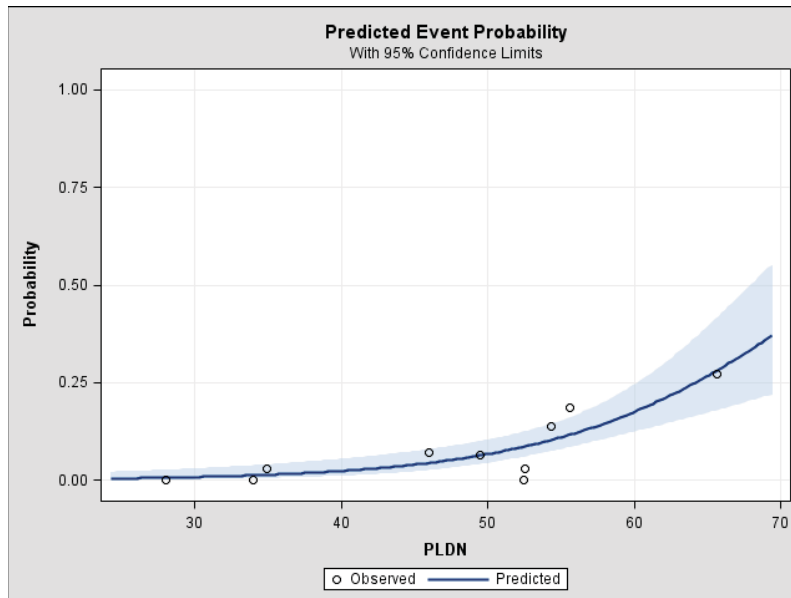
$$\text{Log(odds of being highly annoyed)} = -8.4828 + 0.1148 * (\text{PLDN}) \quad (\text{Equation 4-5})$$

Or equivalently,

$$\text{Odds of being highly annoyed} = (e^{-8.4828}) * (1.122)^{\text{PLDN}} \quad (\text{Equation 4-6})$$

What this means is that for every unit increase in PLDN the odds of a person being highly annoyed increases by a factor of 1.122. If one is interested simply in predicting the probability of a person being highly annoyed, the corresponding equation is:

$$P(\text{HA}) = \frac{e^{-8.4828 * (1.122^{\text{PLDN}})}}{1 + e^{-8.4828 * (1.122^{\text{PLDN}})}} \quad (\text{Equation 4-7})$$



**Figure 80. PLDN logistic regression prediction of the probability of percent highly annoyed.**

The SAS Analysis for Maximum Likelihood Estimates and Odds Ratio Estimates using CDNL are provided in Table 60. A graphical representation of the logistic regression fit for CDNL is provided in Figure 81.

**Table 60. CDNL Maximum Likelihood and Odds Ratio Estimates**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-12.4328	2.0095	38.2778	<.0001
CDNL	1	0.1726	0.0332	27.0497	<.0001

Odds Ratio Estimates		
Effect	Point Estimate	95% Wald Confidence Limits
CDNL	1.188	1.114 1.268

The predicted event probability based on a logistic regression model using CDNL is represented by

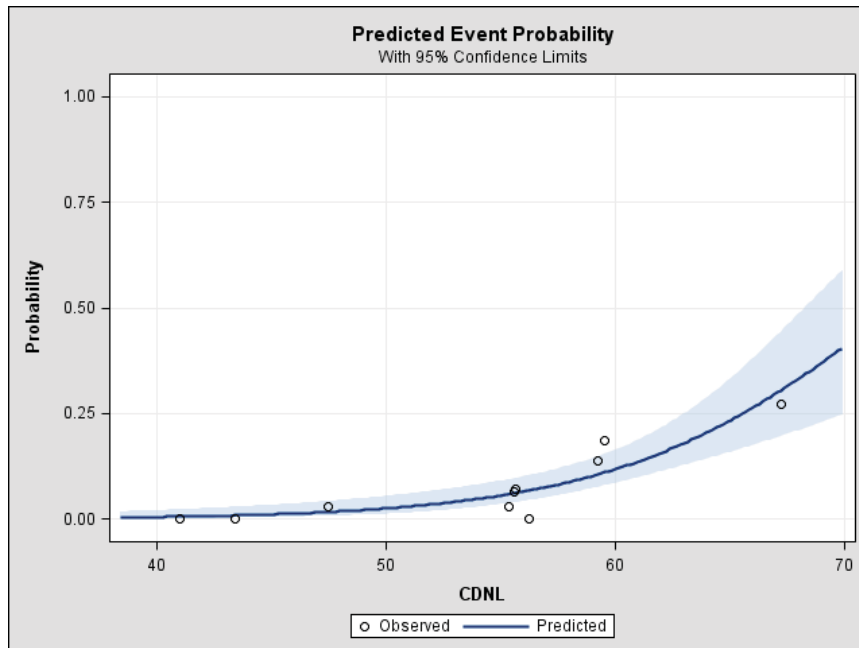
$$\text{Log(odds of being highly annoyed)} = -12.4328 + 0.1726 * (\text{CDNL}) \quad (\text{Equation 4-8})$$

Or equivalently,

$$\text{Odds of being highly annoyed} = (e^{-12.4328}) * (1.188)^{\text{CDNL}} \quad (\text{Equation 4-9})$$

What this means is that for every unit increase in CDNL the odds of a person being highly annoyed increases by a factor of 1.188. If one is interested simply in predicting the probability of a person being highly annoyed, the corresponding equation is:

$$P(\text{HA}) = \frac{e^{-12.4328} * (1.188^{\text{CDNL}})}{1 + e^{-12.4328} * (1.188^{\text{CDNL}})} \quad (\text{Equation 4-10})$$



**Figure 81. CDNL logistic regression prediction of the probability of percent highly annoyed.**

The SAS Analysis for Maximum Likelihood Estimates and Odds Ratio Estimates using DNL are provided in Table 61. A graphical representation of the logistic regression fit for DNL is provided in Figure 82.

**Table 61. DNL Maximum Likelihood and Odds Ratio Estimates**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-6.6027	0.9775	45.6276	<.0001
DNL	1	0.1088	0.0231	22.2478	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
DNL	1.115	1.066	1.167

The predicted event probability based on a logistic regression model using DNL is represented by

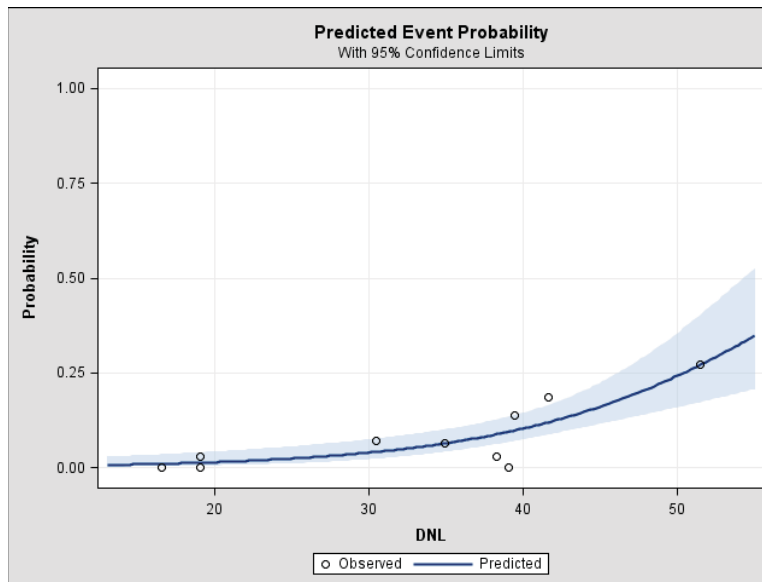
$$\text{Log(odds of being highly annoyed)} = -6.6027 + 0.1088 * (\text{DNL}) \quad (\text{Equation 4-11})$$

Or equivalently,

$$\text{Odds of being highly annoyed} = (e^{-6.6027}) * (1.115)^{\text{DNL}} \quad (\text{Equation 4-12})$$

What this means is that for every unit increase in DNL the odds of a person being highly annoyed increases by a factor of 1.115. If one is interested simply in predicting the probability of a person being highly annoyed, the corresponding equation is:

$$P(\text{HA}) = \frac{e^{-6.6027 * (1.115^{\text{DNL}})}}{1 + e^{-6.6027 * (1.115^{\text{DNL}})}} \quad (\text{Equation 4-13})$$



**Figure 82. DNL logistic regression prediction of the probability of percent highly annoyed.**

### 4.3.5.3 Using Cumulative Noise Metrics to Predict %HA: Best Regression Fit

In the logistic regression analysis, the value of each of the metrics is used to predict the probability of a person being highly annoyed. However, the data that is ultimately used is exactly the same proportion data that was used to fit the piecewise linear regression. Since the piecewise linear regressions yielded a drastically higher R-squared value than any of the logistic regression models, we can conclude that the piecewise linear function is the better predictor of highly annoyed in the observed range of %HA from 0 to 28 percent.

The plot of the piecewise linear regression for CDNL is presented with confidence bands to illustrate this point in Figure 83. The light blue bands surrounding the dark blue regression line represent the 95 percent confidence limits of the regression. The 95 percent confidence limits show where the true population parameter lies, with 95 percent confidence. Ninety-five percent prediction limits, shown as blue dashed lines, show with 95 percent confidence in what range one would expect to see an observation from the distribution he or she is considering. The prediction limits are wider than the confidence limits because they predict individual observations taken at another time, in place of the overall mean from this data set. On another day under the same conditions one could expect to see the percent highly annoyed fall within the 95 percent prediction limits.

As an example, to ensure that the response values are below 12 percent highly annoyed, the CDNL noise dose value would need to be below the level corresponding to the left extreme of the 95 percent confidence limits for the proportion 0.12 (see the red dashed lines for a visual representation in Figure 83). The width of these confidence bands is determined by the variation in responses and in the sample size. As the sample size increases the width of these bands will shrink. An increased sample size would provide a more accurate estimation of annoyance as a function of the sound metric. This gain in precision may be observed by increasing the sample size in future studies in a naïve community.

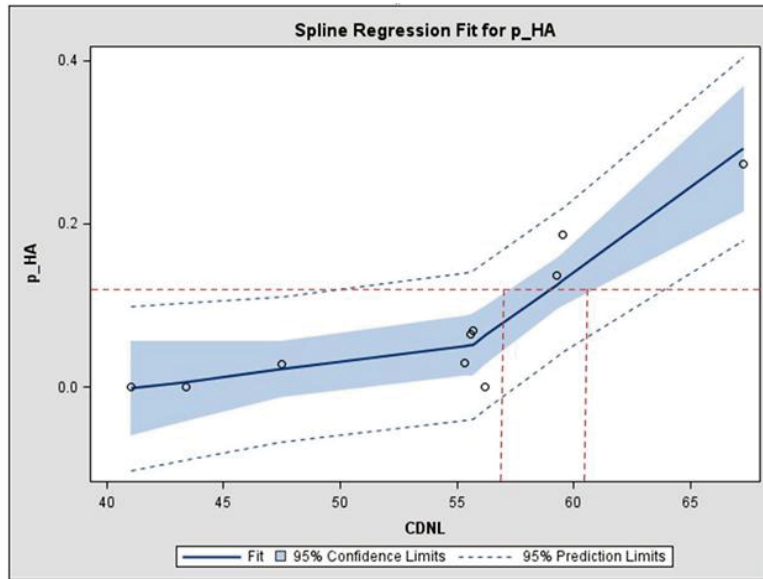


Figure 83. Piecewise Linear Regression and Confidence Bands with CDNL.

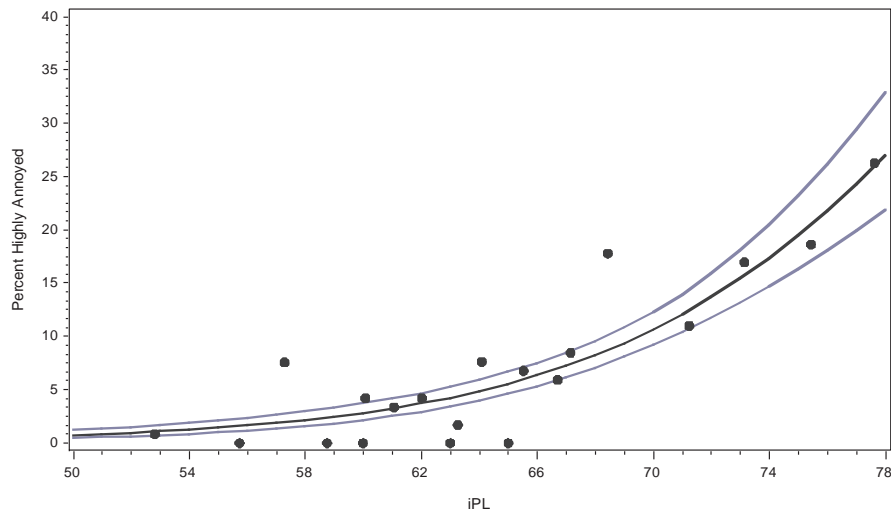
### 4.3.5.4 Logistic Regression to Predict Single Event %HA with Indoor Metrics

Logistic regression was used to fit the indoor metric values, affording a prediction of single event %HA. For the statistical analysis, the data was divided into 9 or 10 bins, so that each dot in the regression figures represents either 144 or 145 responses. For each metric, the logistic regression analysis resulted in an odds ratio, which expresses the increase in likelihood of being highly annoyed with every unit increase in the dependent variable. The metric algorithms were assessed to provide calculated values for inside the participants' household. The measures included iPL, iCSEL, iASEL, iZSEL, iLLZf, iLLZd, iPNL, and iMaxpsf. The metrics were identified as follows:

**Table 62. Indoor Metrics and Definitions**

Metric	Metric Definition
iPL	Steven's Mark VII Perceived Level inside participant home
iCSEL	C weighted sound exposure level inside participant home
iASEL	A weighted sound exposure level inside participant home
iZSEL	unweighted sound exposure level inside participant home
iLLZf	Zwicker's frontal incidence loudness in phons inside participant home
iLLZd	Zwicker's diffuse incidence loudness in phons inside participant home
iPNL	Kryter's perceived noise level inside participant home
iMaxpsf	boom peak inside participant home

An abbreviated summary consisting of the regression figure, SAS output, and three equations of interest is presented. The SAS output for the analysis using iPL is presented in Figure 84 and Table 63.



**Figure 84. Logistic regression using iPL.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -10.4858 + 0.1210*(iPL) \quad (\text{Equation 4-14})$$

$$\text{Odds of being highly annoyed} = e^{-10.4858} * (1.129)^{iPL} \quad (\text{Equation 4-15})$$

$$P(HA) = \frac{e^{-10.48589} * (1.129)^{iPL}}{1 + e^{-10.48589} * (1.129)^{iPL}} \quad (\text{Equation 4-16})$$

For every unit increase in iPL the odds of a person being highly annoyed increases by a factor of 1.129.

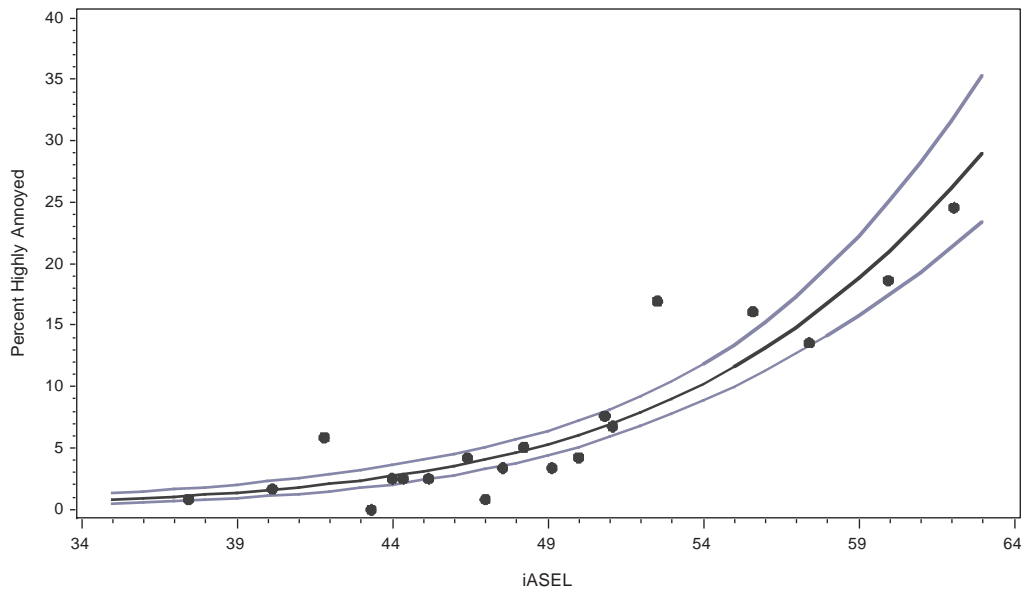


**Table 63. Analysis of Regression Coefficients and Odds Ratio Estimates iPL**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-12.1133	0.9174	174.3434	<.0001
iPL	1	0.1425	0.0132	116.7201	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
iPL	1.129	1.124	1.183

The SAS output for the analysis using iASEL is presented in Figure 85 and Table 64.



**Figure 85. Logistic regression using iASEL.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -9.8513 + 0.1421*(iASEL) \quad (\text{Equation 4-17})$$

$$\text{Odds of being highly annoyed} = e^{-9.8513} * (1.153)^{iASEL} \quad (\text{Equation 4-18})$$

$$P(HA) = \frac{e^{-9.8513} * (1.153)^{iASEL}}{1 + e^{-9.8513} * (1.153)^{iASEL}} \quad (\text{Equation 4-19})$$

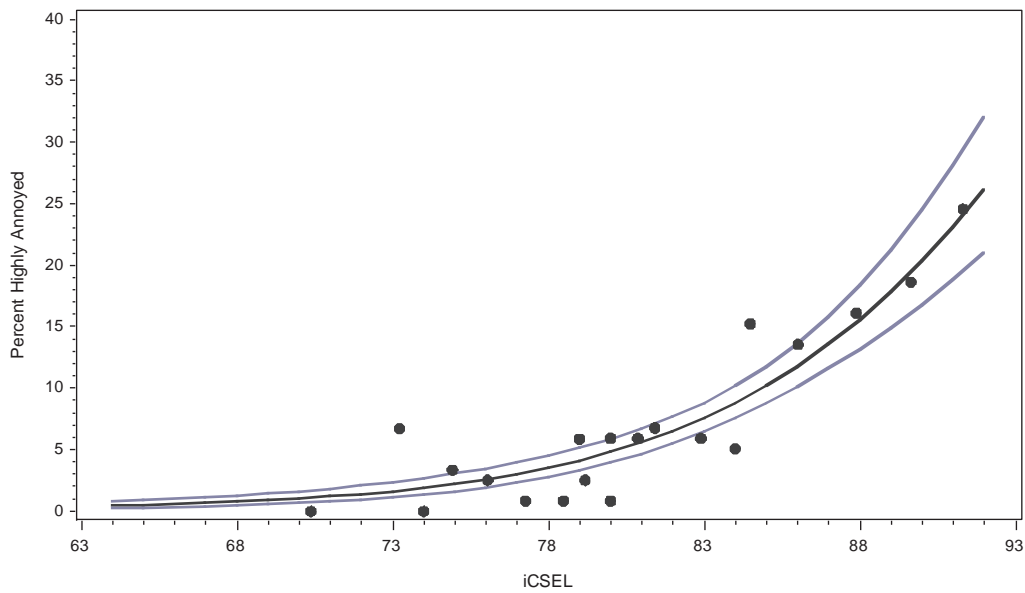
For every unit increase in iASEL the odds of a person being highly annoyed increases by a factor of 1.153.

**Table 64. Analysis of Regression Coefficients and Odds Ratio Estimates Using iASEL**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-9.8513	0.7010	197.5097	<.0001
iASEL	1	0.1421	0.0130	119.6041	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
iASEL	1.153	1.124	1.182

The SAS output for the analysis using iCSEL is presented in Figure 86 and Table 65.



**Figure 86. Logistic regression using iCSEL.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -16.0663 + 0.1633*(iCSEL) \quad (\text{Equation 4-20})$$

$$\text{Odds of being highly annoyed} = e^{-16.0663} * (1.177)^{iCSEL} \quad (\text{Equation 4-21})$$

$$P(HA) = \frac{e^{-16.0663} * (1.177)^{iCSEL}}{1 + e^{-16.0663} * (1.177)^{iCSEL}} \quad (\text{Equation 4-22})$$

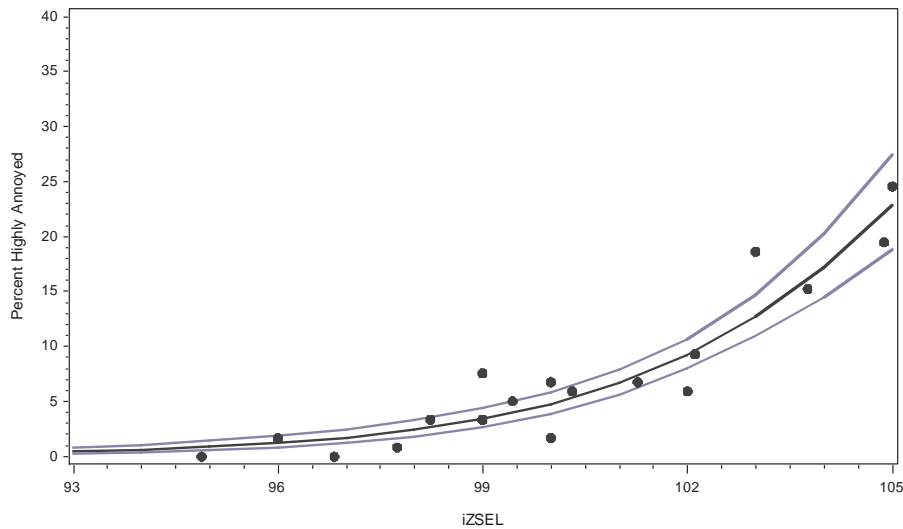
For every unit increase in iCSEL the odds of a person being highly annoyed increases by a factor of 1.177.

**Table 65. Analysis of Regression Coefficients and Odds Ratio Estimates Using iCSEL**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-16.0663	1.3547	140.6456	<.0001
iCSEL	1	0.1633	0.0160	104.1136	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
iCSEL	1.177	1.141	1.215

The SAS output for the analysis using iZSEL is presented in Figure 87 and Table 66.



**Figure 87. Logistic regression using iZSEL.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -38.7508 + 0.3574*(iZSEL) \quad (\text{Equation 4-23})$$

$$\text{Odds of being highly annoyed} = e^{-38.7508} * (1.430)^{iZSEL} \quad (\text{Equation 4-24})$$

$$P(\text{HA}) = \frac{e^{-38.7508} * (1.430)^{iZSEL}}{1 + e^{-38.7508} * (1.430)^{iZSEL}} \quad (\text{Equation 4-25})$$

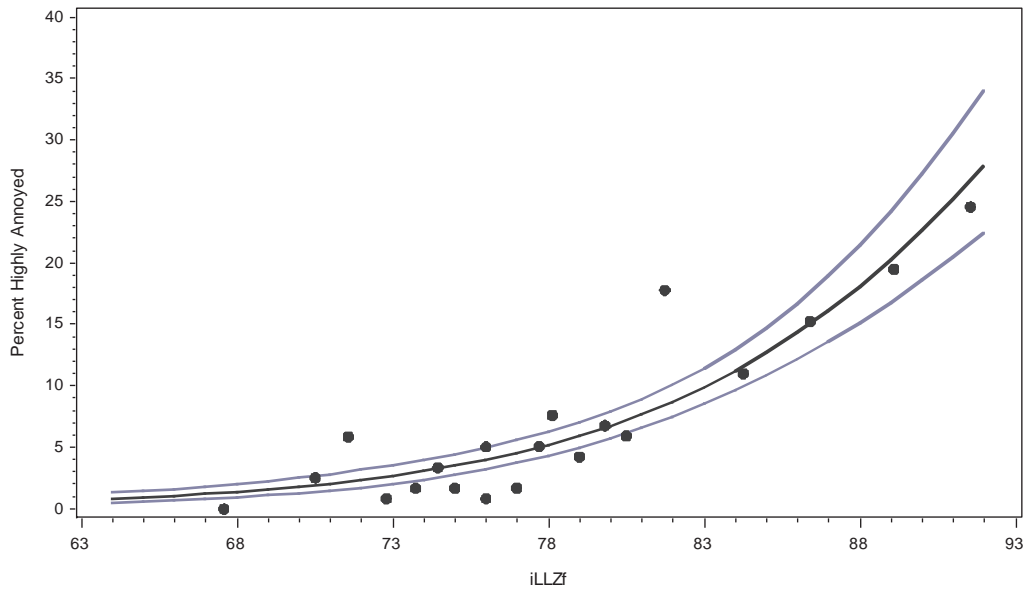
For every unit increase in iZSEL the odds of a person being highly annoyed increases by a factor of 1.430.

**Table 66. Analysis of Regression Coefficients and Odds Ratio Estimates Using iZSEL**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-38.7508	3.4574	125.6243	<.0001
iZSEL	1	0.3574	0.0338	111.6514	<.0001

Odds Ratio Estimates		
Effect	Point Estimate	95% Wald Confidence Limits
iZSEL	1.430	1.338 1.528

The SAS output for the analysis using iLLZf is presented in Figure 88 and Table 67.



**Figure 88. Logistic regression using iLLZf.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -13.8603 + 0.1403*(iLLZf) \quad (\text{Equation 4-26})$$

$$\text{Odds of being highly annoyed} = e^{-13.8603} * (1.151)^{iLLZf} \quad (\text{Equation 4-27})$$

$$P(HA) = \frac{e^{-13.8603} * (1.151)^{iLLZf}}{1 + e^{-13.8603} * (1.151)^{iLLZf}} \quad (\text{Equation 4-28})$$

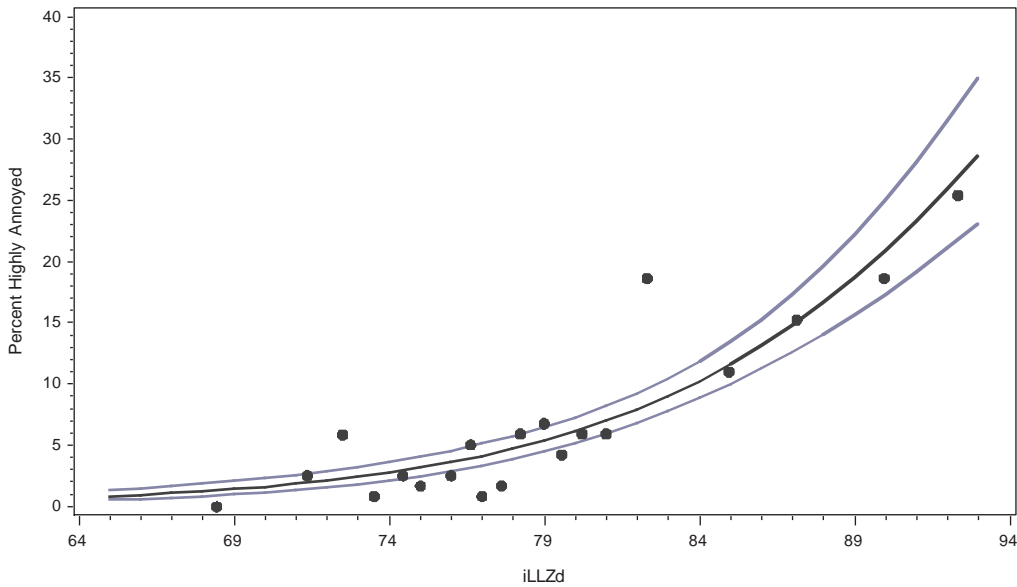
For every unit increase in iLLZf the odds of a person being highly annoyed increases by a factor of 1.151.

**Table 67. Analysis of Regression Coefficients and Odds Ratio Estimates Using iLLZf**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-13.8603	1.0790	165.0206	<.0001
iLLZf	1	0.1403	0.0130	116.2113	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
iLLZf	1.151	1.122	1.180

The SAS output for the analysis using iLLZd is presented in Figure 89 and Table 68.



**Figure 89. Logistic regression using iLLZd.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -13.9824 + 0.1405*(iLLZd) \quad (\text{Equation 4-29})$$

$$\text{Odds of being highly annoyed} = e^{-13.9824} * (1.151)^{iLLZd} \quad (\text{Equation 4-30})$$

$$P(\text{HA}) = \frac{e^{-13.9824} * (1.151)^{iLLZd}}{1 + e^{-13.9824} * (1.151)^{iLLZd}} \quad (\text{Equation 4-31})$$

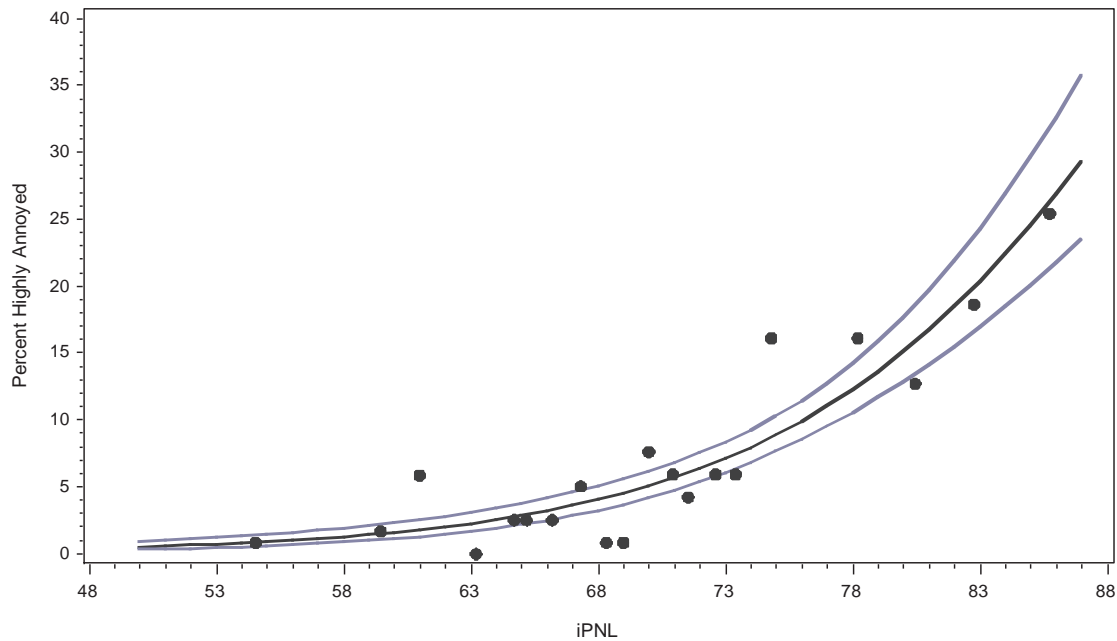
For every unit increase in iLLZd the odds of a person being highly annoyed increases by a factor of 1.151.

**Table 68. Analysis of Regression Coefficients and Odds Ratio Estimates Using iLLZd**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-13.9824	1.0791	167.8885	<.0001
iLLZd	1	0.1405	0.0129	118.6952	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
iLLZd	1.151	1.122	1.180

The SAS output for the analysis using iPNL is presented in Figure 90 and Table 69.



**Figure 90. Logistic regression using iPNL.**

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -11.4081 + 0.1210*(iPNL) \quad (\text{Equation 4-32})$$

$$\text{Odds of being highly annoyed} = e^{-11.4081} * (1.129)^{iPNL} \quad (\text{Equation 4-33})$$

$$P(HA) = \frac{e^{-11.4081} * (1.1297)^{iPNL}}{1 + e^{-11.4081} * (1.1297)^{iPNL}} \quad (\text{Equation 4-34})$$

For every unit increase in iPNL the odds of a person being highly annoyed increases by a factor of 1.1297.

**Table 69. Analysis of Regression Coefficients and Odds Ratio Estimates Using iPNL**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-11.4081	0.8564	177.4374	<.0001
iPNL	1	0.1210	0.0112	115.7128	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
iPNL	1.129	1.104	1.154

Logistic regression was used to fit each of the metric models individually. The odds ratio resulting from a logistic regression analysis expresses the increase in likelihood of being highly annoyed with every unit increase in the dependent variable. The odds ratio for each metric is listed in Table 70. The iZSEL shows the best indoor predictive capability for the likelihood of a participant being highly annoyed. For every unit increase in iZSEL the odds of a person being highly annoyed increases by a factor of 1.430 based on the odds ratio point estimate.

**Table 70. Logistic Regression Odds Ratio Point Estimate**

Indoor Metrics	Odds Ratio Point Estimate
iPNL	1.129
iLLZd	1.151
iLLZf	1.151
iASEL	1.153
iCSEL	1.177
iZSEL	1.430

The SAS output for the analysis using imaxpsf is presented in Figure 91 and Table 71.



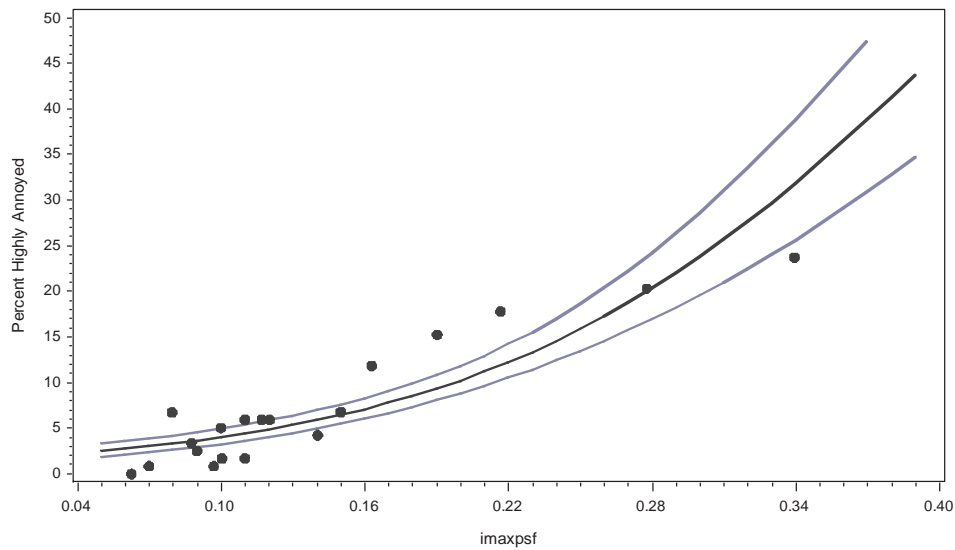


Figure 91. Logistic regression using imaxpsf.

The three equations of interest are

$$\text{Log(odds of being highly annoyed)} = -4.2090 + 10.1384*(imaxpsf) \quad (\text{Equation 4-35})$$

$$\text{Odds of being highly annoyed} = e^{-4.2090} * (e^{10.1384})^{imaxpsf} \quad (\text{Equation 4-36})$$

$$P(\text{HA}) = \frac{e^{-4.2090} * (e^{10.1384})^{imaxpsf}}{1 + e^{-4.2090} * (e^{10.1384})^{imaxpsf}} \quad (\text{Equation 4-37})$$

The imaxpsf is a drastically different scale from the metrics. Imaxpsf has a range of less than 0.4, while the other metrics have ranges of 30 or more. This makes it impossible to compare or even calculate the odds ratio reliably for imaxpsf. For every unit increase in imaxpsf the odds of a person being highly annoyed increases by a factor of  $e^{10.1384}$ , where a single unit increase in imaxpsf is more than the entire range of the data.

Table 71. Analysis of Regression Coefficients and Odds Ratio Estimates Using imaxpsf

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-4.2090	0.1856	514.0877	<.0001
imaxpsf	1	10.1384	0.8765	133.7837	<.0001

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
imaxpsf	>999.999	>999.999	>999.999

On each of the logistic regression plots there are 20 data points. Each of these data points was calculated from the data by binning on the number of responses. The first point represents the percent highly annoyed from the 145 responses with the lowest measured metric. Each point represents about 1/20<sup>th</sup> of the responses. The analysis was conducted to see how well the model fits and to illustrate how differently each of the metrics behave.

With the logistic regression analysis the R-squared is a pseudo R-squared, and the classic measure of R-Squared cannot be calculated. The pseudo R-Squared values indicate the improvement of fit from a null model without predictors. Using this value to compare to an actual R-Squared is not appropriate. It may be of value to compare between different logistic regressions. To afford this comparison, a rescaled R-squared was determined from the pseudo R-squared values. The re-scaled R-Squared values for each of the metrics are provided in Table 72. This comparison is only appropriate between logistic regression fits, and not applicable between logistic and classic R-squared values.

**Table 72. Comparison of R-Squared for Indoor Metric Calculations**

Metric	R-Squared (Pseudo)	Max-Rescaled R-Squared
iASEL	0.0533	0.1333
iZSEL	0.0532	0.1331
iPNL	0.0529	0.1325
iPL	0.0525	0.1314
imaxpsf	0.0512	0.1281
iLLZd	0.0509	0.1273
iLLZf	0.0501	0.1256
iCSEL	0.0478	0.1197

For the indoor metrics, the iASEL, iZSEL, and iPL gave the top three R-squared values for the eight metrics evaluated. All of the metrics have reasonably close values for pseudo R-Squared. iASEL and iZSEL seem to perform slightly better than the rest. The metrics performance are very similar to one another and the differences in the model fit seem to be less from a difference in predictive or explanatory power and more from a difference of location and scale of the metrics. That is, the coefficient estimates show a difference from one metric to another because the actual metric values differ. The indoor metrics do not show as large a difference as was shown between the Sone and Phon metrics.

#### 4.3.5.5 Using Cumulative Metrics to Predict Daily Overall Annoyance Ratings

The dose response relationship was assessed further by evaluating the ability of the cumulative noise metrics to predict the daily annoyance response on the 0 to 10 scale. To address this question, the daily annoyance response was compared to the cumulative noise ratings for PLDN, CDNL, and DNL. The spread in the data is represented in boxplots by displaying the subjective daily annoyance ratings for each of the observed values of the metrics as illustrated for PLDN in Figure 92, for CDNL in Figure 93, and DNL in Figure 94. The trends show that there is the expected tendency for the annoyance rating to increase, on average, as the metrics increase. The line in the center of each box represents the median of the data, the plus sign represents the mean of the data, and the distance between the two data shows the skew of the data. The boxes represent the interquartile region; 75 percent of the data lies below the top of each box and 25 percent of the data lies below the bottom line. The whiskers show the upper and lower 25 percent distributions of the data. The outliers in daily annoyance response results are indicated by the length of the whiskers on the end of each boxplot.

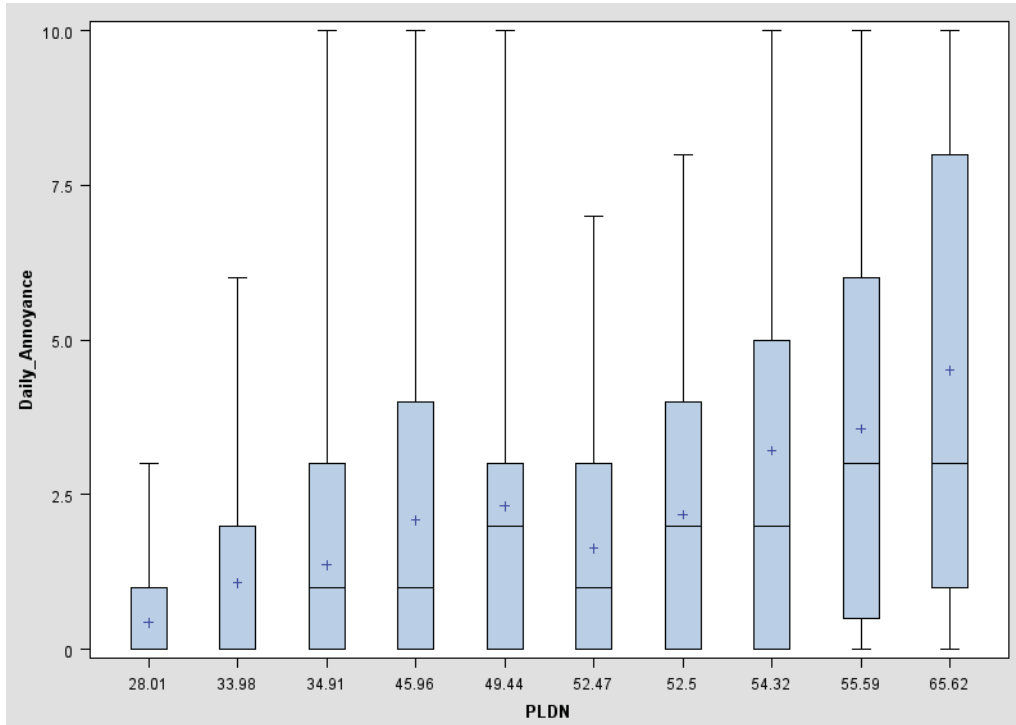


Figure 92. Boxplot of daily annoyance for values of PLDN.

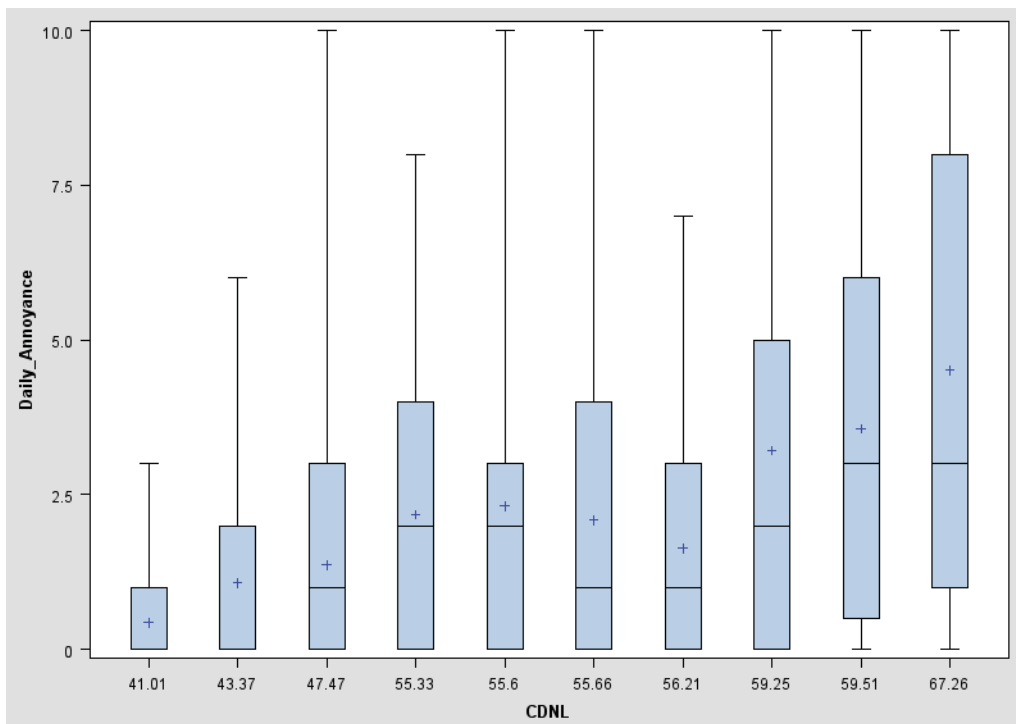
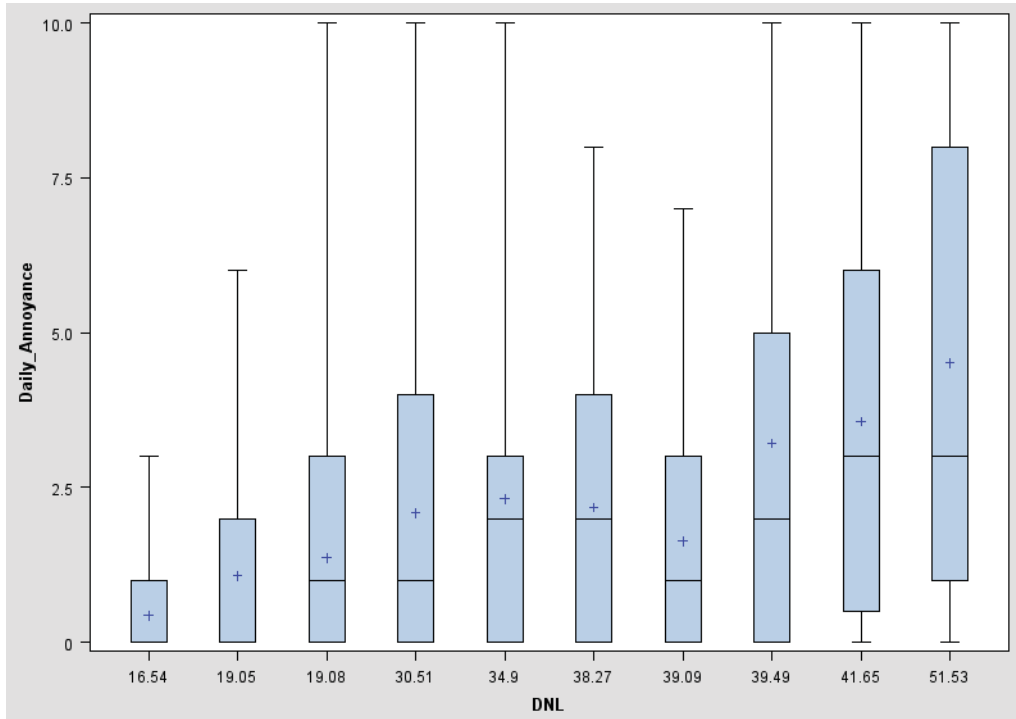


Figure 93. Boxplot of annoyance for values of CDNL.



**Figure 94. Boxplot of annoyance for values of DNL.**

Linear regressions were fit for the cumulative metrics (Table 73) and indicate a low R-squared for the linear regression for daily annoyance ratings. This is due to the fact that there is a large amount of variation in the daily annoyance ratings. On almost every day for which booms occurred there were respondents that answered from 0 to 10 on the daily annoyance scale. This means that there is a large amount of variation in the data, and the regression fit is unable to explain a large amount of it. By comparison, the “percent highly annoyed” data had less variation overall, as there was only highly annoyed or not highly annoyed for each of the 10 test days and they lay in a piecewise linear configuration. The daily annoyance ratings show a trend, but don’t lie in a straight line (piecewise or not). This distinction explains the difference in R-squared values observed for the %HA ratings versus those observed for daily annoyance ratings.

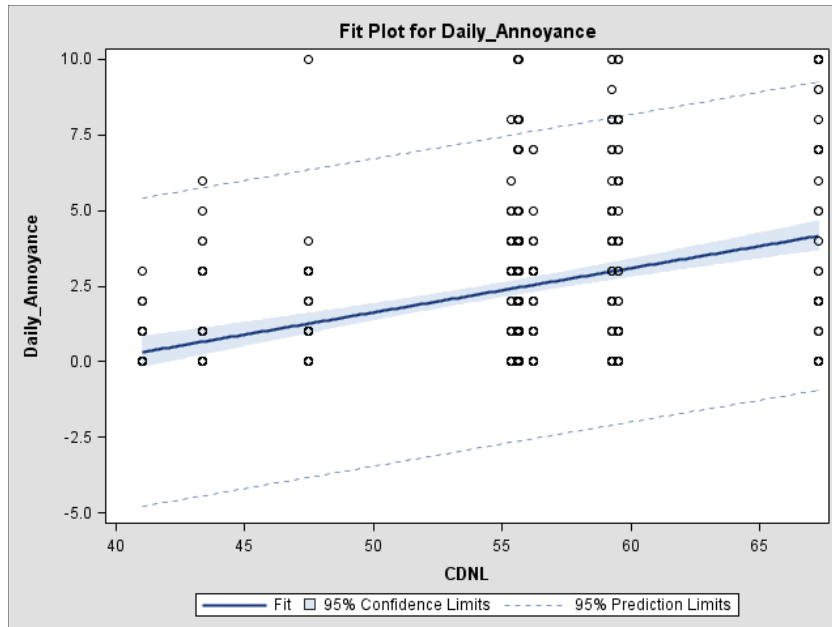
**Table 73. R-squared Values for PLDN, CDNL, and DNL Linear Regression on Daily Annoyance Ratings**

Metric	R-Squared
PLDN	0.140181
CDNL	0.147895
DNL	0.135375

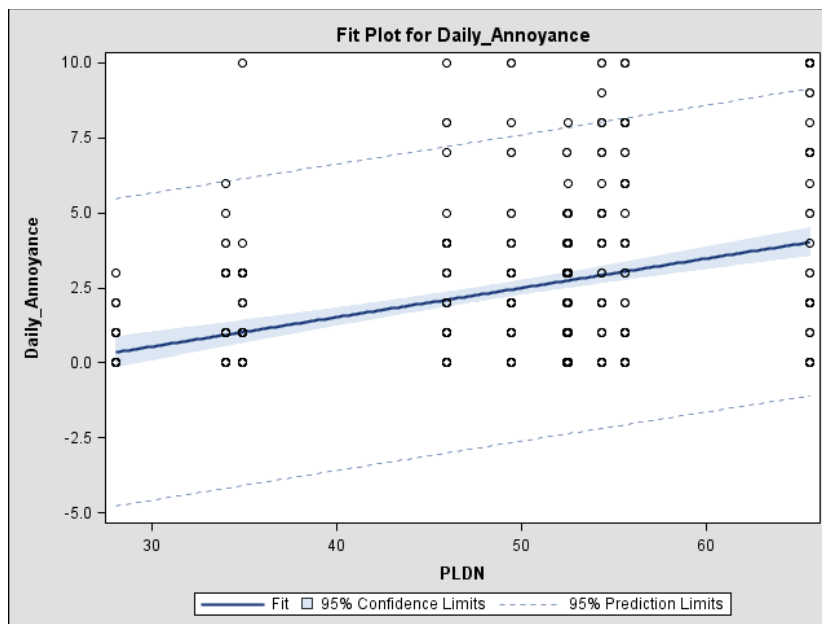
As was the case with %HA, the CDNL also explains the most variance in the daily annoyance ratings with an  $R^2 = 0.147895$  (Table 73). The PLDN followed closely with  $R^2 = 0.140181$  and DNL had  $R^2 = 0.135375$ . However, these correlation coefficients do not account for most of variability in the dose response relationship for the daily annoyance rating. While the metrics showed high correlation with % HA response (CDNL to %HA  $R^2 = 0.8911$ ), they did not correlate well with the daily annoyance ratings as indicated in Table 73. Table 74 presents the regression equations for each of the metrics while Figures 95 to 97 display the linear regressions.

**Table 74. Linear Regression Equations for PLDN, CDNL, and DNL for Daily Annoyance Ratings**

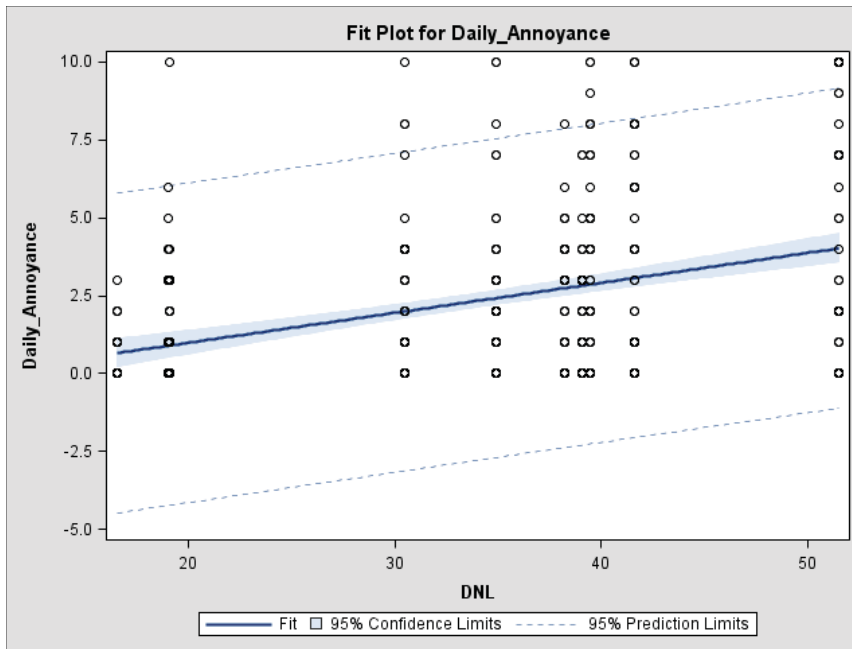
Metric	Regression Equation
PLDN	Daily annoyance = $-2.379022984 + 0.097601875*(PLDN)$
CDNL	Daily annoyance = $-5.684157403 + 0.146342802*(CDNL)$
DNL	Daily annoyance = $-.9325061472 + 0.096142170*(DNL)$



*Figure 95. Linear regression for daily annoyance and CDNL.*



*Figure 96. Linear regression for daily annoyance and PLDN.*



*Figure 97. Linear regression for daily annoyance and DNL.*

#### **4.3.5.6 Pairwise Comparisons: Effects of Daily Level and Number of Booms**

The repetitions of similar DNL levels, created with different combinations of booms, afforded the opportunity to investigate boom number and level effects on both the percent highly annoyed and the daily annoyance ratings. The table of paired days is presented in Table 75. For each of the comparisons examined, the paired days reflected specific differences in DNL level and number of booms. No significance was found in the paired comparisons for Highly Annoyed. When the paired comparisons were evaluated for daily annoyance, one pair showed a significant difference. Day 2 had a DNL of 39.09 due to 9 booms and Day 6 had a DNL of 39.49 with 14 booms. On average day 6 resulted in higher levels of daily annoyance than day 2. The data was not sufficient to clearly assess the relationship between level and number of booms. This may be due to the acclimated community or a relatively small sample size.

**Table 75. Comparison Days for Cumulative Metrics re DNL**

Test Day	DNL	Booms /Day	Boom List	Comparison
9	19.05	8	5L,3M	Same DNL/
5	19.08	4	4M	2x the booms
5	19.08	4	4M	2X the DNL/
1	38.27	4	1L, 1H, 1HR,1F	Same # booms
9	19.05	8	5L,3M	~ 2X the DNL/
2	39.09	9	4L,2M,2H,1F	~ Same # booms
1	38.27	4	1L, 1H, 1HR,1F	Same DNL/
2	39.09	9	4L,2M,2H,1F	~ 2x the booms
2	39.09	9	4L,2M,2H,1F	Same DNL/
6	39.49	14	3L, 6M, 2H, 2HR,1F	~1.5x the booms
7	41.65	14	4L,1M,4H,1HR,4F	Increased DNL/
8	51.53	27	3L, 8M, 2H,1HR,13F	~ 2x the booms

#### 4.3.5.7 Pairwise Comparisons for the Frequency of Highly Annoyed

For each of the pairwise comparisons on the frequency of “Highly Annoyed” a Fisher’s exact test of independence was conducted. This test evaluates whether or not there is a statistically significant difference in the proportion of people who were highly annoyed between each of the two days under consideration. A similar test is the Chi-Squared test. However, in this case, the Fisher’s exact test was warranted because some of the cell counts were low or zero. The Fisher’s exact test still assessed if there was a statistically significant relationship between the day and whether or not people were highly annoyed. For each of the comparisons requested, the days reflected specific differences in DNL level and number of booms. Table 76 gives the days under consideration, the p-value resulting from the Fisher’s exact test, and the conclusion based on this p-value.

**Table 76. Results of Pairwise Comparisons for Highly Annoyed**

Reason for test	Comparison Days	P-value (Two-sided)	Conclusion
<b>Same DNL, 2 times number of booms</b>	Day 9 vs Day 5	1	No significance
	Day 1 vs Day 2	0.4595	No significance
<b>Same number of booms, twice DNL</b>	Day 5 vs Day 1	1	No significance
	Day 9 vs Day 2	NA (no one was highly annoyed either day)	NA
<b>Same DNL, 1.5 times booms</b>	Day 2 vs Day 6	0.0268	No Significance
<b>Twice DNL to 2 times number of booms</b>	Day 7 vs Day 8	0.446	No significance
	Day 6 vs Day 8	0.1855	No significance

One should note that when multiple comparisons were conducted, the findings might have shown significance at the 0.05 level simply by chance. In these cases, a correction was applied to the p-values in order to account for this. The simplest correction was to take the significance level, selected at 0.05, and divide it by the number of comparisons



performed. In this case, there were six comparisons. Thus, using this correction, a test would only be considered significant if the p-value was less than  $0.05/6 = 0.0083$ . When the analysis fails to find significance, it could be because the study lacks power – the ability to detect significance. In this case, in particular, the Fisher’s exact test was warranted in place of a Chi-squared test because of the low cell counts, which resulted in a reduction in power. This happened because there were such low numbers of people that were highly annoyed in the dataset. Under different circumstances where the community was less acclimated, there may be more possibilities of detecting significant differences.

#### 4.3.5.8 Pairwise Comparisons for Daily Annoyance

The repetitions of similar DNL levels created with different combinations of booms afforded the opportunity to investigate boom number and level effects on the daily annoyance ratings as well. For each of the comparisons examined, the paired days reflect specific differences in DNL level and number of booms. The daily annoyance ratings 11-point (0 to 10) scales were compared for each of the pairs of days above. In the ideal case, this would have been done by either performing a pairwise comparison for each day using a t-test or by fitting an ANOVA model to the data and specifying the contrast for each comparison. Both of these procedures would have required that the data be either approximately normal or could have been transformed to approximate normality. The daily data did not transform to normality.

However, with a paired sample test, the variable of interest was the difference between the scores for each participant from the two test days, not the actual daily scores. When these differences were computed, there were varying sample sizes as a result of participants not scoring every single day, but the distribution of these differences looked approximately normal for each of the pairs identified. For this reason, a one sample t-test on the differences of daily annoyance scores for each comparison was utilized. Table 77 presents the results of each pairwise comparison.

Note again that in order to account for multiple comparisons, a correction factor was warranted. In this case, the correction was  $0.05 / 7 = 0.007143$ . Under this conservative threshold, one loses significance for the test between days 2 and 6, but maintains significance for the test comparing days 6 and 8. If one looks at the estimate of the mean difference for this comparison, one will see that it is  $-1.31818$ . Because the estimate of the mean for the difference between day 6 and day 8 is negative, and the result is significant, one can conclude that on average day 8 resulted in higher levels of daily annoyance than day 6.

**Table 77. Results from Pairwise Comparisons of Daily Annoyance**

Reason for test	Comparison Days	Number of observations	P-value (Two-sided)	Conclusion	Estimate of mean difference
Same DNL, 2 times number of booms	Day 9 vs Day 5	27	0.7626	No significance	-0.14815
	Day 1 vs Day 2	33	0.2325	No significance	0.606061
Same number of booms, twice DNL	Day 5 vs Day 1	33	0.0515	No Significance	1.000000
	Day 9 vs Day 2	27	0.6701	No significance	0.222222
Same DNL, 1.5 times booms	Day 2 vs Day 6	40	0.0500	No Significance	-1.30000
Twice DNL to 2 times number of booms	Day 7 vs Day 8	43	0.2087	No significance	-0.93023
	Day 6 vs Day 8	44	0.0071	Significance	-1.31818

#### 4.3.6 Summary: Subjective Annoyance

Two different linear regression approaches were utilized to fit lines to the proportion of people highly annoyed as a function of each of the three cumulative daily metrics. The piecewise linear regression provided the most relevant findings. Using piecewise linear regression, the CDNL metric explains the most variation in the percent highly annoyed

response, with an  $R^2 = 0.8911$ . It was the best metric in this study for correlation with the %HA annoyance response ratings. The PLDN followed closely with  $R^2 = 0.8329$  and DNL had  $R^2 = 0.7984$ . A linear regression line was also fitted to daily annoyance scores using each of the three objective metrics. The CDNL explains the most variance in the daily annoyance ratings with an  $R^2 = 0.1479$ . The PLDN followed closely with  $R^2 = 0.1402$  and DNL had  $R^2 = 0.1354$ . However, these correlation coefficients do not account for most of variability in the dose response relationship for the daily annoyance rating.

While the metrics showed high correlation with %HA response (CDNL vs. %HA  $R^2 = 0.8911$ ), they did not correlate well with the daily 11-point annoyance ratings (CDNL vs. Daily  $R^2 = 0.1479$ ). This was due to the fact that there was a large amount of variation in the daily annoyance ratings that the regression fit was unable to explain. On almost every day for which booms occurred there were respondents that answered from 0 to 10 on the daily annoyance scale. By comparison, the “percent highly annoyed” data had less variation overall, as there was only highly annoyed or not highly annoyed for each of the 10 test days and they lay in a piecewise linear configuration. The daily annoyance ratings showed a trend, but did not lie in a straight line (piecewise or not). This distinction explains the difference in R-squared values observed for the %HA ratings versus those observed for daily annoyance ratings. Because the metrics were slightly different for each respondent for each boom, the WSPR team recorded numerous responses all for different values of the metrics. This was the perfect situation for use of a logistic regression analysis. A logistic regression was conducted to evaluate the likelihood of a participant being highly annoyed (annoy value of 8 or higher). The CDNL showed the best predictive capability for the likelihood of a participant being highly annoyed. For every unit increase in CDNL, the odds of a person being highly annoyed increased by a factor of 1.188 based on the odds ratio point estimate. For PLDN, the factor showed an increase of 1.122, and for DNL the factor increased by 1.115 for each unit increase in the metric level.

A logistic regression was also calculated for the Moore and Glasberg loudness metric using instantaneous, short-term and long-term averaging. For the statistical analysis, the data was divided into 9 or 10 bins, depending on the spread of the data, so that each dot represented the percent highly annoyed of 144 or 145 responses. Within the “Sone” metrics, the logistic regressions were very similar to one another, as they were within the “Phon” metrics. The observed booms were much more concentrated in the low values of the “Sone” metrics but more evenly spaced for the “Phon” metrics. The dots on the regression line are pretty evenly spaced throughout the range of IPhon, and they lie close to the line, indicating that this model fits the data well. This pattern of fit was also observed for Av1Phon and Av2Phon. There is no compelling evidence that there is actually a difference between the logistic regression fit of IPhon and Av1Phon or Av2Phon. There is an observable difference between the “Sone” and “Phon” metrics, but not necessarily differences within the two sets of metrics.

The logistic regression also provided an odds ratio estimate that shows the same pattern of differentiating between “Sone” and “Phon” based metrics, but does not show distinct differences within the sets. For every unit increase in Av2Phon, the odds of a person being highly annoyed increased by a factor of 1.112 based on the odds ratio point estimate. The odds ratios for the three “Phon” based metrics are very similar, indicating that for the Moore and Glasberg metric assessment of low booms, the WSPR team did not see much difference between the instantaneous and the short- and long-term averaging of the methods.

For the indoor metrics, the iASEL, iZSEL, and iPL gave the top three R-squared values for the eight metrics evaluated. The metrics performed very similar to one another and the differences in the model fit seemed to be less from a difference in predictive or explanatory power and more from a difference of location and scale of the metrics. That is, the coefficient estimates showed a difference from one metric to another because the actual metric values differed. The indoor metrics did not show as large a difference as was shown between the Sone and Phon metrics. Pairwise comparisons were conducted using both highly annoyed frequencies and daily annoyance scores to look at the effects of level and number of booms. Once a correction for multiple comparisons was performed, there were no significant differences for the comparison of daily annoyance scores. The data was not sufficient to assess the relationship between level and number of booms.

There are cautions with attempting to generalize the findings beyond the ranges observed. All observed values of annoyance were less than 30 percent highly annoyed. For the daily annoyance data, there was also the issue of limited observations for percent HA. It is difficult, if not impossible, to generalize beyond the range of this observed and binned data. For this reason, none of the methods proposed are perfect. In the quadratic regression analysis, the metric values were used to define bins, and then percent HA was calculated for each of those bins, making the results dependent on that choice of bins. The quadratic regression correlated with the observed data very well, but did not pinpoint the “knee” that a piecewise linear function provided. It is also not trustworthy outside the range of observed data, is not restricted to positive values, and is highly dependent on the choice of bins. The logistic regression analysis does not rely on bin selection, which makes it a more consistent approach. The logistic regression is suitably restricted for positive responses only, does not require any bins, and is often used for this type of data. As with quadratic regression, however, it is not wise to extrapolate outside the range of observed data.

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# Lessons Learned

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The WSPR experiment was conducted to demonstrate the applicability and effectiveness of techniques to gather data relating human subjective response to multiple low-amplitude sonic booms. It was a practice session for future wider scale testing of communities, eventually using a purpose built low-boom demonstrator aircraft. As described in other sections of this report, the WSPR program addressed the following – design and development of an experimental design to expose people to low-amplitude sonic booms, development and implementation of methods for collecting acoustical measures of the sonic booms in the neighborhoods where people live, design and administration of social surveys to measure people's reactions to sonic booms, and assessment of the effectiveness of various elements of the experimental design and execution to inform future wider-scale testing. During the development, execution, and analysis aspects of each of these elements, the WSPR team took note of those elements that worked well and those that might need to be changed during the next low-boom test. This section contains a critical review of the WSPR lessons learned so that future investigators will continue to advance the knowledge base of techniques for conducting low-boom community response research.

## 5.1 *Experimental Design*

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The design was balanced to afford comparisons between days for dose response relationships. The level and the number of booms at each level were varied to create different target DNL values for the test days. This aspect of the design afforded a distribution of DNL levels across the range that has been investigated previously, and provided sufficient data points to compare to previous findings. The design was varied each day to facilitate weather and flight logistics. The design was also varied to adjust for the presence of non-WSPR booms that the community was exposed to from other sources.

The lowest low booms are the most sensitive to weather changes, so the lowest booms were reassigned to days with better weather. The various adjustment factors resulted in the days with the lowest DNL falling on the last 2 days of the test. This was not part of the original noise design, but was a result of other variables. There was an observed decrease in single event response rate on the final day. However, it appears that this was not due to response fatigue, but because the lowest booms weren't heard. On the last day, 35 participants submitted daily summaries, and 15 of those 35 also submitted single event ratings. The daily summaries indicated how many booms were heard that day. About 5 percent of respondents heard more than two booms, and 80 percent of them heard only one or none. This trend in the data is an indication that the participants were still responding, but the lowest low booms were not heard (see Appendix H for more details).

The days that were matched for DNL also afforded the opportunity to see if participants agreed with themselves on the daily ratings of DNL when presented with the same DNL level on 2 days separated across the 2-week design. The design provided the basis for a comparison of days with the same DNL and a different number of booms. However, the data was not sufficient to clearly assess the effects of level and number of booms on the percent highly annoyed or the daily annoyance ratings.

## 5.2 *Recruitment*

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Two important lessons for subject recruitment emerged from the experience at EAFB. First, an early, well-coordinated and sustained communication effort is essential. Subject recruitment for WSPR required a longer time period than anticipated or desirable, and efforts were hampered by the lack of timely and sustained communication to the eligible population. The WSPR team outlined a recruitment plan that included early communication and the use of multiple channels concurrently (or very closely following each other) to maximize coverage and broadcast a consistent message. This plan was developed with the unique circumstances of EAFB in mind (e.g., high personnel turnover, especially in summer) as well as challenges common to many research studies (e.g., varying schedules in the summer months versus school year). However, this plan was not followed by EAFB Public Affairs office, which required lengthy approval

periods and stated a preference for longer intervals between communications. The post-test interviews with subjects emphasize the importance of regular, follow-up announcements. Some participants did not learn about the study until months after the first announcements. Without an immediate follow-up appeal, some may have concluded that the research team did not need more subjects.

- “When I first heard [about the study], I figured they had enough people that were eligible. My husband got another notice about it in his email and when I heard they were having trouble finding volunteers, I decided why not, I’m home anyways.”

Participants learned about the study from a variety of sources, demonstrating the importance of using a range of methods to reach the eligible population.

- “I believe I read [about] it [the study] in the newspaper.”
- “I first heard from a friend who works at NASA.”
- “My husband showed me an email he received.”
- “I found out from an Officer’s Spouse Club Meeting.” [Printed flyers were posted in the club house and NASA Dryden staff liaising with EAFB spoke with club organizers about the study.]

Second, the use of incentives was important to reach the desired number of subjects at EAFB, and a cash incentive may be especially important to enlist willing participants in a naïve community. WSPR subjects received a patch with the study logo, a certificate of appreciation, and a \$50 VISA gift card. The gift card was offered late in the recruitment period when we were unable to meet the target of 100 participants, and interest in the study sharply increased after this notification. In our post-test interviews, not all participants felt a cash incentive was critical and some signed up late because they were not aware of the study earlier, but there is little doubt that a cash incentive was important. We would expect incentives to be similarly, if not more, important in a naïve community that may have more diverse views or enthusiasm for the study objectives.

In our post-test interviews, several participants noted that an incentive seemed fair given the amount of time required to complete the surveys, but sponsorship by NASA – a highly-esteemed Federal agency in the general population – is also an important factor.

- “It takes people’s time. I don’t know if people would want to do it if they didn’t get something out of it. I think \$25 would be reasonable. I think that’s fair. A lot of people work during the day and it takes a lot of time, they may lose interest if they don’t get anything.”
- “Some kind of thank you thing I think will be fine, like a \$5 gift card to Starbucks. Maybe have some options like you can pick from like a t-shirt, a \$5 gift card, an iTunes gift card, just different options they could pick, versus \$50 a pop.”
- “The incentive could even be something little, like a magnet. It doesn’t have to be a gift card (not that I’m complaining). People like NASA, and NASA stuff. Something like that would be good enough.”

## 5.3 *Experimental Execution*

There were several different aspects to the experimental execution – planning, logistics, and instrumentation setup, objective data gathering, aircraft flight operations, and delivery of planned booms. Lessons learned during each of these aspects can advise future test design, planning, and execution, and are described in the sections below. Subsequent to the WSPR experiment and primary analysis, and based on some of the lessons learned, which are documented in this section, NASA funded an additional task to investigate measurement data metric analyses techniques (Section 4.1.6) and explore the viability of using PCBoom for low-boom experimental design over larger communities (Section 6.3).

### 5.3.1 **Planning, Logistics, and Instrumentation Setup**

Preparations for follow-on human subjective response testing should include determining an appropriate microphone density for the community under test. This task can utilize the data collected from the WSPR test. An additional consideration for future testing would be to determine the field kit resources required to support any follow-on testing. There are certain components of the field kits that will readily scale with an increase in the number of system nodes. For example, the primary field kit hardware (batteries, microphones, solar panels, etc.) will readily scale. The infrastructure for both long-range and short-range communication may or may not scale depending on the means of implementation. Future plans for field kit development include remote access and control of the measurement hardware. When moving to larger communities with an increased number of field kits, remote command and control would be extremely useful. Future plans for field kit development also include noise metric calculations at each field kit to provide near “real-time” feedback of sonic boom levels. This would facilitate any adjustments needed to the flight plan for changing the exposure/dosage of the human subjects, potentially allowing closer agreement to the target levels desired for each day/period of testing. Residing at a hotel on base saved a significant amount of time traveling to the test site. This was a logistical advantage over past sonic boom testing where the support team resided off base and traveled an hour each way to and from the test site.

The installation of the field kit solar panels was extremely labor intensive. The bracket design was more suited to a permanent mounting rather than a temporary installation. Future testing should include solar panel installation that can be readily deployed and redeployed. Very low levels of EMI were detected on a select number of channels for certain field kits. Potential causes of this are the proximity of the solar panel controller relative to the electric light post. Magnetic filters should be used on future tests to mitigate possible EMI in the acoustic data.

Analysis of the metric interpolation procedure revealed that the field kit density in the EAFB housing area was more than sufficient to characterize the “baseline” sonic boom environment over a small area. Looking at measured booms across the area (Appendix F) there is considerable variability about the “baseline” sonic boom signatures due to turbulence. It was determined that this region of influence is rather small however multiple monitors are likely required in order to accurately quantify an accurate “baseline” boom level. Had only one field kit been used for the EAFB housing area, those events for which turbulent spiking and rounding occurred would not be suitable for estimating subjective exposure. This suggests that in future testing over a larger community area, a dual set of instrumentation should be deployed – gross coverage to identify the “baseline” sonic boom levels and localized small array of microphones to characterize the turbulence. Perhaps in the future consideration of ‘de-turb’ techniques, such as those that were employed in analysis of the SSBD flight data, could be applied to the WSPR measurement dataset to further develop conceptual field kit layouts for larger communities. Additional considerations for planning low-boom measurements over larger communities are discussed in Section 6.3.

### 5.3.2 **Objective Data Gathering**

During the WSPR experiment, 106 sonic boom events were recorded by a multitude of devices, including 13 Field Kits, 1 SNOOPI, and 1 reference microphone. Four booms were missed by all the recording equipment. Future field kit development should include improving the system’s ability to handle brief disruptions in communication. It was observed that slight interruptions in network connectivity could lead to field kits dropping offline. The field kit reliability could be improved by making the system more robust to intermittent gaps in host-to-node communications that are likely inherent regardless of the communication protocol implemented. All field crew members operating and observing operations at the Host station near Chapel 2 took detailed field notes,



including time and aural estimated sonic boom levels for each sonic boom that was heard. The practice of “guessing the boom level” and followed shortly by determining the actual SNOOPI recorded sonic boom level provided training and improved the research team’s ability to aurally estimate boom levels. These notes, captured by “trained sonic boom listeners” were compared against one another and used to help understand and clarify the measurement data from the multitude of acoustic data recording systems (field kits, SNOOPI, backup recorder at Chapel 2). This was especially critical when assessing low amplitude adventitious booms, which were less likely to be recorded by larger threshold auto-trigger devices such as SNOOPI, and preparing the WSPR Sonic Boom Master List (Table 16). During the course of the WSPR experiment, a total of four sonic booms events were estimated based on field crew notes.

The Auto Boom Finder (ABF) methodology, described in Section 4.1.7, appears to reliably find both the primary and secondary booms from WSPR for even the lowest amplitude booms. Implementing this algorithm into the field kits would eliminate the need for manual triggering/recording of the booms, avoid having multiple modes of control center communication or visual guidance for incoming booms, and provide the potential for unattended field kit operation. This option should be given a high priority and be systematically explored, developed, and tested prior to the next low-boom subjective test.

### **5.3.3 Aircraft Flight Operations**

The test personnel should be equipped with a VHF receiver to monitor pilot/ground communications. There were instances during WSPR execution in which the ground team failed to receive an indication that the airplane had reached the waypoint, so the field kits were not activated. Subsequent to this event, the ground crew proactively watched the sky in the expected region where the F-18B dive maneuver was to be conducted in order to have a visual indication of the in-coming sonic boom.

### **5.3.4 Delivery of Planned Booms**

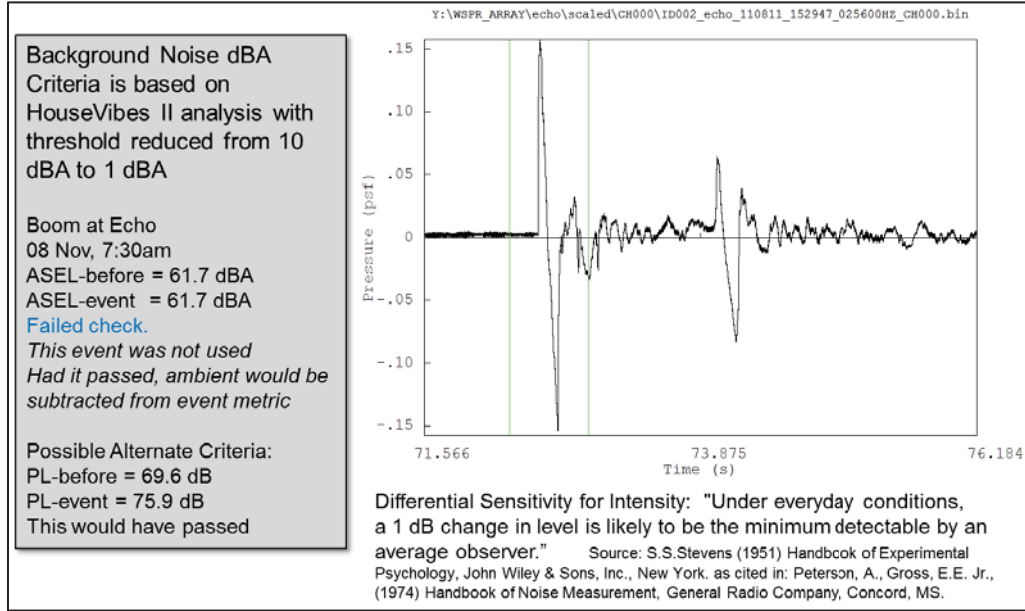
A comparison of the planned and delivered WSPR sonic booms was provided in Section 3.2.1. Figure 23 indicated that delivery of the lowest amplitude booms was more difficult than the higher amplitude booms. This was primarily due to atmospheric conditions and the need for a quiescent air mass to deliver the lower booms. Planning of the waypoints required knowledge of the upper air data as close to flight time and as close to the region between the F-18 and the subject area as possible. The required time for a meteorological balloon equipped with a GPSsonde to travel up to the altitude at which the low-boom dive maneuver was initiated, took about 45 minutes. On calm days when the atmosphere was not as dynamic, it was easier to deliver the low booms. This necessitated a flexible experimental design, one where entire sequences of boom maneuvers could have been swapped for other sequences and tailored for the atmospheric conditions. Unfortunately, the requirement for calm, stable days tended to push those elements of the acoustic design with multiple low-amplitude events either to the early morning or to later in the flight test (while waiting for that perfect day). As was seen in the subjective response data, there was a considerable reduction in single event surveys on the last 2 days of WSPR testing, as numerous low-amplitude booms occurred on those days. However, since these last 2 days came after the loudest day in the experiment, the response rate drop-off could have been due to subjects not noticing the very low booms. Future experiments could benefit from a more rigorous statistical assessment of low-boom delivery success as a function of empirical atmospheric measures such as wind gradients. This could also lead to the development of better quantified atmospheric criteria for deciding the sequence of booms to attempt to deliver.

## **5.4 Objective Data Analysis**

During the course of this research, we identified several areas where additional investigation would help to better prepare for future low-boom testing in a naïve community. The current WSPR team recommendation is to proceed with a subsequent WSPR-like test in a naïve community using the F-18 low-boom dive maneuver. Lessons learned relative to such a future test are itemized later in this section.

Waveforms recorded from the F-18 low-boom dive maneuver employed during the WSPR experiment typically contained a double boom – primary boom and post-focus boom (Figure 98). Subjects were instructed to evaluate the

double booms as a single event. The relative size and spacing of the double booms were dependent on the specific as-flown maneuver and intervening atmosphere. During the WSPR experiment, a large acoustic measurement dataset was gathered (more than 800 individual sonic boom recordings). Automated processing techniques must be employed in such data collecting.



**Figure 98. WSPR sonic boom recording.**

Wyle developed a process by which sonic boom metrics, computed from pressure time histories at microphone locations, could be interpolated to WSPR participant household locations based on a power interpolation technique as was described in Section 4. Based on prior analysis precedents set during the HouseVIBES project, the WSPR team employed a 650 ms time window for computation of the metrics. Attempts to include a larger window introduced significant quantities of background noise into the metric computations, in particular A-weighted levels. Figure 98 illustrates one WSPR boom where the A-weighted noise for 650 ms immediately preceding the sonic boom had approximately the same ASEL as the boom event itself.

The following recommendations, based on the analysis of the WSPR booms, were discussed with NASA during Technical Interchange Meeting 5 and ultimately funded:

1. Perform an assessment of the metric analysis time-window and determine a process that preserves the maximum amount of measured data while not causing undue influence on the metric computation. Determine the metric impact of the “ringing” between the two booms and assess its importance in the metric computation. Consider ambient metrics and explore metric computation schemes that will account for the full double boom event while preserving a scalable automated processing technique.
2. Examine the pre-boom noise seen in Figure 98. Assess its source (i.e., actual background or instrumentation noise), determine why the A-weighted level behavior is different than PL behavior, and recommend processing techniques to handle this type of record.
3. Evaluate the confidence of the metric predictions at the household locations based on the existing WSPR dataset by varying the number of monitors and the house hold locations.
4. Perform an assessment using PCBoom predicted signatures across the low-boom carpet area (area larger than the EAFB household region) using as-flown WSPR tracking and atmospheric data to assess the suitability of the metric prediction scheme for larger areas. Determine possible geographic areas of extents over which the

metric prediction methodology is applicable given the F-18 low-boom dive maneuver. Determine the relationship between metric confidence prediction and field kit recording density.

These additional analyses were conducted and the findings are reported in Chapters 4 and 6. Subsequent to the boom analysis tasks, the following recommendations apply to future testing over larger communities.

For a small community, like the EAFB housing area, the density of field kits was greater than needed. Although the “baseline” boom levels did not vary considerably across the area, multiple field kits were needed to avoid over-estimating the boom levels. Turbulence typically has a range of 300 feet (depending on the scale of the atmospheric turbulence). Metric values for waveforms with turbulent spiking tend to be larger than for those without. Had a single microphone been used to approximate the levels across the whole community, those times it measured a turbulent spiking boom would have resulted in an overestimation of the boom metrics at the household locations.

The metrics computed from the measured pressure waveforms were highly correlated. The statistical analysis of the correlated subjective-objective data revealed no clear metric “winner.” The considerable effort required to process the waveforms and compute a multitude of metrics will be reduced in the future due to the creation of the ABF tool. However, numerous adjustable parameters for metric processing still need further investigation, such as the window size and the handling of ambient noise.

## 5.5 Subjective Data Collection

The WSPR project used three modes of survey administration with a goal of assessing their merits in terms of data quality and effectiveness, but there may not be a single-best mode to use in a future study with a naïve community. No single mode proved to be far superior to the others in terms of convenience, functionality, data quality, and completeness, or perhaps even cost-effectiveness. Several insights were reflected in the comments of participants themselves.

*Among participants, each mode had its fans and detractors. Preconceptions about a preferred mode were not always met, and it is unlikely that offering only a single mode will be well-suited to everyone or ensure maximal response.*

- “There were times where it [paper mode] was a little difficult because I was in the middle of something and had to, because it’s not on my phone and I carry my phone with me everywhere, stop go in the house, fill out the form, because you can’t always remember the information later. So with the phone I could have been done with it and kept going on with my day.” (paper)
- “I kept thinking, oh man if I had a phone it would be easier. But my friend, who was on the iPhone, said she wished it was on the web. I guess the grass was greener on the other side. She didn’t want to carry two phones around along with a diaper bag.<sup>14</sup> I thought it would have been convenient to have because I can’t get to the computer with my kids so maybe I would hide the phone. I didn’t mind using a piece of paper to jot down notes. If I had a phone it would be hard to remember things for the daily summaries. You all did a good job sending information!” (web)
- “It would have been more tedious to use paper or stop to get on the web. I carry my phone everywhere and if I was taking a walk I could do it during the walk, more inconvenient to run to the computer. It was easy to pull out the phone, but the convenience was difficult sometimes when other things were going on.”(Apple)

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<sup>14</sup> The friend this participant refers to may have been a participant in the parallel research effort led by Fidell and Associates. That protocol provided participants with a SmartPhone free-of-charge for the purpose of completing surveys, but it was not an iPhone. As a result, participants may have been carrying their own mobile telephone as well as the study device. We also were aware of one participant in the Wyle-led study who used her husband’s iPhone to participate in the study, and she may have been carrying both her own personal mobile telephone and the spouse’s iPhone on which the survey app was installed.

- “A desktop (the web) would be just as cumbersome as paper and pen because you have to physically stop and get to the computer, get on the website, even if you’re using your phone you sometimes don’t have access to the internet. But the app, the way that works is you pop it open, the form is there, you punch it in, and it sends the information.”
- “Anything you can do to make it as easy and convenient for people to participate to they will be more apt to. Like the envelopes already addressed with stamps on them was very smart. Lots of forms, very easy to fill out, a very simple process.” (paper)

A few participants, who had young children and used web or Apple, mentioned that it could be difficult to complete the single event surveys immediately because their child would also want to use (play with) the device or computer if it was visible or if it became the focus of the parent’s attention. A future study might encounter similar situations if the target population includes individuals who are at home during daytime hours and, as a result, include a disproportionate number of parents with young children.

*Respondent burden was very high and the disruption to daily activities of the sonic booms and the diary-like response tasks may be greater than can be asked in a general population study without substantial compensation.*

- “Some days there was a lot of booms. I thought oh man, I was thinking maybe tomorrow I should go off base. Some days it seemed like it was every 10 minutes, it wasn’t every day so it wasn’t all bad.”
- “It didn’t really interfere, but it was kind of annoying sometimes because I would be outside talking to a friend and 3 would go off in about 30 minutes and I’d have to remember to go in and fill out my forms.”
- “It was ridiculously annoying. My baby didn’t nap, my children didn’t nap at all. I found that most of the moms around here felt the same way. A couple people just moved here and thought that was the norm and they were very concerned about this is what Edwards life is like and I assured them it was not that intense.”

*Impacts on survey data quality should be considered in tandem with design decisions about the number and timing of booms. Generating a very large number of booms in a single day (not always under the team’s control for WSPR) or spacing booms too closely can exacerbate respondent burden, affect participants’ ability to complete surveys, or even shape their reactions to the noise.*

- “A couple days there were so many booms that I just couldn’t stop my day to sit at the desk, there were a couple of days with 20+ booms.”
- “When there were a bunch [booms] [it was] hard to remember how loud each one was. Sometimes I did forget, I knew the time but forgot what happened.”
- “They [booms] are hard not to notice, but I did get more irritated than normal because of the frequency. I would just get the baby to sleep and then the 57 pound dog would start barking. I either had to take him outside or the baby would start crying.”

*Similar comments were voiced by NASA Dryden employees who participated in the pre-test, but these challenges could not be easily overcome within the time and resource constraints of WSPR and still yield sufficient data to support study objectives.*

- “It would get tiresome to complete the survey each time. Probably stop doing it after several days. It will depend on how many booms I hear and how spread out they are.”
- “The survey interfered with my activity, not the boom. And the survey made me jump because I had to find the paper survey to fill out.”

- “...that I would have to fill out surveys every time that I heard a boom, I would fill it out then get back to my activity. Then boom another one happens, the person might make a decision to get to the survey later because there are other pressing things, and if that happens a few times in a row, the people might get confused in the types of booms they heard. This would then add to the aggravation, especially if they follow the rules and fill one out right away each time. It’s hard to stop and start what you’re doing to fill these out...”
- “6 minutes again – I really think these are too close together – it is causing me to notice them more because I’m stopping what I’m doing to answer these questions.”

*Reminder systems are critical to maximizing response. Our analysis of subjects who received text or email reminders to complete the daily summary surveys showed a large difference in response rates (see Section 4.2.2. Participants also commented on the usefulness of the reminders, and began relying on them as early as the first day).*

- [Remembering to complete daily summary] “Right at 6 p.m. when I got the text reminders. I found them useful. The first day I got one and I completely forgot.” (web)
- “If I didn’t have that text message sent to me I would have forgotten all the time.” (web)
- “I do think those daily reminders were key and essential. That was brilliant because the first day I had already forgotten to do it.”

*The ability to implement quality control procedures remotely for Apple and web are important advantages over paper. In addition, Apple- and web-based surveys can be programmed to disallow invalid (out-of-range) answers, minimize missing data, and prevent random error (e.g., transposing digits in an ID number). At the same time, data across all modes yielded ambiguous or un-useable surveys that future efforts should consider steps to address.*

- Respondent IDs, and any other static but critical information should be pre-printed on paper forms to reduce burden and enhance data quality.
- Entries for “time of boom” should be entered by a respondent rather than default to a device time.
- Program instruments (if possible) to prevent duplicate submissions and disallow submission times that occur earlier than a reported “time of boom”.
- *The Apple application was intuitive and easy to use.* This mode, in particular, may be appealing in future studies as the proportion of the population owning and regularly using SmartPhones continues to increase [Pew Research Center, 2012]. *But response among Apple participants was lower than the other modes. Mechanisms to maximize response might include mobile-based non-monetary rewards such as “tokens” or “badges that keep participants engaged and motivated to complete surveys* [Link, Lai, and Vanno, 2012].” Graduated incentives could also be employed (applicable for all modes), although care must be taken to prevent bias.
- *A web-based approach should consider how and to what extent it can be optimized for access by mobile devices.* The number and share of the population who own a computer or use the Internet is likely to change less (or grow less rapidly) than the way in which people access the Internet. Instead of laptop or desktop computers, more users are apt to access the Internet using mobile devices.
- *The paper mode offers important advantages* – survey methodologists can control the layout of the survey questions, including the display and spacing of scales, technological requirements are minimal (a pencil), and demands on personal skills (reading, circling responses, understanding a “form”) are less apt to vary systematically by potential correlates of annoyance or exposure to noise (e.g., socio-economic status, education). WSPR



participants indicated the paper forms were easy to use, and the organization of return mailers simplified the respondent task. In addition, response was highest among paper participants, *but this mode offered the fewest avenues for quality assurance*. A future study might consider augmenting the paper mode with features that would allow the research team to assess quality and take follow-up steps quickly. For example, paper forms or a summary tally, could be scanned and submitted electronically (small, almost pocket-size scanners are available and may be cost-effective). Introducing steps to faster quality assurance without simultaneously increasing costs, technological or skill requirements, however, will be challenging.

- Daily reminder text or email messages substantially increased survey response (see Section 4.2.2). In short, text or other messaging services can be an effective and cost-efficient “adjunct” data collection mode that enhances data quality [Furberg, 2012]. Implementing regular reminders and offering participants a range of channels should be part of a future design, but survey methodologists must be mindful of finding ways to prompt participants to complete survey tasks without biasing responses.

*Subjective response scales, even those recommended by ICBEN, may demand more granularity than respondents can report. The demands of the scale may be especially high for collecting a large number of repeated measures during a fairly short period of time. Participants in both the full-scale experimental test and the pre-test expressed their inability to differentiate points on the numeric 11-point scale.*

- “My opinion of it was they either didn’t impact my life at all, they kind of annoyed me because my dogs went crazy but the kids weren’t upset, or it was a 10. For me it was either a 0 impact on my life, a 5 or a 6, or a 10. That’s how I felt, so I would write the time of the day a 0, 5, or a 10.” (EAFB participant)
- “I also feel there was a huge discrepancy for the vibration or rattle. I thought those were pretty similar. Maybe I’m just ignorant. For me I would just do the same all the way down the line. I would just write down the time and level of impact on the family. I couldn’t differentiate between a 3 and a 5. For me it was either DEFCON 5 around here, everyone’s going bananas or just the dogs are going bananas.” (EAFB participant)
- “On the number scale, it was hard to figure out where to place them. I had to put a lot of thought into it.” (NASA Dryden pre-test participant)
- “I thought that the range of values that were available for different questions was weird. There were so many levels. I had too many options: i.e., what’s the difference between a 5 and 7 in terms of severity?” (NASA DFRC pre-test participant)

*Some wording or instructions in the survey were not sufficiently precise. For example, participants felt “at home” was not well-defined.*

- “I think the one thing that would have been easier about the directions would be a more defined parameter of what was considered at your home. Sometimes I would be at the playground about 1 and a half houses away and wasn’t sure if I needed to respond. Wanted more specific boundaries.” (web)

*Participants could not always differentiate “vibration” and “rattle” and were unsure how to respond if they were outside.*

- “The way you described rattle and vibration, to those who don’t experience booms like we do, I’m not sure how they would comprehend it. You should be more clear as to what they should expect.”
- “One of the things on the question was the questions about vibration and rattle, it was only how much was inside your home but if I was outside my home, I would enter 0 since it didn’t apply. It was really specific to being inside the house. So that one was always off to me.”

The daily survey (or other mechanism) should gather information that would allow the research team to more accurately identify exposure – which booms or at which times of the day was the participant at home and for what duration.

## 5.6 Subjective-Objective Data Correlation

The baseline survey, single event survey, and the daily summary all provided valuable data that can be used to assess the noise impact of low booms on community residents. The analysis of the baseline survey provided information that can be used in developing the survey for the naïve community. The surveys were designed to look at both single event and daily cumulative impact from the low-boom noise design.

One of the considerations in developing the design was minimizing costs based on flight resources. As such, an attempt was made to maximize the number of booms per flight. This resulted in a planned boom spacing that varied from 8 – 20 minutes between booms. The longer a respondent took to rate a single event boom, the greater the chance that the next boom would occur. The WSPR analysis used a  $\pm 10$  minute time window for associating responses with the boom time. Using a longer period between the booms would help to facilitate the analysis efforts to associate the response with a given boom.

For the daily annoyance survey, the respondents were asked to rate their annoyance on both the 11-point and 5-point categorical scale. The experimental design was implemented to utilize just the 11-point scale for ratings on the single event and daily summary surveys for all other attributes (interference, loudness, etc.) assessed. The responses in this study indicated that the 5-point annoyance scale was not simply a compression of the 11-point annoyance scale. Respondents were not always consistent with their daily rating of the same day on the two different scales. A comparison of the daily annoyance ratings on the 11-point numerical scale with the ratings on the 5-point categorical scale for the same day was conducted. When the range of daily annoyance response was tabulated, each of the 5-point scale annoyance categories span several 11-point scale categories. The 5-point scale was included and compared to the 11-point scale based on recommendations in ICBEN to use both of these scales.

The statistical analysis of respondent ratings was conducted beyond the typical dose response %HA relationship in order to evaluate alternative methods of analysis. The assessment of alternative methods was critical, since it is anticipated that the naïve community effort will have only low-boom noise levels and will most likely result in few data points in the highly annoyed range. The WSPR team identified methods to assess categorical attributes that contribute to annoyance and adequately assessed metric correlations to single event ratings.

The WSPR team did not have an optimal means to evaluate daily annoyance ratings due to the variability in the data. The team identified outliers in the responses in the background survey. The team clearly noted the removal of the outliers from the data and re-analyzed, in order to assess the trends in the majority of respondents. This could potentially help identify a method that would work to assess the daily annoyance in the naïve community. However, the team needed to be aware that there would be noise-sensitive individuals in the naïve community as well. This aspect of the data analysis warranted further investigation.

## 5.7 Dose Response Analysis

The WSPR data covers a range from approximately 15 to 50 DNL and a corresponding 41 to 67 CDNL. This range was optimal for comparison to the CHABA data that ranged from 38 to 70 CDNL. The piece-wise linear function was the best predictor to use to predict the proportion of highly annoyed in the observed range of 0 to 28 %HA. Most notably, the piece-wise linear regression analysis provided the knee in the curve where the response changes as well as a means to predict the %HA based on levels above and below that knee for the PLDN, CDNL, and DNL metrics. These tools are of value for future community designs and for engineering noise goals in designs of low-boom test demonstrator vehicles.



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# Conclusions and Recommendations

Overland supersonic flight has long been prohibited due to the impact of sonic boom noise on communities. Recent advances in aircraft design suggest the possibility of softening the sonic boom noise, perhaps to levels that are acceptable for flight over residential communities. To establish a foundation for further scientific research and wider-scale testing in a general population community, NASA sponsored a pilot study at EAFB to design, execute, and assess methods for collecting subjective response to low-amplitude booms. The WSPR program was designed to test and demonstrate the applicability and effectiveness of techniques to gather data relating human subjective response to multiple low-amplitude sonic booms.

This chapter summarizes our findings from recruitment activities, gathering and analyzing subjective and objective data from sonic booms. Comparisons of WSPR data with other impulsive noise event social survey results are presented. A review of prior reports discussing acoustic surveys in non-acclimated communities, introduction of new noise sources, and adaptation to noise is provided. Analysis of WSPR operations using PCBoom and assessment of low-boom footprint sizes and proposed objective monitor density is discussed. The WSPR team concludes with suggestions for additional research and a concept for future non-acclimated community testing with a purpose-built low-boom aircraft.

## 6.1 Summary of Findings

The low-boom community response pilot experiment acquired sufficient data to assess and evaluate the effectiveness of the various physical and psychological data gathering techniques and analysis methods. It provided sufficient information to prepare an OMB application for future experiments to gather low-boom community response data from the general public. The following sub-sections will discuss recruitment, subjective and objective data gathering and analyses.

Because this was a pilot study, an attempt was made to assess the applicability of multiple analysis methods to enhance interpretation of the data. The objective was to investigate different analysis methods in order to expand the tools available for assessing data in a future naïve community. The design included an assessment of response mode, survey questions, survey findings, and the analysis of the noise dose response relationship through the implementation of various statistical methods. The statistical approaches included a descriptive assessment of the background survey responses, categorical assessment of response variables, and the use of linear quadratic regression, linear piece-wise regression, or logistic regression to evaluate different relationships in the noise response data. The logistic regression results in a pseudo-R-squared, which cannot be directly compared with the linear R-squared, but does provide comparisons within each type of regression.

### 6.1.1 Noise Design

The noise design was balanced to provide a distribution of sonic booms that resulted in DNL levels across the range that has been investigated previously, and provided sufficient data points to compare to previous findings. The design was varied each day to facilitate weather and flight logistics, and to adjust for the presence of non-WSPR booms that the community was exposed to from other sources.

The lowest low booms are the most sensitive to weather changes, so the lowest booms were reassigned to days with better weather. The various adjustment factors resulted in the days with the lowest DNL falling on the last 2 days of the test. This was not part of the original noise design, but was a result of other variables. While there was an observed decrease in single event response rate on the final day, the findings suggest that this was not due to response fatigue, but because the lowest booms weren't heard.

### 6.1.2 Subject Recruitment

The WSPR team successfully recruited more than the target number of 100 individuals. The team coordinated with

EAFB Public Affairs personnel to reach out to the community of residents using a range of media – email, hard-copy letters mailed to homes, news articles and advertisements, printed flyers, website postings, and other social media announcements as well as personal outreach to organized groups. A financial incentive proved decisive in reaching a sufficient number of subjects.

A recruitment screening interview was implemented as a web survey that interested residents completed on their own. Only three individuals completed the screening interview by telephone. Ultimately, 60 eligible subjects were randomly assigned to the Wyle-led team and 55 were assigned to the team led by Fidell and Associates, but 203 residents completed the screening questionnaire. Of these 203 residents, 171 (84 percent) met the eligibility criteria and were considered to be generally at home during days and times when low-amplitude booms would occur. The 115 test subjects were randomly selected from this group of 115.

The screening questionnaire collected detailed information on when subjects were usually at home and which modes of survey administration they could use (web, Apple, or SmartPhone). Both types of screening questions appear to have been successful: All but two subjects who started the field test submitted surveys recording their reactions to low-amplitude booms. Only a small number of subjects (five in the Wyle-led study) were ostensibly exposed to (submitted surveys corresponding to) less than 20 percent of all sonic booms occurring during the test period. None of the subjects assigned to the Wyle-led team later requested, or needed, to change the survey mode to which they had been assigned.

### **6.1.3 Subjective Data Collection**

The subjective data collection involved administration of three survey types – a background survey administered via phone, and daily and single event surveys administered by three modes – web, paper, and Apple device. Conclusions are described below.

#### **6.1.3.1 WSPR Subject Demographics**

The WSPR respondents represented a reasonable distribution of demographic variables. There were a total of 60 respondents at the time the baseline survey was conducted. There was some attrition of participants before the experimental test period started because recruited subjects were re-locating off base. Only two subjects dropped out after the test period began, and 52 respondents participated in the field test by completing surveys for the 2-week period. A total of 11 males and 49 females participated in the initial phase of the study. The age of respondents ranged from 18 to 48, with an average age of 32.12 years and a median of 32 years. Of the 60 baseline respondents, 8 had completed high school or obtained a GED, 20 had done some college work, gone to a technical school, or obtained a 2-year degree, 18 had earned a bachelor's degree, and the remaining 14 had obtained masters, doctoral, or professional degrees. The vast majority have lived at EAFB less than 3 years, with almost 42 percent of the sample living there for less than a full year at the time of the survey.

#### **6.1.3.2 Survey Methods for Collecting Subjective Response Data**

Three modes of survey administration were used to gather subjective responses to sonic booms, and all three modes were successfully deployed and yielded valid data for analysis. In terms of response rates, completeness of data gathered, and timeliness of response, no one mode proved far superior to the others; likewise, no mode was an obvious failure. Instead, each survey mode had advantages and disadvantages, many of which were discussed in Chapter 5 in an effort to identify ways to improve the methods or supplement them in ways to optimize data quality.

The overall response rate on the single-event surveys is lower (51 percent) and declined eight points between the first and second weeks of the test period (57 percent to 49 percent). The single-event response rate is a conservative calculation that likely overestimates exposure. Only individuals who were not at home the entire day or reported hearing zero sonic booms were considered to be “not exposed” to sonic booms.

Single-event response rates were consistently highest among subjects using paper (58 percent), followed by web (50 percent), and Apple (45 percent). Declines in response over time, and particularly the final 2 days of the test, were exhibited across all three modes and to approximately the same extent (8 to 10 percentage points week 1 to week 2 and

18 to 22 points the final 2 days). However, the data suggests that on the last 2 days, this decline in response was most likely because the last 2 days were the quietest in the test design, and the lowest low booms were not heard. For example, on the last day, 35 participants submitted daily summaries, and 15 of those 35 also submitted single event ratings. The daily summaries indicated how many booms were heard that day. About 5 percent of respondents heard more than two booms, and 80 percent of them heard only one or none. This trend in the data is an indication that the participants were still responding, but the decline in single event response rates was because the lowest low booms were not heard.

Subjects using Apple devices submitted the survey forms most quickly – almost three-quarters of their single-event forms were submitted no more than 1 minute after the boom was reported to have occurred. Subjects using the web showed more variation in their response time (less than 40 percent within 1 minute of the reported boom), and this type of data is unavailable for paper respondents. While survey methodologists typically point to response time as an indicator of data quality (i.e., completing a survey after a longer elapse of time can affect the accuracy of subjective reports), it could not be determined when subjects actually noted their reactions nor was it concluded with certainty that all reactions were entered directly into the survey mode provided. Interviews with a subset of subjects after the test period revealed that participants might have noted the time and their reactions separately (e.g., on a notepad) and entered the data into their devices or on the web forms later. This practice could possibly facilitate more survey responses and minimize recall bias in future studies, but it introduces possible error due to inaccurate transcription of the handwritten notes into the survey form.

### **6.1.3.3 Baseline Survey Findings**

In addition to physical factors, an individual's personality, mood, environment, and current activity contribute to their perception of the noise impact. The questions in the WSPR baseline survey were designed to glean the respondents' perception of an individual's ability to adapt to noise, the extent to which they are sensitive to noise in their surroundings, and their perceptions of noise in general.

The WSPR team found that in response to baseline survey questions a6b (I believe that with time most people adapt to noise) and a6c (I believe that with time I can adapt to noise) 95 percent of respondents answered either 4 or 5 (moderately or strongly agree) to these questions, indicating that they all feel that people in general, and themselves in particular, can adapt to noise given time. Respondents indicated that they can adapt to even the loudest noise (60 percent responded with 4 or 5 to a6d), although a sizeable proportion (25 percent) actually responded with a 2 (moderately disagree).

The WSPR test was conducted in an acclimated community, and the participants were accustomed to hearing full-boom noise. It is reasonable, however, to assume that their perspectives reflect a distribution of perspectives that would be found in a non-acclimated community as well. The WSPR findings indicate a perceived ability on the part of respondents to adapt to noise in their environment. Because the WSPR participants were accustomed to hearing full-boom noise, the test design was not able to assess what period of acclimation is recommended when introducing a new noise source to a community. This factor warrants further investigation.

The respondents indicated that noises from street traffic, thunder, and commercial aircraft were least annoying, barking dogs and military aircraft were more annoying, and sonic booms were the most annoying. When asked about their ability to adapt to noise, 95 percent of the respondents indicated that they felt that people, in general, and themselves in particular, can adapt to noise given time. Sixty percent of the respondents indicated that they could adapt to even the loudest noise, although a sizeable proportion (25 percent) actually responded that they moderately disagreed about adapting to even the loudest noise.

In the telephone survey conducted before the experimental test, 39 of the 60 respondents said their neighborhood was quiet, 19 said average, and the remaining 2 described it as noisy. Respondents tended to find the booms quite loud and startling, experienced vibration and rattle to a lesser extent, and tended to not experience a great deal of interference in conversations due to booms.

### 6.1.3.4 Categorical Attributes of Annoyance

The WSPR data included assessments of single events during the day as well as a cumulative daily summary assessment of annoyance and categorical variables including loudness, interference, startle, vibration, and rattle. A correlation of respondent ratings of categorical attributes with their concurrent annoyance ratings showed that interference had the largest dependence with annoyance for both the single event and daily summary ratings. For the daily summary ratings, interference was followed by loudness, vibration, and rattle in that order in strength of the dependence between variables. For the single event rating, interference was followed by startle, loudness, vibration, and rattle in that order in strength of the dependence between variables. Startle was not evaluated on the daily summary ratings as it is a single event response, rather than a response that is reported for a daily average.

### 6.1.3.5 Comparisons of Mode of Response

The paper mode showed a difference in the annoyance ratings for both single events and daily summaries when compared to the web and Apple smart phone modes. As the response rate time window was decreased, the range of acceptability narrowed and fewer reports were included for analysis. Reports of booms that were within the  $\pm 10$ -minute window of the boom event were included in this analysis. Using a longer period between the booms would have helped to facilitate the analysis efforts to associate the response with a given boom across all modes.

### 6.1.3.6 Single Event Percent Highly Annoyed and Noise Metric Correlations

The single event percent highly annoyed was correlated with a series of noise metrics to identify an objective metric that best predicts the potential for single event high annoyance response for the  $\pm 10$ -minute response window dataset. The noise ratings used were ASEL, CSEL, ZSEL, PL, PNL, LLZF, and LLZD. The correlation coefficient ( $R^2$ ) values are provided in Table 78 below. The CSEL had the highest correlation with an  $R^2 = 0.9627$ .

**Table 78. R-Squared Values for Single Event Metrics**

Metric	R-Squared
CSEL	0.9627
PL	0.9538
PNL	0.9195
ASEL	0.9174
ZSEL	0.8890
LLZD	0.8712
LLZF	0.8262

### 6.1.3.7 Analysis of Daily Response to Cumulative Exposure

An in-depth statistical analysis was performed on the subjective responses to cumulative daily noise exposure for a variety of metrics. A factor likely of key importance to regulators in the future is the relationship between percent highly annoyed (%HA) and cumulative exposure to the low booms. Moving towards non-acclimated communities, decisions need to be made with regard to the importance of inclusion of sufficient daily exposure to evoke sufficient response to capture “Highly Annoyed”. There is a direct and strong correlation between annoyance and the multitude of metrics analyzed. Subjects reported daily annoyance using both the 11-point and 5-point scales. Comparisons between the two required clumping of the 11-point data into the 5-point scales. There were insufficient data points from this WSPR experiment with an acclimated community to draw a definitive conclusion. However, indications from the study suggest the continued use of the 11-point annoyance response scale. The remainder of this section summarizes conclusions from other aspects of the daily response analysis.

#### *Comparison of 11-Point Numerical vs. 5-point Categorical Annoyance Scales*

The daily annoyance rating was obtained using both the 11-point numerical and 5-point categorical annoyance rating scales. Both scales were used for the daily annoyance rating only. The 11-point scale was used to assess the daily rating of other perception related attributes (loudness, interference, vibration, and rattle). The 11-point responses were not

always consistent with the 5-point categories. For example, a “10” on the 11-point annoyance scale may have been reported as a “4” on the 5-point scale. Both the 5-point verbally anchored scale and the 11-point numerical scale were recommended for use by IC BEN as each has its own strengths.

### Daily Response Rate

The Daily Summary Analysis showed that over 65 percent of the participants responded for 9 or 10 days of the 10 day field test. Respondents indicated that they had their windows closed 90 percent of the time on days during the flight tests. The data shows that 86 percent of the responses were made while participants were indoors at home.

### Daily Summary Correlation of Categorical Attributes Ratings with Annoyance Ratings

The WSPR data shows that interference had the largest dependence with annoyance for both the single event and daily summary ratings. For the daily summary ratings, interference was followed by loudness, vibration, and rattle in that order in strength of the dependence between variables. For the single event rating, interference was followed by startle, loudness, vibration, and rattle in that order in strength of the dependence between variables. Startle was not evaluated on the daily summary ratings, as it is a single event response rather than a response that is reported for a daily average.

### Correlation of Cumulative Noise Metrics and %HA

The test was conducted to determine what the annoyance level ratings are for low-level sonic booms. The %HA was defined based on those who reported an annoyance rating of 8 – 10 for the annoyance response rating. The CDNL metric explains the most variation in the percent highly annoyed response, with an  $R^2 = 0.8911$ . The correlations are given in Table 79.

**Table 79. R-Squared Values for Daily %HA Ratings Using Piecewise Linear Regression**

Metric	R-Squared
PLDN	0.8329
CDNL	0.8911
DNL	0.7984

The correlation of the metrics with the %HA response was conducted by fitting a piece-wise linear function to the data. The breakpoint is referred to as the knee in the curve, where the trend line changes and the two piece-wise linear regressions meet. Table 80 provides the regression equations centered on the knee in each metric. Separate equations for the %HA are provided for values of the metric to the left of the knee and the value of the metric to the right of the knee.

**Table 80. %HA Regression Equation for PLDN, CDNL, and DNL**

Metric	Value	Regression Equation
PLDN	< 52.47	%HA = -7.3281820 + 0.2595982*(PLDN)
	> 52.47	%HA = -83.3523 + 1.7085*(PLDN)
CDNL	< 55.66	%HA = -14.295404 + 0.342541*(CDNL)
	> 55.66	%HA = -109.494 + 2.062903*(CDNL)
DNL	< 38.27	%HA = -3.6747571 + 0.2622964*(DNL)
	> 38.27	%HA = -56.7666477 + 1.6495943*(DNL)



### *Using Daily Cumulative Noise Metrics to Predict Daily %HA*

A logistic regression was conducted to evaluate the likelihood of a participant being highly annoyed (annoy value of 8 or higher). The output was an odds ratio, which expresses the increase in likelihood of being highly annoyed with every unit increase in the dependent variable.

The CDNL showed the best predictive capability for the likelihood of a participant being highly annoyed. For every unit (1 dB) increase in CDNL the odds of a person being highly annoyed increased by a factor of 1.188 based on the odds ratio point estimate. For PLDN, the factor showed an increase of 1.122, and for DNL the factor increased by 1.115 for each unit increase in the metric level.

### *Using Single Event Moore and Glasberg Metrics to Predict Single Event %HA*

A logistic regression was calculated for the Moore and Glasberg loudness metric using instantaneous, short-term and long-term averaging. The observed booms were much more concentrated in the low values of the 'Sone' metrics but more evenly spaced for the 'Phon' metrics. The dots on the regression line are pretty evenly spaced throughout the range of IPhon, and they lie close to the line, indicating that this model fits the data well. There is no compelling evidence that there is actually a difference between the logistic regression fit of IPhon and Av1Phon or Av2Phon. There is an observable difference between the 'Sone' and 'Phon' metrics, but not necessarily differences within the two sets of metrics.

The logistic regression also provided an odds ratio estimate that shows the same pattern of differentiating between 'Sone' and 'Phon' based metrics, but does not show distinct differences within the sets. For every unit increase in Av2Phon the odds of a person being highly annoyed increased by a factor of 1.112 based on the odds ratio point estimate. The odds ratios for the three 'Phon' based metrics were very similar, indicating that for the Moore and Glasberg metric assessment of low booms, the research team did not see much difference between the instantaneous, short-term averaging and long-term averaging methods.

### *Using Indoor Metrics to Predict Single Event %HA*

Logistic regression was used to fit the indoor metric values, affording a prediction of single event %HA. The metric algorithms were assessed to provide calculated values for inside the participant's household. The measures included iPL, iCSEL, iASEL, iZSEL, iLLZf, iLLZd, iPNL, and iMaxpsf. The iZSEL odds ratio estimate shows the best indoor predictive capability for the likelihood of a participant being highly annoyed. For every unit increase in iZSEL the odds of a person being highly annoyed increased by a factor of 1.360 based on the odds ratio point estimate.

Logistic regression results in a pseudo-R-squared. To afford this comparison between different logistic regressions, a re-scaled R-squared was determined from the pseudo-R-squared values. For the indoor metrics, the iASEL ( $R^2 = 0.1216$ ), iZSEL ( $R^2 = 0.1200$ ), and iPL ( $R^2 = 0.1192$ ) gave the top three R-squared values for the eight metrics evaluated. The performances of the indoor metrics were very similar to one another and the differences in the model fit seemed to be less from a difference in predictive or explanatory power and more from a difference of location and scale of the metrics. That is, the coefficient estimates show a difference from one metric to another because the actual metric values differ.

### *Cumulative Metrics that Predict Daily Annoyance Ratings*

Regressions were tabulated for the cumulative metrics and the daily annoyance ratings. Table 81 indicates a very low R-squared for the linear regression on daily annoyance ratings. This is due to the fact that there was a large amount of variation in the daily annoyance ratings. On almost every day for which booms occurred there were respondents that answered from 0 to 10 on the daily annoyance scale. This means that there was a large amount of variation in the data, and the regression fit is unable to explain a large amount of it.

The %HA data had less variation overall, as there were only 10 data points to consider, and they more or less lied in a piece-wise linear configuration. The daily annoyance ratings showed a trend, but did not lie in a straight line.



**Table 81. R-Squared Values for PLDN, DNL, and DNL for Linear Regression on Daily Annoyance Ratings**

Metric	R-Squared
PLDN	0.140181
CDNL	0.147895
DNL	0.135375

### *Pairwise Comparisons of Level and Number of Booms*

The repetitions of similar DNL levels, created with different combinations of booms, afforded the opportunity to investigate boom number and level effects on both the percent highly annoyed and the daily annoyance ratings. For each of the comparisons examined, the paired days reflected specific differences in DNL level and number of booms. No significance was found in the paired comparisons for Highly Annoyed. When the paired comparisons were evaluated for daily annoyance, one pair showed a significant difference. Day 2 had a DNL of 39.09 due to 9 booms and Day 6 had a similar DNL of 39.49 with 14 booms. On average day 6 resulted in higher levels of daily annoyance than day 2, presumably due to the increased number of booms on day 6. The data was not sufficient to clearly assess the relationship between level and number of booms. This may have been due to the acclimated community or due to an insufficient sample size.

Each method provided different insights into the research findings. The use of categorical analysis provided a relationship between annoyance response and contributing attributes such as interference, startle, loudness, vibration, and rattle. The quadratic regression verified that the data obtained resulted in a similar annoyance response curve as previous research efforts. The piece-wise linear regression afforded the opportunity to identify the knee in the curve for the outdoor metrics, providing a specific level of metric where the annoyance response increased. The logistic regression resulted in an odds ratio estimate that provided the ability to predict an increase in annoyance response for each additional unit increase in the noise metric. Each approach provided a different insight that afforded a detailed analysis of this dataset and provided valuable insight into future research designs.

### **6.1.4 Objective Data Gathering and Analysis**

WSPR successfully refined, deployed, and utilized field kits to gather objective sonic boom data for all but 4 of the 110 sonic booms to which the subjects were exposed. The data was gathered by field kits operated with a manual triggering mechanism. Measured data was processed and metrics derived and interpolated across the housing area to subject locations. Automated boom extraction techniques were developed and might be applied in the future to field kits so that unattended monitoring techniques can be used for the next low-boom subjective test. Turbulence was seen across the subject areas during WSPR and is portrayed graphically in Appendix F. Quantification of turbulence effects needs to be addressed in future studies.

#### **6.1.4.1 Sonic Boom Measurements**

WSPR planning was effectively demonstrated, and day-of-flight waypoint calculation techniques and skilled piloting of the F-18 low-boom dive maneuver were successful in providing a variety of booms of desired levels with a prescribed distribution over the course of several weeks, while accounting for local EAFB weather variability.

The development of the objective dataset considered only the initial booms of the typical two-boom sequence created by the low-boom dive maneuver. The WSPR team found that the second booms were often comparable in size (and metric level) to the initial boom. Additional investigation of alternate automated boom identification techniques and methods for handling background noise were conducted. The team found that simply using a longer time period to capture the entire double-boom event resulted in excessive noise. Subjects were instructed to evaluate the double booms as a single event so proper capturing of the full-noise exposure in order to quantify the absolute level of the exposure metrics led to additional analyses. The team found that using the simple A-weighted ambient threshold algorithms, as had been applied in the past, eliminated too much of the objective data. Procedures were developed to instead perform a band-by-band metric subtraction while computing the full-boom event contribution to the metrics. The team noticed that the post boom noise “rumble” levels, especially from the larger and full-size booms, tended to be

significant, especially when compared with the low booms. Further research is needed to understand the source of the rumble, to be able to predict it, and to determine which elements of this should be included in subjective exposure computations. The team does not believe that the validity of adding metrics and subtracting ambient levels has been definitively settled and suggests that additional research is needed in this area.

Time proved to be a critical element in associating subjective response with an objective measurement. In the future, interpolation of arrival time of the boom at a subject location may help correlate participant responses. This aspect will become more critical as the area of interest and arrival times of the sonic booms increases in the future.

#### **6.1.4.2 Automatic Boom Finder Algorithm**

An automated boom finder algorithm was developed based on a hybrid technique encompassing the BASS triggering algorithm and a low-pass filter. It was tested on the empirical WSPR data and found to be very effective. The algorithm was provided to NASA with user adjustable parameters that can be further evaluated with other low-boom datasets. This algorithm is suitable for incorporation into the field kits so that they could be operated in auto-mode without dedicated triggering.

#### **6.1.4.3 Interpolation of Subject Noise Exposure**

An analysis of the measurement data was conducted by systematically eliminating microphone data and using the inverse distance based power interpolation technique to predict metric levels and determine the confidence of the interpolation method. The WSPR team found that most metrics could be interpolated within 3dB over the relatively small WSPR subject area. This small area had a negligible variation in the baseline sonic boom or metric levels. Future testing could use a significantly reduced field kit density in order to capture the baseline sonic boom contour variation. However, clusters of monitors will be needed to quantify turbulence effects.

#### **6.1.4.4 Turbulence Effects**

Turbulence typically occurs over a scale of several hundred feet. The effects of turbulence on metrics must be incorporated into the planning process, particularly in the development of noise exposure designs for future low-boom tests. The WSPR program did not include a dedicated task for investigating turbulence modeling and identification techniques. Atmospheric turbulence was clearly observed and had a definite impact on the subject exposure interpolation. Quantification of turbulence from empirical data must be approached statistically. Existing data sources could be leveraged to obtain a better understanding of turbulence effects on measured ground booms including:

- Classic NASA flight-test studies [Maglieri, 1967].
- WSPR data is modern, high resolution.
- SSBE data [Plotkin, Haering, Murray, Maglieri, Salamone, Sullivan, and Schein, 2005], but that was low turbulence.
- Boomfile II data [Lee and Downing, 1991], although that was well worked over during HSR.
- JAPE II flight-test data [Wilshire, 1992].

The classic NASA studies and JAPE II are the only flight tests in this list that set out to relate turbulence to boom distortion. The classic NASA data generally exists only as presented in reports – original analog recordings are lost. JAPE II boom data is limited in that the booms were recorded on BEAR [Bass, Raspet, Chambers, and Kelly, 2002] systems, which are relatively low resolution. The status and availability of JAPE II data is uncertain.

A problem with past turbulent effects data is that most were collected in desert climates. It would be very useful to obtain regional turbulent flight-test measurements under a variety of conditions. This could be conducted in existing regional supersonic airspaces and with existing supersonic aircraft. The analysis techniques employed for turbulent analysis of Boomfile II and SSBE data would be very productive on such a data set. There has also been considerable development of theoretical and numeric models for atmospheric propagation of booms (e.g., [Bass, Raspet, and Kelly, 2002]), which would be invaluable for guiding the design of a new flight-test series. Laboratory simulations (e.g., [Lipkens, 1993]) have also shed light on mechanisms, but full-scale data are needed for quantitatively credible analysis.

## 6.2 WSPR Comparison with Other Work

Subjective noise impacts were assessed in terms of an averaged long-term annoyance response, quantified as the percent of the population that was highly annoyed. The annoyance-based method was founded on procedures that were established for transportation noise.

Schultz [1982] identified three models of annoyance based on the relationship of the background level to the impact level. The detectability model is appropriate for very low background levels, where the noise, or vibration, is intrusive, even though it is barely detectable. The energy average model assumes an averaging effect, in which individuals show tolerance for occasional high levels in exchange for normally low levels. The high threshold model assumes that communities will respond to the peak noise or vibration levels. In addition to these psychophysically-based models, other variables that influence noise perception are individual and environmental situational and psychosocial factors.

During the 1970's, the United States Environmental Protection Agency recommended that federal agencies adopt some variant of day-night average sound level (DNL) to assess all types of intrusive noise exposures. The National Academy of Sciences-National Research Council Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) recommended the C-weighted sound exposure level for the measurement of impulsive noise. The standard method used today for relating annoyance to DNL was established by the transportation industry based on many social surveys and research studies shown in Figure 6-1 [Schultz, 1978]. The assessment of high-energy impulsive noise is primarily based on five studies, as documented in CHABA [1996].

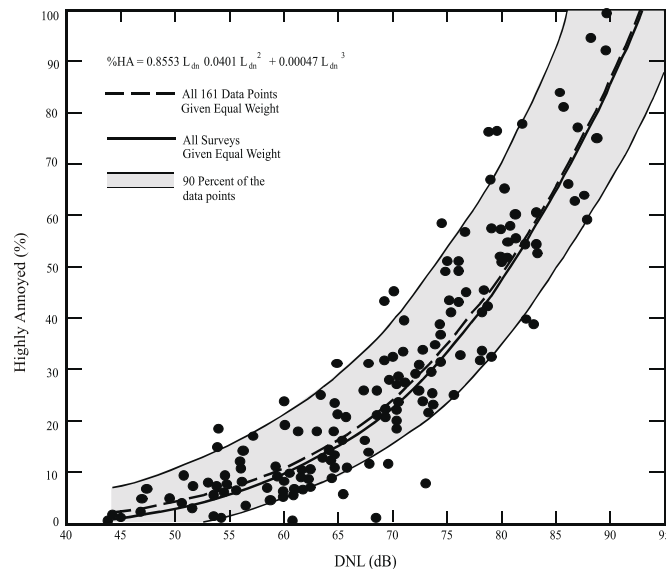
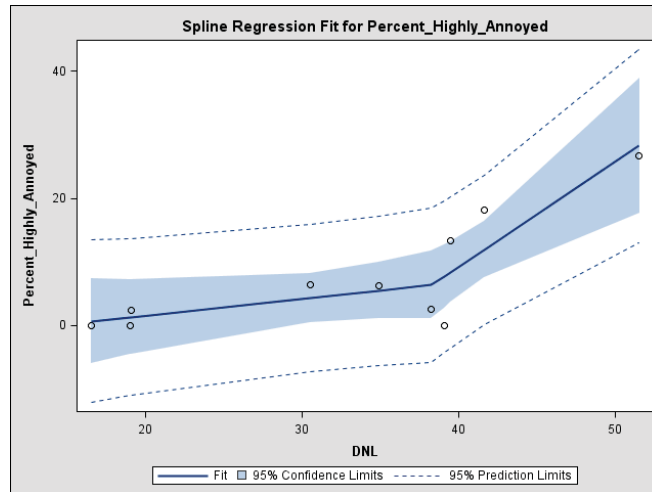


Figure 99. Highly Annoyed (%) vs. DNL (db) (from Schultz, 1978).

This DNL method does not account for differences in individual perceptions and community response that are based on variations in the level and in the number of events in a given time period (e.g., hourly, daily, weekly, or monthly variations). It also does not account for other important variables such as how familiar the noise source is (acclimation) or the elapsed time since the last set of noise events.

The WSPR test was conducted to determine what the annoyance level ratings are for low level sonic booms. The percent Highly Annoyed (%HA) was defined based on those who reported an annoyance rating of 8 – 10 for the annoyance response rating on an 11-point scale. The correlation of the metrics with the %HA response was conducted by fitting a piece-wise linear function to the data. A breakpoint value, referred to as the knee in the curve, is where the trend line changes and the two linear regressions meet. A plot of the regression line for WSPR %HA vs. DNL is provided in Figure 100.



**Figure 100. WSPR Piece-wise Linear Regression of Percent Highly Annoyed (%HA) vs. DNL (dB).**

The data in the Schultz curve spans a DNL range from approximately 40 to 95 dB in DNL, while the WSPR data covers a range from approximately 15 to 50 dB. The piece-wise linear function was the best predictor to use to predict the percent of highly annoyed in the observed range of 0 to 28 percent. The plot of the piece-wise linear regression for DNL is presented with confidence bands to illustrate this point. The light blue bands surrounding the dark blue regression line in Figure 100 represent the 95 percent confidence limits of the regression. The width of these confidence bands is determined by the variation in responses and the sample size. As the sample size increases, the width of these bands will shrink. An increased sample size would provide a more accurate estimation of annoyance as a function of the sound metric. This gain in precision may be observed by increasing the sample size in future studies in a non-acclimated community.

### *CHABA [1996]*

The CHABA [1996] dataset consists of five datasets that investigated impulsive noise sources. The dataset is made up of two sonic boom studies and three blast noise studies. The sonic boom studies include data from Oklahoma City reported by Borsky [1965] and NASA data reported by Fields et al. [1994]. The blast noise assessments include data from Ft. Bragg, as reported by Schomer [1981], data from Ft. Lewis, as reported by Schomer [1985], and data from Sweden, as reported by Rylander and Lundquist [1996]. The findings are presented in terms of the percent highly annoyed as a function of the yearly averaged metric C-weighted Day-Night Level (CDNL).

### *Oklahoma City Study Reported by Borsky [1965]*

The Oklahoma City sonic boom study consisted of carefully controlled sonic boom flights. Peak overpressure noise measurements for each sonic boom were recorded during a 6-month study. During the last 4 months of the noise study, 8,997 interviews were conducted. The response to the sonic booms was measured in terms of annoyance on a four-point scale and in terms of interference with six specific tasks – interference with radio or TV, startle or fright, sleep disturbance, house rattle/vibration, interference with rest/relaxation, and interference with conversation.

The social survey report [Borsky, 1965] did not contain estimates of the sonic boom exposures. Estimates of ASEL and CSEL measurements were later calculated from the peak overpressure and the lateral distance of the aircraft from the microphone position. These estimated ASEL and CSEL metrics were then combined into A-weighted Day-Night Level (ADNL) and CDNL measurements for the re-analysis of the data that was included in CHABA [1996] and Fields [1997].

### *NASA Study Reported by Fields et al. [1994]*

A NASA report by Fields [1994] provided a summary of reactions of people routinely exposed to sonic booms over a long time period. The interviews were conducted after 6 months of measuring the noise in those areas in terms of CDNL, ADNL, C-weighted 24-Hour Equivalent Level ( $LC_{eq24}$ ), and  $LA_{eq24}$ . Most survey areas were exposed to an average of two booms per day with one boom per week over 2 pounds per square foot (psf).

The report documented a combined social survey and noise measurement program that included 14 communities that were regularly exposed to sonic booms for many years. The summary included 1,573 interviews that were completed with 20 sets of residents from two regions in the western United States [Fields, 1997]. The noise exposure was found to be very dissimilar in different time periods in each region and between the regions in the study. In order to increase the precision of the estimates of noise exposure and to facilitate comparisons, three noise exposure strata were defined based on the boom level and density over a given time period.

In general, the respondents reported that the three aspects of sonic booms that were most disturbing were being startled, noticing rattles or vibrations, and being concerned about the possibility of property damage from the booms. In region A, 1,036 interviews were conducted in the two survey phases. The findings indicated that for a noise dose of about 30 to 40 DNL about 75 percent of the residents were at least a little annoyed by sonic booms and about 35 percent were “very” annoyed on a 4-point verbal annoyance scale. In region B, 537 interviews were conducted. The findings in Region B indicated that for a noise dose of about 30 to 40 DNL about 50 percent were at least a little annoyed and about five percent were “very” annoyed. There was no indication that errors in social survey or acoustical measurement procedures could be responsible for the differences observed in the reactions between the two regions. The data from the Fields survey suggested that the A-weighting (DNL) was equal or better at predicting reactions than measures of average peak noise levels or metrics based on a C-weighting. A little over half of the respondents reported that their startle reactions did not lessen from the time when they first heard the booms. The reactions in Region B, the less annoyed community, were roughly equivalent to the reactions observed in the 1965 Oklahoma City study of residents’ reactions to temporary exposure to sonic booms over a 6-month time period.

### *Ft. Bragg Study Reported by Schomer [1981]*

In 1978, an Army survey was conducted on and around Ft. Bragg, North Carolina. Values of the noise stimulus were both predicted and measured. The predicted measurements were reported as a yearly averaged CDNL and were made with computer software that used operational range records from 1 year preceding and following the study. Actual measurements were made after the study was completed at 17 different locations for an average of 25 days per site. The predicted CDNL that was used for correlation with the percent highly annoyed in the community was lowered slightly because the actual measured results were on the average of 3 to 5 dB lower than the model predictions. The survey found that there were four primary factors that correlated with annoyance – belief that one should complain about government activities, sensitivity to noise, belief that more could have been done to reduce the noise, and fear that the source would cause damage [Schomer, 1981].

### *Ft. Lewis Study Reported by Schomer [1985]*

An Army survey of 1253 residents was completed in the early 1980’s and reported in Schomer (1985). Values of the noise stimulus were both predicted and measured. Operational range records from 1 year preceding and 1 year following the study were evaluated in a computer model to obtain the predicted values. The predicted values were reported as a yearly averaged CDNL. Noise level measurements were made 6 months prior to the survey. The measurements were not used to modify the predicted CDNL values used in the analysis of correlation with percent highly annoyed. This study found that building rattle was the main adverse blast noise factor and that C-weighting was the best available weighting scale to use because it accounted for the low frequencies that were responsible for causing house vibrations and rattle. Schomer reported that the actual noise measurements were inconsistent with the survey results. He made an observation that the attitudinal survey results implied too much annoyance when arrayed against the measured noise data [Schomer, 1985].

*Swedish Study Reported by Rylander and Lundquist [1996]*

A mail survey was conducted of 1483 residents in households in the vicinity of eight shooting ranges in Sweden. Noise stimulus values were obtained by using a computer program that estimated the levels from operational data and assumed propagation over different types of terrains. The major findings of this study were that blast noise interfered with rest, recreation, and sleep, and the effects were most prominent during the evening and the night [Rylander and Lundquist, 1996].

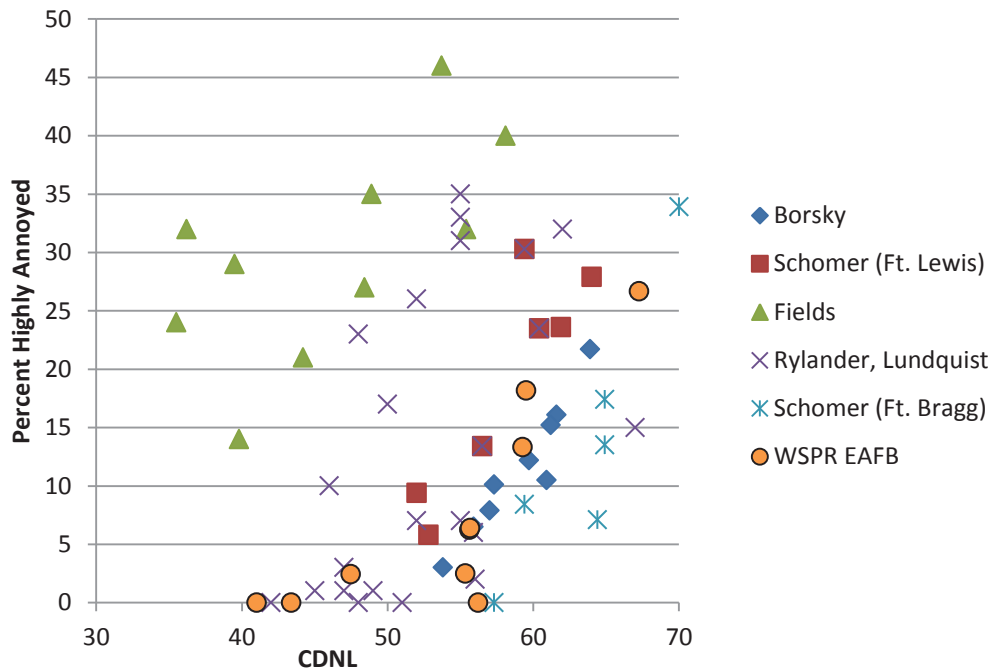
*Summary of WSPR Data vs. CHABA Data*

The WSPR data is provided in comparison to the CHABA data in Table 82. The previous findings used a dose response curve to relate the subjective annoyance ratings to the noise dose. The WSPR data spans a noise dose range comparable to that of other studies and is lower in annoyance compared to some of the previous annoyance data.

**Table 82. WSPR Data vs CHABA Data CDNL**

Source	Research Team	Approx. CDNL
Low Boom	WSPR NASA, 2011 EAFB	41 - 67
Sonic Boom	Borsky 1965, OK City	54 - 64
Sonic Boom	Fields et al., 1994 Nellis AFB	38 - 56
Artillery	Schomer 1981, Ft. Bragg	58 - 70
Gunfire	Sweden Rylander Lundquist, 1996	41 - 68
Artillery	Schomer, 1985, Fort Lewis	51 - 65

The graph in Figure 101 presents the CHABA (1996) datasets vs. WSPR data, expressed in terms of the percent highly annoyed as a function of the yearly averaged metric C-weighted Day-Night Level (CDNL). The WSPR data is within the range of the other five datasets. The annoyance ratings for WSPR are lower than was observed in Fields [1994] or Rylander and Lundquist [1996]. In the data range below 60 dB CDNL, the WSPR data generally shows less annoyance than other studies reporting values in that range.



**Figure 101. CHABA (1996) datasets with WSPR data, %HA vs. CDNL.**



In several of the CHABA studies, predicted measures were utilized to determine stimulus noise levels. The WSPR study had noise measurement field kits at locations throughout the test community in order to obtain better assessments of the stimulus noise impact. In several of the CHABA studies, the noise measurement values were made during a different time period than the time period in which the survey was administered. These variables in the CHABA data afford greater uncertainty regarding the noise stimulus level that resulted in a given survey response. The WSPR objective experimental design afforded an improved ability to correlate the noise stimulus level with the survey response than was possible based on the design of some of the CHABA studies.

The data from the Fields survey suggested that the A-weighting (DNL) was equal or better at predicting reactions than measures of average peak noise levels or metrics based on a C-weighting. For WSPR, the CDNL metric explained the most variation in the percent highly annoyed response, with an  $R^2 = 0.8911$ . It was the best metric in this study for correlation with the %HA annoyance response ratings when compared to PLDN ( $R^2 = 0.8329$ ) and DNL ( $R^2 = 0.7984$ ).

The Fields study indicated that the respondents reported that the three aspects of sonic booms that were most disturbing were being startled, noticing rattles or vibrations, and being concerned about the possibility of property damage from the booms. In the WSPR baseline survey, the respondents indicated that they tended to find the booms quite loud and startling, experienced vibration and rattle to a lesser extent, and tended to not experience a great deal of interference in conversations due to booms.

In the Fort Bragg study [Schomer, 1981], the survey found that there were four primary factors that correlated with annoyance – belief that one should complain about government activities, sensitivity to noise, belief that more could be done to reduce the noise, and fear that the source would cause damage. WSPR found that in response to baseline survey questions a6b (I believe that with time most people adapt to noise) and a6c (I believe that with time I can adapt to noise), 95 percent of the respondents answered either 4 or 5 (moderately or strongly agree) to these questions, indicating that they all feel that people in general, and themselves in particular, can adapt to noise given time. Respondents indicated that they can adapt to even the loudest noise (60 percent responded with 4 or 5 to a6d), but a sizeable proportion (25 percent) actually responded with a 2 (moderately disagree).

The Fort Lewis study [Schomer, 1985] found that building rattle was the main adverse blast noise factor and that C-weighting is the best available weighting scale to use because it accounts for the low frequencies that are responsible for causing house vibrations and rattle. The WSPR data included assessments of single events during the day as well as a cumulative daily summary assessment of annoyance and categorical variables including loudness, interference, startle, vibration, and rattle. A correlation of respondent ratings of categorical attributes with their concurrent annoyance ratings using Kendall's Tau-b correlation was conducted. The WSPR data showed that interference had the largest dependence with annoyance for both the single event and daily summary ratings. For the daily summary ratings, interference was followed by loudness, vibration, and rattle in that order in strength of the dependence between variables. For the single-event rating, interference was followed by startle, loudness, vibration, and rattle in that order in strength of the dependence between variables. Startle was not evaluated on the daily summary ratings as it is a single-event response, rather than a response that is reported for a daily average. The values of the strength of the dependence for the daily summaries are provided in Table 83 and for the single events in Table 84.



**Table 83. Kendall's Tau-b Correlation of Annoyance and Other Attributes for the Daily Summaries**

Attribute	Tau-b	95% Lower Confid. Limit	95% Upper Confid. Limit
Interference	0.7461	0.7030	0.7893
Loudness	0.6377	0.5820	0.6935
Vibration	0.4878	0.4225	0.5531
Rattle	0.4725	0.4036	0.5413

**Table 84. Kendall's Tau-b Correlation of the Annoyance and Other Attributes for Single Events**

Attribute	Tau-b	95% Lower Confid. Limit	95% Upper Confid. Limit
Interference	0.7626	0.7460	0.7792
Startle	0.6969	0.6756	0.7181
Loudness	0.5499	0.5258	0.5739
Vibration	0.4505	0.4228	0.4781
Rattle	0.4174	0.3886	0.4461

### 6.3 *Non-Acclimated Communities, New Noise Sources, and Adaptation*

Research has been conducted over the past several decades that assesses the reactions of residents to sonic boom noise environments [Borsky, 1965], [Hubbard and Mayes, 1967], [Kryter, 1967], [Kryter et al., 1968], [Fields, 1997] and [Leatherwood et al., 2002]. One combined social survey and noise measurement program assessed reactions of 14 communities in the western United States exposed over a long period of time to sonic booms generated by military training exercises and aircraft testing programs [Fields, 1997]. This study assessed subjective responses from single and multiple N-wave sonic booms and explored such metrics as A-weighting (DNL, LAeq24hr), C-weighting (LCeq24hr) and Pmax, Lpeak, Perceived Noise Level, Number of Events, Noise Exposure Forecast (NEF), Noise and Number Index (NNI), and Perceived Level (PL). Comparisons were made with the community response results of 20 previous surveys of residents' reactions to aircraft noise and various types of impulsive noise. From these comparisons, it was possible to delineate, to a limited degree, differences in response between habituated communities and those exposed temporarily (6-month duration) to sonic booms.

Analysis techniques applied to community response data from a study of varying numbers of helicopter operations at Ft. Eustis [Fields et al., 1985], provided impetus for subsequent analyses [Fields, 1997 and Fields et al., 2000] that developed a more rigorous theory for determining community reactions to abrupt changes in noise exposure. These techniques provide insight for predicting the effects of introduction of a new noise source for future sonic boom experiments on a non-acclimated community. This prior study is relevant to future low-boom subjective response testing, and lays the groundwork to estimate the impacts of a newly introduced noise source using a fairly sophisticated approach to planning a survey, including the use of a statistical tool to estimate the precision of results for a planned survey.

The SERDP Personal Interview protocol (PI) [Hodgdon et al., 2009] was developed and administered between October 2008 and February 2009 at three participating military installations. The objective was to identify the language and terminology that residents living near military installations use to describe their community, environment, and blast

noise. The PI protocol utilized interviews that were transcribed verbatim, then parsed and analyzed based on thematic features in the narrative content. The themes were compared to previous research findings and the language used as a reference for the other protocols. Qualitative PI findings indicate that residents living near military installations are aware of the installation and the noise generated by the installation. Participants reported that they adapt to the basic noise environment over time and often do not notice smaller noise events, but do notice unusually large noise events or noise in conjunction with house vibrations. This research, conducted in an acclimated community, embodies a significant attention by researchers and respondents to impulsive event terminology and self-reported responses to adaptation to noise. This prior work was leveraged in the WSPR design and administration of the baseline survey.

The SERDP team is conducting a series of protocols to investigate community attitudes towards impulsive blast noise around military installations. In addition to the Personal Interview, the series included a Complaint Survey, an In-Situ protocol (IS), and a General Community Survey protocol (GCS). The IS survey is completed by participants for each individual noise event, and is also completed each morning and evening to get a “daily” dose. The SERDP IS survey was leveraged for application to the WSPR single event and daily summary surveys. The IS protocol includes noise and vibration measurements in the community at each participant’s house as well as noise monitors on the installation. The GCS includes surveys of a sample of general households in the surrounding community in addition to the in-situ participants, to include a larger number of respondents, and obtain a broader assessment of the general noise environment. The SERDP GCS provided a basis from which the WSPR baseline survey was developed. These surveys were conducted over a 9-month period with a repeated cross-section/panel design. For this on-going program, the in-situ participants are completing the general survey as a comparison tool for the other respondents. This area of active research [Pater et al., 2007] will be completed in 2013. The SERDP findings on the response to impulsive blast noise will be relevant to future low-boom subjective testing. Lessons learned and practical experiences of a large-scale community field study with corresponding dose response data analyses will benefit future low-boom designs.

Other studies have been conducted that assess community attitudes toward noise, and address variables that can be applied to the introduction of a new noise source when implemented in the non-acclimated community. The method of continuous judgment by category was used in an experiment conducted by Namba and Kuwano [1988] to assess the ability to adapt to noise. They had subjects rate the noisiness of recordings of street vendors that were presented in different background noise environments while the subjects conducted one of three different mental tasks. The method [Namba and Kuwano, 1998] used a 7-point category scale in which the anchored response categories ranged from very noisy to very quiet. The subjects judged the sound using a numbered keyboard (each number corresponding to a response category) at any moment of their choice. A period of no response was taken as a measure of adaptation to the noise. Both personality factors and physical factors were analyzed. All subjects answered two questionnaires at the end of the experiment, one addressing their impression of the experiments and the other focused on their general attitude toward noise problems. The findings suggested that there are two distinct groups – those sensitive to noise and those less sensitive to noise. The Weinstein Noise Sensitivity Scale [Ekehammar and Dornic, 1990] is a self-report test that is designed to capture this noise sensitivity. Several questions in the WSPR background survey were included to glean aspects of noise sensitivity from the respondents. Consideration will be given to noise sensitivity in future low-boom subjective response testing.

To address the novelty effect, Fields et al. [2000] utilized the mixed model procedure in SAS in their analyses of two datasets that pertain to annoyance from new noise sources. In that model, Fields accounted for effects due to steady-state exposure, “novelty”, and abrupt noise level changes. They also stated that “the actual analysis for an abrupt change study is likely to be complex and to involve professional judgment and adaptations to the data that are collected. There are likely to be additional modifications to the model as well as theory as a data set is examined” [Fields et al., 2000, p. 46].

WSPR initially proposed to analyze the low-boom annoyance by implementing a mixed effects linear model in SAS similar to that implemented by Fields. The intent of the WSPR team was to develop a model that incorporated the participants’ subjective reactions to sonic booms as well as their contributing non-noise variables. However, the data was not normally distributed and was resistant to all attempts to transform the data. As such, the ANCOVA method proposed by the WSPR team was not implemented. The subjective noise ratings were instead treated as categorical

variables.

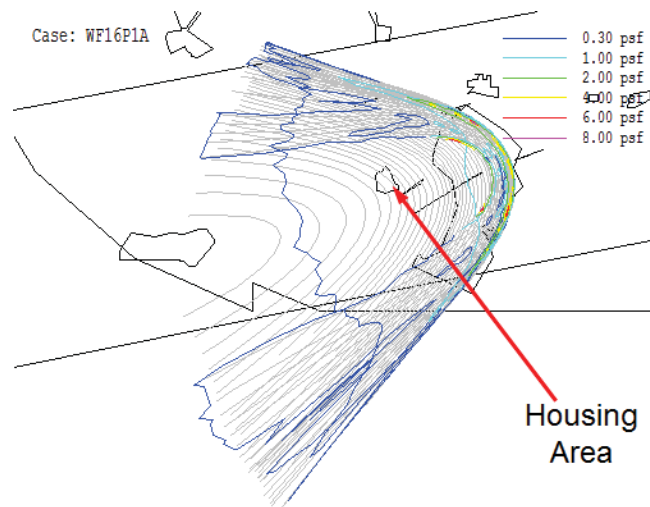
For a complete model, the team would need to test all three effects that are modeled in the Fields et al. [2000] paper, which are the effect due to steady-state exposure, the novelty effect, and the effect due to abrupt noise level changes. Because the data was from an acclimated community, the team did not have data with which to test a novelty effect. Given the chance to collect data from a non-acclimated community, the team would proceed with a mixed effects linear model similar to that utilized in Fields et al.

## 6.4 Application of PCBoom for Larger Communities

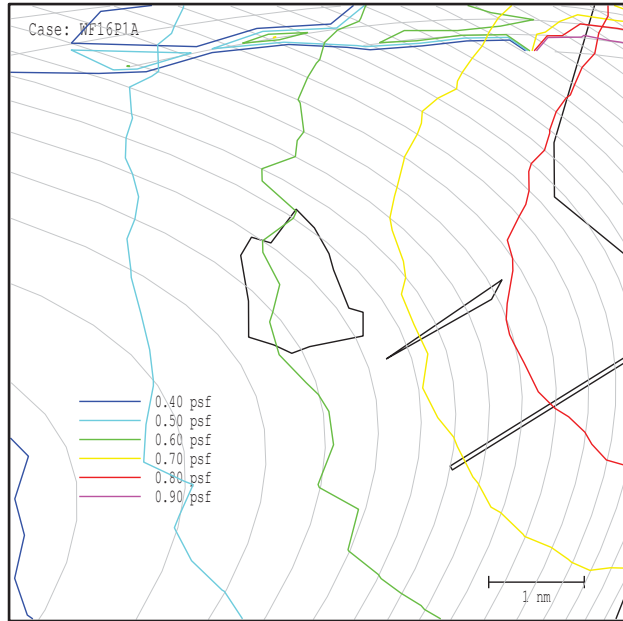
Booms in the WSPR project were planned using the F-18 low-boom maneuver. This maneuver was developed by NASA DFRC for the purpose of obtaining low-amplitude booms within a limited area from a conventional N-wave aircraft. The low booms are generated from the unloaded top of the aircraft during the dive portion of the maneuver, and the lowest booms are associated with long-range propagation to the locations around the edge of the carpet. The maneuver was designed with the aid of PCBoom. PCBoom is used for flight planning – adjusting the waypoint via a PCBoom run with a pre-flight atmospheric profile.

### 6.4.1 As-Flown WSPR Low-Boom Footprints

Figure 102 shows the PCBoom footprint for WSPR Flight 16, Pass 1. Part a shows the full footprint. The housing area is indicated. Part b shows a close-up of the vicinity around the housing area. Note that the gradient of the boom amplitude, in psf, is rather gentle across the housing area. PCBoom footprints do not display the spatial variations associated with turbulence. Those variations occur over distances of a few hundred feet, and must be regarded as a statistical variance relative to the expected values predicted by PCBoom. Note that the PCBoom contours themselves exhibit irregularities. These are due to irregularities in the measured aircraft trajectory and in the atmospheric profile.



a. Full footprint.

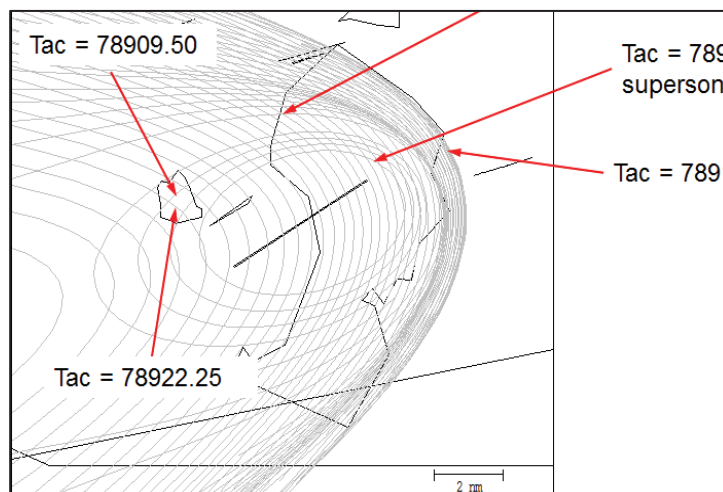


b. Region around housing area.

**Figure 102. PCBoom footprint for Flight 16, Pass 1.**

Booms from the low-boom maneuver differ from the carpet boom for a low-boom shaped aircraft in that they are – a) N-wave variations rather than shaped booms, and b) there are typically multiple booms. Figure 103 shows the isopemps for one pass, and indicates the origin of the two booms reaching the housing area. The origin is identified by the boom generation time indicated for several of the isopemps. Note that there are two regions:

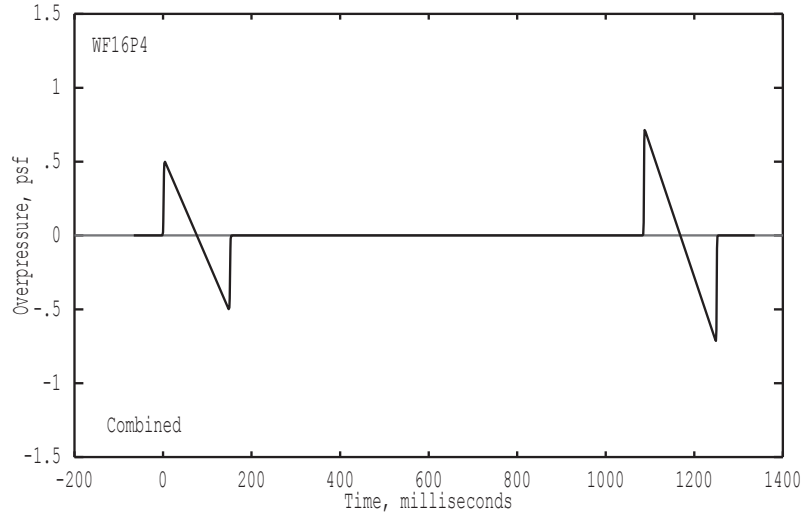
- “Early” booms generated in the initial part of the dive, with egg-shaped isopemps. These go full circle ( $-180^\circ < \phi < 180^\circ$ ) because of the low Mach number and steep descent. Note that the region around  $\phi \approx 0^\circ$  progresses uptrack with generation time, while the region around  $\phi \approx \pm 180^\circ$  progresses downtrack. They widen with generation time, eventually broadening into more familiar forward-facing crescents.
- Forward-facing crescents, which progress in the downtrack direction with generation time.



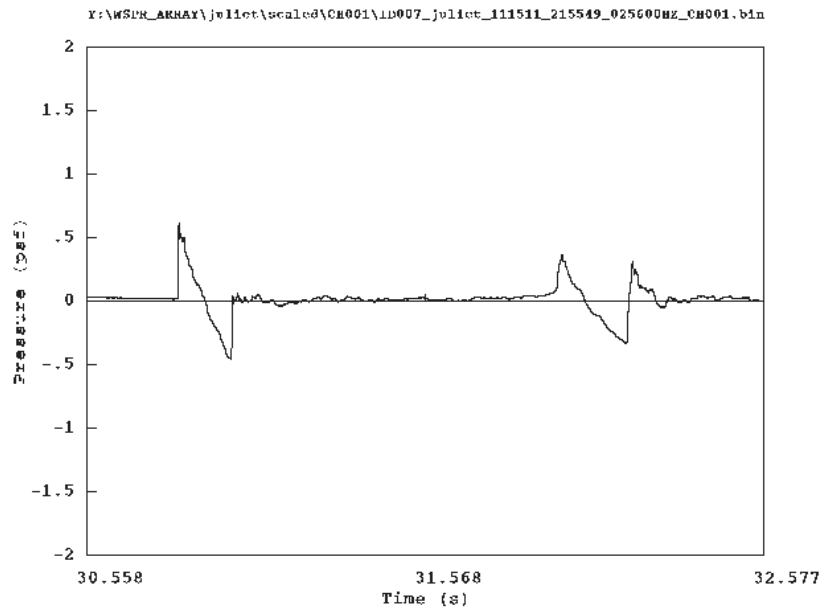
**Figure 103. Isopemps of boom footprint, Flight 16, Pass 4.**

Where there is overlap, booms on the egg-shaped isopemps arrive before those on the crescents. Figure 104 shows the measured and predicted booms in the housing area for this case. Prediction of the amplitude of the second boom is generally not as good as that of the first, but prediction of the spacing between the two booms is generally good. Note that the spacing between arrival times is much shorter than between generation times.

Tac = 78922.125 sec, Phi = -21.37 deg, Xac = 71.06 -23.10 36.51 kft  
 Pmax, Pmin = 0.71, -0.71 psf, Tg = 78984.289 sec, Xg, Yg = 17.38, -26.66 kft  
 Lpk = 124.7 dB, Lflt = 113.9 dB, CSEL = 101.7 dB, ASEL = 80.5 dB, Loud = 98.3 PLdB  
 Ray coming from 89.2 degrees, elevation 26.2 degrees



a. PCBoom prediction.



b. Measured.

**Figure 104. PCBoom predicted and measured booms in housing area, Flight 16 Pass 4.**

PCBoom footprints, as shown in Figures 101 through 103, depict peak overpressures. The contours are based on the booms at ray ends, can become complex in overlapping regions, and represent the pressure associated with single booms. Metrics associated with single booms are computed and are displayed along with signatures. PCBoom can display combined booms in overlap regions via the “p” mode in the wcon display module, and the displayed metrics are

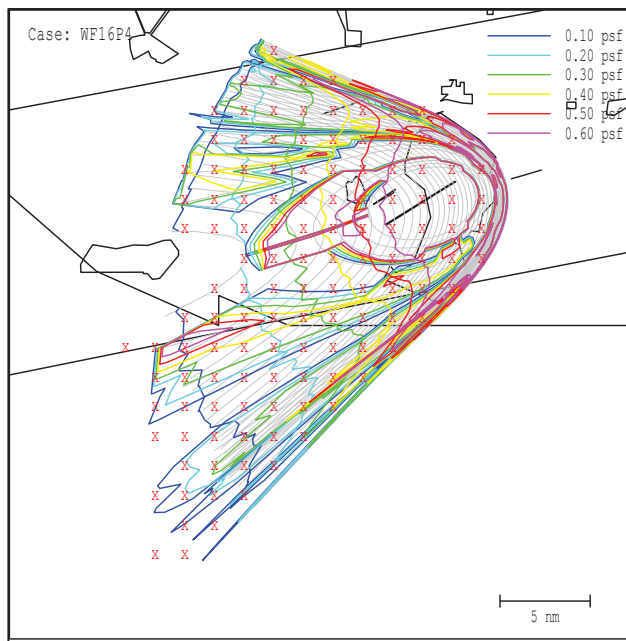
the combination of the overlapping booms. The auditory metrics (ASEL and PL), which depend on high-frequency content, are nominal, since a  $1/p$  thickness Taylor shock structure is assumed, but are a reasonable indicator of trends.

### 6.4.2 Perceived Level (PL) Footprints

Application of PCBoom to larger communities requires preparation of footprints that show PL for a given flight. These can be generated by extracting “p” location signatures on a grid across the footprint, then fitting contours to the point-by-point loudness. This has been done for 12 WSPR flights. The process is:

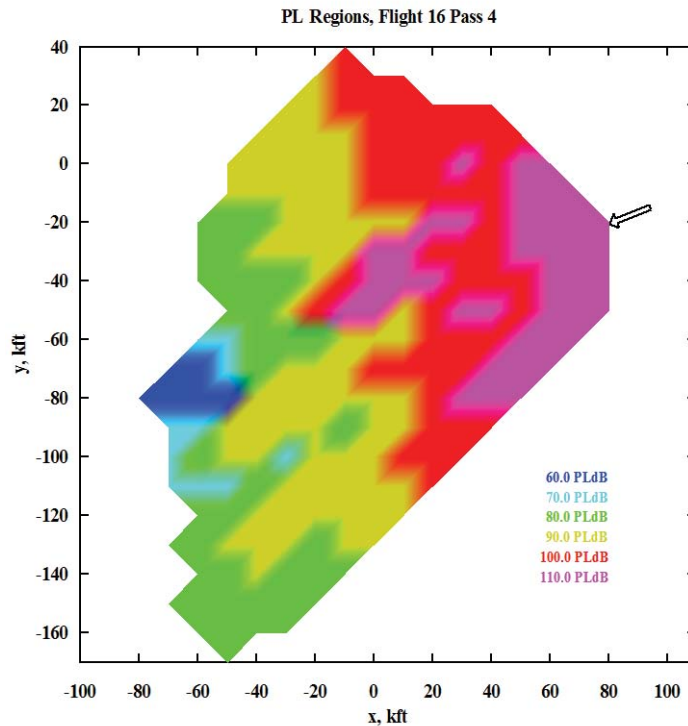
1. PCBoom is run and the footprint plotted.
2. “p” points are extracted on a regular grid.
3. Contours are generated for the PL values on the grid of “p” points.

Figure 105 shows the footprint for WSPR Flight 16, Pass 4, together with “x” markers on a 10,000-foot grid. This is a somewhat coarse grid, but is adequate to show the trend for general feasibility. The markers appear only at those points within the footprint, where PCBoom predicts that a boom will exist. There is a modest extrapolation beyond the edge of the geometrical footprint.



**Figure 105. PCBoom footprint, Flight 16, Pass 4, 10kft x 10 kft grid points indicated.**

Figure 106 shows the PL footprint as a shaded gradient map. The flight track is indicated by an arrow. Note that lower PL values (below 80 dB) cover a fairly large area on the down-track side of the footprint, while high levels appear in the up-track portion. This footprint would be very well suited for acceptability studies in a shoreline community, where the higher boom levels can be placed offshore and the lower levels on land.



**Figure 106. Perceived Level footprint, Flight 16, Pass 4.**

Figures 107 through 109 show similar footprints for four passes of Flight 08, four passes of Flight 16 (in addition to that shown in Figures 105 and 106), and four passes of Flight 21. The footprints in Figures 107 and 108 are similar to that shown in Figure 106. There is a fairly large low-boom area in the down-track region of the footprint, well away from the high-amplitude region that can be placed offshore.

The footprints in Figure 109 are different in that they are somewhat smaller and also do not show substantial low-boom regions. When the footprints are overlaid on a map of the EAFB area, the western edge of the footprints lie on or close to Rogers Dry Lake, and do not reach into the housing area. Those flights did, however, yield low booms of the planned low amplitude in the housing area. It is not clear how the details of planning were conducted, but, from the success experienced during WSPR, the four passes for this flight have the same general conclusion as for the other two flights – there is a large useful low-boom region on the down-track side of the footprint.



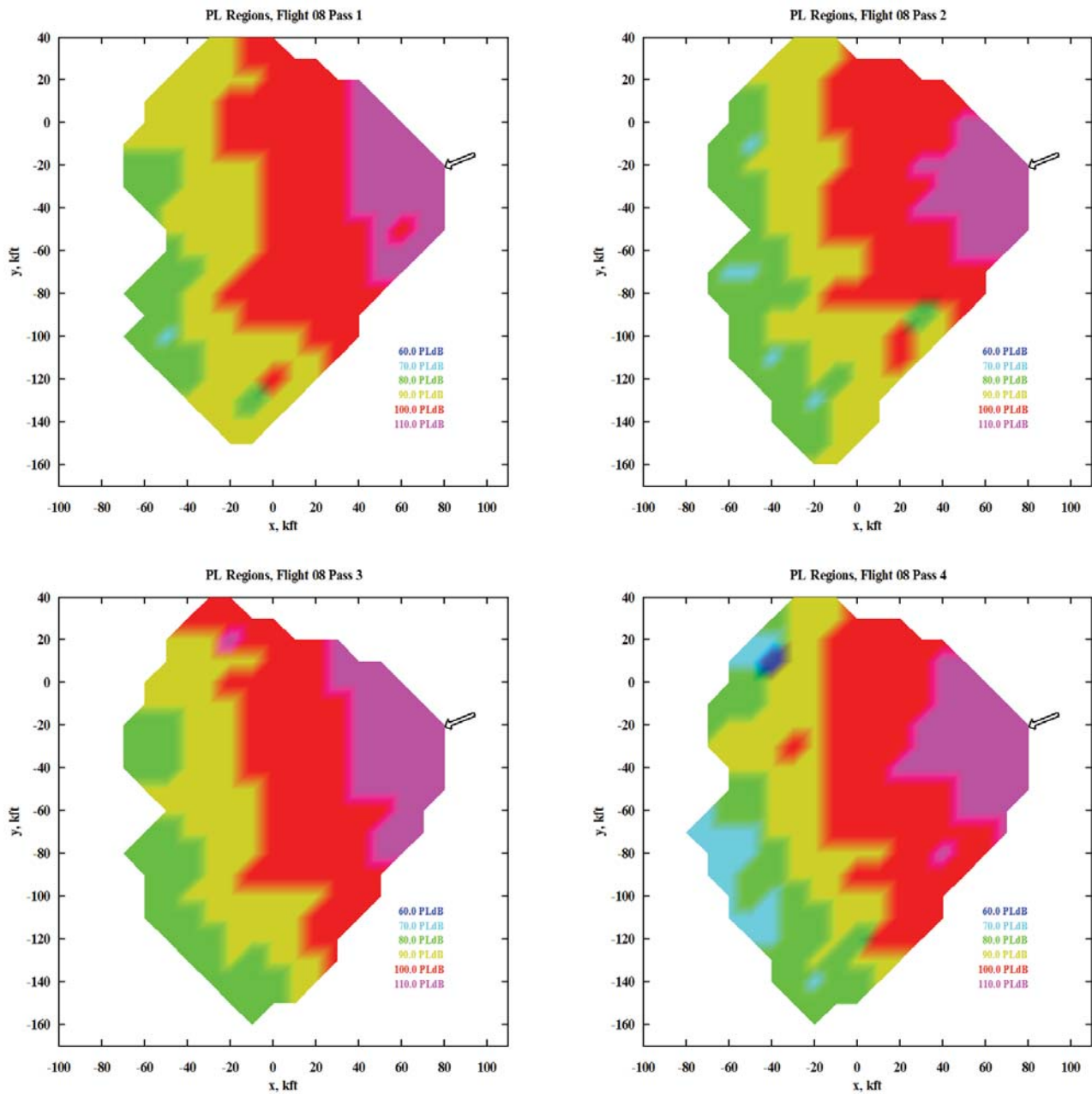


Figure 107. Perceived Level footprints, Flight 08, Passes 1,2,3,4.

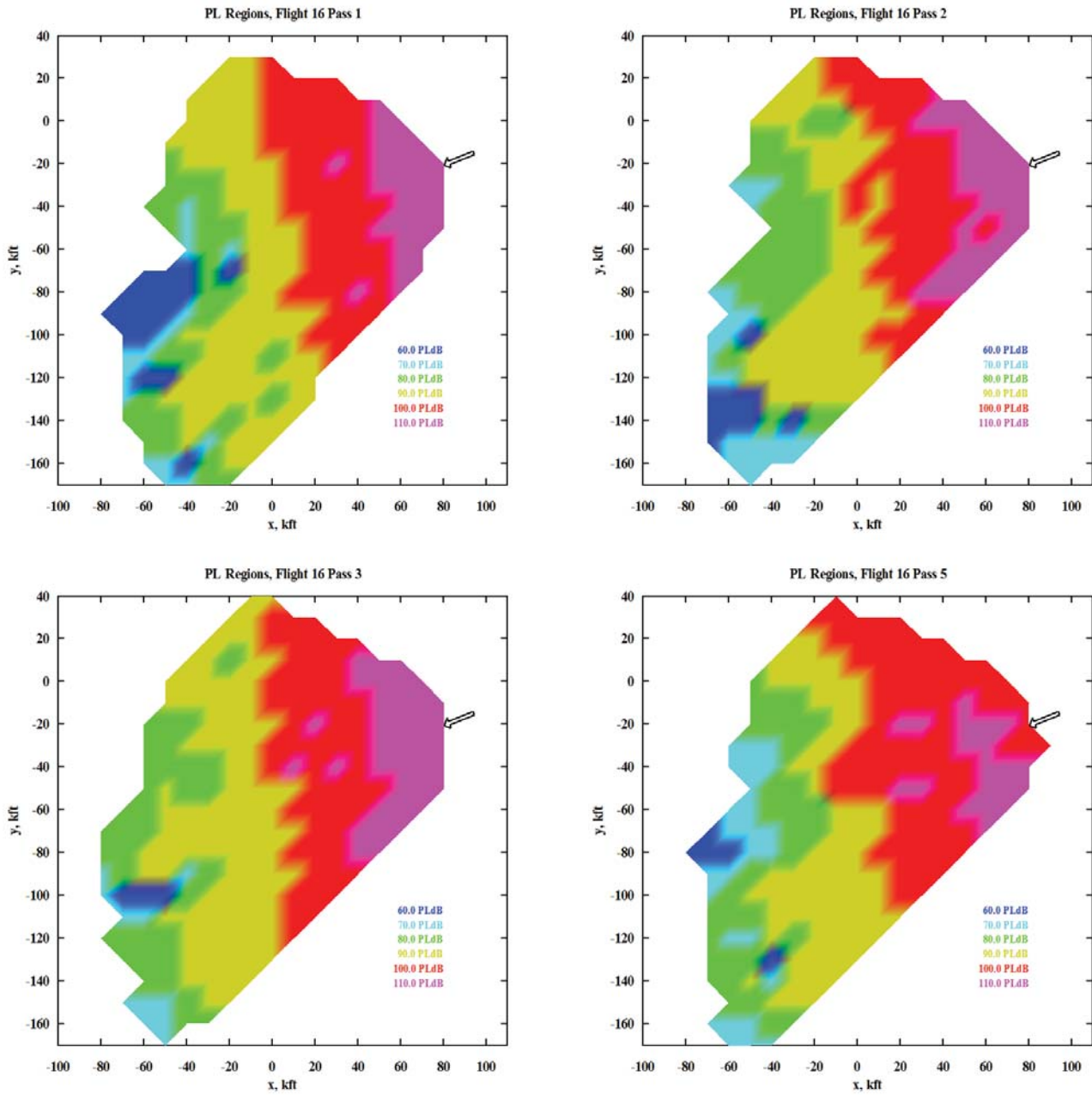


Figure 108. Perceived Level footprints, Flight 16, Passes 1,2,3,5.

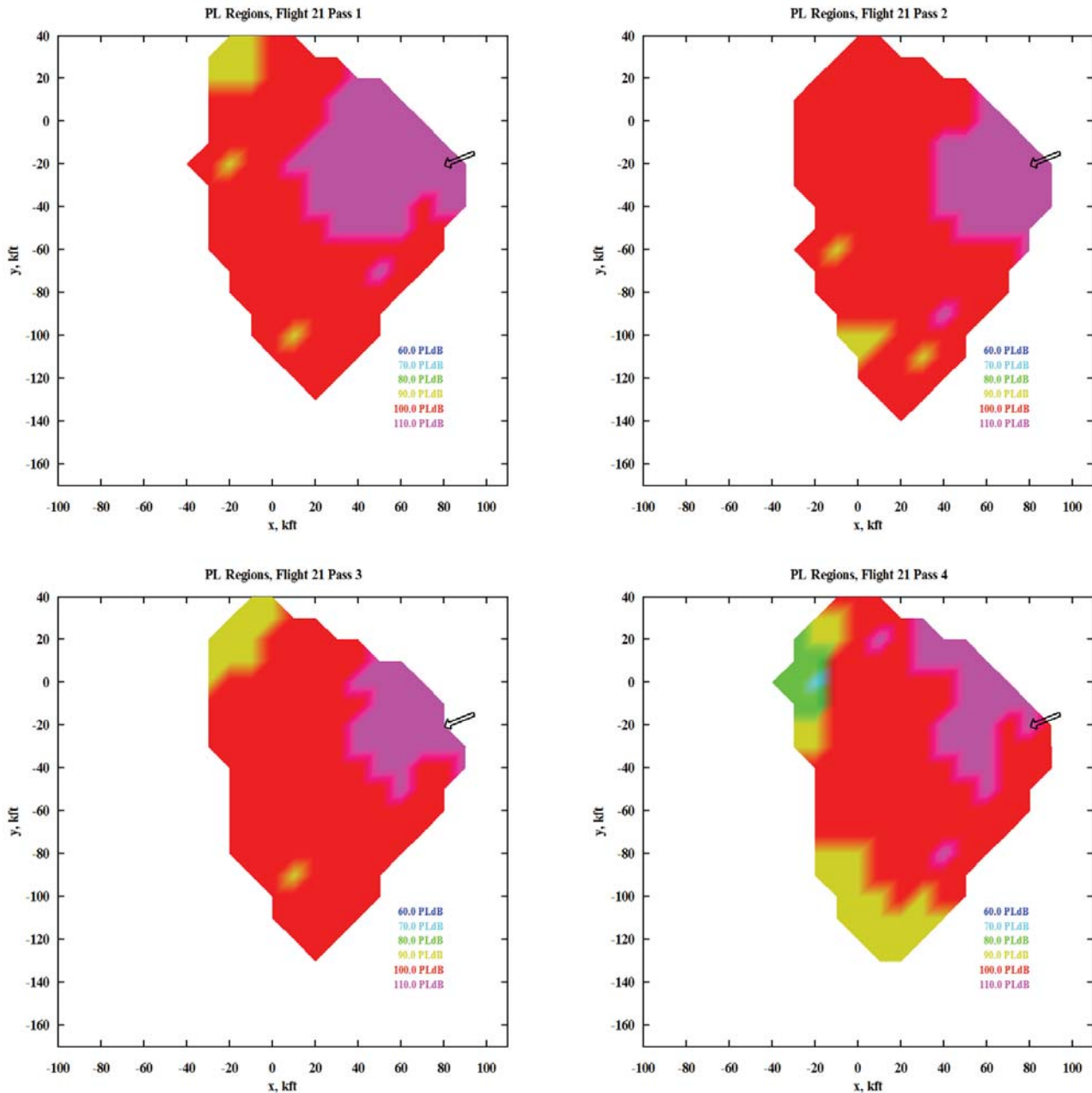


Figure 109. Perceived Level footprints, Flight 21, Passes 1,2,3,4.

### 6.4.3 Usable Low-Boom Footprint Size

In order to quantify the size of usable Perceived Level regions from typical low-boom dives, PCBoom was run using a nominal (template) trajectory and atmosphere. Perceived Level values based on a  $1/p$  Taylor shock were extracted from horizontal and vertical cuts through the footprint region and tabulated. Figure 110 displays one such example as predicted by PCBoom. The red X marks, spaced 10,000 feet apart, indicate the extracted Pmax (psf) and PL (dB) data locations. This maneuver provides a low-boom region over an east-west span of approximately 4-6 miles located towards the western edge of the footprint. Vertical cuts of data were extracted from the same footprint, at 20,000-foot east-west intervals. Figures 111 through 115 suggest a north-south low-boom region ranging from a few miles on the

eastern region to the full span of the footprint on the western edge, approximately 30 miles across.

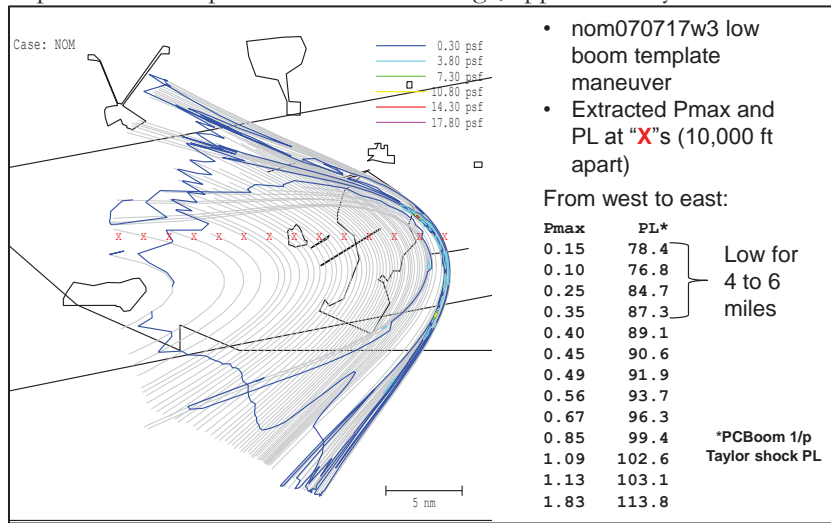


Figure 110. Nominal Low-Boom Footprint with extracted Pmax and PL along a West to East Cut.

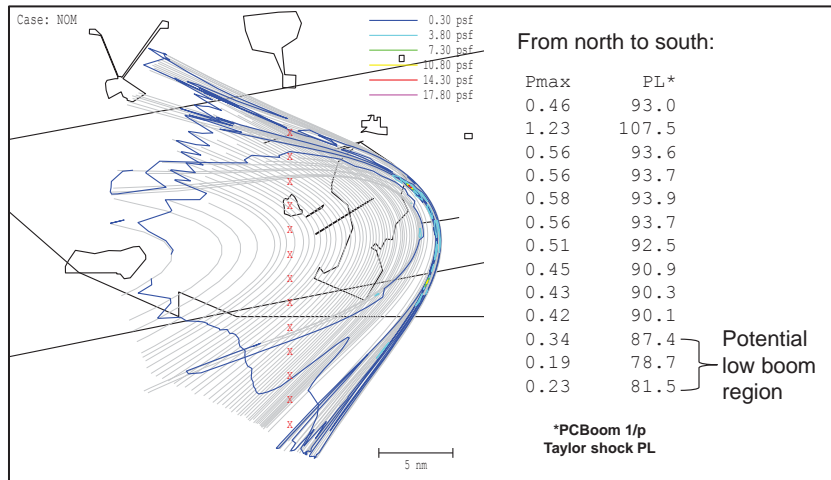


Figure 111. Nominal Low-Boom Footprint with extracted Pmax and PL along a North to South Cut #1.

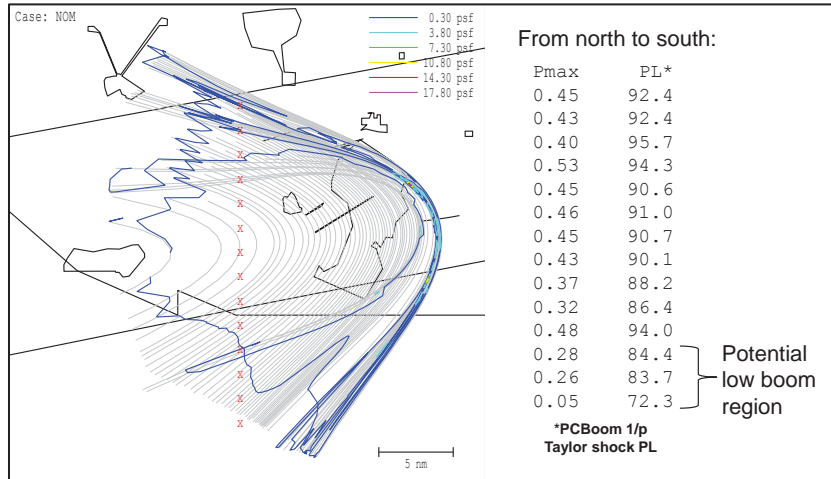


Figure 112. Nominal Low-Boom Footprint, North to South Cut #2, 20 kFt West of Cut #1.

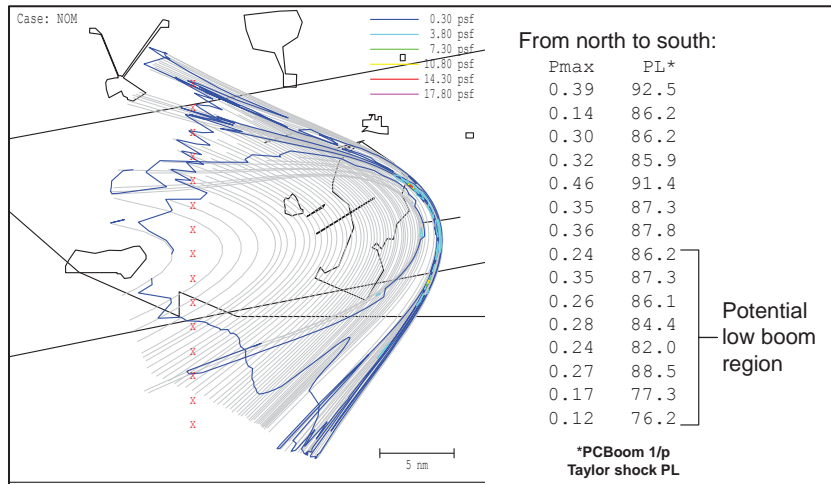


Figure 113. Nominal Low-Boom Footprint, North to South Cut #3, 20 kFt West of Cut #2.

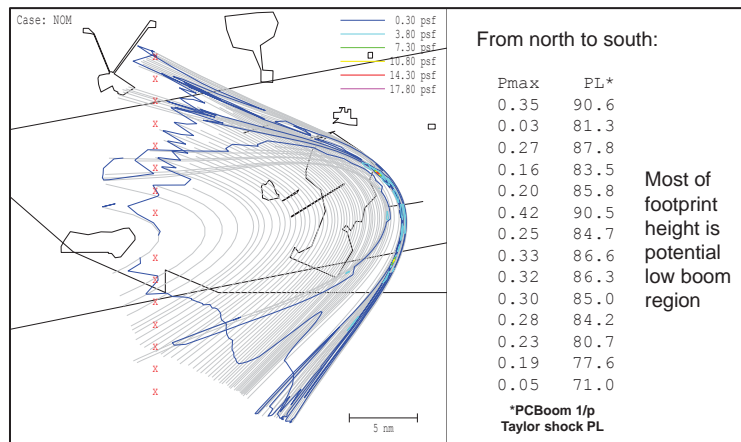
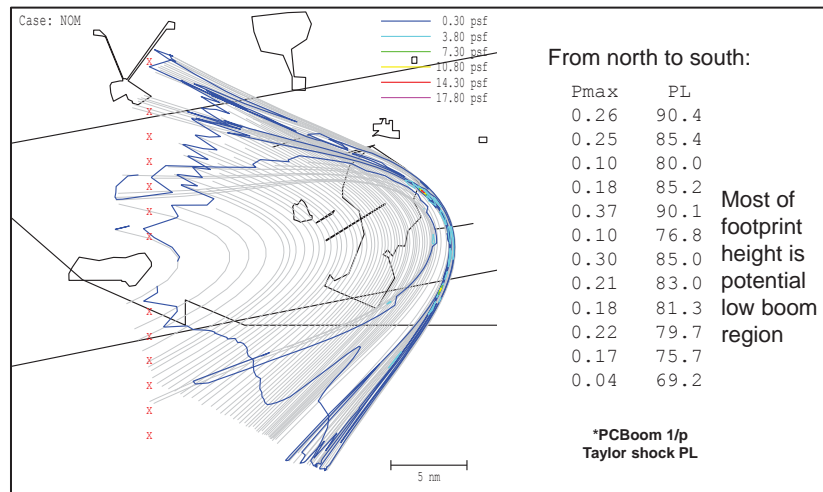


Figure 114. Nominal Low-Boom Footprint, North to South Cut #4, 20 kFt West of Cut #3.





**Figure 115. Nominal Low-Boom Footprint, North to South Cut #5, 20 kFt West of Cut #4.**

Clearly there is a useful low-boom area, away from focal zone uptrack. This suggests future testing consider coastal communities, where the focused boom can be placed offshore. Regions below 80 dB are generally found to be 2–8 miles in track wise direction and 20–40 miles across track.

PCBoom analysis predicts footprints with a certain degree of predictable variability and a useful subject region encompassing a scale of miles. Monitors spaced 1 to 5 miles apart in study region would verify nominal (non-turbulent) “backbone” sonic boom and contour variations. There is some variability in footprints, associated with differences in the as-flown trajectories and atmospheric profiles. Note that the variability in the low-boom region from propagation effects (e.g., turbulence) is not deterministically defined. Given that turbulent variations are expected over distances of several hundred feet, clusters of monitors will be needed to obtain local turbulence statistics in several regions of the subject area. Future planning and research should target techniques for quantifying turbulence effects on sonic boom footprints.

## 6.5 Concept for Future Non-Acclimated Community Testing

The long-term goal to enable future supersonic overland commercial flight is to conduct a national scale flight research program in the US National Airspace System using a low-boom designed flight research aircraft. Experimental data, both objective (noise and vibration) and subjective (human response) is necessary to support ICAO/CAEP rule-making efforts to establish a new international sonic boom standard. WSPR aimed to develop methodology and data gathering procedures to inform researchers preparing for future non-acclimated community testing. The WSPR objectives included:

- Test planning and noise exposure design.
- IRB approval and drafting materials required for OMB submission for future testing off-range.
- Developing and deploying instruments for subjective data collection and post-test analysis.
- Subject recruitment, training, and coordination.
- Field instrumentation deployment and post-test data analysis.

The WSPR experiment was conducted on an acclimated community on United States Government property with no additional environmental impact analysis or approval needed. This testing environment offered significant low-risk advantages:

- No special aircraft handling or off-range FAA approvals needed.
- No civilian Air Traffic Control involvement.
- No local government interaction, although EAFB presented some unique challenges.
- Minimal socio-economic factors to consider.
- Subjects were United States Government or former United States Government employees or their families.
- Minimal involvement with the general public and media with a small risk of significant negative feedback.
- Minimal terrain and population density variation.
- Minimal atmospheric variability.
- USAF operations were expected to provide some full booms, but WSPR included test adaptation if required.
- Sufficient room for focus boom and minimal repercussions if the research team experienced inadvertent placement.

International rule-making for sonic boom standards may require a significant amount of data collected over multiple locations with variation in population density, a multitude of different residential structure types, and different atmospheric conditions, to name a few. The research team expects that tens of millions of single event responses could be needed to gather the required subjective-objective correlated results from which the regulatory bodies can draw conclusions.

The WSPR program demonstrated the effectiveness of a well-planned experimental design that was able to obtain both objective and subjective data using methods and protocols that can be modified for application to a future non-acclimated community test. Considering the long-term goal, and in preparation of the arrival of a low-boom test aircraft, the WSPR team recommends the following framework for a non-acclimated community low-boom response test:

- Off-range F-18 low-boom dive maneuver conducted in multiple non-acclimated communities.
- Domestic test only/United States National Air Space experiment at a minimum of two different sites.
- Multiple short duration test campaigns encompassing 15–20 flights over 2–3 weeks each.
- The test design should use “sampling theory” to limit subjective data required and include appropriate factor analysis to account for demographics, atmosphere, terrain, etc.
- Cumulative rather than single event response data is required, with smaller subject pools for targeted single event response research.
- WSPR instrumentation must be scaled up and further automated for acquiring objective data (signatures) including addition of remote deployment capability with web-based monitoring and fail-safe network and power.

### **6.5.1 Areas for Future Research**

The WSPR test provided a wealth of information to facilitate the planning of a non-acclimated community test. However, several design and planning techniques still need to be developed that can adequately account for ambient noise handling, distinguishing impulsive events, indoor vs. outdoor environment, and acclimation.

Ambient noise can greatly influence the objective measurement and prediction of metrics for low-boom signatures. The WSPR program continued research exploring techniques for extracting low signal-to-noise signatures from the background. It is important to understand how subjects will identify low booms vs. other noise sources in their communities, such as car door slams that approximate the sound of the lowest low-boom noise. Will there be misidentification of low booms? This becomes a greater concern in a non-acclimated community, particularly in more urban areas with additional noise sources.

Should subjective-objective analysis be based on indoor or outdoor noise? WSPR provided estimates of indoor metrics based on simple transmission filters for a particular housing type. If the regulatory framework will be based upon actual



exposure, then consideration and possible measurement of sonic booms inside different types of housing structures could be important.

It is also assumed that there will not be any full booms in the non-acclimated community design. The typical measure of community response to full boom noise is the percent highly annoyed within the community. However, without the use of full booms, it is conceivable that the noise exposure will not result in high annoyance in the non-acclimated community. As such, the WSPR data analysis was conducted on the %HA, the daily annoyance response, and the single event response data. This was done to test and evaluate assessment procedures other than percent highly annoyed in anticipation that there may not be any highly annoyed response data in the next field design.

Subject acclimation to new noise is very difficult to quantify. Is slow introduction of new noise with longer test duration required? Prior research was reviewed and has indicated that one of the best solutions to minimizing the effects of introduction of a new noise source into a non-acclimated community is outreach and introducing the new stimulus gradually. The WSPR team does not know what the right rate of introduction is, but one needs to gradually increase exposure to the new noise source, closely coupled with outreach.

### **6.5.2 Outreach**

Careful and controlled interaction with the general public, media, and local governments will absolutely be required for the next subjective boom test if conducted in a non-acclimated community. Outreach is like subjective testing. It is a multi-faceted nuanced effort that is often overlooked because people do not realize its depth and effectiveness. The solution to acclimation is outreach, which is more involved than appears on the surface. Risk mitigation of this very important element for the next test demands early involvement, trust, and ownership. Any non-acclimated community under consideration should be brought into the planning process at the outset – the beginning of the test planning effort rather than after the test has been fully planned and is ready for implementation.

For FAA related matters, community outreach, education, and involvement are key. The process for engaging the FAA in the design process should begin as soon as possible. The FAA involvement will be required not only for the obvious operational and ATC elements, but also because they are stakeholders in the research as the governing regulatory agency.


An outreach campaign needs to involve the general public and carefully monitor and assess the media response and reaction. Local communities and governments need to be engaged. From these activities surrounding an F-18 low-boom dive test on a non-acclimated community, the research team can identify important data points prior to future testing with a low-boom demonstrator aircraft.

### **6.5.3 Testing Objectives: Cost Control and Risk Mitigation**

Experience with non-acclimated community testing will help to contain the size, scope, and costs of a future demonstrator test program. Conducting experiments in coastal regions using the F-18 low-boom dive maneuver is a risk reduction item in preparation for the low-boom designed aircraft.

Outreach will be a critical element moving into non-acclimated communities. The research team needs to explore various means of communication and determine effective terminology for engaging communities and garnering support. Future testing can inform us on introduction of new noise sources to non-acclimated subjects. The team needs to better understand subject non-response and fatigue for longer duration tests.

Physical data gathering and understanding of the influence of varying atmospheres, humidity, and turbulence, and gaining practical experience dealing with test planning and execution is important. Management of focus booms is a critical item and if not handled properly, could lead to negative responses from the general public or the media. Educating all those community members involved on focus boom, the intricacies associated with its placement away from the community, and the risk associated with inadvertent placement due to atmospheric or pilot variation will also be key to mitigating any potential negative response due to focus boom management.



Larger datasets are needed to better ascertain the suitability of using cumulative response data in lieu of single event response data. Parallel testing protocols with multiple groups and tasks could provide additional insight. Longer-duration tests with fewer signatures per week and a lower operational tempo could be considered to determine whether it provides a better acclimation response or cost advantages. There is a need to identify logistical challenges for off-range base operations and handling longer-term deployment.

There are significant regulatory hurdles that will need to be overcome, both for coastal community testing and for the future low-boom designed aircraft. These include preparation of environmental assessments or environmental impact statements in compliance with NEPA requirements. In addition to standard IRB approvals, testing must obtain approval from the federal level at the Office of Management and Budget (OMB).

It remains clear that any future off-range sonic boom testing will not be without challenges. NASA and industry continue to advance low-boom aircraft designs that could meet acceptable ground signature levels. In order to prepare for a national-scale flight program, continuation of flight testing using the F-18 low-boom dive maneuver in non-acclimated communities may be necessary to further understand the nuances and risks associated with introducing these unique quiet ground signatures into communities and to educate the general public on scientific progress in mitigating sonic boom over the past few decades.

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# Appendices

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## Appendix A: Survey Instruments

**A-1a: Single Event Survey, Paper Version**

**A-1b: Single Event Survey, Web Version**

**A-1c: Single Event Survey, Apple Version**

**A-2a: Daily Summary Survey, Paper Version**

**A-2b: Daily Summary Survey, Web Version**

**A-2c: Daily Summary Survey, Apple Version**

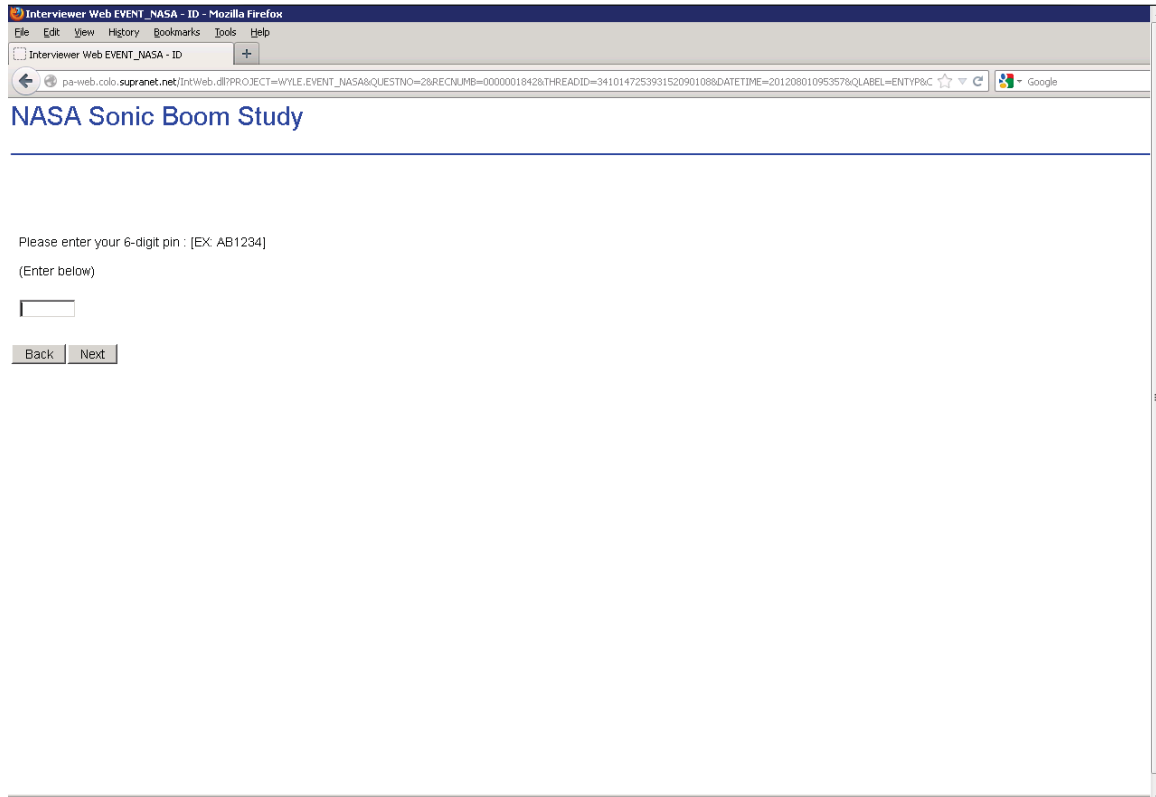
**A-3: Baseline Survey**



# A-1b: Single Event Survey, Web Version

## WSPR Low Boom Response Pilot Program Subjective Response to Flight Booms Single Boom Web Screen Shots

### IDCODE





# A-1b: Single Event Survey, Web Version

## ENTYP

Interviewer Web EVENT\_NASA - ENTYP - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - ENTYP

pa-web.colorado.supranet.net/IntWeb.d/PIID=ab12348&PROJECT=WYLE.EVENT\_NASA&QUESTNO=1&RECNUMB=0000001842&THREADID=341014725393152090108&DATEIME=20120801095402&QLABI

### NASA Sonic Boom Study

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Enter responses for...

(Select one)

Single Boom (each time you notice a sonic boom)

Daily Summary (at the end of each day after 6 P.M.)

Back Next

# A-1b: Single Event Survey, Web Version

## Single Sonic Boom Event

### E1B

Interviewer Web EVENT\_NASA - E1B - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - E1B

pa-web.colο:supranet.net/IntWeb.dl?ENTYP=1&PROJECT=WYLE.EVENT\_NASA&QUESTNO=2&RECNUMB=000001842&THREADID=341014725393152090108&DATETIME=20120801095445&QLABEL Google

### NASA Sonic Boom Study

---

Date of sonic boom:  
(Select below)

Day

November

04  
05  
06  
07  
08  
09  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22

Back Next

# A-1b: Single Event Survey, Web Version

## E2

The screenshot shows a Mozilla Firefox browser window. The title bar reads "Interviewer Web EVENT\_NASA - E2 - Mozilla Firefox". The address bar contains the URL: "ps-web.colorado.supranet.net/IntWeb.d/FE1b=059questlist=E1b%3E8SCREEN=18&PROJECT=WYLE.EVENT\_NASA&QUESTNO=3&RECNUMB=0000001842&THREADID=341014725393152090108&DATETI". The page title is "NASA Sonic Boom Study".

Time of the sonic boom [EX: 1240]:  
(Please use military time)  
(Enter below)

Back Next

# A-1b: Single Event Survey, Web Version

## E3

The screenshot shows a Mozilla Firefox browser window. The title bar reads "Interviewer Web EVENT\_NASA - E3 - Mozilla Firefox". The address bar contains the URL: "pa-web.colorado.edu/supranet.net/int/Web.dl?E2=1240&PROJECT=WYLE.EVENT\_NASA&QUESTNO=46&RECNUMB=0000018428&THREADID=3410147253931520901088&DATETIME=20120801095615&QLABEL". The page content includes the title "NASA Sonic Boom Study" followed by a question: "When the sonic boom occurred, were you...". Below the question is the instruction "(Select one)" and four radio button options: "Indoors at home", "Indoors somewhere else", "Outdoors at home", and "Outdoors somewhere else". At the bottom of the question area are two buttons: "Back" and "Next".

Interviewer Web EVENT\_NASA - E3 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - E3

pa-web.colorado.edu/supranet.net/int/Web.dl?E2=1240&PROJECT=WYLE.EVENT\_NASA&QUESTNO=46&RECNUMB=0000018428&THREADID=3410147253931520901088&DATETIME=20120801095615&QLABEL

### NASA Sonic Boom Study

---

When the sonic boom occurred, were you...

(Select one)

Indoors at home

Indoors somewhere else

Outdoors at home

Outdoors somewhere else

Back Next

# A-1b: Single Event Survey, Web Version

## E4-E7

Interviewer Web EVENT\_NASA - E4 - Mozilla Firefox

Interviewer Web EVENT\_NASA - E4

ps-web.colo.supranet.net/IntWeb.d/FE3=18/PROJECT=WYLE\_EVENT\_NASA9/QUESTNO=78/RECNUMB=0000018426/THREADID=3410147253931520901088/DATETIME=201208010957338/QLABEL=E3

### NASA Sonic Boom Study

	Not at all	0	1	2	3	4	5	6	7	8	9	Extremely	10
How much did the sonic boom <b>bother, disturb, or annoy</b> you?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How <b>loud</b> was the sonic boom?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How much did the sonic boom <b>interfere</b> with your activity?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How much did the sonic boom <b>startle you or make you jump</b> ?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[Back](#) [Next](#)

# A-1b: Single Event Survey, Web Version

## E8-E9

Interviewer Web EVENT\_NASA - E8 - Mozilla Firefox

Interviewer Web EVENT\_NASA - E8

pa-web.colo.supranet.net/int/Web.dll?QUESTLIST=E4%3E5%3E6%3E7%e4-00%e5-00%e6-00%e7-00&SCREEN=1&PROJECT=WYLE.EVENT\_NASA&QUESTNO=8&RECNUMB=000001942&THRE

### NASA Sonic Boom Study

	None	0	1	2	3	4	5	6	7	8	9	10	A great deal
Vibration is a motion. The motion may be seen or felt. How much <b>vibration</b> from the sonic boom did you see or feel in your home?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rattle is a type of noise that can occur when objects move due to a vibration. How much <b>rattle</b> from the sonic boom did you experience in your home?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Back Next





## A-1c: Single Event Survey, Apple Version

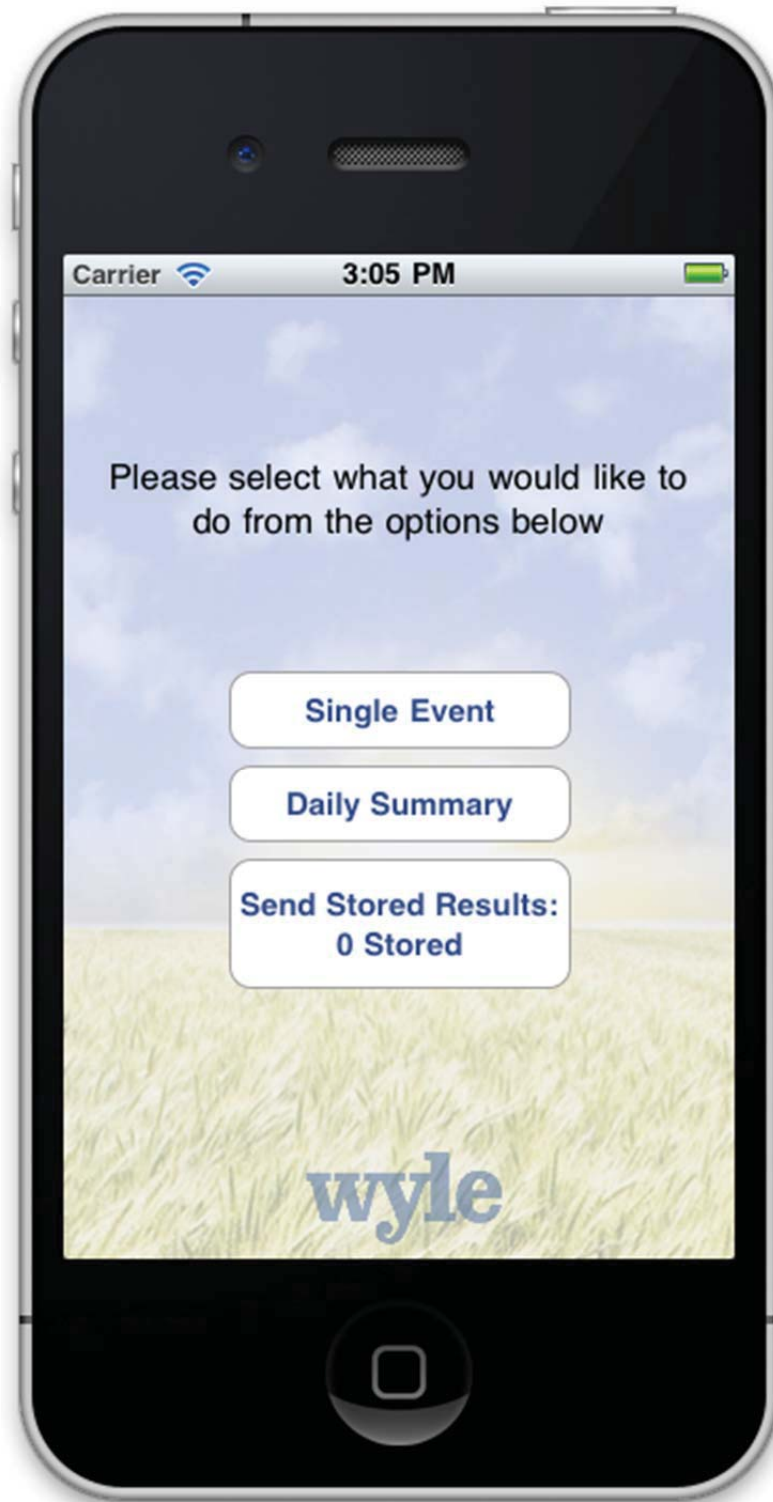


Figure A1c-1 – Start Screen for Single Event Mode

A-1c: Single Event Survey, Apple Version



Figure A1c-2 – Date Selection Screen for Single Event Mode

## A-1c: Single Event Survey, Apple Version

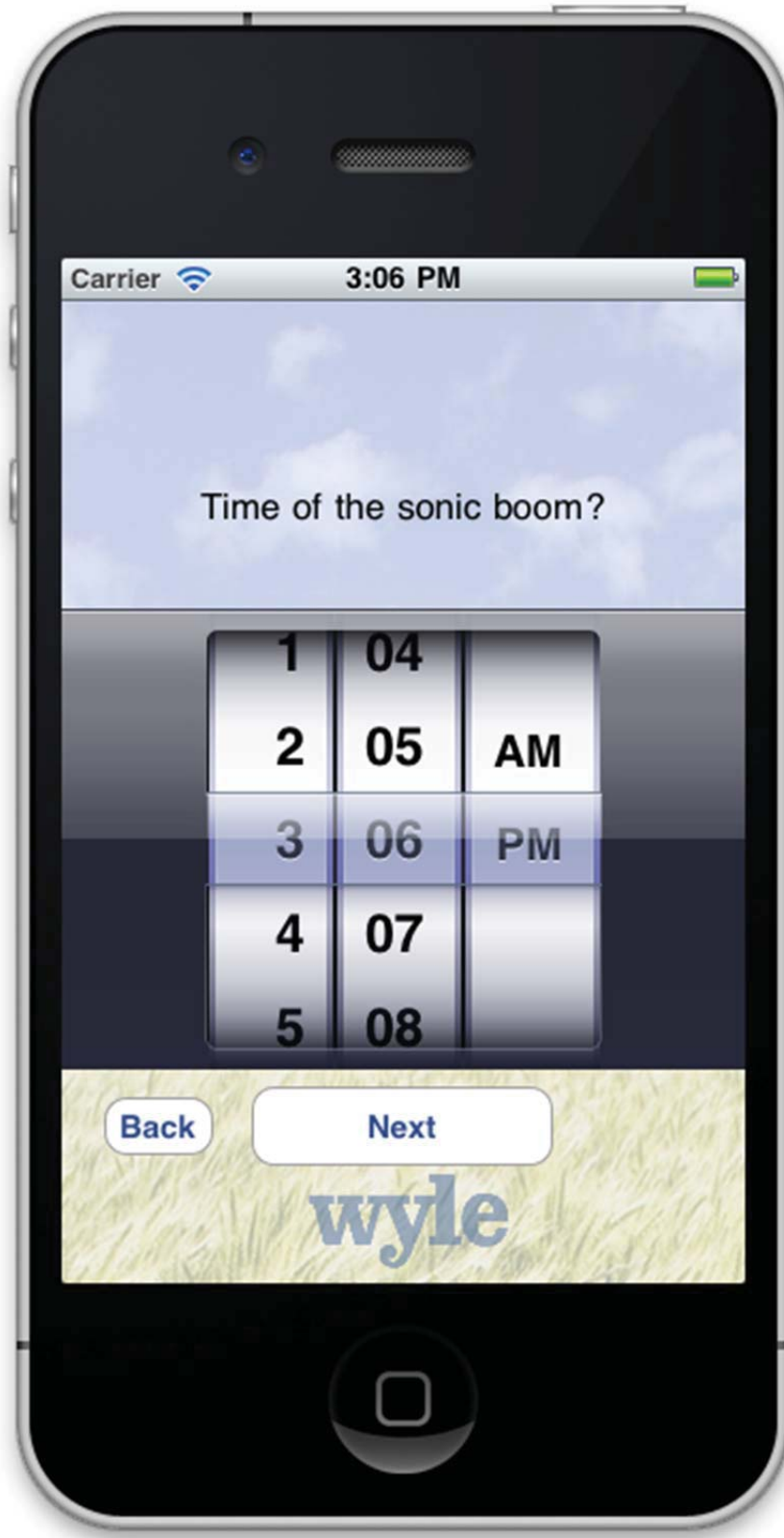


Figure A1c-3 – Time Selection Screen for Single Event Mode

## A-1c: Single Event Survey, Apple Version

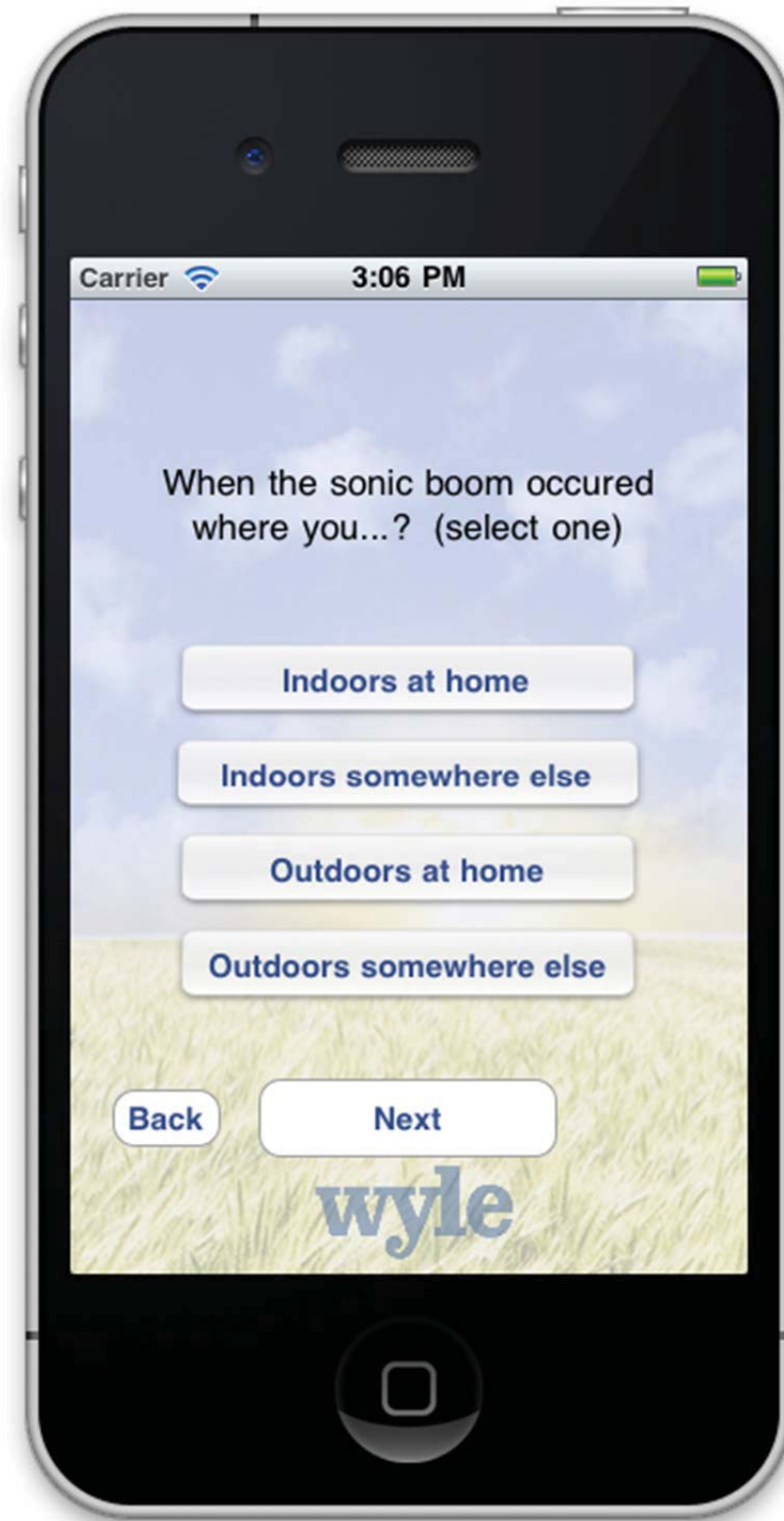


Figure A1c-4 – Location Selection Screen for Single Event Mode

## A-1c: Single Event Survey, Apple Version

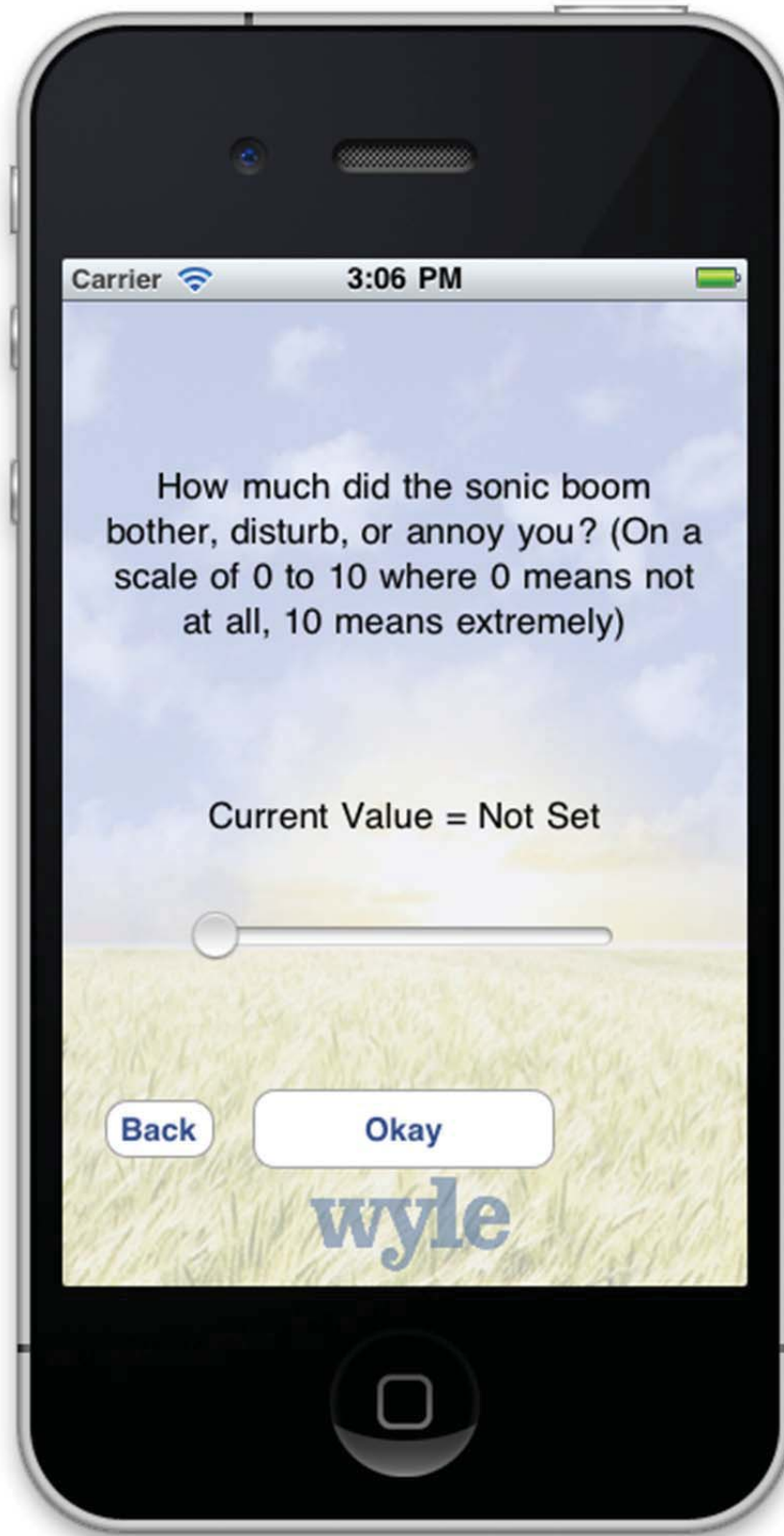


Figure A1c-5 – Bother, Disturb, or Annoy slider selection screen for Single Event Mode

## A-1c: Single Event Survey, Apple Version

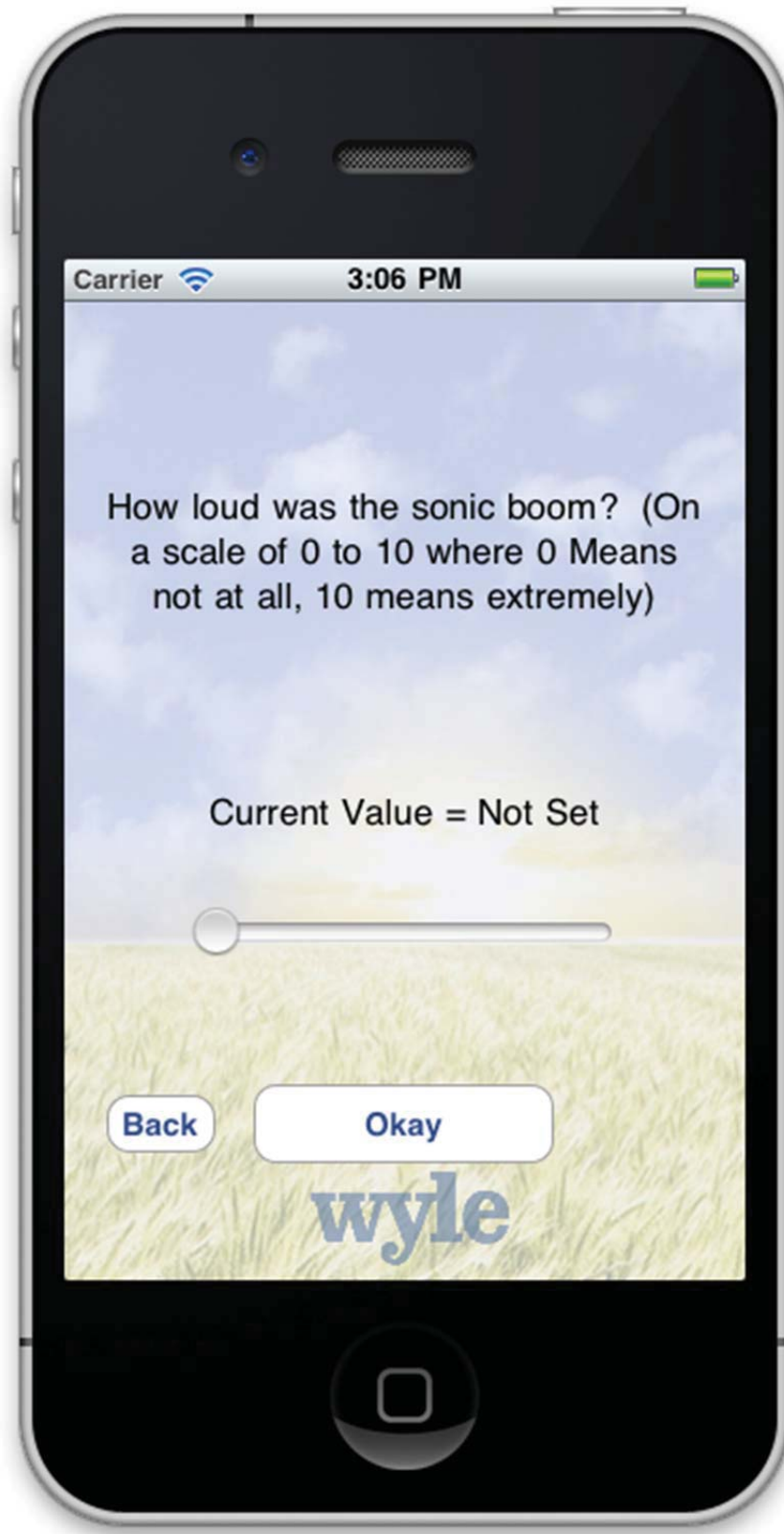


Figure A1c-6 – Loudness slider selection screen for Single Event Mode



## A-1c: Single Event Survey, Apple Version

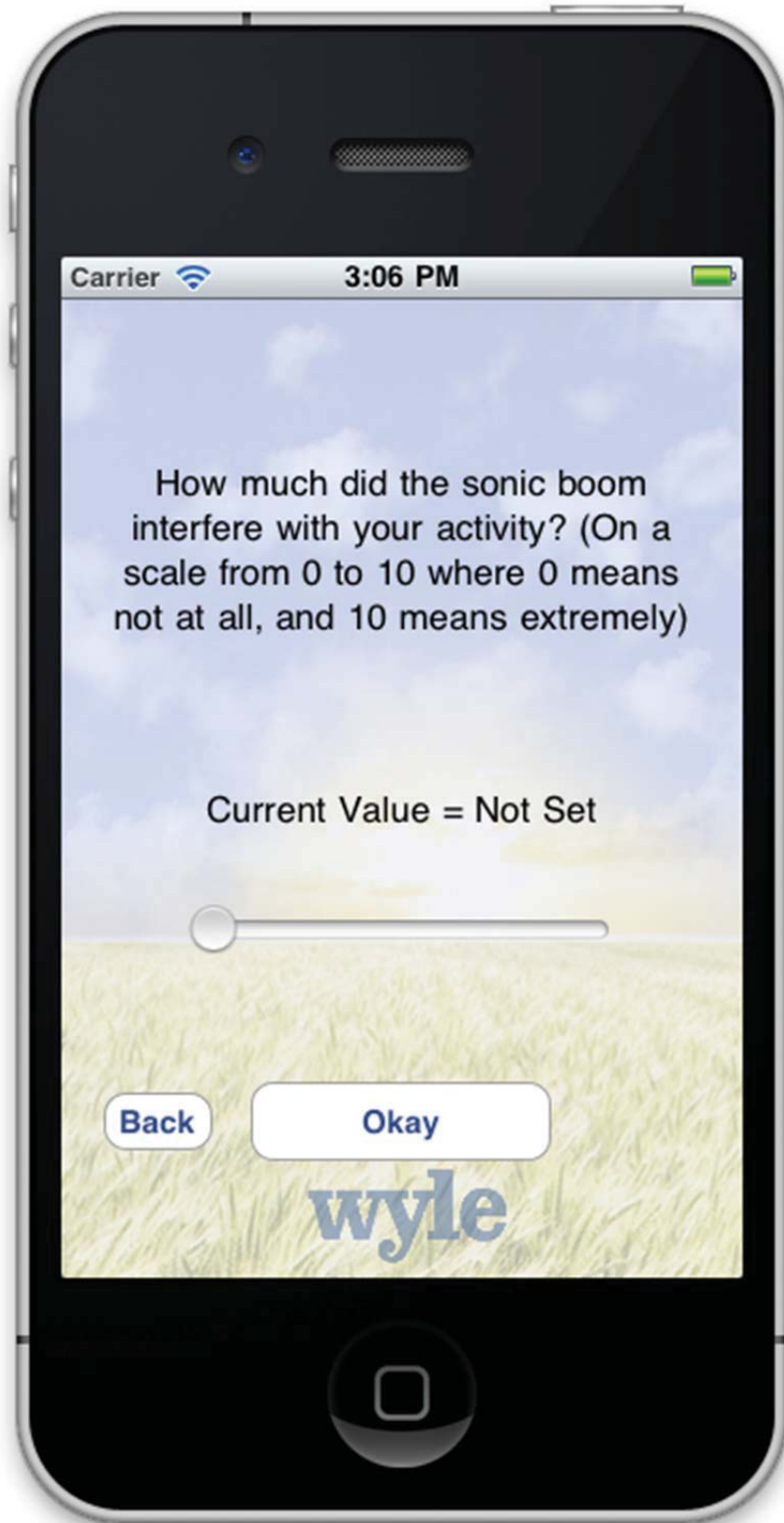


Figure A1c-7 – Interference slider selection screen for Single Event Mode



## A-1c: Single Event Survey, Apple Version

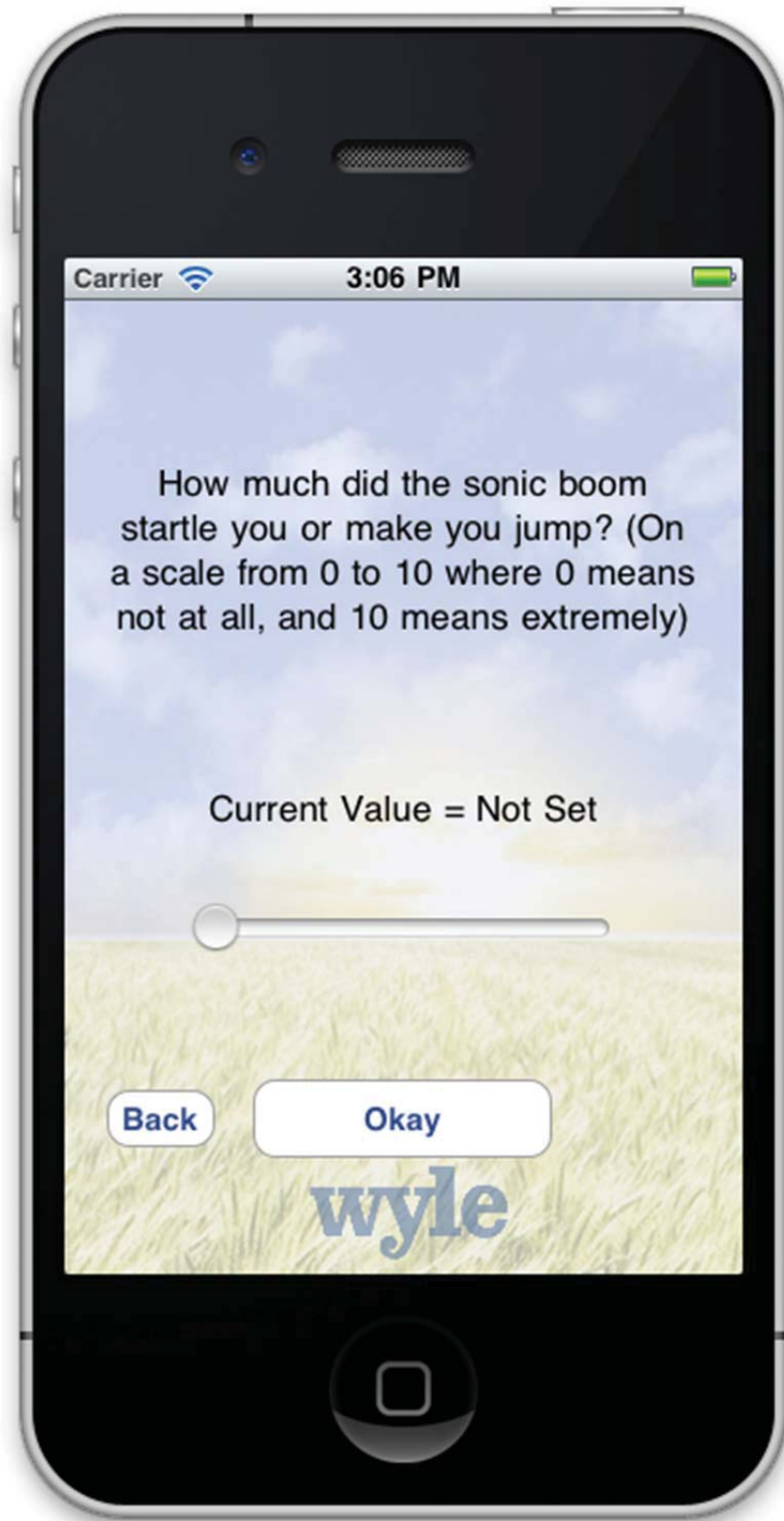


Figure A1c-8 – Startle slider selection screen for single event mode

## A-1c: Single Event Survey, Apple Version

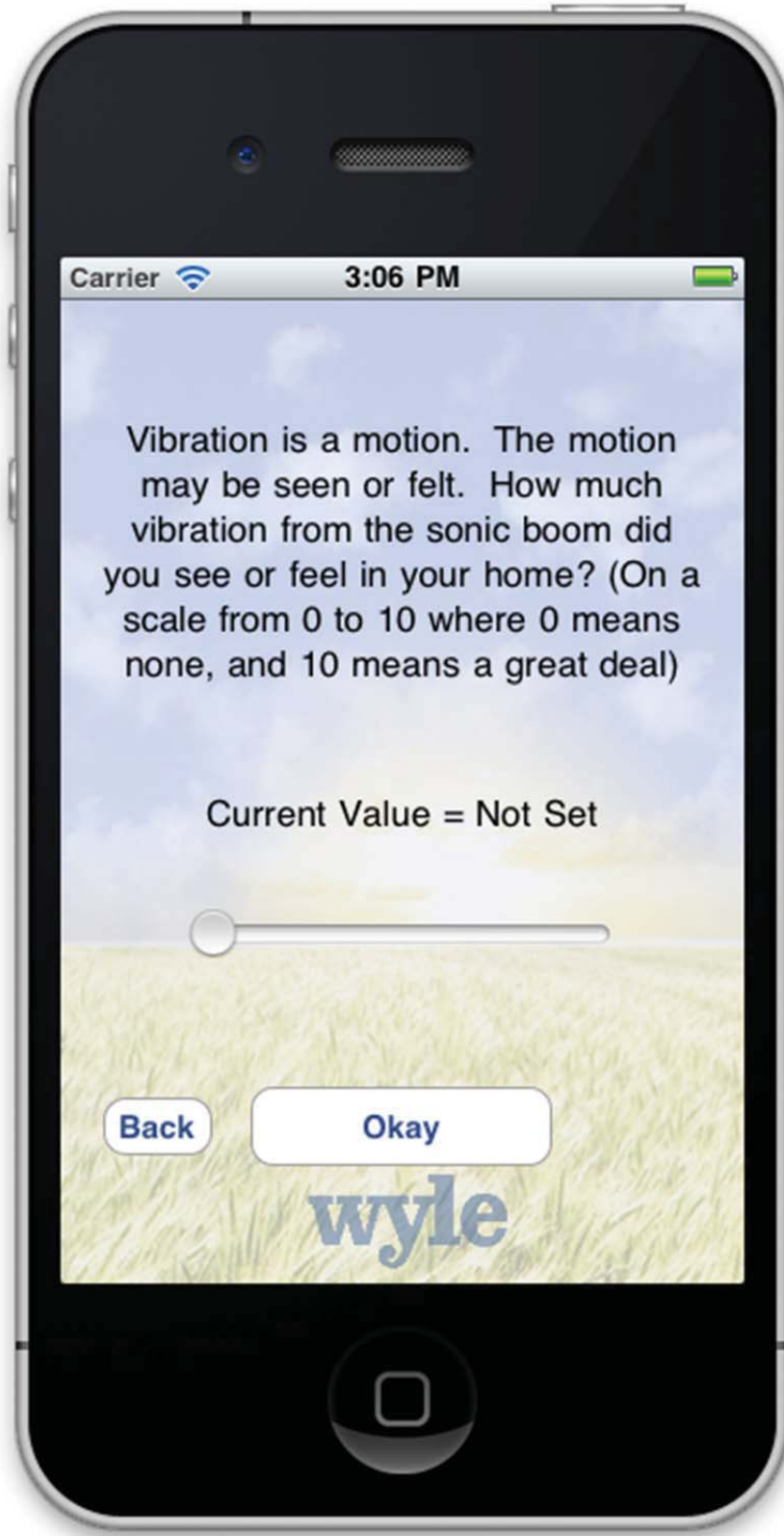


Figure A1c-9 – Vibration slider selection screen for single event mode

## A-1c: Single Event Survey, Apple Version

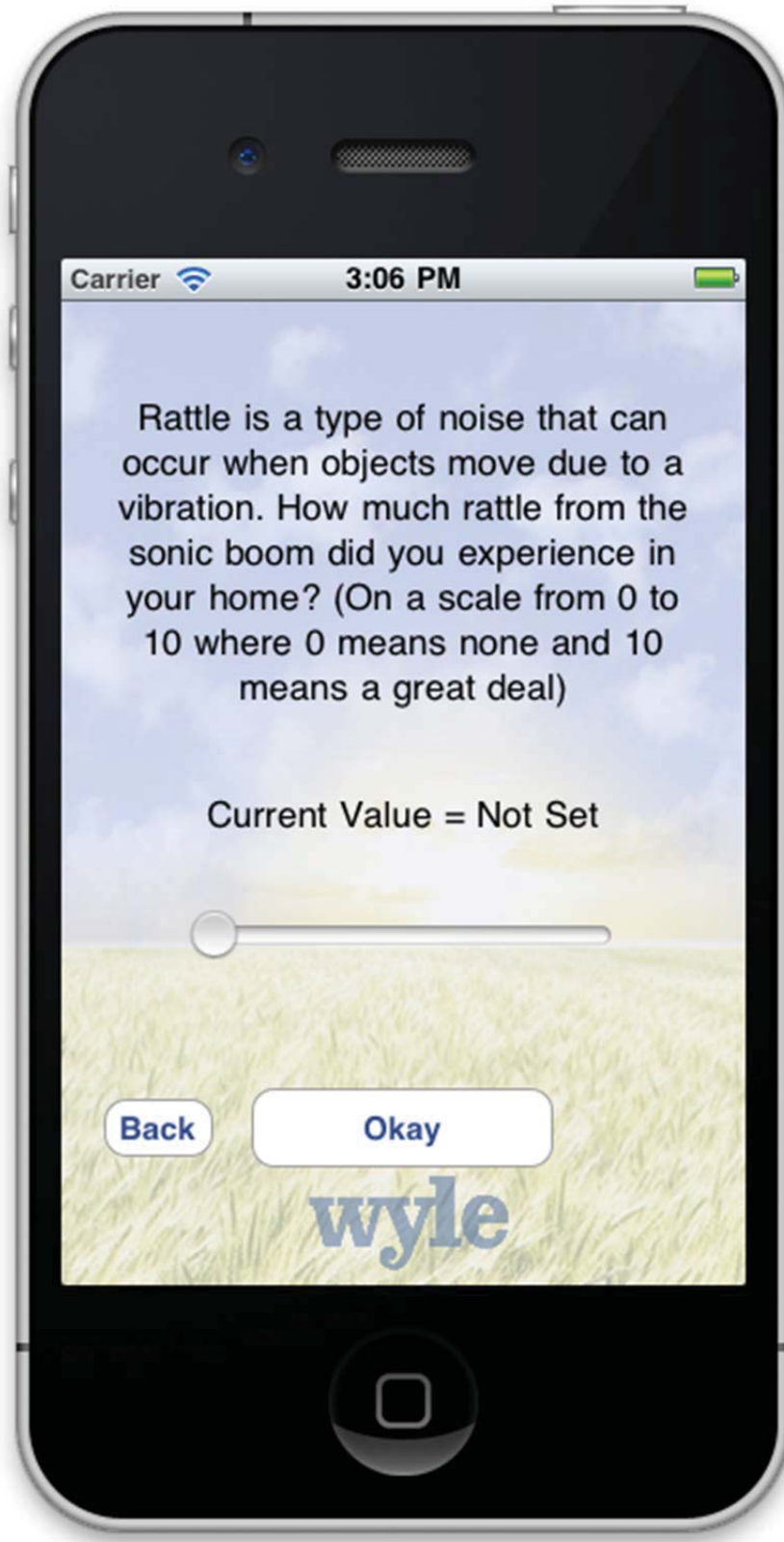


Figure A1c-10 – Rattle slider selection screen for single event mode

## A-1c: Single Event Survey, Apple Version

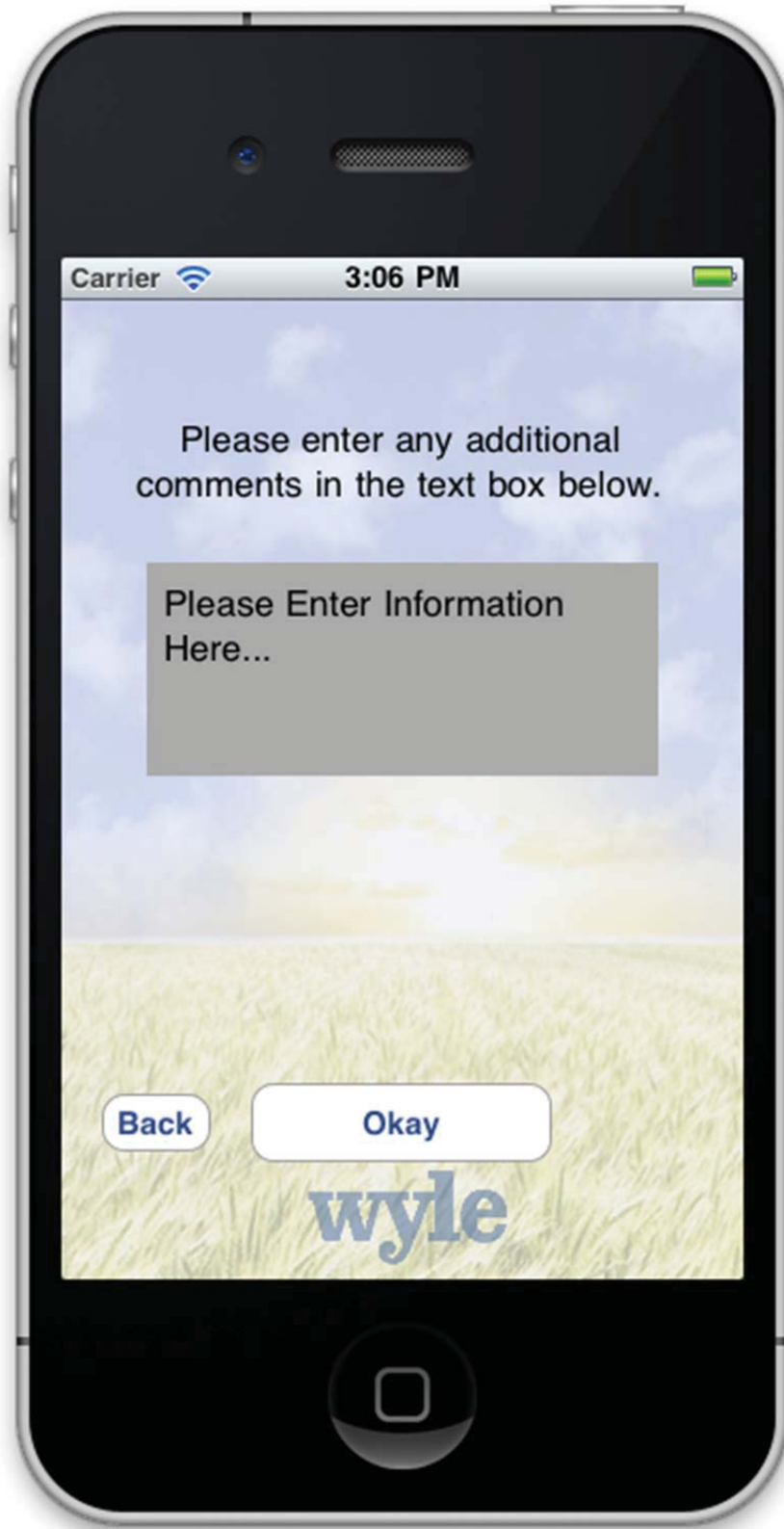


Figure A1c-11 – Comment entry screen for single event mode

## A-1c: Single Event Survey, Apple Version

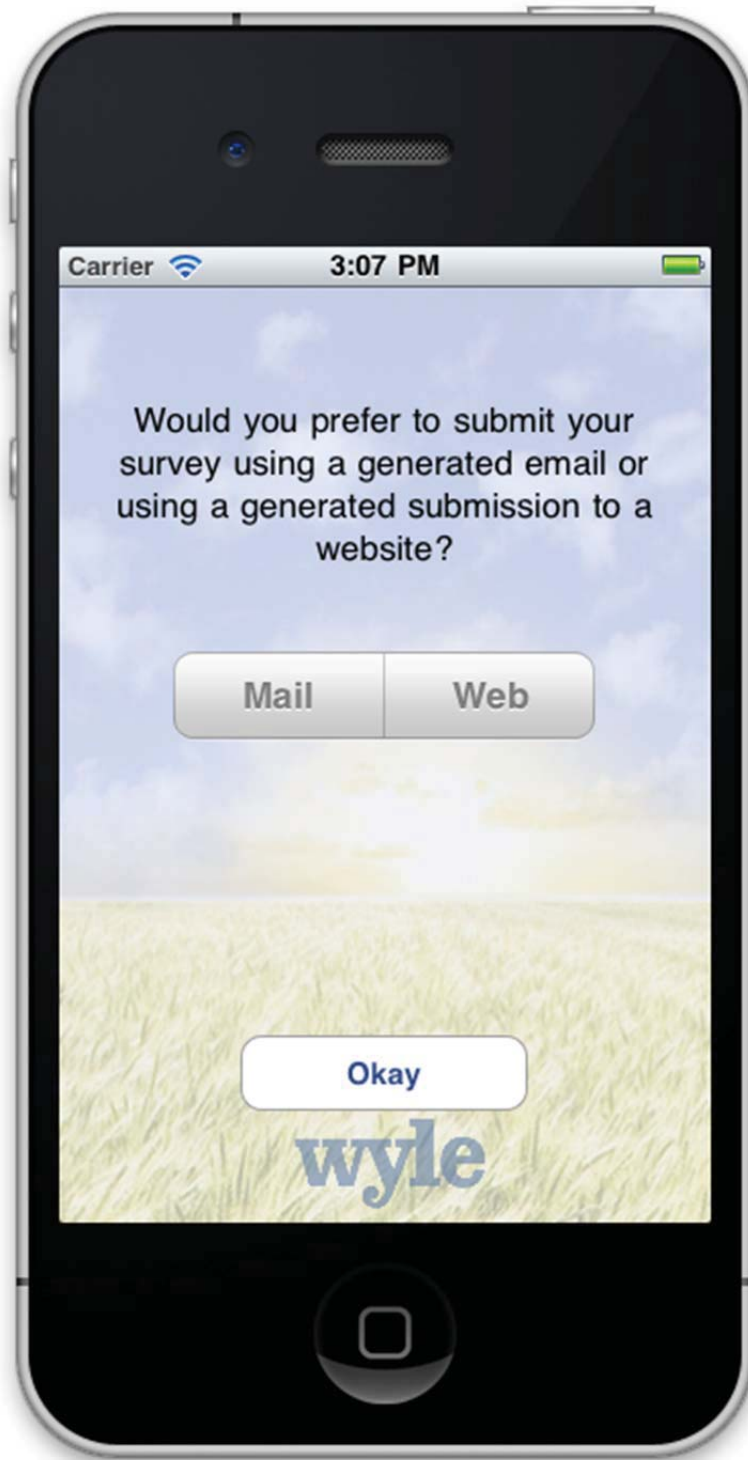


Figure A1c-12 – Web based or email based selection screen for single event mode

Web selection automatically submits results and closes the application. Mail selection causes figure A1c-13 to be instantiated and displayed.

## A-1c: Single Event Survey, Apple Version

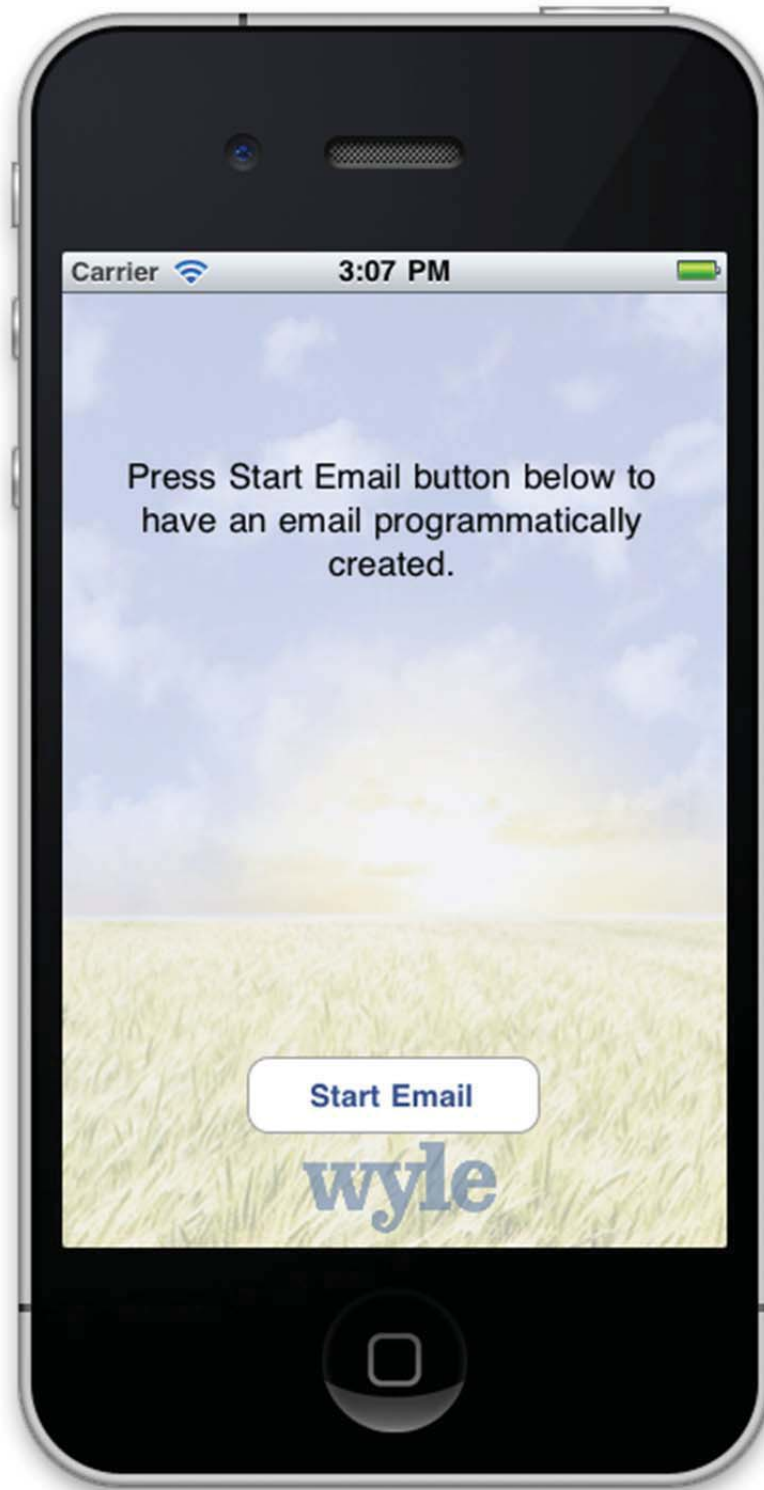


Figure A1c-13 – Start Email creation screen for single event mode

Pressing the start email button triggers the programmatic creation of an email to be sent containing the survey result data



## A-1c: Single Event Survey, Apple Version

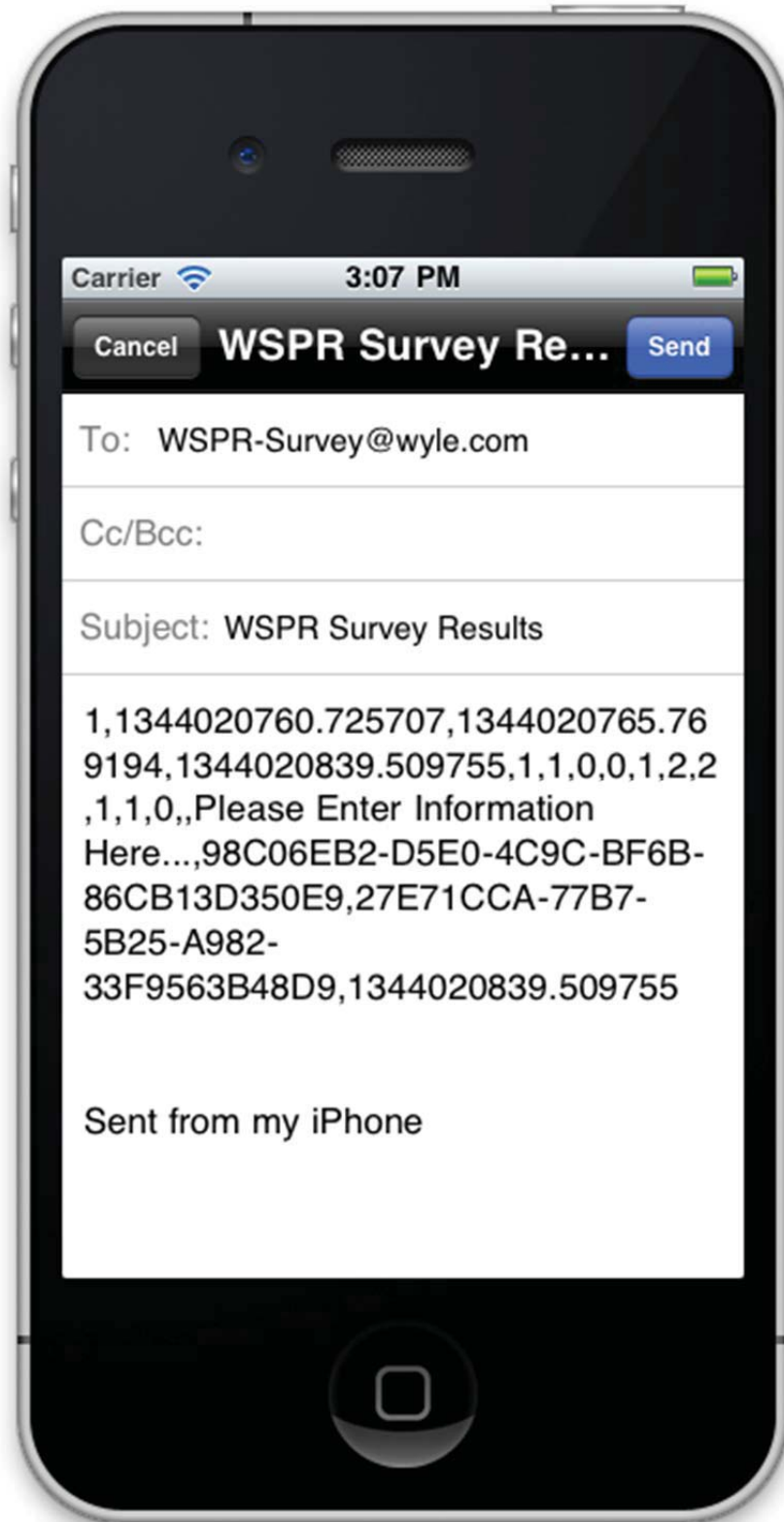


Figure A1c-14 – Sample single event mode survey email.



# A-2a: Daily Summary Survey, Paper Version

National Aeronautics and Space Administration



## Daily Summary Response Form

A1 Date: \_\_\_\_/\_\_\_\_/\_\_\_\_  
MM DD

ID: \_\_\_\_\_

A2 Which parts of the day were you at home for at least one hour? (select all that apply)

- 1  Morning (7:00 AM to Noon)      3  Evening (5:00 PM to 7:00 PM)  
2  Afternoon (Noon to 5:00 PM)      4  Not at home today (*end survey*)

A3 During the time you were at home today, how many sonic booms did you hear? (enter number below)

\_\_\_\_\_ # of sonic booms heard today (*If 0 booms heard today, go to A10*)

For the next questions, please think about the sonic booms you heard today while at home.

		Not at all										Extremely
(select one)		0	1	2	3	4	5	6	7	8	9	10
A4	How much did the sonic booms <b>bother, disturb, or annoy</b> you?	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	8 <input type="checkbox"/>	9 <input type="checkbox"/>	10 <input type="checkbox"/>

- A5 Which of the following categories best describes how much the sonic booms **bothered, disturbed, or annoyed** you? (select one)
- 1  Not at all  
2  Slightly  
3  Moderately  
4  Very  
5  Extremely

		Not at all										Extremely
(select one for each)		0	1	2	3	4	5	6	7	8	9	10
A6	How <b>loud</b> were the sonic booms?	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	8 <input type="checkbox"/>	9 <input type="checkbox"/>	10 <input type="checkbox"/>
A7	How much did the sonic booms <b>interfere</b> with your activities?	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	8 <input type="checkbox"/>	9 <input type="checkbox"/>	10 <input type="checkbox"/>

		None										A great deal
(select one for each)		0	1	2	3	4	5	6	7	8	9	10
A8	Vibration is a motion. The motion may be seen or felt. How much <b>vibration</b> from the sonic booms did you see or feel in your home today?	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	8 <input type="checkbox"/>	9 <input type="checkbox"/>	10 <input type="checkbox"/>
A9	Rattle is a type of noise that can occur when objects move due to a vibration. How much <b>rattle</b> from the sonic booms did you experience in your home today?	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	8 <input type="checkbox"/>	9 <input type="checkbox"/>	10 <input type="checkbox"/>

A10 During the time you were at home today, were your windows closed most of the time or were they open most of the time? (select one)

- 1  Closed most of the time      2  Open most of the time

A11 Did you hear any noises today that might have been sonic booms but you are not sure? (select one)

- 1  Yes ----- A12 Please describe what that noise sounded like. \_\_\_\_\_  
2  No

A13 Please enter any additional comments. \_\_\_\_\_

## A-2b: Daily Summary Survey, Web Version

### WSPR Low Boom Response Pilot Program Subjective Response to Flight Booms Daily Summary Web Screen Shots

#### IDCODE

Interviewer Web EVENT\_NASA - ID - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - ID

pa-web.colο.supranet.net/IntWeb.dll?PROJECT=WYLE.EVENT\_NASA&QUESTNO=2&RECNUMB=000001842&THREADID=341014725393152090108&DATETIME=20120801095357&QLABEL=ENTYP&C

### NASA Sonic Boom Study

---

Please enter your 6-digit pin : [EX: AB1234]  
(Enter below)

Back Next

# A-2b: Daily Summary Survey, Web Version

## ENTYP

The screenshot shows a Mozilla Firefox browser window with the following details:

- Browser Title: Interviewer Web EVENT\_NASA - ENTYP - Mozilla Firefox
- Address Bar: pa-web.colorado.supranet.net/IntWeb.d/PIID=ab1234&PROJECT=WYLE.EVENT\_NASA&QUESTNO=1&RECNUMB=0000001842&THREADID=341014725393152090108&DATEIME=20120801095402&QLABI
- Page Title: NASA Sonic Boom Study
- Form Content:
  - Enter responses for...
  - (Select one)
  - Single Boom (each time you notice a sonic boom)
  - Daily Summary (at the end of each day after 6 P.M.)
  - Buttons: Back, Next

# A-2b: Daily Summary Survey, Web Version

## Daily Summary

### A1B

The screenshot shows a Mozilla Firefox browser window with the following details:

- Browser Title: Interviewer Web EVENT\_NASA - A1B - Mozilla Firefox
- Address Bar: ps-web.colc.supranet.net/int/Web.dl?ENTYP=2&PROJECT=WYLE.EVENT\_NASA&QUESTNO=2&RECNUMB=000001843&THREADID=341014723&1802100108&DATETIME=20120801100223&QLABEL
- Page Title: NASA Sonic Boom Study

The main content area contains a form with the following elements:

- Text label: Date of sonic boom:
- Text label: (Select below)
- Text label: Day
- Month selection: November
- Day selection: A vertical list of days from 04 to 22.
- Navigation: 'Back' and 'Next' buttons.

# A-2b: Daily Summary Survey, Web Version

## A2

Interviewer Web EVENT\_NASA - A2 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - A2

pa-web.colo.supranet.net/int/Web.dl?A1b=0&questlist=A1b%3B&SCREEN=1&PROJECT=WYLE.EVENT\_NASA&QUESTNO=14&RECNUMB=000001943&THREADID=341014723&218&210010&DATE1

### NASA Sonic Boom Study

---

Please indicate which parts of the day you were at home for at least one hour.

(Select all that apply)

- Morning (7:00AM to Noon)
- Afternoon (Noon to 5:00PM)
- Evening (5:00PM to 7:00PM)
- Not at home today

Back Next

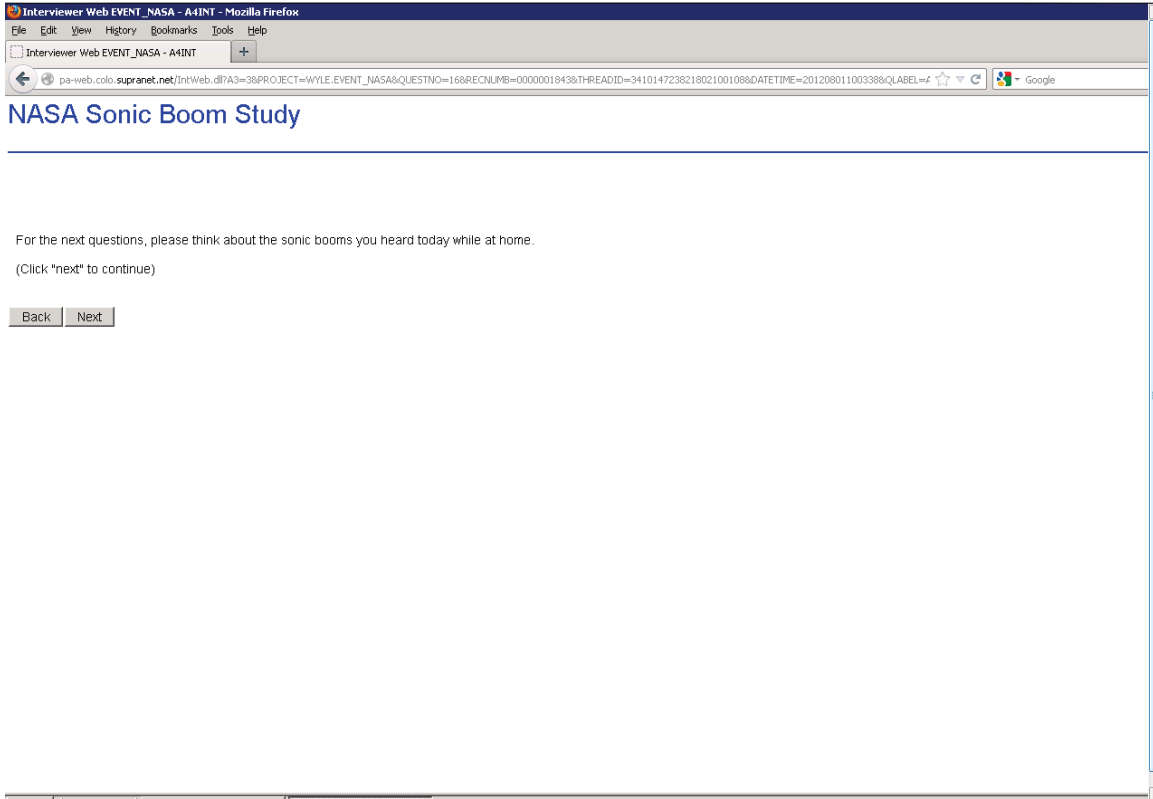
# A-2b: Daily Summary Survey, Web Version

A3

The screenshot shows a Mozilla Firefox browser window with the title "Interviewer Web EVENT\_NASA - A3". The address bar contains the URL "pa-web.colorado.supranet.net/int/Web.d/17A2%3A2=28PROJECT=WYLE.EVENT\_NASA&QUESTNO=15&RECNUMB=0000018438&THREADID=3410147238218021001089&DATETIME=20120801100306&QLA". The page content includes the heading "NASA Sonic Boom Study" followed by a question: "During the time you were at home today, how many sonic booms did you hear? (Enter a number)". Below the question is a text input field. At the bottom of the form are two buttons labeled "Back" and "Next".

# A-2b: Daily Summary Survey, Web Version

## A4INT





# A-2b: Daily Summary Survey, Web Version

A4

The screenshot shows a Mozilla Firefox browser window with the title "Interviewer Web EVENT\_NASA - A4". The address bar contains the URL "pa-web.colorado.edu/supranet.net/IntWeb.dillPROJECT=WYLE\_EVENT\_NASA&QUESTNO=188&RECNUMB=0000001843&THREADID=341014723821802100108&DATETIME=20120801100407&QLABEL=A4INT&". The page title is "NASA Sonic Boom Study".

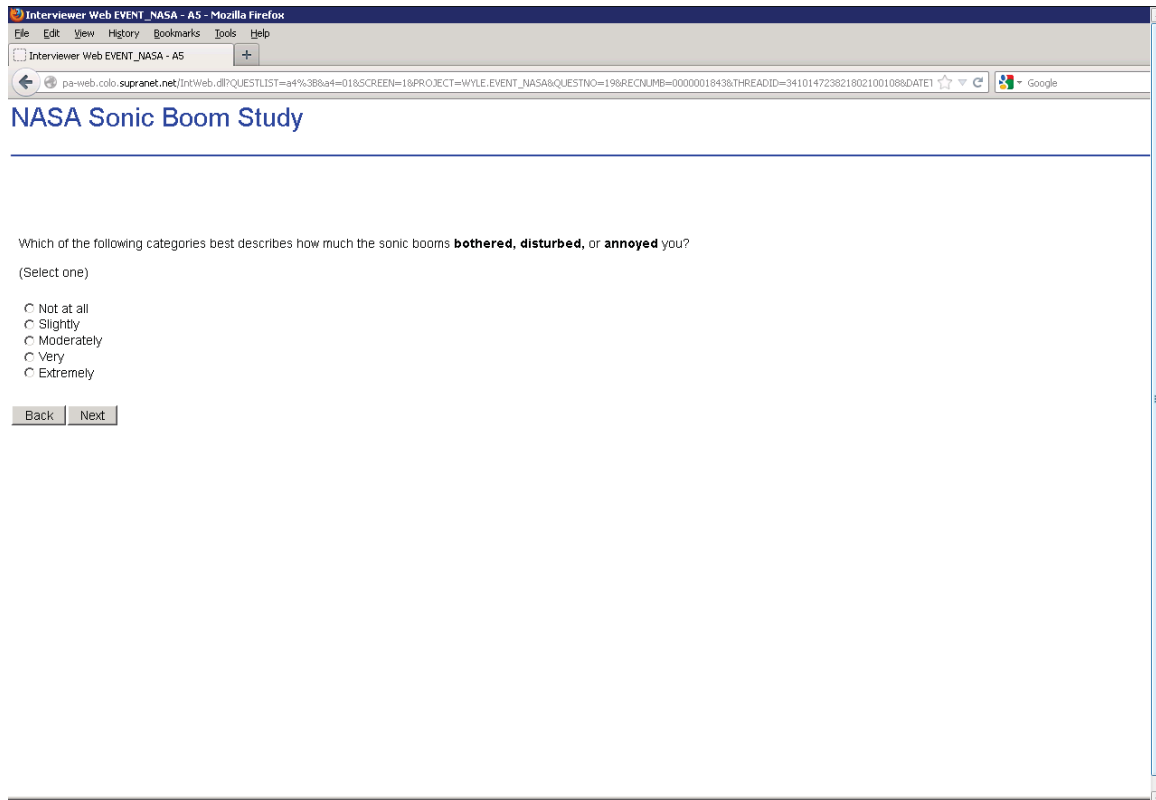
The survey question is: "How much did the sonic booms **bother, disturb, or annoy you?**"

The response scale is a horizontal line with 11 radio buttons, numbered 0 to 10. "Not at all" is positioned above the 0 button, and "Extremely" is positioned above the 10 button.

Below the scale are two buttons: "Back" and "Next".

# A-2b: Daily Summary Survey, Web Version

A5



# A-2b: Daily Summary Survey, Web Version

## A6-A7

Interviewer Web EVENT\_NASA - A6 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - A6

ps-web.colorado.supranet.net/intWeb.dl?AS=38PROJECT=WYLE.EVENT\_NASA&QUESTNO=20&RECNUMB=000001843&THREADID=341014723821802100108&DATETIME=20120801100514&QLABEL=& Google

### NASA Sonic Boom Study

	Not at all	0	1	2	3	4	5	6	7	8	9	10	Extremely
How <b>loud</b> were the sonic booms?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How much did the sonic booms <b>interfere</b> with your activities?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

# A-2b: Daily Summary Survey, Web Version

## A8-A9

Interviewer Web EVENT\_NASA - AB - Mozilla Firefox

Interviewer Web EVENT\_NASA - AB

pa-web.colο.supranet.net/int/Web.dif?QUESTLIST=66%3B7%3B8a6=028a7=028SCREEN=18PROJECT=WYLE\_EVENT\_NASA9QUESTNO=218RECNUMB=0000018438THREADID=34101472382180 Google

### NASA Sonic Boom Study

	None										A great deal
	0	1	2	3	4	5	6	7	8	9	10
Vibration is a motion. The motion may be seen or felt. How much <b>vibration</b> from the sonic booms did you see or feel in your home today?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rattle is a type of noise that can occur when objects move due to a vibration. How much <b>rattle</b> from the sonic booms did you experience in your home today?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Back Next

# A-2b: Daily Summary Survey, Web Version

A10

The screenshot shows a Mozilla Firefox browser window titled "Interviewer Web EVENT\_NASA - A10". The address bar contains the URL: "pa-web.colo.supranet.net/IntWeb.dll?QUESTLIST=a8%3b9%3b8a8-01&a9=01&SCREEN=1&PROJECT=WILE\_EVENT\_NASA&QUESTNO=23&RECNUM=000001843&THREADID=34101472382180". The page title is "NASA Sonic Boom Study". The main content area contains the following text:

During the time you were at home today, were your windows closed most of the time or were they open most of the time?  
(Select one)

- Closed most of the time
- Open most of the time

At the bottom of the question area, there are two buttons: "Back" and "Next".

# A-2b: Daily Summary Survey, Web Version

## A11

The screenshot shows a Mozilla Firefox browser window. The title bar reads "Interviewer Web EVENT\_NASA - A11 - Mozilla Firefox". The address bar contains the URL "pa-web.colorado.edu/supranet.net/IntWeb.dl?A10=1&PROJECT=WYLE.EVENT\_NASA&QUESTNO=25&RECNUMB=0000001843&THREADID=3410147238218021001088&DATETIME=20120801100701&QLABEL=" and the search engine is set to Google. The page content includes the heading "NASA Sonic Boom Study" followed by a survey question: "Did you hear any noises today that might have been sonic booms but you are not sure?". Below the question is a "(Select one)" label and two radio button options: "Yes" and "No". At the bottom of the question area are two buttons: "Back" and "Next".

Interviewer Web EVENT\_NASA - A11 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - A11

pa-web.colorado.edu/supranet.net/IntWeb.dl?A10=1&PROJECT=WYLE.EVENT\_NASA&QUESTNO=25&RECNUMB=0000001843&THREADID=3410147238218021001088&DATETIME=20120801100701&QLABEL= Google

### NASA Sonic Boom Study

Did you hear any noises today that might have been sonic booms but you are not sure?

(Select one)

Yes

No

Back Next

# A-2b: Daily Summary Survey, Web Version

O\_A12

The screenshot shows a Mozilla Firefox browser window with the title "Interviewer Web EVENT\_NASA - A12 - Mozilla Firefox". The address bar contains the URL "pa-web.colorado.supranet.net/int/Web.d?A11=1&PROJECT=WYLE.EVENT\_NASA&QUESTNO=26&RECNUMB=000001843&THREADID=341014723&21802100108&DATEIME=20120801100735&QLABEL=" and the Google search engine logo. The page content includes the heading "NASA Sonic Boom Study" followed by a horizontal line. Below the line, the text "Please describe what that noise sounded like:" is displayed, followed by "(Enter below)". A text input field is provided for the user's response. At the bottom of the form, there are two buttons: "Back" and "Next".



# A-2b: Daily Summary Survey, Web Version

## Final Question- both surveys

A13

Interviewer Web EVENT\_NASA - A13 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Interviewer Web EVENT\_NASA - A13

pa-web.colο.supranet.net/IntWeb.dtl?QUESTLIST=e8%38e9%38e9=05&SCREEN=18&PROJECT=WYLE.EVENT\_NASA&QUESTNO=128&RECNUMB=0000001842&THREADID=34101472539315

### NASA Sonic Boom Study

Please enter any additional comments:  
(Enter below)

Enter comments

No comments

## A-2c: Daily Summary Survey, Apple Version

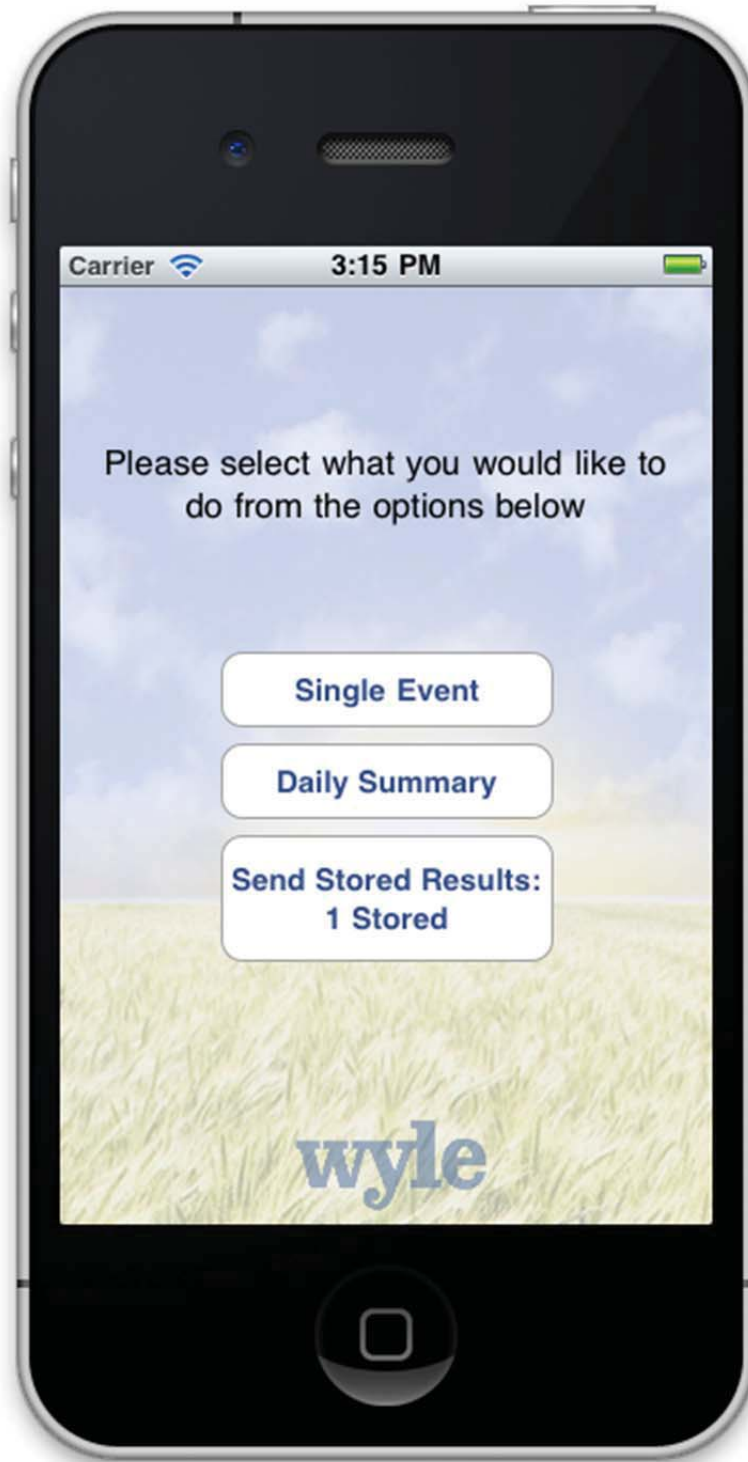


Figure A2c-1 – Start Screen for Daily Summary Mode

## A-2c: Daily Summary Survey, Apple Version



Figure A2c-2 – Date Selection Screen for Daily Summary Mode

## A-2c: Daily Summary Survey, Apple Version

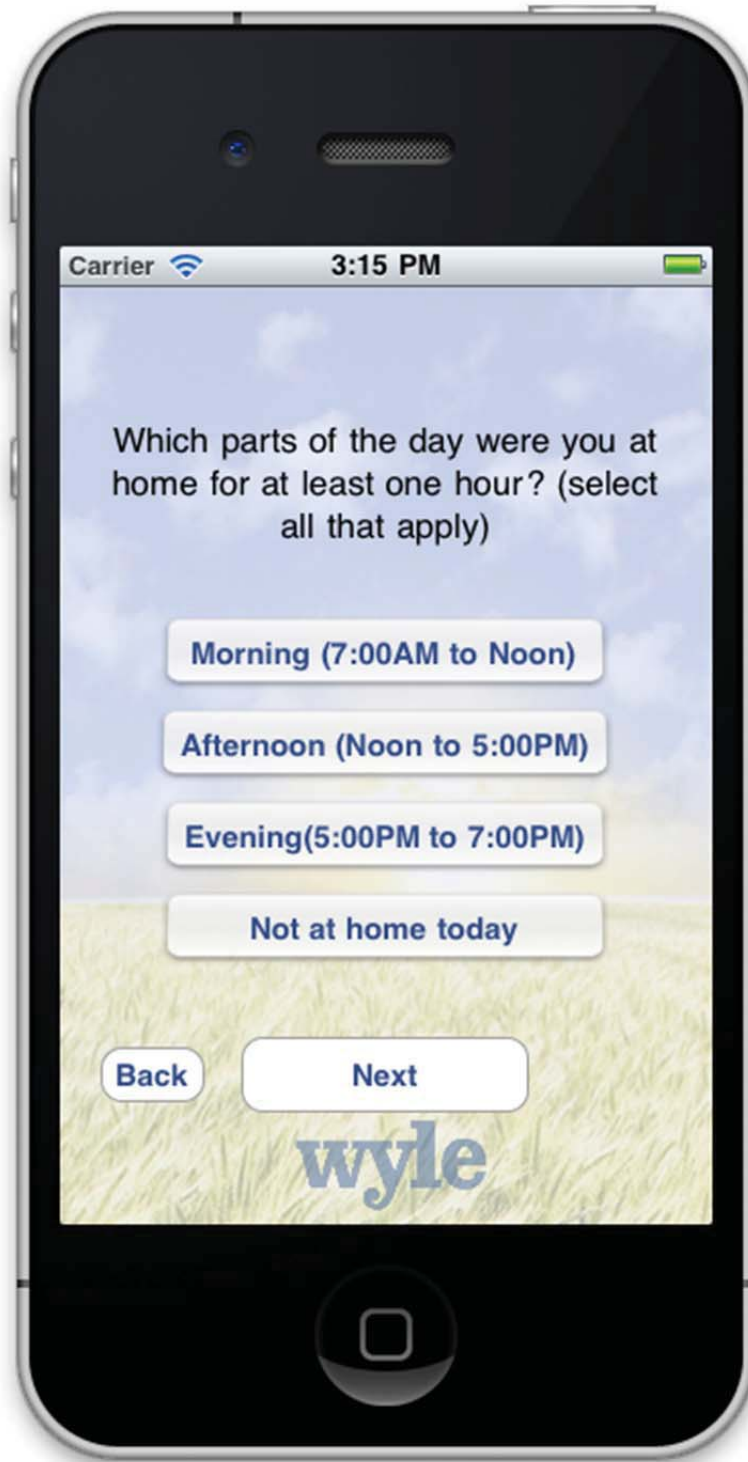


Figure A2c-3 – Times respondent was home multiple selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

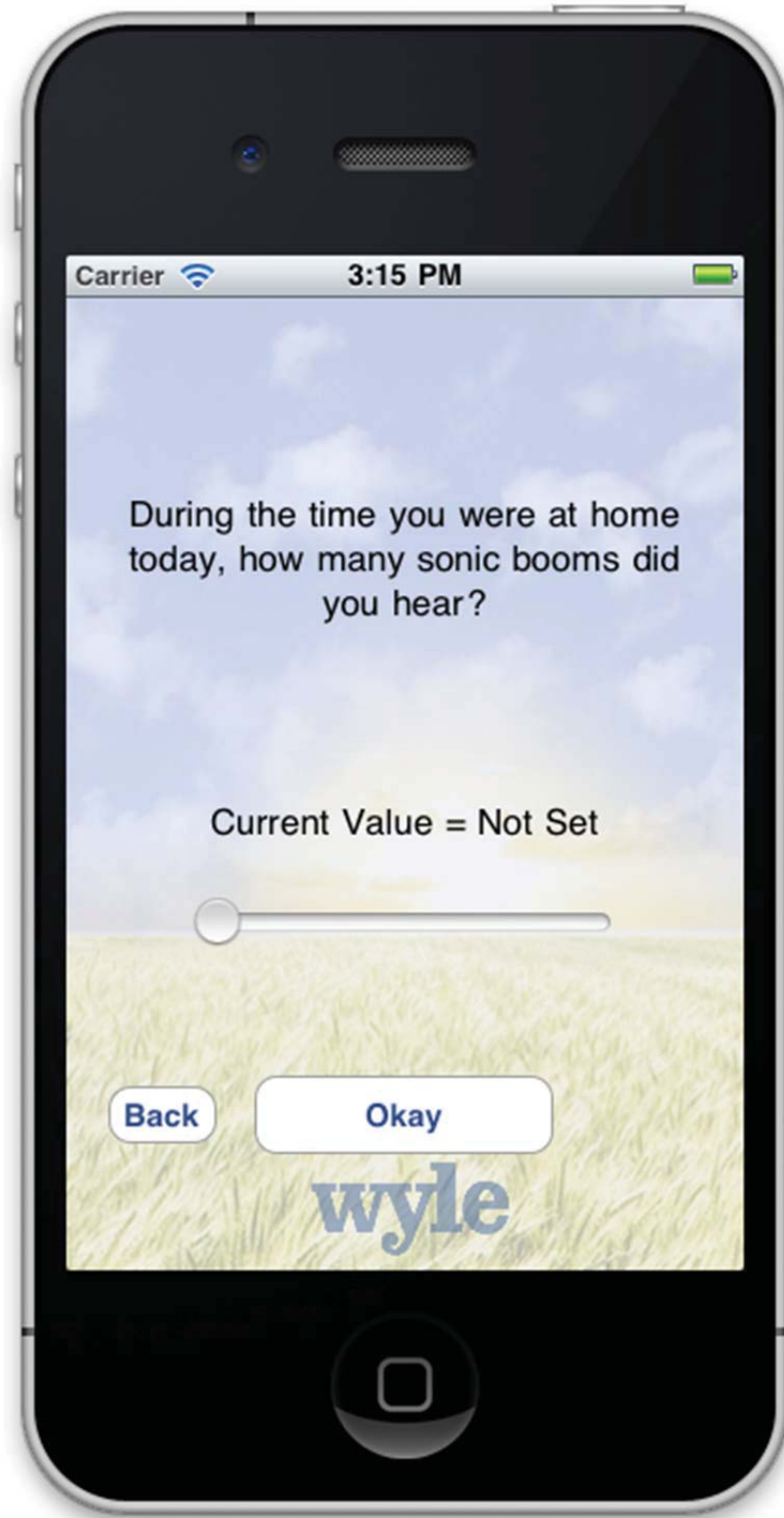


Figure A2c-4 – Number of Booms slider selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

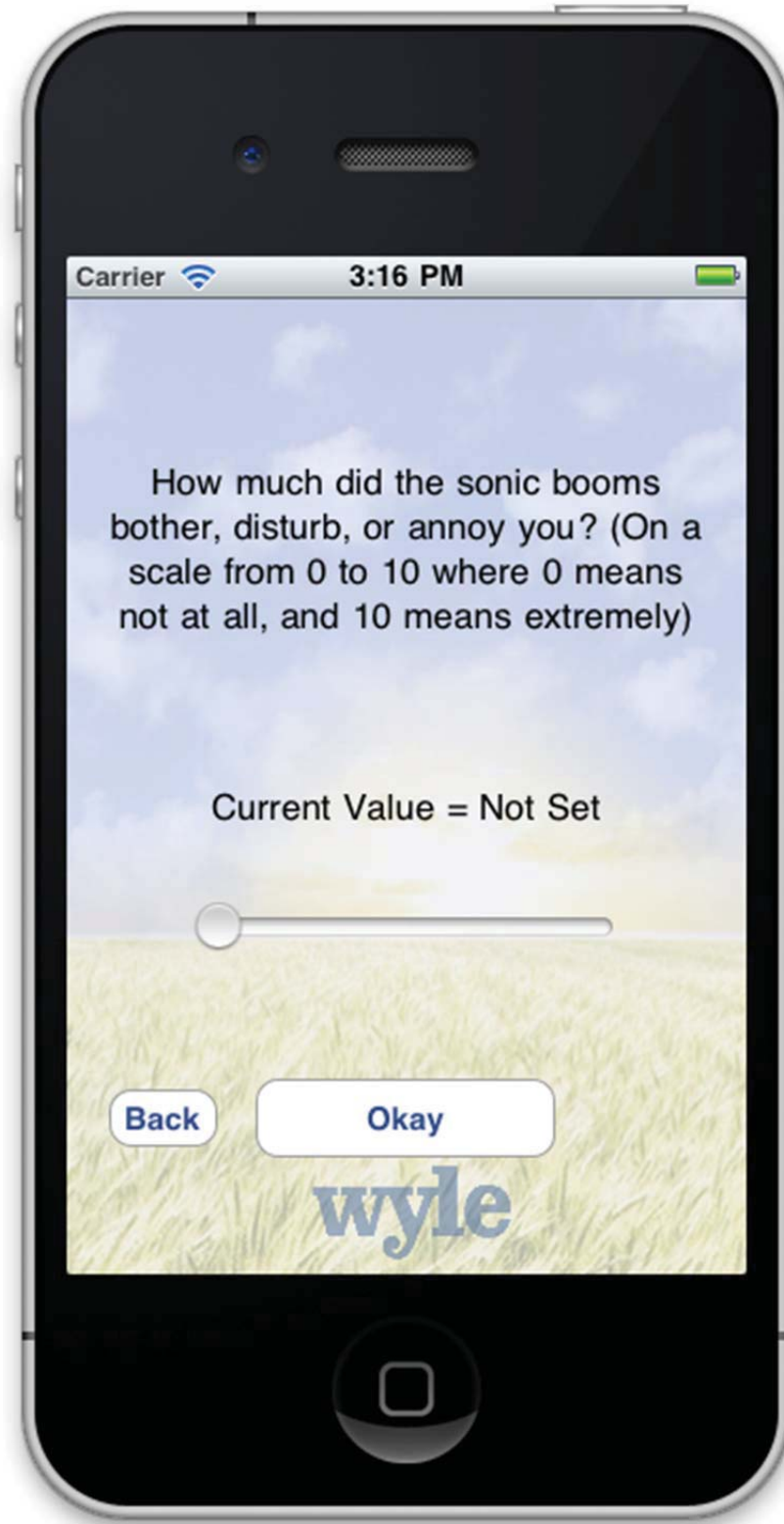


Figure A2c-5 – Bother, Disturb, or Annoy slider selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

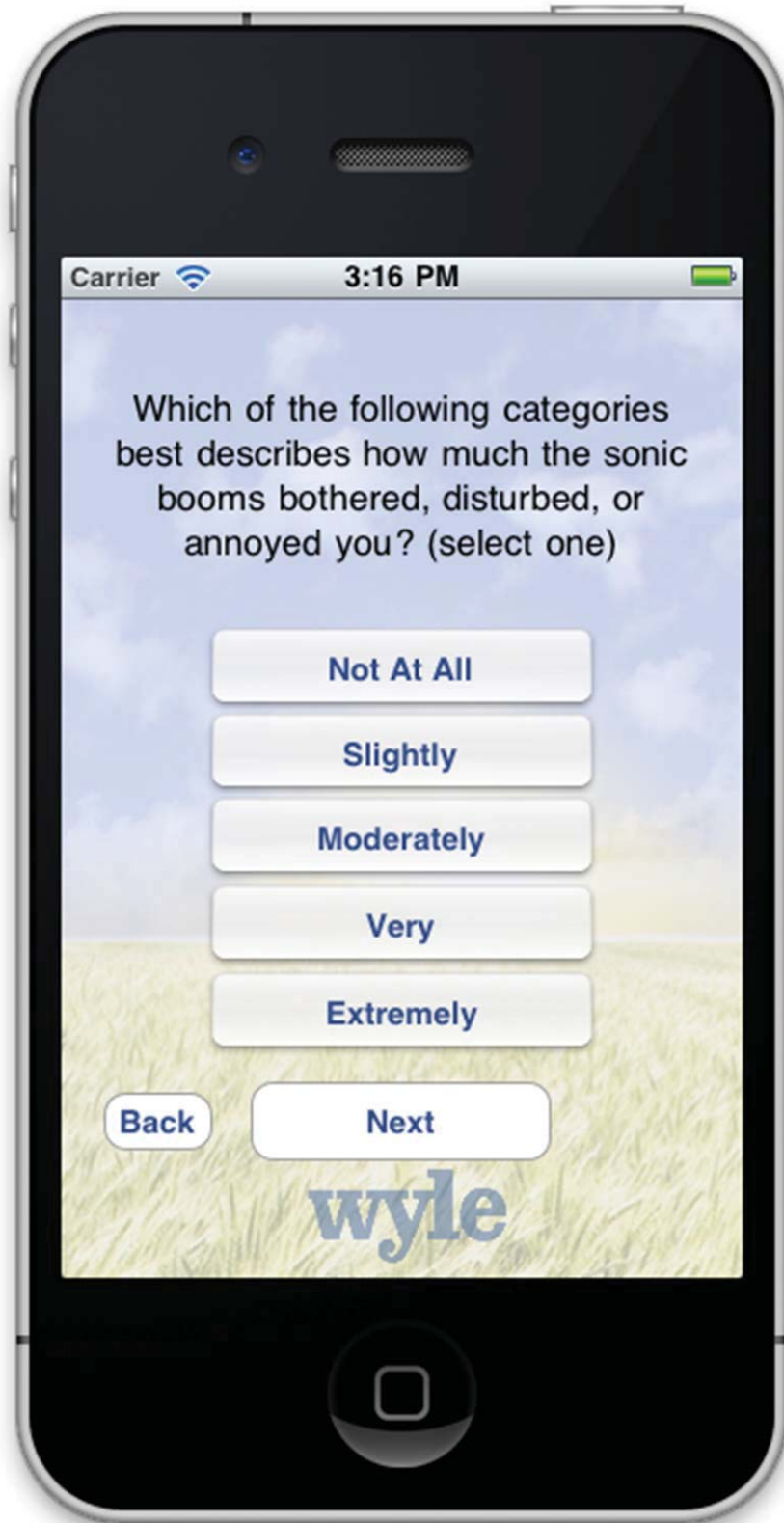


Figure A2c-6 – Bother, Disturb, or Annoy second question format for Daily Summary mode



## A-2c: Daily Summary Survey, Apple Version

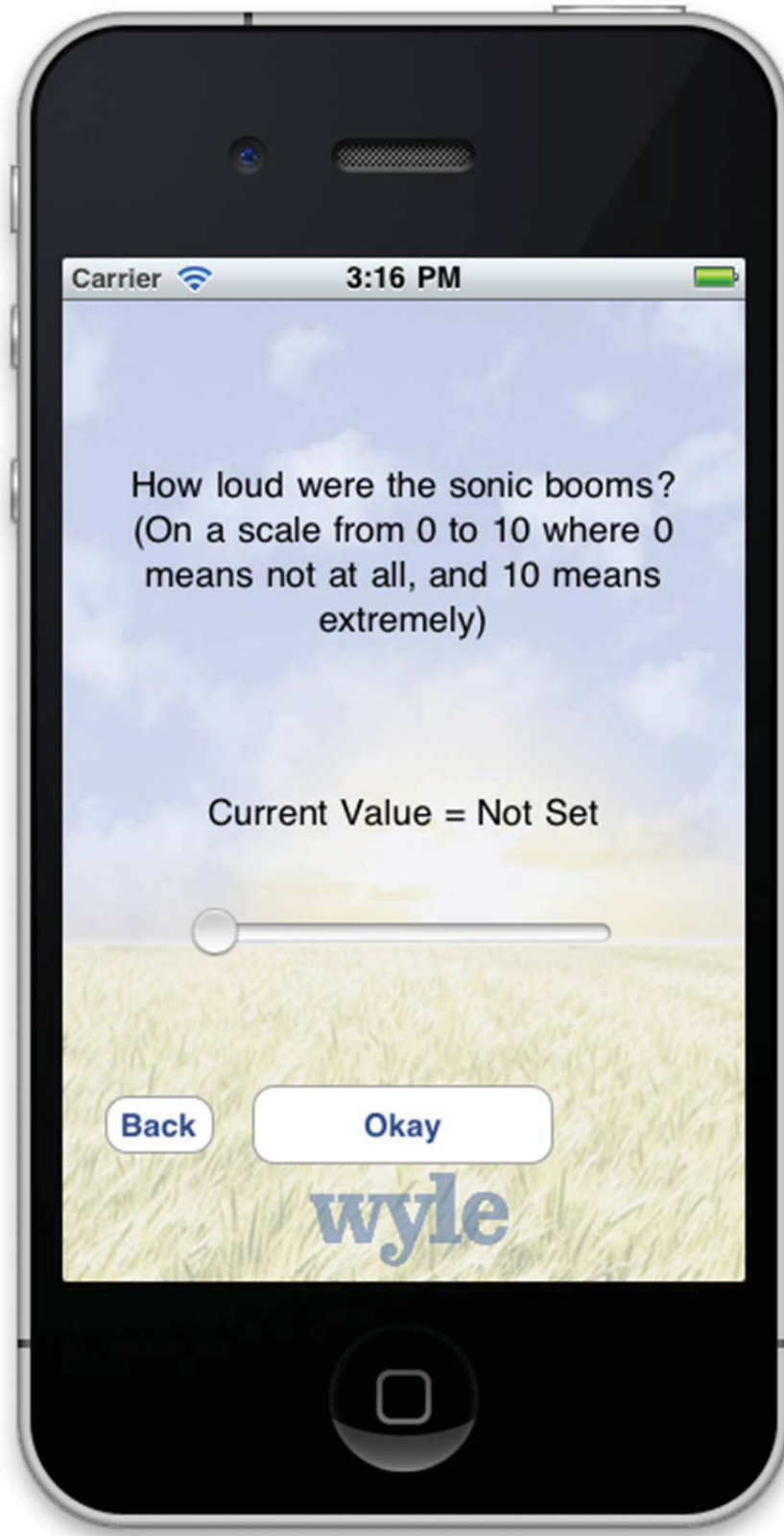


Figure A2c-7 – Loudness slider selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

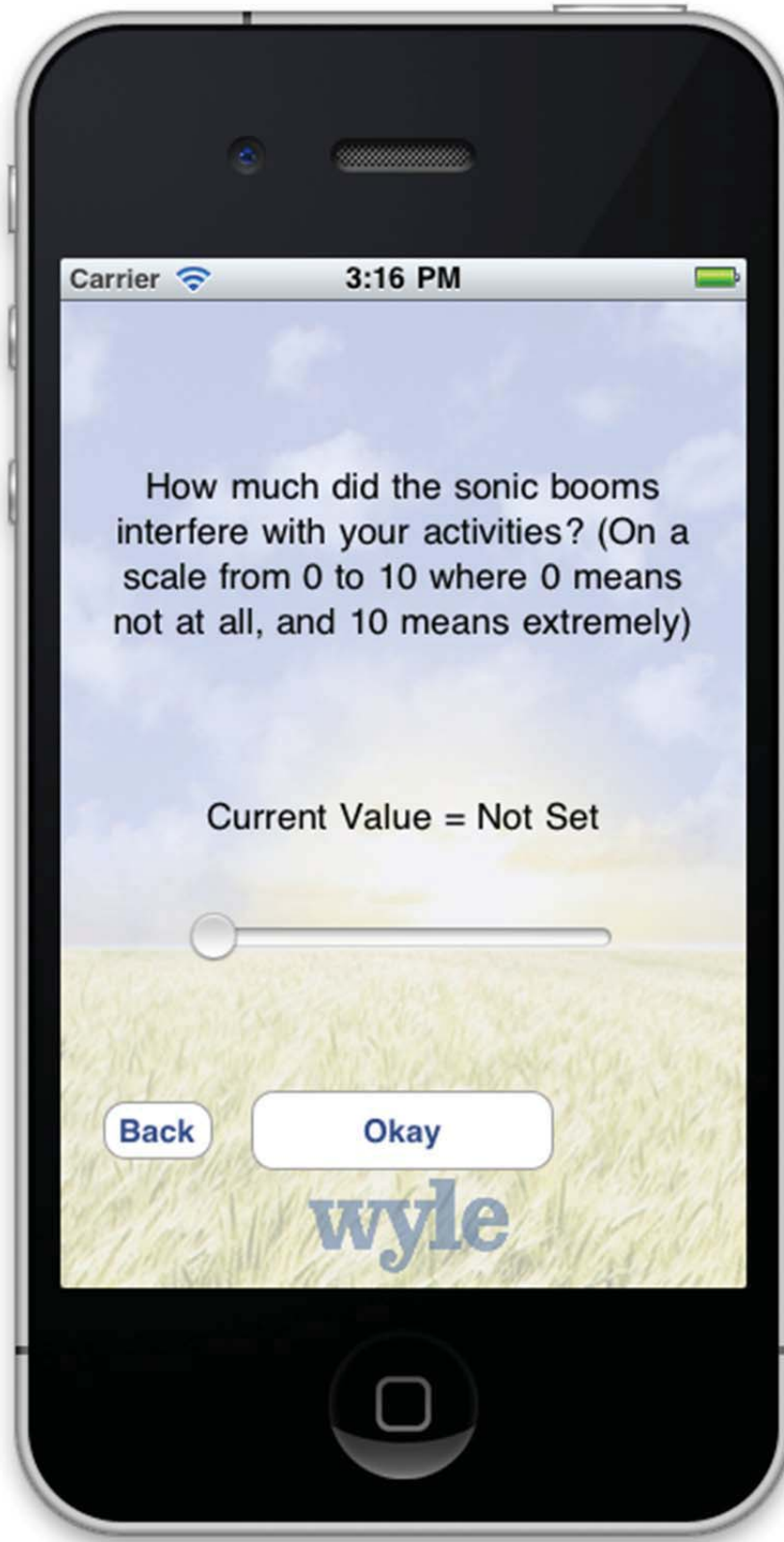


Figure A2c-8 - Interference slider selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

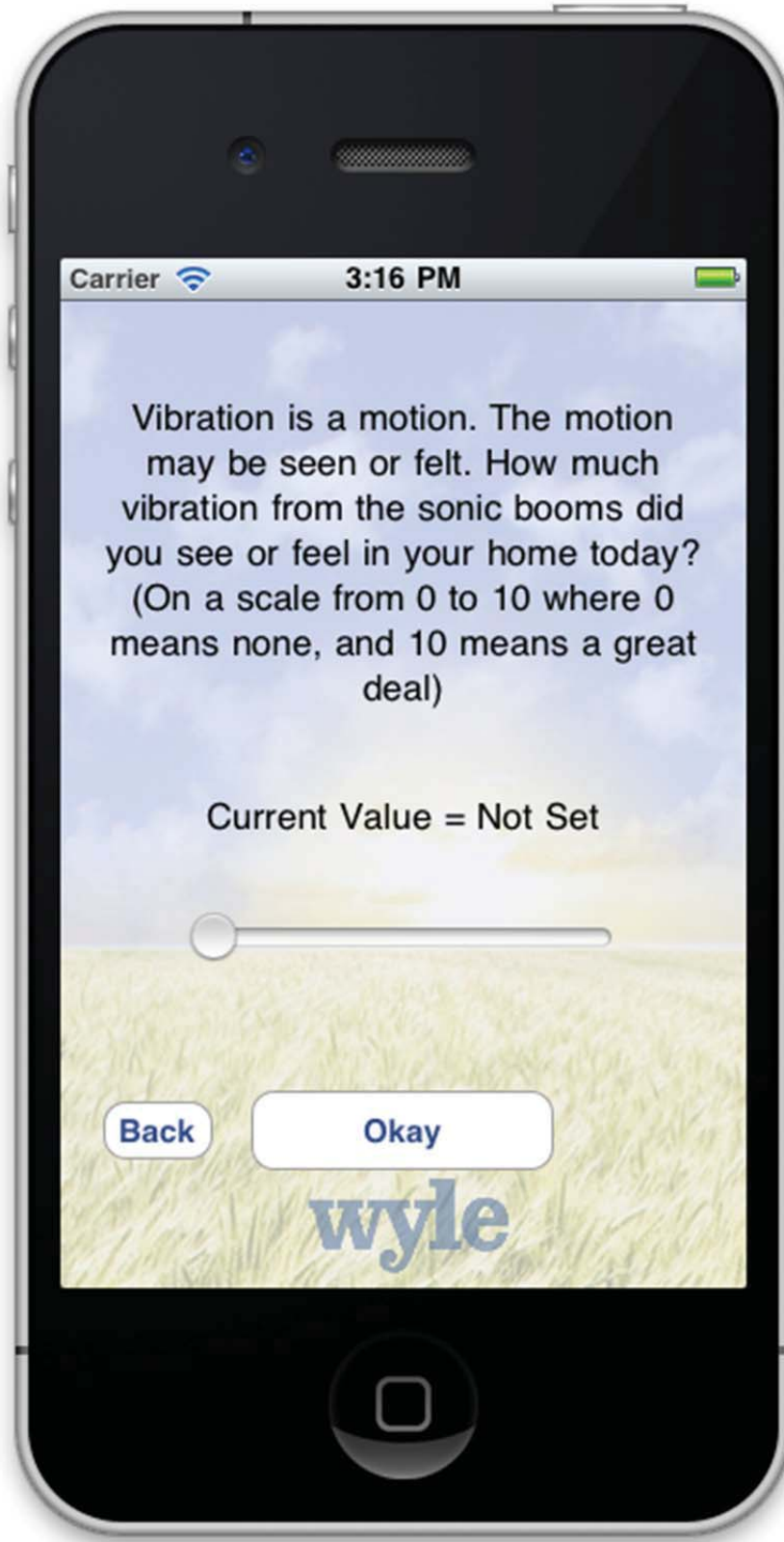


Figure A2c-9 – Vibration slider selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

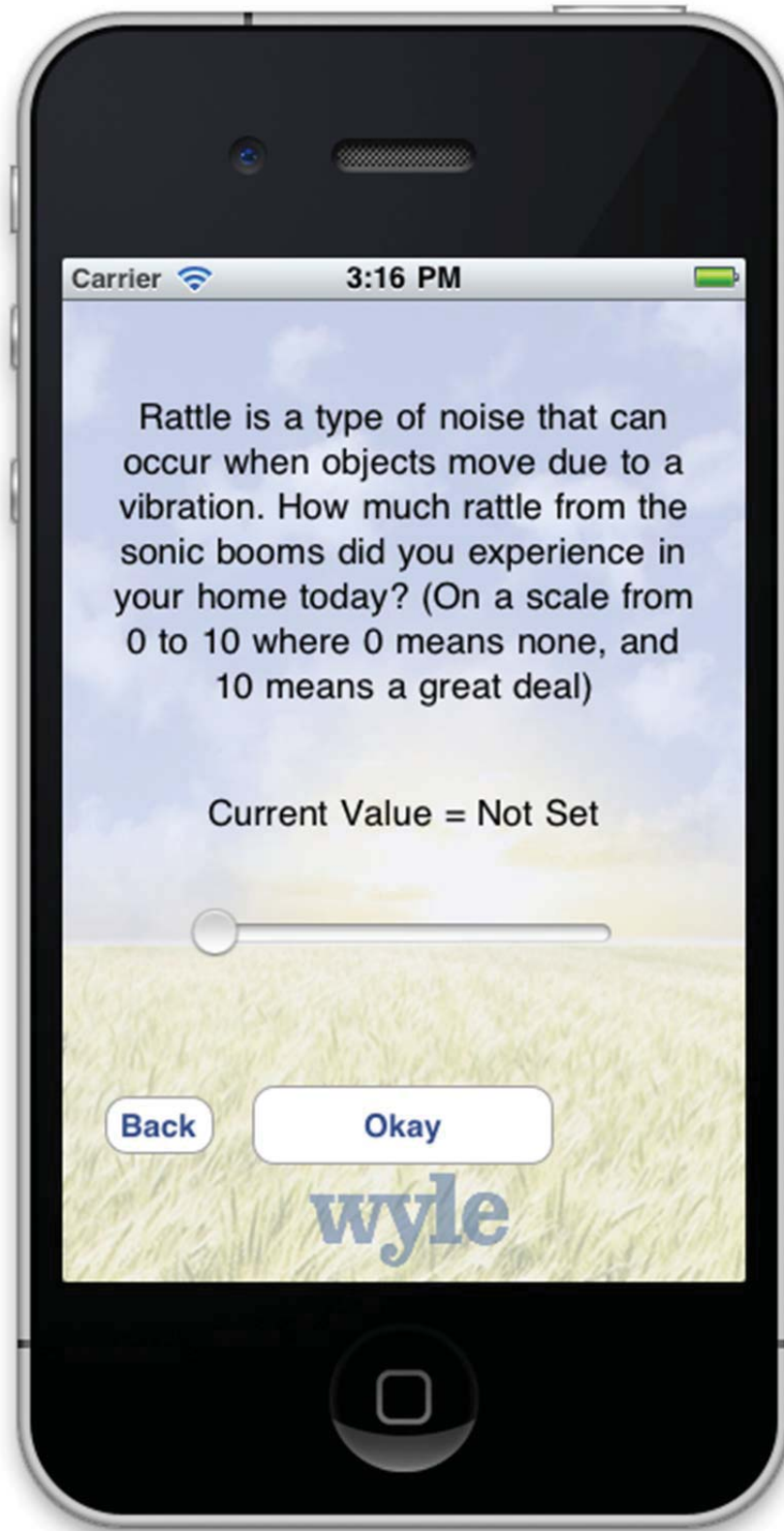


Figure A2c-10 – Rattle slider selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

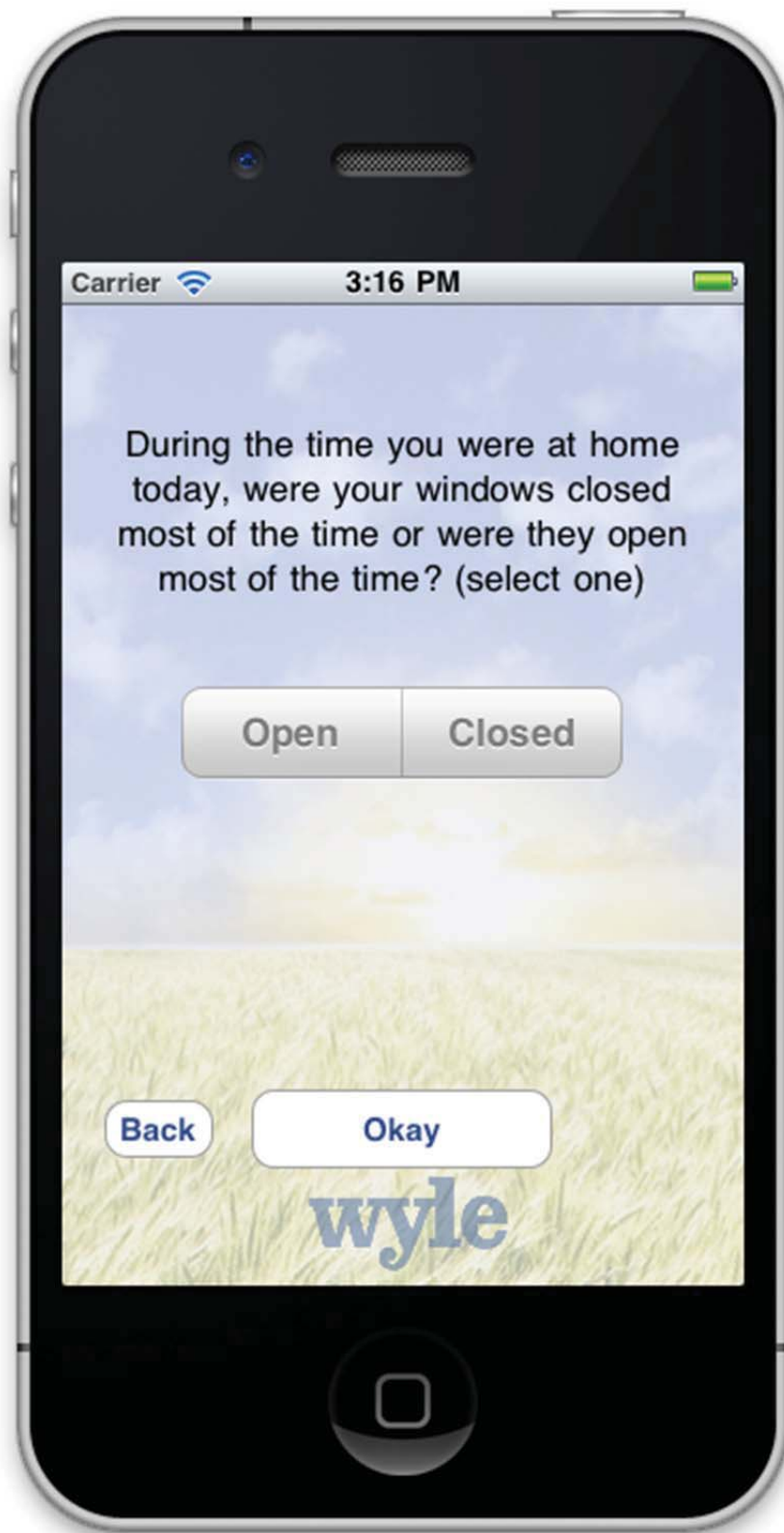


Figure A2c-11 – Window position selection screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

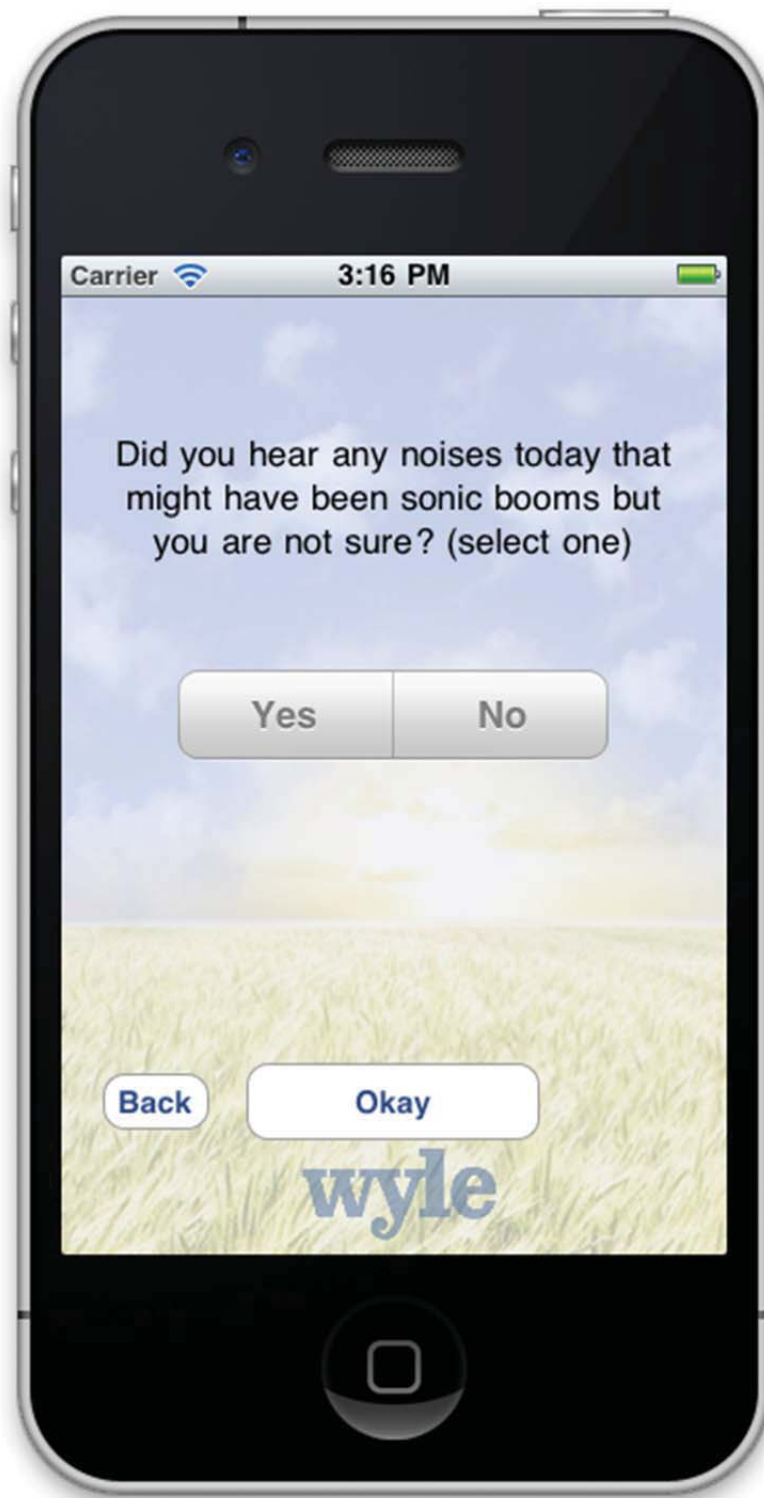


Figure A2c-12 – Additional noises selection screen for Daily Summary mode

Selecting “Yes” on the screen in figure A2c-12 causes an instance of Figure A2c-13 to be displayed to the respondent.



## A-2c: Daily Summary Survey, Apple Version

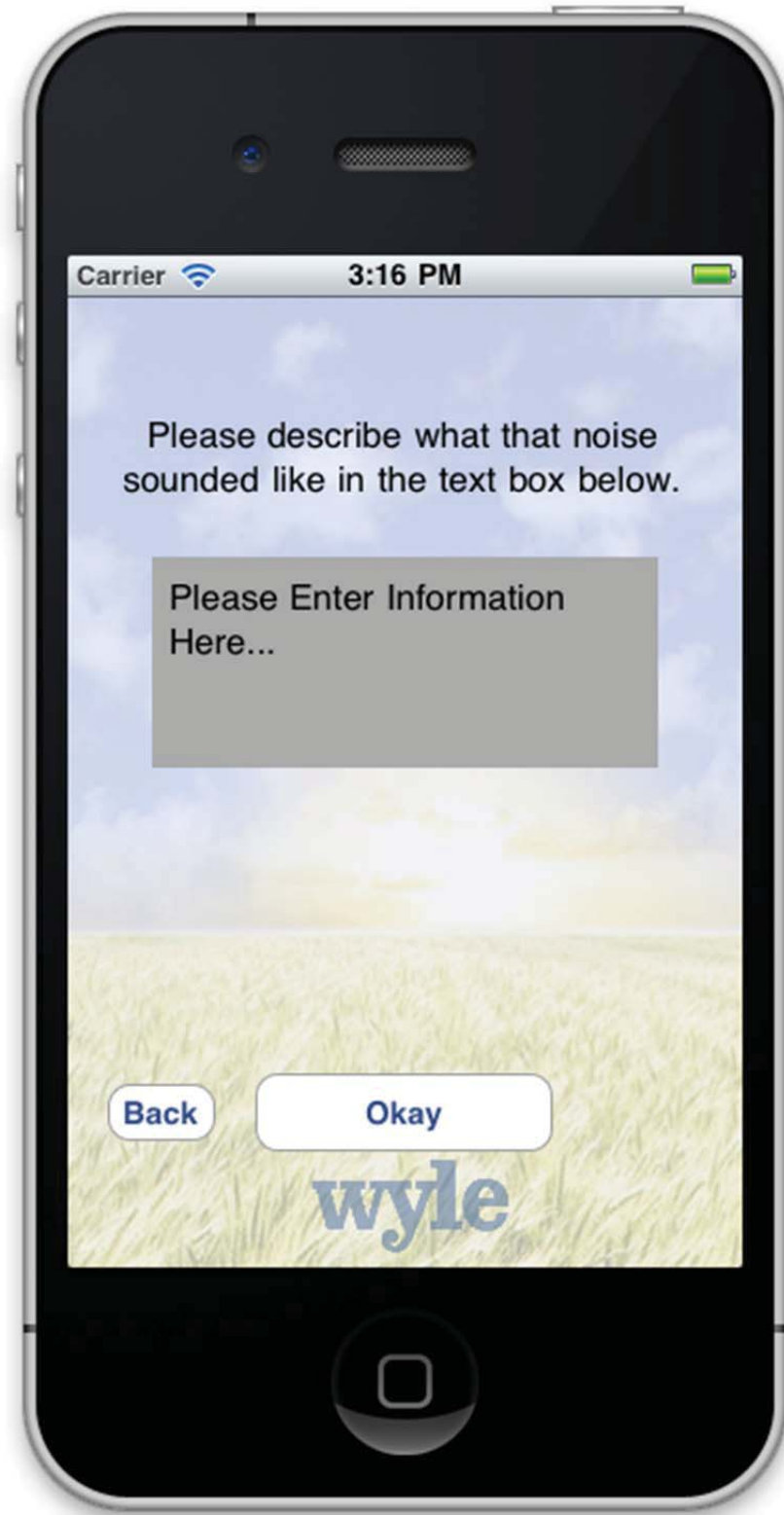


Figure A2c-13 – Additional Noise description entry screen for Daily Summary mode



## A-2c: Daily Summary Survey, Apple Version

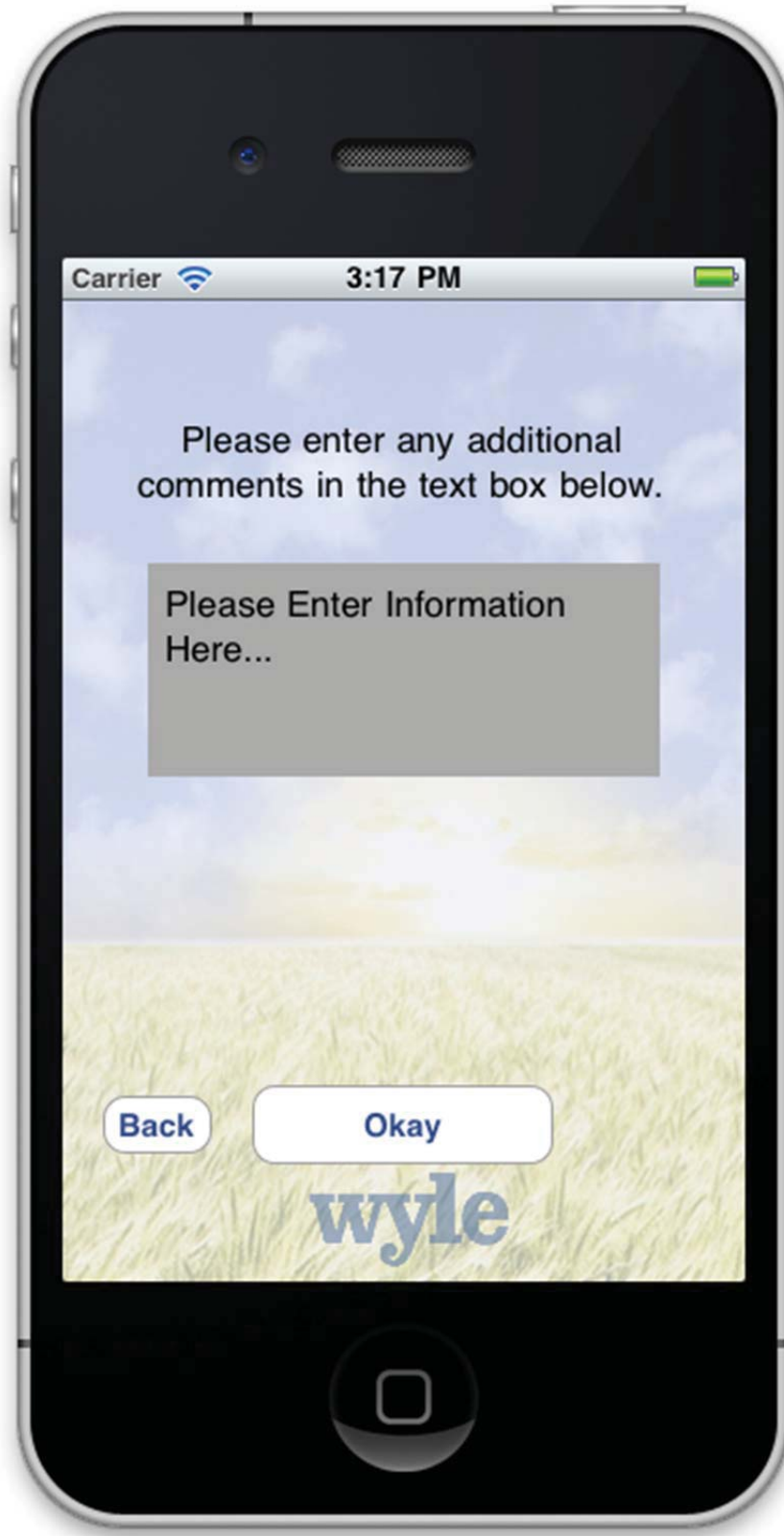


Figure A2c-14 – Comment entry screen for Daily Summary mode

## A-2c: Daily Summary Survey, Apple Version

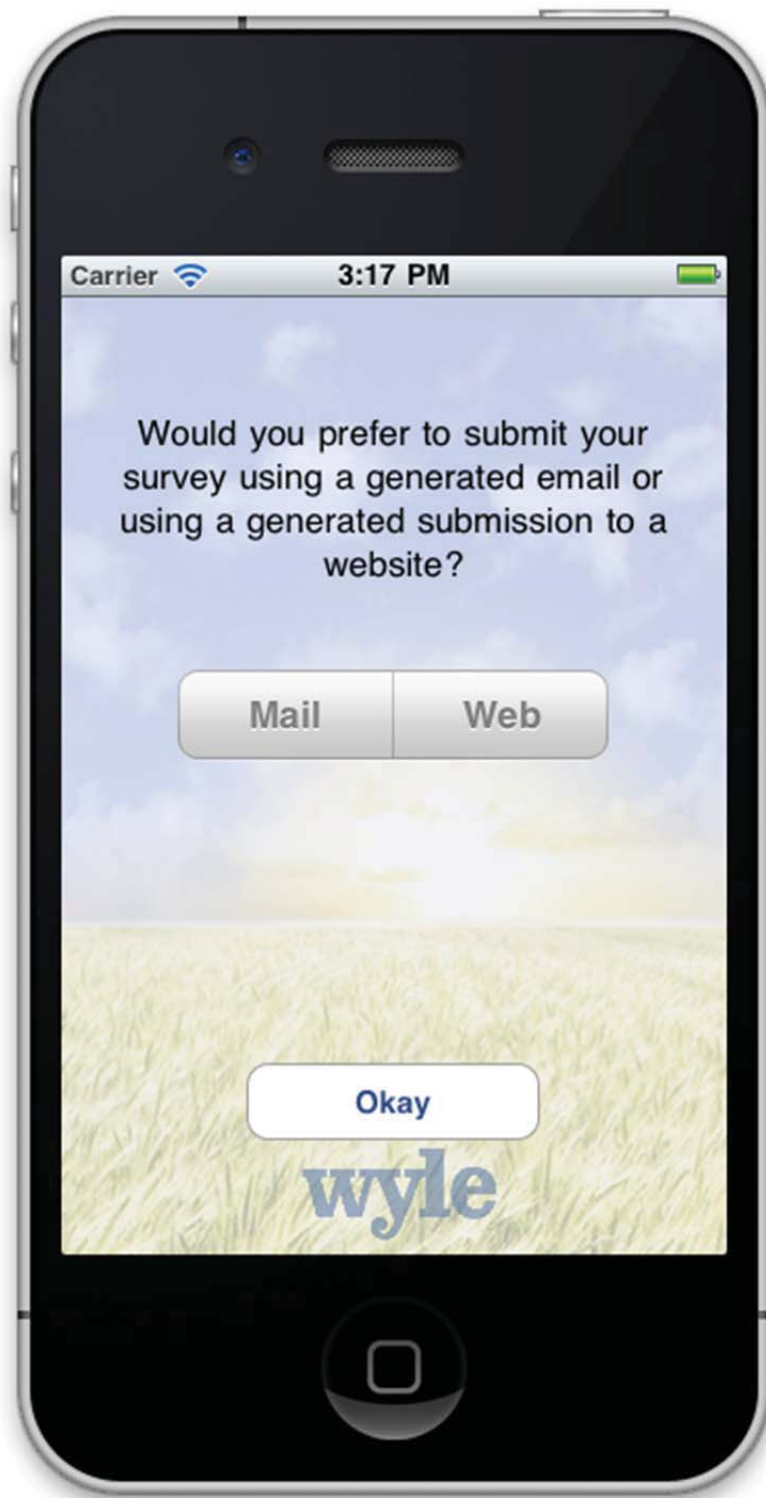


Figure A2c-15 – Web based or email based selection screen for Daily Summary mode

Web selection automatically submits results and closes the application. Mail selection causes figure A16 to be instantiated and displayed.

## A-2c: Daily Summary Survey, Apple Version

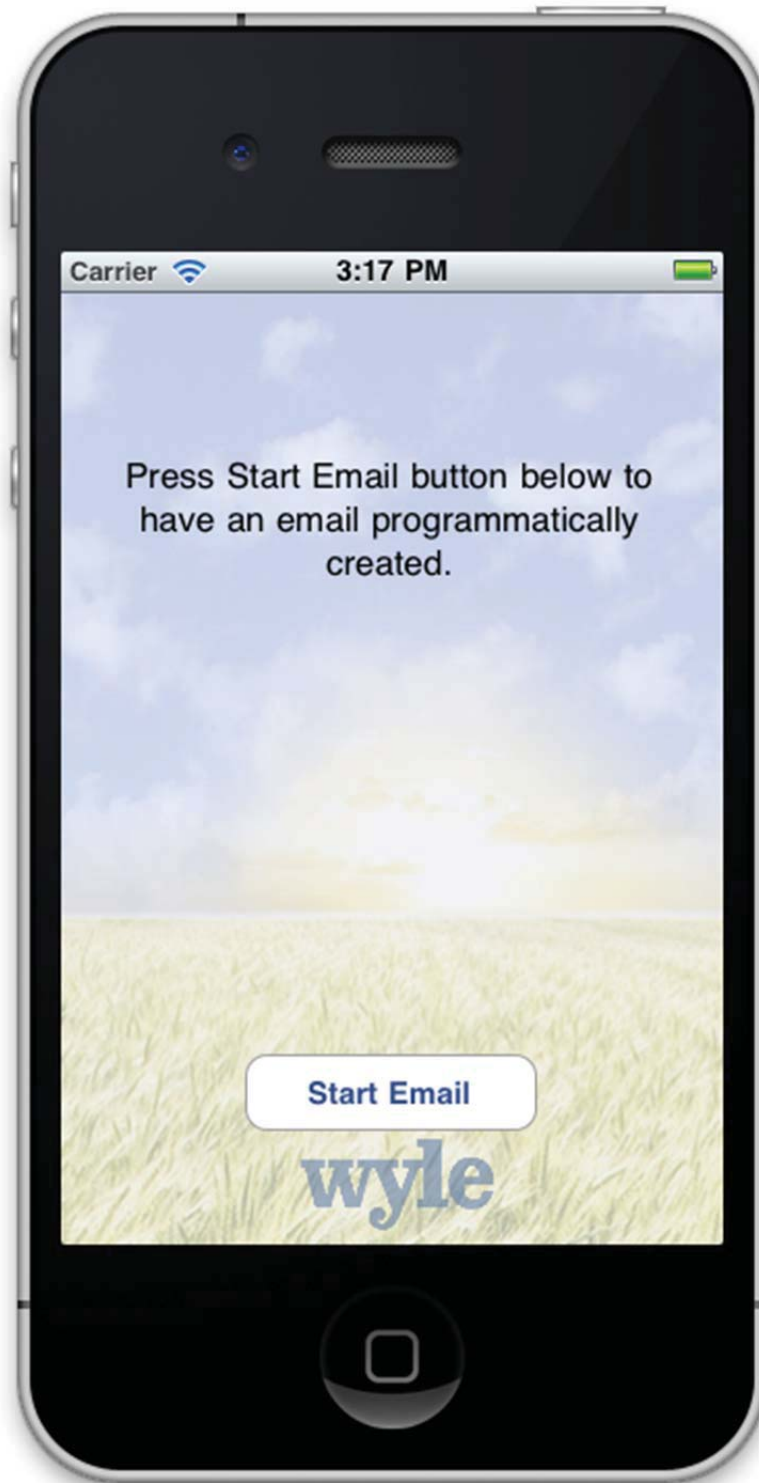


Figure A2c-16 – Start Email creation screen for Daily Summary mode

Pressing the start email button triggers the programmatic creation of an email to be sent containing the survey result data

## A-2c: Daily Summary Survey, Apple Version

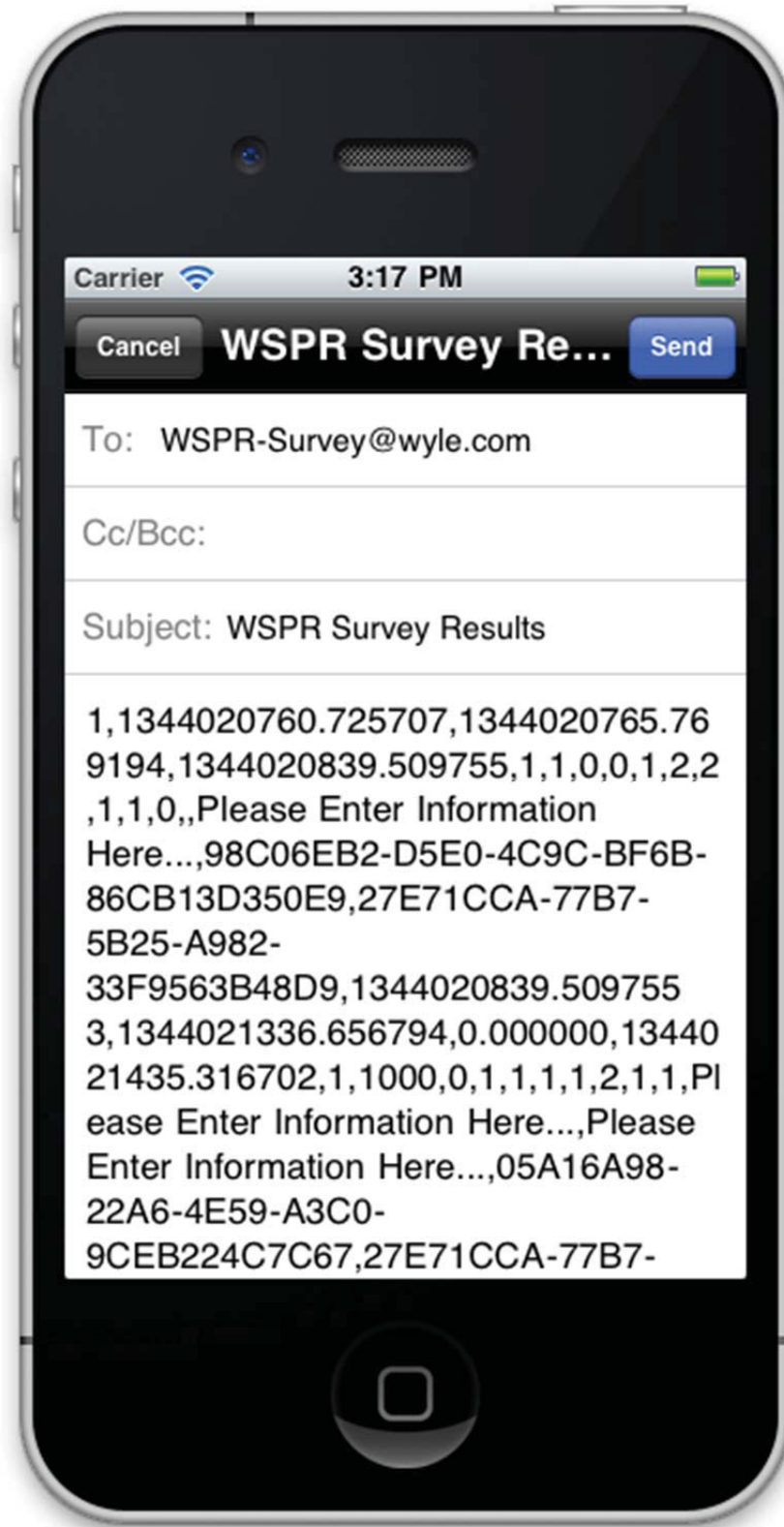


Figure A2c-17 – Sample Daily Summary mode survey email.

## A-3: Baseline Survey

### WSPR Sonic Boom Study Baseline Survey Codebook

#### NOTE:

- Variable names are in bold type.
- Questions were asked of all respondents unless indicated otherwise.
- A code of (-4) means skip due to a question removed during field period.
- A code of (-5) means a respondent indicated that the question was not applicable.
- A code of (-6) means a logical programmed skip.
- A code of (-9) means refused.

### Survey File

Data file: WSPR Low Boom Response Pilot Program\_Baseline Data\_31Oct2011.xlsx

Open-end file: WSPR Low Boom Response Pilot Program\_Baseline Open ends\_31Oct2011.xlsx

### Introduction

DIALSCR Hello, my name is \_\_\_\_\_ and I'm calling on behalf of NASA. May I speak with *[RESPONDENT NAME]*?

1 Yes

2 No *[PROBE FOR A BETTER TIME TO CALL R]*

INTRO A while back you expressed interest in a research study about noise from sonic booms at Edwards Air Force Base. You have been selected to participate in the study, which is being conducted for research purposes to learn about people's reactions to sonic booms.

I'm calling now for two reasons. First, all individuals who are eligible and agree to participate in the full study will receive a \$50 VISA gift card. We know your time is valuable and we appreciate your help with this research.

Second, I have some questions about your neighborhood and your attitudes about noise that will help us understand information we collect later.

*[IF NEEDED: YOU WOULD RECEIVE THE GIFT CARD WHEN THE STUDY ENDS.]*

1 Continue

## A-3: Baseline Survey

INTRO2 Before we begin, I need to tell you that your participation is voluntary and confidential. If we get to a question you do not want to answer, just say so and we'll go to the next question. The results of the study will be summarized so that the answers you provide cannot be associated with you or anyone in your household. This call should take about 15 minutes of your time. You must be 18 years of age or older to consent to participate in this research. Responding to the survey questions implies your consent to participate. This team is affiliated with researchers from Penn State University. If you have any questions about this study, you can contact Kathleen Hodgdon of Penn State at [kkh2@psu.edu](mailto:kkh2@psu.edu) or call (814) 865-2447.

The call will be recorded and monitored for quality control purposes.

1 Continue

A1 Before we begin I need to confirm your street address. We have your address as [ADDRESS]. Is this correct? [SELECT ONE]

1 Yes [SKIP TO A4]  
2 No

A2 Are you still living on Edwards Air Force Base? [SELECT ONE]

1 Yes  
2 No [SKIP TO NOTQAL]  
-6 Programmed skip

A3 Can I please get your current address? [RECORD NEW ADDRESS]

*[IF NEEDED: WE NEED THIS INFORMATION SO THAT WE CAN SEND YOU PRINTED INSTRUCTIONS AND OTHER MATERIALS THAT YOU'LL NEED TO PARTICIPATE IN THE STUDY.]*

*[SEE RESPONSES IN OPEN END FILE]*

A4 We are interested in the noises that people hear in their neighborhood. Do you think your neighborhood is quiet or noisy or about average? [SELECT ONE]

1 Quiet  
2 Noisy  
3 Average

### A-3: Baseline Survey

A5 Can you tell me more about why you feel that way? *[RECORD VERBATIM RESPONSE]*

*[SEE RESPONSES IN OPEN END FILE]*

A6 I'm going to read several statements. For each statement, please tell me if you strongly disagree, moderately disagree, neither agree nor disagree, moderately agree or strongly agree. *[SELECT ONE]*

**A6A** I believe that people have a hard time getting used to noise.

**A6B** I believe that with time most people adapt to noise.

**A6C** I believe that with time I can adapt to noise.

**A6D** I believe that with time I can get used to even the loudest noise.

For A6A through A6D

- 1 Strongly disagree
- 2 Moderately disagree
- 3 Neither agree nor disagree
- 4 Moderately agree
- 5 Strongly agree

#### Experience with Neighborhood Noises

B1 I am going to read a list of noises that might occur in your neighborhood. Please tell me how much each noise bothers, disturbs or annoys you. Use a scale from 0 to 10 where 0 means "not at all bothered or annoyed" and 10 means "extremely bothered or annoyed."

When you are at home, how much does noise from *[ NOISE SOURCE]* bother, disturb, or annoy you? *[SELECT RATING]*

For B1A through B1F

\_\_\_\_\_ *[0-10 RATING]*  
-5 Not applicable

**B1A** Barking Dogs

**B1B** Thunder

**B1C** Street traffic such as cars, trucks or motorcycles

**B1D** Commercial Aircraft noise

**B1E** Sonic booms

**B1F** Military aircraft noise, not including sonic boom noise



## A-3: Baseline Survey

### Experience with Sonic Booms

- C1** The next questions ask about your experience with sonic booms when you are at home.
- How **loud** is noise from sonic booms when you are in or near your home? Please use a scale from 0 to 10 where 0 means “not at all loud” and 10 means “extremely loud.” *[SELECT RATING]*
- \_\_\_\_\_ *[0-10 RATING]*
- C2** How much does noise from sonic booms **interfere** with your ability to talk with others or hear conversations **inside** your home? *[SELECT RATING]*
- [REPEAT AS NECESSARY: PLEASE USE A SCALE FROM 0 TO 10 WHERE 0 MEANS “NOT AT ALL” AND 10 MEANS “EXTREMELY.”]*
- \_\_\_\_\_ *[0-10 RATING]*
- C3** How much does noise from sonic booms **interfere** with your ability to talk with others or hear conversations **outside** your home? *[SELECT RATING]*
- \_\_\_\_\_ *[0-10 RATING]*
- C4** How much does noise from sonic booms **startle you or make you jump**? *[SELECT RATING]*
- \_\_\_\_\_ *[0-10 RATING]*
- C5** Vibration is a motion. The motion may be seen or felt. Using a scale from 0 to 10 where 0 means “none” and 10 means “a great deal,” how much **vibration** from sonic booms do you see or feel in your home? *[SELECT RATING]*
- \_\_\_\_\_ *[0-10 RATING]*
- C6** Rattle is a type of noise that can occur when objects move due to a vibration. Using a scale from 0 to 10 where 0 means “none” and 10 means “a great deal,” how much **rattle** from sonic booms do you experience in your home? *[SELECT RATING]*
- \_\_\_\_\_ *[0-10 RATING]*

## A-3: Baseline Survey

### Social and Demographic Characteristics

**D1** How long have you lived on Edwards Air Force Base? *[ENTER NUMBER OF YEARS]*

\_\_\_\_\_ *[NUMBER OF YEARS]*  
0 Less than 1 full year

**D2** Compared to the neighborhood where you lived before you moved to Edwards Air Force Base, would you say the noise at Edwards Air Force Base is much more annoying, somewhat more annoying, about the same, somewhat less annoying, or much less annoying? *[SELECT ONE]*

1 Much more annoying  
2 Somewhat more annoying  
3 About the same  
4 Somewhat less annoying  
5 Much less annoying

**D3** Including yourself, how many people live in your household? *[ENTER NUMBER OF PEOPLE]*

\_\_\_\_\_ *[NUMBER OF PEOPLE]*

**D4** *[IF D3 > 1]* Do any children under age 6 live in your household? *[SELECT ONE]*

1 Yes  
2 No  
-6 Programmed skip

**D5** *[IF D3 > 1]* Including yourself, how many adults age 18 or older live in your household? *[ENTER NUMBER OF ADULTS]*

\_\_\_\_\_ *[NUMBER OF ADULTS]*  
-6 Programmed skip

## A-3: Baseline Survey

- D6** What is the highest grade or year of schooling that you completed?  
*[SELECT ONE]*
- 1 Grades 1 to 11
  - 2 12th Grade No Diploma
  - 3 High School Graduate or Equivalent (GED)
  - 4 Some college, technical school, or 2-year degree
  - 5 Bachelor's Degree (BA, AB, BS)
  - 6 Some graduate work (no degree)
  - 7 Masters, Doctoral, or Professional degree
- D7** In what year were you born? *[ENTER YEAR]*
- [ENTER 4-DIGIT YEAR]*
- \_\_\_\_\_ *[YEAR]*
- 9 Refused
- D8<sup>1</sup>** Which of the following best describes the type of home in which you live?  
*[READ LIST; SELECT ONE]*
- 1 Single-family detached (no common walls)
  - 2 Duplex or single-family attached (at least one common wall)
  - 3 Apartment building or dormitory *[SKIP TO E1]*
  - 4 Other *[SPECIFY]*
  - 4 Question not asked
  - 6 Programmed skip
- D9<sup>1</sup>** The research team may need to put noise monitoring equipment in residents' yards. This equipment also requires an electrical power source for the equipment. Would you be willing to have noise monitoring equipment located outdoors on your property and be able and willing to supply the power? *[SELECT ONE]*
- [IF NEEDED: THE EQUIPMENT REQUIRES STANDARD HOUSEHOLD 110 VOLT ELECTRICAL POWER.]*
- 1 Yes
  - 2 No
  - 3 Depends
  - 4 Question not asked
  - 6 Programmed skip

---

<sup>1</sup> As of October 10, 2011 respondents were no longer asked D8 and D9 as staff no longer needed resident property for noise equipment.

## A-3: Baseline Survey

### Mode Assignment

E1A Thank you. As part of the research study, you will be asked to complete a short questionnaire each time you hear a sonic boom over 2 to 3 weeks. The questions will ask things like what time you heard the sonic boom, whether you were inside or outside, and how you reacted to the noise. We will also ask you to complete a short survey at the end of each day.

I have more instructions about *how* you will complete the surveys, but first I need to read a brief statement.

1 Continue

E1B Your participation is voluntary and you may stop at any time. Please notify us if you decide to withdraw from the study.

You will receive a \$50 VISA gift card for your participation at the end of the study. The results of the study will be summarized so that the answers you provide cannot be associated with you or anyone in your household. Your confidentiality will be kept to the degree permitted by the technology used. No guarantees can be made regarding the interception of data sent via the Internet by any third parties. However, no personal identifiers (name, address) are included on any survey forms, only anonymous CASEIDs or PIN numbers.

Responding to the survey questions implies your consent to participate in the study being conducted at Edwards Air Force Base.

If you have any questions about this study, you can contact Kathleen Hodgdon of Penn State University at [kkh2@psu.edu](mailto:kkh2@psu.edu) or call (814) 865-2447.

1 Continue

## A-3: Baseline Survey

- E4** You will complete the surveys by *[MODE]*.
- [IF MODE=PAPER]* A FedEx package will be sent to your home in a few days. The package will contain survey forms, instructions, and return mail supplies. We will contact you the following week to confirm that you received the package and answer any questions you might have.
- [IF MODE=APPLE]* “your Apple device using an application that will be provided to you. A research representative will be in contact with you in the next few weeks to schedule a time to install the application on your device. A FedEx package will also be sent to your home in the next few days with study instructions and study forms for back-up. We will contact you the following week to confirm that you received the package and answer any questions you might have.
- [IF MODE=WEB]* In the next few days, we will send you an email message with instructions and a link to the website where you will enter answers to survey questions. We will contact you the following week to confirm that you received the message and answer any questions you might have. In addition, a FedEx package will be sent to your home with study forms to use for back-up in case the website or web access is unavailable at any time during the study period.
- To verify, we have your email address as *[EMAIL]*. Is that correct?
- 1 Yes *[GO TO E6]*
  - 2 No
- E5** What is the correct email address? *[ENTER EMAIL ADDRESS AND READ BACK]*
- [SEE RESPONSES IN OPEN END FILE]*
- E6** Do you have any questions or comments? *[SELECT ONE]*
- 1 Yes *[SPECIFY]*
  - 2 No
- E6O** Respondent comments specified.
- [SEE RESPONSES IN OPEN END FILE]*

## A-3: Baseline Survey

### Interviewer Observations – Not Read to Respondent

- F1** *[INTERVIEWER ONLY]* Record respondent gender. *[SELECT ONE]*
- 1 Male
  - 2 Female
- F2** *[INTERVIEWER ONLY]* Did the respondent's hearing capacity seem to be: *[SELECT ONE]*
- 1 Normal *[GO TO F4]*
  - 2 Somewhat diminished
  - 3 Severely diminished
- F3** Describe extent of hearing problem. *[ENTER DETAILED COMMENTS]*
- [SEE RESPONSES IN OPEN END FILE]*
- F4** *[INTERVIEWER ONLY]* Did the Respondent voice any concerns about participating in the study? *[SELECT ONE]*
- 1 Yes
  - 2 No *[SKIP TO END]*
- F5** Describe the concerns. *[RECORD VERBATIM RESPONSE]*
- [SEE RESPONSES IN OPEN END FILE]*
- END** Press 1 for any additional comments regarding the respondent: *[SELECT ONE]*
- 1 Enter comments
  - 2 No comments
- ENDO** Additional comments specified. *[RECORD VERBATIM RESPONSE]*
- [SEE RESPONSES IN OPEN END FILE]*

## A-3: Baseline Survey

NOTQAL      Unfortunately only individuals who live in housing on Edwards Air Force Base are eligible to participate in this study. Thank you.

We appreciate your interest.

*[PRESS 1 TO TERMINATE]*

1      Terminate

<b>Sample Variables</b>
-------------------------

**CASEID**      Unique identifier code

**MODE**      Study mode

1      Apple  
2      Web  
3      Paper





# Appendices

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## Appendix B

**B-1: PSU IRB Application**

**B-2: PSU IRB Approval**

**B-3: NASA IRB Approval**

**B-4a: OMB Support Statement**

**B-4b: OMB 83-I Paperwork Reduction Act Submission Form**

## B-1 PSU IRB Application



Institutional Review Board (IRB)  
The Office for Research Protections  
The 330 Building, Suite 205  
University Park, PA 16802 | 814-865-1775 | [ORProtections@psu.edu](mailto:ORProtections@psu.edu)

**Submitted by:** Kathleen Hodgdon  
**Date Submitted:** May 13, 2011 5:27:07 PM  
**IRB#:** 36961  
**PI:** Kathleen Kindlin Hodgdon  
**Review Type:** Exemption  
**Protocol Subclass:** Social Science  
**Approval Expiration:** -pending-  
**Class Project:** No

### *Study Title*

1>Study Title  
Low Boom Community Response Pilot Program

2>Type of eSubmission  
New

### *Home Department for Study*

3>Department where research is being conducted or if a student study, the department overseeing this research study.  
Applied Research Laboratory

### *Review Level*

4>What level of review do you expect this research to need? NOTE: The final determination of the review level will be determined by the IRB Administrative Office.  
Choose from one of the following:  
Exemption

5>Exempt Review Categories:

Choose one or more of the following categories that apply to your research. You may choose more than one category but your research must meet one of the following categories to be considered for expedited review.

Category 2: Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observations of public behavior unless:

### ***Basic Information: Association with Other Studies***

**6>Is this research study associated with other IRB-approved studies, e.g., this study is an extension study of an ongoing study or this study will use data or tissue from another ongoing study?**

No

**7>Where will this research study take place? Choose all that apply.**

Other Site(s)

**You have indicated that the research study location will include an outside laboratory or other non-PSU site(s).**

**8>List each site and provide contact information [name & address] for each site.**

Edwards Air Force Base

NASA Dryden Research Center

Name:Larry J. Cliatt, II

Aerospace Engineer

RA / Aerodynamics

NASA Dryden Flight Research Center

Tel: 661.276.7617

E-mail: Larry.J.Cliatt@nasa.gov

Both Ed Haering and Larry Cliatt completed training under affiliation with NASA. They are participating on the team as part of the NASA sponsor team. Ed Haering's certificate will be uploaded. I will upload Larry Cliatt's on receipt.

PSU is the primary IRB. We intend to submit the PSU IRB package to the NASA Langley Research Center IRB once we have the PSU recommended language in place.

**9>Do any of these sites have an IRB?**

Yes

**If you answer "No" to the above question, provide a letter of agreement/permission from an individual in a decision making position indicating their willingness to participate in the research study.**

**10>List the site(s) that have an IRB.**

NASA

**11>Has the site's IRB reviewed and approved the research study or does it plan to defer review to PSU's IRB?**

The site will defer review to PSU's IRB

**12>Does this research study involve any of the following centers?**

None of these centers are involved in this study

**13>Describe the facilities available to conduct the research for the duration of the study.**

This is a survey research project sponsored by NASA and being conducted in cooperation with Edwards Air Force Base. The participants will be recruited from residents living in on base housing at Edwards Air Force Base. On base housing is available to individuals associated with EAFB. Participants will be sought from among the residents, which may include employees, spouses, or civil servants.

**14>Is this study being conducted as part of a class requirement? For additional information regarding the difference between a research study and a class requirement, see IRB Policy I – “Student Class Assignments/Projects” located at <http://www.research.psu.edu/policies/research-protections/irb/irb-policy-1>.**

No

**Personnel**

**15>Personnel List**

PSU User ID	Name	Department Affiliation	Role in this study
kkh2	Hodgdon, Kathleen Kindlin	Applied Research Laboratory	Principal Investigator
64272	Cliatt, II, Larry	Non PSU Site	Research Support
63531	Cowart, Robert	Non PSU Site	Research Support
tlg210	Gaugler, Trent Lee	Statistics	Research Support
64271	Haering, Edward	Non PSU Site	Research Support
63064	Hobbs, Christopher	Non PSU Site	Research Support
62320	Koenig, Carrie	Non PSU Site	Research Support
47581	Krecker, Peg	Non PSU Site	Research Support
62805	Page, Juliet	Non PSU Site	Co-Investigator

Hodgdon, Kathleen Kindlin (Principal Investigator)	
PSU User ID: kkh2	Phone: 865 2447
Email: kkh2@psu.edu	Alt: 814 880 3468
Email Notifications: Yes	Pager:
PSU Person Type: Faculty	Fax:
Dept: Applied Research Laboratory	
Address 1: Applied Research Laboratory	
Address 2:	
Mail Stop: 2210G	
City, State, Zip: University Park, PA 16802	

Hodgdon, Kathleen Kindlin (Principal Investigator)

Procedures: Subjective team lead, who is responsible for the development of the subjective research design. Participate in research design, conduct of field study and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Access to noise measurements and survey response data, no access to master list linking participants and subject numbers, may have limited access to participants (if approached by participant while conducting noise measurements at EAFB). She has successfully completed the Citi IRB training course.

Experience: PSU Research Associate who serves as the ARL liaison to the PSU IRB. She has been the Pincipal and co-Principal Investigator on noise and vibration research due to automotive vehicles, air conditioners, commercial aviation, military sonic booms, and military blast noise due to training, with an emphasis on human perception. She has conducted psychoacoustic based noise research since 1986, including research on perception of annoyance, noise metric assessment and development, assessment of sound quality, and task interference due to noise. She is the instructor of the Sound Quality course for the PSU Graduate program in Acoustics, and has acted as an advisor to graduate students on noise perception research.

Cliatt, II, Larry (Research Support)

PSU User ID: 64272

Phone:

Email: Larry.J.Cliatt@nasa.gov

Alt:

Email Notifications: No

Pager:

PSU Person Type: Other

Fax:

Dept: Non PSU Site

Address 1: NASA Dryden Flight Research Center

Address 2:

Mail Stop:

City, State, Zip: Edwards, CA 93523

Procedures: Participate in research design, conduct of field study and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. He is the team liaison between our team and the housing and public affairs office at Edwards Air Force Base. Access to noise measurements and survey response data, no access to master list linking participants and subject numbers, may have limited access to participants (if approached by participant while conducting noise measurements at EAFB). He has successfully completed the Citi IRB training course.

Experience: Larry Cliatt is an Aerospace Engineer at NASA Dryden Flight Research Center who currently works on supersonic research projects. He previously worked as a flight test engineer at Bell Helicopter, and graduate from the Georgia Institute of Technology with an MS in Aerospace Engineering in 2007. He is our NASA Dryden primary point of contact. He is leading the on site coordination effort between our team, researchers at NASA Dryden Research Center and the Air Force representatives at Edwards Air Force Base Housing and Public Affairs office that review and approve distribution of our recruitment documents on EAFB. He has successfully completed the Citi IRB training course.

Coward, Robert (Research Support)	
PSU User ID: 63531	Phone:
Email: robbie.coward@gulfstream.com	Alt:
Email Notifications: No	Pager:
PSU Person Type: Other	Fax:
Dept: Non PSU Site	
Address 1: Gulfstream Aerospace	
Address 2: POB 2206 M/S R-07	
Mail Stop:	
City, State, Zip: Savannah, GA 31402	
<p>Procedures: Participate in research design, conduct of field study and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Access to noise measurements and survey response data, no access to master list linking participants and subject numbers, may have limited access to participants (if approached by participant while conducting noise measurements at EAFB). He has successfully completed the Citi IRB training course.</p>	
<p>Experience: Robert Coward is director of Supersonic Technology Development at Gulfstream Aerospace Corporation where he has worked for over 18 years. His background spans a broad range of disciplines, including structures, systems, ground/flight test, and various R&amp;D activities. He has worked in production, service, and completion engineering roles at Gulfstream. His current work involves managing supersonic research focusing on sonic boom mitigation and enabling civil supersonic overland flight. He serves on the FAA's PARTNER advisory board advocating supersonics and participates in CAEP 's WG1/Supersonic Task Group (SSTG). He has participated in other subjective assessments of human perception of sonic boom noise through the PARTNER PSU research efforts. Gulfstream has successfully executed two key flight programs with NASA: F-15 Quiet Spike and F-18 eXternal Vision System (XVS), and has played key roles in other flight activities related to NASA's low sonic boom research. He received a B.S. and M.S. in Aeronautical Engineering from Georgia Tech. He has successfully completed the Citi IRB training course.</p>	

Gaugler, Trent Lee (Research Support)	
PSU User ID: tlg210	Phone:
Email: tgaugler@stat.psu.edu	Alt:
Email Notifications: No	Pager:
PSU Person Type: Faculty	Fax:
Dept: Statistics	
Address 1: 325 Thomas Building	
Address 2:	
Mail Stop:	
City, State, Zip: University Park, PA 16802	
<p>Procedures: Participate in research design and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Access to noise measurements and survey response data. No access to participants and identities.</p>	

Gaugler, Trent Lee (Research Support)

Experience: Gaugler is a faculty consultant in the Statistical Consulting Center. His current duties include instruction of the Graduate Consulting course and the Experimental Methods course; and involvement on long-term fee-based consulting projects with other faculty of the university and other members of the community. Gaugler has also been involved in teaching several courses online through the Penn State World Campus. Gaugler has conducted the statistical analysis of community response survey data for the research team conducting An Investigation of Community Attitudes towards Military Blast Noise.

Haering, Edward (Research Support)

PSU User ID: 64271

Phone:

Email: edward.a.haering@nasa.gov

Alt:

Email Notifications: No

Pager:

PSU Person Type: Other

Fax:

Dept: Non PSU Site

Address 1: NASA Dryden Flight Research Center

Address 2:

Mail Stop:

City, State, Zip: Edwards, CA 93523

Procedures: Participate in research design, conduct of field study and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Access to noise measurements and survey response data, no access to master list linking participants and subject numbers, may have limited access to participants (if approached by participant while conducting noise measurements at EAFB). He has successfully completed the Citi IRB training course.

Experience: Ed is an aerospace engineer at NASA's Dryden Flight Research Center in Edwards, Ca. His research focus is on quieting sonic booms and the potential to develop a future supersonic vehicle. His efforts include starting new research programs, computer simulations and analysis, troubleshooting instrumentation on test aircraft, and conducting field measurements in remote locations. He has successfully completed the Citi IRB training course.

Hobbs, Christopher (Research Support)

PSU User ID: 63064

Phone:

Email: chris.hobbs@wyle.com

Alt:

Email Notifications: No

Pager:

PSU Person Type: Other

Fax:

Dept: Non PSU Site

Address 1: Wyle Labs

Address 2: 241 18th Street South, Suite 701

Mail Stop:

City, State, Zip: Arlington, VA 22202



Hobbs, Christopher (Research Support)

Procedures: Senior Acoustician. Participate in research design, conduct of field study and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Access to noise measurements and survey response data, no access to master list linking participants and subject numbers, may have limited access to participants (if approached by participant while conducting noise measurements at EAFB). He has successfully completed the Citi IRB training course.

Experience: Chris Hobbs is a Senior Acoustician and has been with Wyle since 1997. He is our senior instrumentation lead and has extensive experience in aircraft sonic boom measurements. Mr. Hobbs has been involved in many phases of sonic boom research including design of aircraft flight trajectories, designing and conducting field experiments and gathering high fidelity acoustic and meteorological data. He has experience conducting community response measurements and in situ measurements of aircraft and weapons noise and sonic booms and has successfully completed the Citi IRB training course.

Koenig, Carrie (Research Support)

PSU User ID: 62320	Phone:
Email: carrie.koenig@tetrattech.com	Alt:
Email Notifications: No	Pager:
PSU Person Type: Other	Fax:
Dept: Non PSU Site	
Address 1: 6410 Enterprise Lane, Suite 300	
Address 2:	
Mail Stop:	
City, State, Zip: Madison, WI 52719	
Procedures: Participate in recruitment and survey administration and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Will have full access to participants and identities. She has successfully completed the Citi IRB training course.	
Experience: Carrie Koenig is a survey researcher on staff at TetraTech who will be conducting recruitment and phone surveys for the NASA low boom effort. She has successfully completed the Citi IRB training course.	

Krecker, Peg (Research Support)

PSU User ID: 47581	Phone:
Email: Peg.Krecker@tetrattech.com	Alt:
Email Notifications: No	Pager:
PSU Person Type: Other	Fax:
Dept: Non PSU Site	
Address 1: PA Consulting Group	
Address 2: 6410 Enterprise Lane, Suite 300	
Mail Stop:	
City, State, Zip: Madison, WI 53719	

Krecker, Peg (Research Support)	
Procedures: Team lead for the recruitment and conduct of over the phone surveys. Participate in research design, recruitment and survey administration and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Will have full access to participants and identities.	
Experience: Peg Krecker has been conducting social science research for over 20 years, specializing in survey methodology, statistical analysis, and questionnaire design. She has led data collection and statistical analysis projects for Federal and State government agencies, private sector clients, and university researchers in the areas of transportation, health and health technology, poverty and welfare reform. Dr. Krecker is leading Tetra Tech 's five-year collaboration with the US Army Corps of Engineers and Penn State University to measure human response to blast noise in residential communities near military installations. Tetra Tech is conducting telephone surveys in areas where noise complaints are received, general community surveys of over 2,000 households across three communities using a repeated cross-section/panel design, and coordinating these community surveys with subsamples of households equipped with noise monitors that complete daily ratings of noise events. Prior to working as a consultant, Dr. Krecker was a professor of sociology and research scientist at the University of Michigan 's Population Research Institute, research scientist at the University of Wisconsin –Madison 's Institute for Research on Poverty and the Center for Demography and Ecology. She has successfully completed the Citi IRB training course.	

Page, Juliet (Co-Investigator)	
PSU User ID: 62805	Phone: 703 4154550 X17
Email: juliet.page@wyle.com	Alt:
Email Notifications: Yes	Pager:
PSU Person Type: Other	Fax:
Dept: Non PSU Site	
Address 1: Wyle Laboratories	
Address 2: 241 18th Street South, Suite 701	
Mail Stop:	
City, State, Zip: Arlington, VA 22202	
Procedures: Overall team lead, responsible for the full research design, implementation of the field study and data analysis. Participate in research design, conduct of field study and data analysis. Participate in development of research survey instruments, including recruitment, consent and survey documents. Access to noise measurements and survey response data, no access to master list linking participants and subject numbers, may have limited access to participants (if approached by participant while conducting noise measurements at EAFB). She has successfully completed the Citi IRB training course.	
Experience: Juliet Page is a Principal Engineer and has been with Wyle for more than 18 years and was previously with Douglas Aircraft for 7 years. Her expertise in sonic boom research includes flight testing and acoustic measurements, analysis, methodology development and low-boom aircraft design. She is experienced in designing and conducting sonic boom field measurement programs, conducting basic sonic boom research and working with acoustic and meteorological instrumentation. She has also been involved in several community noise research programs for commercial aircraft and airport noise. Ms. Page has successfully completed the Citi IRB training course.	

## ***Funding Source***

**16>Is this research study funded? Funding could include the sponsor providing drugs or devices for the study.**

Yes

**NOTE: If the study is funded or funding is pending, submit a copy of the grant proposal or statement of work for review.**

### **17>Sponsor List**

Sponsor Name

Wyle Laboratories

- **Sponsor Name**

Wyle Laboratories

**Sponsor address or other contact information**

Juliet Page

Principal Engineer, Acoustics

Senior Engineering Manager, Research Group

Acoustics Research and Consulting

Wyle Laboratories

241 Eighteenth Street – South Suite 701

Arlington, VA 22202

703.415.4550.x17 Voice

703.415.4556 Fax

Juliet.Page@Wyle.com

**18>Is the funding awarded through a subcontract?**

Yes

**19>Who is the prime sponsor (i.e., if the University of Michigan subcontracts part of an NIH study to PSU, NIH is the prime sponsor)?**

NASA Langley Research Center

NASA Program Manager:

Alexandra Loubeau

Structural Acoustics Branch

NASA Langley Research Center

MS 463

Hampton, VA 23681

(757) 864-2361

a.loubeau@nasa.gov

In addition, both Ed Haering and Larry Cliatt (included on team list) completed CITI training under affiliation with NASA. They are participating on the team as part of the NASA sponsor team. Ed Haering's certificate will be uploaded. I will upload Larry Cliatt's on receipt.

20>Is the sponsor providing drug, device, etc, free of charge?

No

21>Does this research study involve prospectively providing treatment or therapy to participants?

No

### ***Conflict of Interest***

22>Do any of the investigator(s), key personnel, and/or their spouses or dependent children have a financial or business interest(s) as defined by PSU Policy RA20, "Individual Conflict of Interest," associated with this research? NOTE: There is no de minimus in human participant research studies (i.e., all amount must be reported).

No

### ***Exemption Questions (Prescreening)***

23>Does this research study involve prisoners?

No

24>Does this research study involve the use of deception?

No

25>Does this research study involve any FDA regulated drug, biologic or medical device?

No

26>Does this research study involve the use of protected health information covered under the Health Insurance Portability & Accountability Act (HIPAA)?

No

### ***Exemption Questions***

27>Maximum number of participants/samples/records to be enrolled.

150

28>Age range – Check all that apply:

18 – 25 years

26 – 40 years

41 – 65 years

65 + years

29>Describe the steps that will be used to identify and/or contact prospective participants. If applicable, explain how you have access to lists or records of potential participants.

Participants will be identified working with personnel from NASA Dryden Flight Research Center and Edwards Air Force Base, using a recruitment letter to on base addresses and through use of local telephone

databases. The increased use of cell phones, and the transient nature of the on base population may limit the number of phone listings that are associated with a street address. The primary recruitment will most likely be through the direct mail of the recruitment letter.

NASA is sponsoring two studies to conduct survey research during the period of the low boom community impact flight tests. Our team is the lead team and our efforts are described on this application. Our research team and a separate smaller team are using similar survey methods (smart phone), but with some changes in survey questions and implementation. We are the only team conducting the recruitment and noise measurement efforts, in addition to implementing our survey research design.

There is a limited population on Edwards Air Force Base from which we can recruit participants. As such, NASA has funded only our team to conduct the recruitment for both research studies, to minimize the contact and impact on residents at EAFB. Participants will be contacted and recruited and then divided between the two teams. The identities of the participants assigned to the related project will only be known by the recruitment team at TetraTech, and not by any other members of our team. Once assigned to the other project, those recruits will have no further affiliation with our team. Our recruitment screener presents a research description that covers both teams, and as such contains a broader portrayal of the overall NASA research effort.

A complete enumeration of households will be conducted in the community. Volunteers will be solicited for inclusion in participation. A systematic sample will be selected by determining a random starting point on the enumerated list of households that volunteer to participate, and using a sampling interval, based on the ratio of required respondents to the total number of available households.

**30>Choose the types of recruitment materials that will be used.**

Telephone Script (Verbal)

Letter

**31>When and where will participants be approached to obtain informed consent/assent? If participants could be non-English speaking, explain how consent/assent will be obtained. If consent/assent will not be obtained, explain why consent/assent will not be obtained.**

The population of participants will be drawn from residents at Edwards Air Force Base. The informed consent will be included in the text at the beginning of the Baseline Survey, which will be conducted by phone. Completion of the Baseline survey will constitute an implied consent to participate in the study. The field test will be conducted after the Baseline survey, and requests that participants complete the single event survey after each boom and complete a survey providing their daily rating of the noise environment. Participants will need to be sufficiently literate in English to read and understand the verbal informed consent.

**32>Provide the background information and rationale for performing the study.**

The NASA sponsored Wyle led Low Boom Community Response Pilot Program team is conducting this research effort. This project is investigating the noise impact of supersonic flight for small business jets over land. NASA is working to identify future innovations in aviation technology that will contribute to the advancement of the US Aerospace industry. There is great interest in the prospect of building a supersonic business jet. In order for such a plane to reach its full potential it would need to be able to fly supersonic over land, which is at present not permitted by FAA regulation in commercial airspace. Previous research efforts have been conducted as part of the Quiet Supersonic Demonstrator project, which was designed to gather information for FAA review and consideration in regard to changes in FAA regulations.

This research is to further provide information about the probable effects of aircraft noise and low-level

sonic booms on people. The information derived from this study may be from either measured or predicted effects. The findings will be published in technical reports that will be available to interested users, such as aircraft designers, government officials, and other researchers. The focus of the research will be acceptability of low level sonic boom noise, with the premise that the variables influencing acceptability are stimulus factors, situational factors, and psychosocial factors.

**33>Summarize the study’s key objectives, aims or goals.**

Our objective is to enhance understanding of human response to low-level sonic boom noise, and to determine a methodology to more accurately assess and predict human response to low-level boom noise in communities. The low boom level sounds similar to distant thunder.

This research is intended to provide information about the probable effects of aircraft noise and low-level sonic booms on people. The participants are residents living in the housing communities at Edwards Air Force Base who routinely hear full level sonic booms as part of their natural sound environment. The study is designed to measure the perception of low-level booms as rated by participants using single event and daily response surveys. After completing a baseline survey, recruits will participate in a field study. Participants will be asked to rate their perception of the low booms each time they notice a boom event, and as a daily summary of their low boom perception.

The field test design will gather respondents’ data that will be used to compare across the participants’ ratings of perception for single events and daily ratings, and to compare to noise and vibration measurements of the noise source. The data analysis will compare findings within each individual across different boom levels, between individuals across different boom levels, and compare subjective response ratings to various noise and vibration metrics. This will allow us to identify trends that can be generalized to exposure-response relationships for low boom noise.

**34>Describe the major inclusion and exclusion criteria.**

Subjects are required to reside on Edwards Air Force Base, be over the age of 18 (no upper limit is applied), and be home at least part of the day during weekday, daytime hours. It is anticipated that approximately 50 subjects will participate in the Wyle PSU team study. An attempt to recruit a diverse group of subjects will be made. Race and gender are not variables for excluding subjects. Subjects must be able to read and write in English and give verbal informed consent for participation.

The participants will be included based on the community in which they live at Edwards Air Force Base. The participants will represent a sampling of that particular community, and may not necessarily include all groups equally.

Exclusion will be based on those who do not reside at EAFB, who are not older than 18 and who do not read and write English.

**35>Summarize the study’s procedures by providing a step-by-step process of what participants will be asked to do.**

This study is designed to compare the perception of low level booms presented via fly-bys of F-18 aircraft. The research falls under Category 2, Survey Procedures, in which the individual participants will not be able to be identified once the data is gathered. Participation is voluntary, and participants will be responding to low boom noise while they go about their daily activities. Boom noise is heard in their community routinely. They are not at risk due to participation in this study. They are providing their opinions regarding low level boom noise.

The informed consent will be included in the written text which will be verbally read at the beginning of the Baseline Survey. Completion of the Baseline survey will constitute an implied consent to participate in the study. Participants will need to be sufficiently literate in English to understand the verbal informed consent. In the opening paragraphs respondents will be told that their responses are voluntary and will be



kept strictly confidential. All individual's who participate will be assigned a unique identification number for the forms recording the information they provide. That number will be associated with their name to document participation for the survey protocols. On all test documents the subject number will be used and the individual's identity will be protected. The list of names associated with the numbers will be kept confidential. Individual names or other identifiers will not be associated with the tabulated survey responses.

Participants will go about their normal activities during the 2-week test period. During the test period, participants will complete a single event survey when they hear a boom and a daily rating of each day's noise environment. The field test will include a maximum of 10 low booms per day during the 2-week testing period. The booms will be generated by 16 flights of F-18 aircrafts over the 2-week period at Edwards Air Force Base. These low level sonic booms are lower than the normal levels generally heard from flights at Edwards AFB. It is likely that other booms may be generated by other Air Force flights doing routine training during our 2-week test period. We will record all boom noise, and the participants will be instructed to respond to all booms heard.

The participants will be divided into three response categories for the field test. Some will respond by web-based survey, some by a smart phone survey application and some by paper and pencil. Participants will use their own computers for the web survey and their own smart phones using a phone based survey application.

The survey research instruments include:

1. Baseline survey to determine participant specific variables and attitudes, such as age, number of year exposed to sonic boom noise, attitudes towards noise, etc.
2. Field test Single Event survey to obtain the participant's response to each sonic boom event that the respondent hears.
3. Field Test Daily Rating of the noise environment for that day. This short survey obtains the participants response to noise over the course of each day.
4. Post-test survey, where the participants will be called and asked to provide their open-ended opinion and feedback to assess the ease of using their assigned response method (i.e. paper/pencil, web based, smart phone).

Microphones will be located strategically throughout the community to record the low-level sonic boom noise from the F-18 aircraft flights. The microphones will be located in areas within the community near participant addresses, using latitude and longitude coordinates to identify the location of the noise monitoring microphones. A sampling of a few representative, but empty houses within the community will be instrumented with microphones and accelerometers to measure the noise and vibration impact in a typical home. The participant responses will be compared across their rating of the individual booms, the rating of the daily noise environment, and comparisons of the ratings to the measured noise levels.

Since this test is at an active Air Force Base where training is conducted routinely, it is possible that there will be sonic booms from flights of other Air Force vehicles during our testing period. We will gather data on all sonic booms, with time stamps recorded that indicate the time of the flight. The participants will be asked to respond to each noise event. The participants will not know which aircraft flew over, they will simply respond to the noise. We will track the data with noise monitors and time stamps. All testing should be conducted in a 2-week period in November 2011 at NASA Dryden Flight Research Center.

There is no undue physical or psychological risk or discomfort associated with this test. The test requires that participants respond to individual booms as they go about their normal daily activities in the housing communities at Edwards Air Force Base. The levels presented as part of this field test are lower than the levels that are typically heard from sonic booms in the daily noise environment at Edwards Air Force Base.

**36>Indicate the type(s) of compensation that will be offered. Choose all that apply.**

Other (e.g., items such as iPods)

**37>Describe the ‘other’ type of compensation that will be offered.**

A yet to be identified token incentive, such as a pen or a coffee cup, that expresses NASA's appreciation for their participation but does not have a significant dollar value.

**38>Will any type of recordings (audio, video or digital) or photographs be made during this study?**

No

**39>Will any data collection for this study be conducted on the Internet or via email (e.g., on-line surveys, blogs or chat room observations, on-line interviews, email surveys)?**

Yes

**40>Does this study involve any foreseeable risks and/or discomforts to participants – physical, psychological, social, legal or other?**

No

**41>Will data be stored securely and accessible only to the research personnel listed on this application?**

Yes

**42>Describe how data confidentiality will be maintained.**

Participation in this research is confidential. Only the necessary members of the research team will have access to the subject's identity and to information that can be associated with that identity. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

All individual's who participate will be assigned a unique identification number for the forms recording the information they provide. That number will be associated with their name to document participation for the survey protocols. On all test documents the subject number will be used and the individual's identity will be protected. The list of names associated with the numbers will be kept confidential. Individual names, addresses or other identifiers will not be associated with the tabulated responses.

Respondent's names or other identifying information will not be part of the data results. The researchers administering the survey will maintain a master log that associates each individual with their contact information. The master log will be kept stored in a secure location during the survey administration. The information that is provided to the sponsor and any other stakeholders will not contain any information that can be used to identify respondents.

Because the study is being conducted at a limited access military base, the presence of our team conducting noise measurements during the flight tests may be noticed by residents. There is the possibility that a participant may approach a member of our team while they are conducting noise measurements at EAFB. The noise assessment research team will not have access to the master list associating participants with their assigned subject number.



## ***Document Upload***

### CONSENT FORMS

Document 1001 Received 05/13/2011 17:19:32 - Scripts Implied Informed Consent in Baseline Survey

### DATA COLLECTION INSTRUMENTS

Document 1001 Received 04/26/2011 15:08:01 - Low Boom Single Event Survey

Document 1002 Received 04/26/2011 15:08:49 - Low Boom Daily Rating of Noise Survey

### RECRUITMENT

Document 1001 Received 05/13/2011 17:20:18 - Recruitment Materials Recruit Letter Revised 5 2011

Document 1002 Received 05/13/2011 17:21:12 - Recruitment Materials Recruit Screener Rev 5 2011

### REVIEW - REQUEST INFO

Document 1001 Received 05/13/2011 17:24:23 - Additional information comments addressed

### SUBMISSION FORMS

Document 1001 Received 04/26/2011 15:05:38 - Grant Proposal Low Boom PSU task description subcontrac

Document 1002 Received 04/27/2011 07:53:38 PM - Application Auto-generated by eSubmission Approval

### SUPPORTING DOCUMENTS

Document 1001 Received 05/13/2011 17:25:47 - Education Certifications Citi Training for NASA Sponsor

## B-2: PSU IRB Approval

**From** "Brown, Amanda" <aeb29@rtto.psu.edu> [⊕](#)  
**To** "kkh2@psu.edu" <kkh2@psu.edu> [⊕](#)  
**Subject** IRB#36961 Low Boom Community Response Pilot Program  
**Date** Mon, May 23, 2011 04:23 PM  
**CC** "juliet.page@wyle.com" <juliet.page@wyle.com> [⊕](#)  
**Safe View** On [\[Turn Off\]](#) [What is "Safe View"?](#)

Kathleen Hodgdon,

The Office for Research Protections (ORP) has reviewed the eSubmission application for your research involving human participants and determined it to be exempt from IRB review. You may begin your research. This study qualifies under the following category:

**Category 2:** Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observations of public behavior unless: (i) information obtained is recorded in such a manner that human participants can be identified, directly or through identifiers linked to the participants; **and** (ii) any disclosure of the human participants' responses outside the research could reasonably place the participants at risk of criminal or civil liability or be damaging to the participants' financial standing, employability, or reputation. [45 CFR 46.101(b)(2)]

**Comment:** If it is determined that IRB submission is required by NASA's IRB, please submit a copy of the approval letter. If submission is not required, please submit an email/memo from the IRB Office indicating such.

### PLEASE NOTE THE FOLLOWING:

- The principal investigator is responsible for determining and adhering to additional requirements established by any outside sponsors/funding sources.
- Record Keeping
  - The principal investigator is expected to maintain the original signed informed consent forms, if applicable, along with the research records for at least three (3) years after termination of the study.
  - This correspondence will also be available to you in PRAMS at [www.prams.psu.edu](http://www.prams.psu.edu).
- Consent and Recruitment Document(s)

## B-2: PSU IRB Approval

- The exempt consent form(s) will no longer be stamped with the approval/expiration dates.
- The most recent consent form(s) that you uploaded for review is the one that you are expected to use
- **Follow-Up**
  - The Office for Research Protections will contact you in five (5) years to inquire if this study will be on-going.
  - If the study is completed within the three year period, the principal investigator may complete and submit a **Project Close-Out Report:**  
<http://www.research.psu.edu/orp/areas/humans/applications/index.asp#other>
- **Revisions/Modifications**
  - Any changes or modifications to the study must be submitted through the eSubmission application for this protocol in PRAMS ([www.prams.psu.edu](http://www.prams.psu.edu)).

Please do not hesitate to contact me if you have any questions or concerns.

Thank you,

Amanda E. Brown, CIP

Research Compliance Coordinator II  
The Pennsylvania State University | Office for Research Protections | The 330 Building, Suite 205 | University Park, PA 16802

Telephone (814) 865-7986 | Main Line (814) 865-1775 | Fax (814) 863-8699 | EMAIL: [aeb29@psu.edu](mailto:aeb29@psu.edu) | WEB [www.research.psu.edu/orp](http://www.research.psu.edu/orp)

## B-3: WSPR NASA IRB

National Aeronautics and  
Space Administration

**Langley Research Center**  
100 NASA Road  
Hampton, VA 23681-2199



June 9, 2011

Alexandra Loubeau, PhD  
Structural Acoustics Branch  
Research Directorate  
Mail Stop 463  
NASA Langley Research Center  
Hampton, VA 23681-2199

Subject: WSPR Low Boom Community Response Pilot Program

Dr. Loubeau,

The LaRC IRB has received the subject study application, accompanying materials, and the Penn State University IRB approval memo. As this research involving human test subjects is being conducted solely by another institution the LaRC IRB accepts the governance of the local Institutional Review Board (Penn State University).

If significant changes are made to the study or its procedures, a subsequent review and approval by the LaRC IRB must be obtained prior to implementation.

Review is valid through 8 June, 2012.  
NASA LaRC IRB MPA Code NASA3082281305HR

A handwritten signature in black ink, appearing to read "JSHill", written in a cursive style.

Jeffrey S. Hill  
Chairman, Institutional Review Board  
MS 285, NASA Langley Research Center

Cc:  
Patricia G. Cowin, CIH, CSP  
Vice Chair, Institutional Review Board  
Safety and Facility Assurance Office, MS 305  
NASA Langley Research Center

## **B-4a: OMB Support Statement**

[DRAFT] OMB Application NASA Low Boom Community Response

### **Support Statement for Information Collection Requirements**

#### **WSPR Program**

#### **Experimental Test Plan**

Team Members:

Juliet Page, Chris Hobbs, Wyle  
Kathleen Hodgdon, PSU  
Peg Kreckler, TetraTech  
Robbie Cowart, Gulfstream

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response  
**Justification**

1. **Need for the Information Collection: Explain the circumstances that make the collection of information necessary. Identify any legal or administrative requirements that necessitate the collection. Attach a copy of the appropriate section of each statute and regulation mandating or authorizing the collection of information.**

The NASA sponsored Wyle led Low Boom Community Response team is conducting this research effort. This project is investigating the noise impact of supersonic flight for small business jets over land. NASA is working to identify future innovations in aviation technology that will contribute to the advancement of the US Aerospace industry. There is great interest in the prospect of building a supersonic business jet. In order for such a plane to reach its full potential it would need to be able to fly supersonic over land, this is at present not permitted by FAA regulation in commercial airspace. Previous research efforts have been conducted as part of the Quiet Supersonic Demonstrator project, which was designed to gather information for FAA review and consideration in regard to changes in FAA regulations and by the NASA Low Boom Community Response Pilot Program to assess methods for conducting low boom dose response tests in communities.

2. **Use of this Information: Indicate how, by whom, and for what purpose the information is to be used. Except for a new collection, indicate the actual use the agency has made of the information received from the current collection.**

The information from this research effort will be used to provide information and guidance to decision-makers responsible for assessing noise impacts and mitigation and for advancement of aviation technology for the future. This research is to further provide information about the probable effects of aircraft noise and low-level sonic booms on people. The information derived from this study may be from either measured or predicted effects. The findings will be published in technical reports that will be available to interested users, such as aircraft designers, government officials, and other researchers. The focus of the research will be acceptability of low level sonic boom noise, with the premise that the variables influencing acceptability are stimulus factors, situational factors, and psychosocial factors.

The survey instruments include:

1. Baseline survey to determine participant specific variables and attitudes, such as age, number of year exposed to sonic boom noise, attitudes towards noise, etc.
2. Field test Single Event survey to obtain the participant's response to each sonic boom event that the respondent hears.
3. Field Test Daily rating of the noise environment for that day. This short survey obtains the participants response to noise over the course of each day.

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response

- a. Post-test survey, where the participants will be called and asked to provide their open-ended opinion and feedback to assess the ease of using their assigned response method (i.e. paper/pencil, web based, smart phone).

These questions will also provide data to assist in interpreting the results of the dose-response models. For example, we anticipate these qualitative data will help to potentially explain why some low boom noise events are more annoying than others, even though the actual measured noise level appears to be similar.

### Single Event and Daily Survey Questions

The event-based surveys will include only 7-10 questions, including the following types:

- Response (on a 10-point scale) for annoyance
- Response (on a 10-point scale) for loudness
- Response (on a 10-point scale) for intrusiveness
- Response (on a 10-point scale) for vibration
- Response (on a 10-point scale) for rattle
- Whether the R was indoors or outdoors
- What time of day the noise event occurred

Each of the above questions will be used to measure the participants' response to each noise event they experience. These data will be time stamped for each questionnaire participants complete, providing the response measures for developing a dose-response model. The data from the noise monitoring equipment will be correlated with the appropriate response measures, using the time stamp for the response questionnaire, to provide a series of ordered pairs of dose (measured noise) and response data for each noise event that participants' experience. A copy of the questionnaire forms for the single event and daily survey are shown in Attachment 1.

**[NOTE: The questions in the Single event and Daily questionnaire have received OMB Approval for a prior study – OMB Approval No. 0710-0015]**

### Baseline Survey Questions

The Baseline Survey contains questions regarding:

- Information about the household composition, the residence, and the individual respondent
- General questions about all types of noise sources
- Attitudes and beliefs that are important mediators of noise annoyance

Data from the Baseline Survey will be included as variables in developing dose-response models that estimate the percent of the population that will experience a high level of



## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response annoyance at different noise levels. A copy of the Baseline Survey questionnaire is shown in Attachment 2. The following is a discussion of how specific questions in the Baseline Survey will be used.

- Questions A1-A3 confirms the location of the residence. D1 –D 7 collect information about the composition of the household and will be used to determine if certain households are more likely to experience and express annoyance with noise sources in particular.
- Questions A4 –A5 ask about the residents’ perception of how quiet or noisy their neighborhood is. These variables provide information regarding how tolerant they are of community noise.
- Question A6A-A6D is a series of questions about the individuals’ beliefs regarding the average person’s ability to adapt to noise and their own ability to adapt to noise. These responses will be used to assess ability to habituate to noise.
- Questions B1A-B1F measure annoyance from a variety of different noise sources. They will be used to identify if there are any aspects of noise impacts that affect community residents and to evaluate how annoyance to low booms compares with other noise sources.
- Questions C1-C6 collect information on previous exposure to sonic booms. These variables will be used to determine how their response to full booms compares to the field study responses to low booms.

**[NOTE: The questions in the Baseline Survey, with the exception of C1-C6, have received OMB Approval for a prior study – OMB Approval No. 0710-0015]**

**3. Use of Information Technology: Describe whether, and to what extent, the collection of information involves the use of automated, electronic, mechanical, or other technological collection techniques or other forms of information technology, e.g., permitting electronic submission of responses, and the basis for the decision for adopting this means of collection. Also describe any consideration of using information technology to reduce burden.**

Both the daily summary and single event surveys will utilize a web based survey or a smart phone to facilitate “real-time” data collection of response to noise events.

**4. Efforts to Identify Duplication: Describe efforts to identify duplication. Show specifically why any similar information already available cannot be used or modified for use for the purposes described in Item 2 above.**

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response

The acoustics literature and literature on impulsive noise were studied extensively, through a literature search and through personal contacts with individuals who are active in this field. Review and consideration of sonic boom studies suggested that the following acoustic and non-acoustic factors should be considered and evaluated during the proposed research:

- Loudness
- Annoyance
- Startle
- Habituation
- Perception of vibration and rattle
- Interference with various activities

The low boom community test program follows patterns established in previous research tests. However, the low boom noise level is less than a full boom noise level. The testing of these quieter booms has only been conducted in an acclimated community, with residents accustomed to hearing full booms. This quieter test has not been completed in a naïve, or non-acclimated community.

**5. Burden on Small Business: If the collection of information impacts small businesses or other small entities (Item 5 of OMB Form 83-I), describe any methods used to minimize burden.**

Collection of this information does not have a significant impact on small businesses.

**6. Consequences of Not Collecting the Information: Describe the consequence to Federal program or policy activities if the collection is not conducted or is conducted less frequently, as well as any technical or legal obstacles to reducing burden.**

This information is not scheduled to be collected by any other agency or program. If the information is not collected, NASA will not be able to develop improved methodologies to assess and predict human response to low boom noise.

**7. Special Circumstances: Explain any special circumstances that would cause an information collection to be conducted in a manner:**

There are no special circumstance that require this collection to be conducted in a manner that is inconsistent with the guidelines in 5 CFR 1320.5(d)(2).

**8. Consultation and Public Comments: If applicable, provide a copy and identify the date and page number of publication in the Federal Register of the agency's notice, required by 5 CFR 1320.8(d), soliciting comments on the information collection prior to submission to OMB. Summarize public comments received in response to that notice and describe actions taken by the agency in response to these comments. Specifically address comments received on cost and**

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response

**hour burden. Describe efforts to consult with persons outside the agency to obtain their views on the availability of data, frequency of collection, the clarity of instructions and recordkeeping, disclosure, or reporting format (if any), and on the data elements to be recorded, disclosed, or reported. Consultation with representatives of those from whom information is to be obtained or those who must compile records should occur at least once every 3 years - even if the collection of information activity is the same as in prior periods. There may be circumstances that may preclude consultation in a specific situation. These circumstances should be explained.**

The 60-day Federal Register notice will be published for comments.

**9. Payments to Respondents: Explain any decision to provide any payment or gift to respondents, other than remuneration of contractors or grantees.**

A token incentive, such as a patch or a pen that expresses NASA's appreciation for their participation but does not have a significant dollar value will be provided to participants.

**10. Assurance of Confidentiality: Describe any assurance of confidentiality provided to respondents and the basis for the assurance in statute, regulation, or agency policy.**

The survey will conform to the practices as approved by the Institutional Review Board at The Pennsylvania State University. In the cover letter accompanying each survey respondents will be told that their responses are voluntary and will be kept strictly confidential. For all individual's who participate, they will be assigned a unique identification number for the forms recording the information they provide. Respondent's names or other identifying information will not be part of the data records. The staff administering the survey will maintain a master log that associates each individual with their contact information. The master log will be kept stored in a secure and confidential location during the survey administration. Upon completion of the survey and the data processing, the master log and any other identifying information about respondents will be destroyed after an established period of time. The information that is provided to the sponsor and any other stakeholders will not contain any information that can be used to identify respondents.

**11. Sensitive Questions: Provide additional justification for any questions of a sensitive nature, such as sexual behavior and attitudes, religious beliefs, and other matters that are commonly considered private. This justification should include the reasons why the agency considers the questions necessary, the specific uses to be made of the information, the explanation to be given to persons from whom the information is requested, and any steps to be taken to obtain their consent.**

There are no questions of a sensitive nature in any of the information collection protocols.

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response

**12. Respondent Burden Hours and Labor Costs: Provide estimates of the hour burden of the collection of information.**

**A. ANNUAL BURDEN HOURS:**

**B. NUMBER OF RESPONDENTS:**

100

**C. RESPONSES PER RESPONDENT:**

Daily Survey: Daily over 3 week period

Single Event: Up to 20 per day over 3 week period

**D. AVERAGE BURDEN PER RESPONSE:**

Baseline Survey	20 minutes total
Single Event	1 minute up to 20 times per day
Daily Survey	1 minute per day for 3 weeks

**E. FREQUENCY OF RESPONSES:**

Single Event	1 minute up to 20 times per day
Daily Survey	1 minute per day for 3 weeks

**13. Estimates of Cost Burden to the Respondent for Collection of Information: Provide an estimate for the total annual cost burden to respondents or recordkeepers resulting from the collection of information. (Do not include the cost of any hour burden shown in Items 12 and 14).**

No additional cost burden will be imposed on respondents aside from the labor cost of the burden hours shown above.

**14. Cost to the Federal Government: Provide estimates of annualized costs to the Federal government.**

Annual cost of the information collection to the Federal government ranges is shown below. Note that this cost includes salaries of research team members, and all expenses associated with measuring noise levels and collecting survey research data from community residents. NASA is providing funding for this effort. {Insert Project Budget Totals}

**15. Changes in Burden: Explain the reasons for any program changes or adjustments reported in Items 13 or 14 of the OMB Form 83-I.**

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response  
This is a new information collection.

**16. Publication of Results: For collections of information whose results will be published, outline plans for tabulation and publication. Address any complex analytical techniques that will be used. Provide the time schedule for the entire project, including beginning and ending dates of the collection of information, completion of report, publication dates, and other actions.**

A comprehensive report to NASA is planned upon completion of the research, documenting the procedures, analysis, results, and interpretation of the results and recommended guidelines for noise impact due to low booms. Findings will be published in peer-reviewed journals and presented at appropriate conferences.

These articles may be published in professional refereed journals, such as: Journal of the Acoustical Society of America, American Institute of Aeronautics and Astronautics, Noise and Health, Noise Control Engineering Journal, Journal of Sound and Vibration.

**17. If seeking approval to not display the expiration date for OMB approval of the information collection, explain the reasons that display would be inappropriate.**

Not applicable. This research is not seeking approval to not display the expiration date for OMB approval of this information collection.

**18. Explain each exception to the certification statement identified in Item 19, "Certification for Paperwork Reduction Act Submissions," of OMB Form 83-I.**

Not applicable. There are no exceptions to the certification statement.

### B. Collections of Information Employing Statistical Methods

#### 1. Description of the Activity

The potential respondent area is considered to be all households within an area adjacent to the boom impact area. A complete enumeration of households will be conducted in the community. Volunteers will be solicited for inclusion in participation. A systematic sample will be selected by determining a random starting point on the enumerated list of households that volunteer to participate, and using a sampling interval, based on the ratio of required respondents to the total number of available households.

#### 2. Procedures for the Collection of Information

- a. Statistical methodologies for stratification and sample selection.

## B-4a: OMB Support Statement

[DRAFT] OMB Application NASA Low Boom Community Response

There is a limited population from which we can recruit participants. Participants will be contacted and recruited. The identities of the participants assigned to the related project will only be known by the recruitment team, and not by any other members of our team.

### Estimation Procedures

Survey data will be combined with acoustical measurement data to develop dose-response models that estimate the level of response for a specific noise event. Currently the primary estimation procedure for measuring community reaction to noise events is in terms of “annoyance” (the response metric) correlated to long-term-average noise (the stimulus metric).

For this study, we will advance the use of dose-response cause-and-effect functional relationships to estimate the impacts of low sonic boom noise on residential communities. Our acoustic monitoring equipment will obtain data from which a range of stimulus metrics, including those that measure discrete noise events, can be developed. Our survey data will provide a range of response metrics, including the traditional long-term annoyance measure, as well as other response measures.

### 3. Maximization of Response Rates, Non-response, and Reliability

The team will work to maximize response rates and mitigate the potential for non-response bias in the information collection process. The team will develop well-designed and “respondent-friendly” questionnaires and employ well-designed contact and implementation procedures.

To maximize response rate the team the questionnaires have been developed in a fashion that takes the respondent’s point of view into account while designing questions, formats and layout, and interviewer and administration procedures. The current survey is based on recommendations from the International Commission on the Biological Effects of Noise (ICBEN) for socio-acoustic surveys.

### 4. Tests of Procedures or Methods

No tests of procedures or methods will be undertaken for this information collection. The procedures and implementation methods for the information collection will follow the generally accepted social science research standards.

### 5. Statistical Consultation and Information Analysis

Standards and guidelines published by organizations, such as the International Commission on the Biological Effects of Noise (ICBEN) have been consulted to develop the statistical analysis of noise impacts on individuals and communities.

## **B-4a: OMB Support Statement**

[DRAFT] OMB Application NASA Low Boom Community Response

In addition, our team contains several individuals with well-recognized expertise in noise analysis and/or in the statistical analysis of dose-response data on noise impacts. The team includes researchers from Wyle, Gulfstream Aerospace, Penn State University and TetraTech.

**PAPERWORK REDUCTION ACT SUBMISSION**

Please read the instructions before completing this form. For additional forms or assistance in completing this form, contact your agency's Paperwork Clearance Officer. Send two copies of this form, the collection instrument to be reviewed, the Supporting Statement, and any additional documentation to: **Office of Information and Regulatory Affairs, Office of Management and Budget, Docket Library, Room 10102, 725 17<sup>th</sup> Street NW Washington, DC 20503.**

<p><b>1. Agency/Subagency originating request</b></p>	<p><b>2. OMB control number</b> <span style="float: right;"><b>b. <input checked="" type="checkbox"/> None</b></span>                  a. _____</p>
<p><b>3. Type of information collection (check one)</b></p> <p>a. <input checked="" type="checkbox"/> New Collection                  b. <input type="checkbox"/> Revision of a currently approved collection                  c. <input type="checkbox"/> Extension of a currently approved collection                  d. <input type="checkbox"/> Reinstatement, without change, of a previously approved collection for which approval has expired.                  e. <input type="checkbox"/> Reinstatement, with change, of a previously approved collection for which approval has expired                  f. <input type="checkbox"/> Existing collection in use without OMB control number</p> <p>For b-f, note item A2 of Supporting Statement instructions</p>	<p><b>4. Type of review requested (check one)</b></p> <p>a. <input checked="" type="checkbox"/> Regular                  b. <input type="checkbox"/> Emergency – Approval requested by __/__/__                  c. <input type="checkbox"/> Delegated</p> <p><b>5. Small entities</b>                  Will this information collection have a significant economic impact on a substantial number of small entities? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No</p>
<p><b>3a. Public Comments</b></p> <p>Has the agency received public comments on this information collection?  <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No</p>	<p><b>6. Requested expiration date</b></p> <p>a. <input checked="" type="checkbox"/> Three years from approval date <span style="margin-left: 50px;">b. <input type="checkbox"/> Other __/__/__</span></p>
<p><b>7. Title:</b>                  Low Boom Community Response</p>	
<p><b>8. Agency form number(s) (if applicable).</b></p>	
<p><b>9. Keywords</b>                  Community noise survey, low-level sonic boom noise</p>	
<p><b>10. Abstract</b> This research is to further provide information about the perception of aircraft noise and low-level sonic booms. Members of a community in the noise impact area from a low boom flight pattern will be asked to provide information on social survey documents designed to assess their perceptions of noise. The information derived from this study may be from either measured or predicted effects. The focus of the research will be acceptability of low level sonic boom noise, with the premise that the variables influencing acceptability are stimulus factors, situational factors, and psychosocial factors.</p>	
<p><b>11. Affected public (Mark primary with "P" and all others that apply with "X")</b></p> <p>a. <input checked="" type="checkbox"/> Individuals or households <span style="margin-left: 100px;">d. <input type="checkbox"/> Farms</span>                  b. <input type="checkbox"/> Business or other for-profit <span style="margin-left: 100px;">e. <input type="checkbox"/> Federal Government</span>                  c. <input type="checkbox"/> Not-for-profit institutions <span style="margin-left: 100px;">f. <input type="checkbox"/> State, Local or Tribal Government</span></p>	<p><b>12. Obligation to respond (Mark primary with "P" and all others that apply with "x")</b></p> <p>a. <input checked="" type="checkbox"/> Voluntary                  b. <input type="checkbox"/> Required to obtain or retain benefits                  c. <input type="checkbox"/> Mandatory</p>
<p><b>13. Annual reporting and recordkeeping hour burden</b></p> <p>a. Number of respondents _____                  b. Total annual responses _____                     1. Percentage of these responses collected electronically _____ %                  c. Total annual hours requested _____                  d. Current OMB inventory _____                  e. Difference _____                  f. Explanation of difference                     1. Program change _____                     2. Adjustment _____</p>	<p><b>14. Annual reporting and recordkeeping cost burden (in thousands of dollars)</b></p> <p>a. Total annualized capital/startup costs _____                  b. Total annual costs (O&amp;M) _____                  c. Total annualized cost requested _____                  d. Current OMB inventory _____                  e. Difference _____                  f. Explanation of difference                     1. Program change _____                     2. Adjustment _____</p>
<p><b>15. Purpose of information collection (Mark primary with "P" and all others that apply with "X")</b></p> <p>a. <input type="checkbox"/> Application for benefits <span style="margin-left: 100px;">e. <input type="checkbox"/> Program planning or management</span>                  b. <input type="checkbox"/> Program evaluation <span style="margin-left: 100px;">f. <input checked="" type="checkbox"/> Research</span>                  c. <input type="checkbox"/> General purpose statistics <span style="margin-left: 100px;">g. <input type="checkbox"/> Regulatory or compliance</span>                  d. <input type="checkbox"/> Audit</p>	<p><b>16. Frequency of recordkeeping or reporting (check all that apply)</b></p> <p>a. <input type="checkbox"/> Recordkeeping <span style="margin-left: 150px;">b. <input type="checkbox"/> Third party disclosure</span>                  c. <input checked="" type="checkbox"/> Reporting                     1. <input checked="" type="checkbox"/> On occasion <span style="margin-left: 50px;">2. <input type="checkbox"/> Weekly</span> <span style="margin-left: 50px;">3. <input type="checkbox"/> Monthly</span>                     4. <input type="checkbox"/> Quarterly <span style="margin-left: 50px;">5. <input type="checkbox"/> Semi-annually</span> <span style="margin-left: 50px;">6. <input type="checkbox"/> Annually</span>                     7. <input type="checkbox"/> Biennially <span style="margin-left: 50px;">8. <input type="checkbox"/> Other (describe) _____</span></p>
<p><b>17. Statistical methods</b>                  Does this information collection employ statistical methods?    <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No</p>	<p><b>18. Agency contact (person who can best answer questions regarding the content of this submission)</b></p> <p>Name: _____                    Phone: _____</p>



## 19. Certification for Paperwork Reduction Act Submissions

On behalf of this Federal agency, I certify that the collection of information encompassed by this request complies with 5 CFR 1320.9

**Note:** The text of 5 CFR 1320.9, and the related provisions of 5 CFR 1320.8 (b) (3), appear at the end of the instructions. Their certification is to be made with reference to those regulatory provisions as set forth in the instructions.

The following is a summary of the topics, regarding the proposed collection of information, that the certification covers:

- (a) It is necessary for the proper performance of agency functions;
- (b) It avoids unnecessary duplication;
- (c) It reduces burden on small entities;
- (d) It uses plain, coherent, and unambiguous terminology that is understandable to respondents;
- (e) Its implementation will be consistent and compatible with current reporting and recordkeeping practices;
- (f) It indicates the retention periods for recordkeeping requirements;
- (g) It informs respondents of the information called for under 5 CFR 1320.8 (b) (3) about:
  - (i) Why the information is being collected;
  - (ii) Use of information;
  - (iii) Burden estimate;
  - (iv) Nature of response (voluntary, required for a benefit, or mandatory);
  - (v) Nature and extent of confidentiality; and
  - (vi) Need to display currently valid OMB control number;
- (h) It was developed by an office that has planned and allocated resources for the efficient and effective management and use of the information to be collected (see note in Item 19 of the instructions);
- (i) It uses effective and efficient statistical survey methodology (if applicable); and
- (j) It makes appropriate use of information technology.

If you are unable to certify compliance with any of these provisions, identify the items below and explain the reason in Item 18 of the Supporting Statement.

Signature of Senior Official or Designee

Date

# Instructions for Completing OMB Form 83-I

Please answer all questions and have the Senior Official or designee sign the form. These instructions should be used in conjunction with 5 CFR 1320, which provides information on coverage, definitions, and other matters of procedure and interpretation under the Paperwork Reduction Act of 1995.

## 1. Agency/Subagency originating request

Provide the name of the agency or subagency originating the request. For most cabinet-level agencies, a subagency designation is also necessary. For non-cabinet agencies, the subagency designation is generally unnecessary.

## 2. OMB Control number

a. If the information collection in this request has previously received or now has an OMB control number or comment number, enter the number.

b. Check "NONE" if the information collection in this request has not previously received an OMB control number. Enter the four digit agency code for your agency.

## 3. Type of Information Collection (check one)

a. Check "NEW" collection when the collection has not previously been used or sponsored by the agency.

b. Check "EEXTENSION" when the collection is currently approved by OMB, and the agency request includes a material change to the collection instrument, instructions, its frequency of collection, or the use to which the information is to be put.

c. Check "EXTENSION" when the collection is currently approved by OMB, and the agency wishes only to extend the approval past the current expiration date without making any material change in the collection instrument, instructions, frequency of collection, or the use to which the information is to be put.

d. Check "Reinstatement without change" when the collection previously had OMB approval, but the approval has expired or was withdrawn before this submission was made, and there is no change to the collection.

e. Check "Reinstatement with change" when the collection previously had OMB approval, but the approval has expired or was withdrawn before for this submission was made, and there is change to the collection.

f. Check "Existing collection in use without OMB control number" when the collection is currently in use but does not have a currently valid OMB control number.

## 4. Type of review requested (check one)

a. Check "Regular" when the collection is submitted under 5 CFR 1320.10, 1320.11, or 1320.12 with a standard 60 day review schedule.

b. Check "Emergency" when the agency is submitting the request under 5 CFR 1320.13 for emergency processing and provides the required supporting material. Provide the date by which the agency requests approval.

c. Check "Delegated" when the agency is submitting the collection under the conditions OMB has granted the agency delegated authority.

## 5. Small entities

Indicate whether this information collection will have a significant impact on a substantial number of small entities. A small entity may be (1) a small business which is deemed to be one that is independently owned and operated and that is not dominant in its field of operation; (2) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field; or (3) a small government jurisdiction which is a government of a city, county, town, township, school district, or special district with a population of less than 50,000.

## 6. Requested expiration date

a. Check "Three years" if the agency requests a three year approval for the collection.

b. Check "Other" if the agency requests approval for less than three years. Specify the month and year of the requested expiration date.

## 7. Title

Provide the official title of the information collection. If an official title does not exist, provide a description which will distinguish the collection from others.

## 8. Agency form number(s) (if applicable)

Provide any form number the agency has assigned to this collection of information. Separate each form number with a comma.

## 9. Keywords

Select and list at least two keywords (descriptors) from the "Federal Register Thesaurus of Indexing Terms" that describe the subject area(s) of the information collection. Other terms may be used but should be listed after those selected from the thesaurus. Separate keywords with commas. Keywords should not exceed two lines of text.

## 10. Abstract

Provide a statement, limited to five lines of text, covering the agency's need for the information, uses to which it will be put, and a brief description of the respondents.

## 11. Affected public

Mark all categories that apply, denoting the primary public with a "P" and all others that apply with "X".

## 12. Obligation to respond

Mark all categories that apply, denoting the primary obligation with a "P" and all others that apply with "X".

a. Mark "Voluntary" when the response is entirely discretionary and has not direct effect on any benefit or privilege for the respondent.

b. Mark "Required to obtain or retain benefits" when the response is elective, but is required to obtain or retain a benefit.

c. Mark "Mandatory" when the respondent must reply or face civil or criminal sanctions.

## 13. Annual reporting and recordkeeping hour burden

a. Enter the number of respondents and/or recordkeepers. If a respondent is also a recordkeeper, report the respondent only once.

b. Enter the number of responses provided annually. For recordkeeping as compared to reporting activity, the number of responses equals the number of recordkeepers.

b1. Enter the estimated percentage of responses that will be submitted/collected electronically using magnetic media (i.e., diskette), electronic mail, or electronic data interchange. Facsimile is not considered and electronic submission.

c. Enter the total annual recordkeeping and reporting hour burden.

d. Enter the burden hours currently approved by OMB for this collection of information. Enter zero (0) for any new submission or for any collection whose OMB approval has expired.

e. Enter the difference by subtracting line d from line c. Record a negative number (d larger than c) within parentheses.

f. Explain the difference. The difference in line e must be accounted for in lines f.1 and f.2.

f.1. "Program change" is the result of deliberate Federal government action. All new collections and any subsequent revision of existing collections (e.g., the addition or deletion of questions) are recorded as program changes.

f.2. "Adjustment" is a change that is not the result of a deliberate Federal government action. Changes resulting from new estimates or action not controllable by the Federal government are recorded as adjustments.

## 14. Annual reporting and recordkeeping cost burden (in thousands of dollars)

The costs identified in this item must exclude the cost of hour burden identified in item 13.

a. Enter the total dollar amount of annualized cost for all respondents of any associated capital or start-up costs.

b. Enter recurring annual dollar amount of cost for all respondents associated with operating or maintaining systems or purchasing services.

c. Enter total (14.a + 14.b) annual reporting and recordkeeping cost burden.

d. Enter any cost burden currently approved by OMB of this collection of information. Enter zero (0) if this is the first submission after October 1, 1995.

e. Enter the difference by subtracting line d from line c. Record a negative number (d larger than c) within parenthesis.

f. Explain the difference. The difference in line e must be accounted for in lines f.1 and f.2.

f.1. "Program change" is the result of deliberate Federal government action. All new collections and any subsequent revisions or changes resulting in cost changes are recorded as program changes.

f.2. "Adjustment" is a change that is not the result of a deliberate Federal government action. Changes resulting from new estimates

or actions not controllable by the Federal government are recorded as adjustments.

#### **15. Purpose of information collection**

Mark all categories that apply, denoting the primary purpose with a "P" and all others that apply with "X"

- a. Mark "Application for benefits" when the purpose is to participate in, receive, or qualify for a grant, financial assistance, etc. from a Federal agency or program.
- b. Mark "Program evaluation" when the purpose is a formal assessment, through objective measures and systematic analysis, of the manner and extent to which Federal programs achieve their objective or produce other significant effects.
- c. Mark "General purpose statistics" when the data is collected chiefly for use by the public or for general government use without primary reference to the policy or program operations of the agency collecting the data.
- d. Mark "Audit" when the purpose is to verify the accuracy of accounts and records.
- e. Mark "Program planning or management" when the purpose related to progress reporting, financial reporting and grants management, procurement and quality control, or other administrative information that does not fit into any other category.

f. Mark "Research" when the purpose is to further the course of research, rather than for specific program purpose.

g. Mark "Regulatory or compliance" when the purpose is to measure compliance with laws or regulations.

#### **16. Frequency of recordkeeping or reporting**

Check "Recordkeeping" if the collection of information explicitly includes a recordkeeping requirement.

Check "Third party disclosure" if a collection of information includes third-party disclosure requirement as defined by 1320.3(c).

Check "Reporting" for information collections that involve reporting and check the frequency of reporting that is requested or required of a respondent. If the reporting is on "an event" basis, check "On occasion".

#### **17. Statistical Methods**

Check "Yes" if the information collection uses statistical methods such as sampling or imputation. Generally, check "No" for applications and audits (unless a random auditing scheme is used). Check "Yes" for statistical collections, most research collections, and program evaluations using scientific methods. For other types of data collection, the use of sampling, imputation, or other statistical estimation techniques should dictate the response for this item. Ensure that supporting documentation is provided in accordance with Section B of the Supporting Statement.

#### **18. Agency contact**

Provide the name and telephone number of the agency person best able to answer questions regarding the content of this submission.

#### **19. Certification for Paperwork Reduction Act Submissions**

The Senior Official or designee signing this statement certifies that the collection of information encompassed by the request complies with 5 CFR 1320.9. Provisions of this certification that the agency cannot comply with should be identified here and fully explained in item 18 of the attached Supporting Statement. NOTE: The Office that "develops" and "uses" the information to be collected is the office that "conducts or sponsors" the collection of information. (See 5 CFR 1320.3(d)).

## Certification Requirement for Paperwork Reduction Act Submission

5 CFR 1320.9 reads "As part of the agency submission to OMB of a proposed collection of information, the agency (through the head of the agency, the Senior Official, or their designee) shall certify (and provide a record supporting such certification) that the proposed collection of information-

"(a) is necessary for the proper performance of the functions of the agency, including that the information to be collected will have practical utility;

"(b) is not unnecessarily duplicative of information otherwise reasonably accessible to the agency;

"(c) reduces to the extent practicable and appropriate the burden on persons who shall provide information to or for the agency, including with respect to small entities, as defined in the Regulatory Flexibility Act (5 U.S.C. § 601(6)), the use of such techniques as:

"(1) establishing differing compliance or reporting requirements or timetables that take into account the resources available to those who are to respond;

"(2) the clarification, consolidation, or simplification of compliance and reporting requirements; or collections of information, or any part thereof;

"(3) an exemption from coverage of the collection of information, or any part thereof;

"(d) is written using plain, coherent, and unambiguous terminology and is understandable to those who are to respond;

"(e) is to be implemented in ways consistent and compatible, to the maximum extent practicable, with the existing reporting and recordkeeping practices of those who are to respond;

"(f) indicates for each recordkeeping requirement the length of time persons are required to maintain the records specified;

"(g) informs potential respondents of the information called for under §1320.8(b)(3); [see below]

"(h) has been developed by an office that has planned and allocated resources for the efficient and effective management and use of the information to be collected, including the processing of the information in a manner which shall enhance, where appropriate, the utility of the information to agencies and the public;

"(i) uses effective and efficient statistical survey methodology appropriate to the purpose for which the information is to be collected; and

"(j) to the maximum extent practicable, uses appropriate information technology to reduce burden and improve data quality, agency efficiency and responsiveness to the public."

NOTE: 5 CFR 1320.8(b)(3) requires that each collection of information:

"(3) informs and provides reasonable notice to the potential persons to whom the collection of information is addressed of:

"(i) the reasons the information is planned to be and/or has been collected;

"(ii) the way such information is planned to be and/or has been used to further the proper performance of the functions of the agency;

"(iii) an estimate, to the extent practicable, of the average burden of the collection (together with a request that the public direct to the agency any comments concerning the accuracy of this burden estimate and any suggestions for reducing this burden);

"(iv) whether responses to the collection of information are voluntary, require to obtain or retain a benefit (citing authority) or mandatory (citing authority);

"(v) the nature and extent of confidentiality to be provided, if any (citing authority); and

"(vi) the fact that an agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number."



# Appendices

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## Appendix C

**C-1: EAFB News Article, 22 Jun 2011**

**C-2: EAFB Desert Wings, 24 June 2011**

**C-2a: EAFB Desert Wings, 24 June 11**

**C-3: EAFB Desert Wings, 07 July 11**

**C-4: Thank You Email, 28 June 2011**

**C-5: WSPR Resident Email, 27 May 2011**

**C-6: Recruit Letter, 28 June 2011**

**C-7: Sonic Boom Flyer**

**C-8: Repost June 22 News Article, 25 July 2011**

**C-9: Recruit Notification Email, 27 July 2011**

**C-10: Repost June 22 News Article, 22 September 2011**

**C-11: Resident Email w-Incentive, 12 September 2011**

**C-12: Recruitment Screener**



## Boom! NASA-Dryden asks base residents to lend ear for sonic boom study

by Kate Blais  
95th Air Base Wing Public Affairs

6/22/2011 - **EDWARDS AIR FORCE BASE, Calif.** -- The NASA-Dryden Flight Research Center is calling upon base residents to lend a keen ear to the skies above Edwards and participate in an upcoming sonic boom research study.

Commencing this fall, the NASA-sponsored study will gather data on individuals' attitudes toward aircraft noise, specifically sonic booms. The data collected will contribute to the design of quieter supersonic aircraft.

Those who participate will help engineers understand how individuals experience sonic booms.

"We need residents' help to understand how individuals experience this noise in their homes and neighborhoods in order to advance the necessary technologies for commercial supersonic transportation," said Larry Cliatt, an aerospace engineer at Dryden and principal investigator for the study.

"The testing phase will consist of producing a varying number of sonic booms per day, while collecting participant response data from the Edwards Air Force Base residential community."

Using standardized survey questions, each participant will be asked to complete a short questionnaire survey every time he or she hears any sonic boom while on base.

Surveys will be administered in paper form, a Web-based form and an application compatible with Apple mobile devices. In addition, a smartphone will be lent to some participants for the duration of the study.

Those interested in participating in the study will undergo a preliminary phone or Web interview - via the study's Web site - in order for researchers to collect more detailed information on the amount of time individuals are typically home during the day.

Participants must live on base, be at least 18 years old and be home at least part of the day during the week.

NASA is hoping to recruit at least 100 participants, 50 of whom are needed by August. 1. Each participant will receive a token of appreciation from NASA.

"Understanding residents' responses to sonic booms is very important to NASA," concluded Mr. Cliatt. "We are looking for at least 100 base residents during a time of high base turnover. So, it is very important to get as many volunteers as possible."

For more information about the research study and whether you are eligible, please call 1-800-454-5070 or e-mail [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com) or visit [www.NASABoomStudy.com](http://www.NASABoomStudy.com).



A NASA F-18 banks left in flight over the desert. The NASA-Dryden Flight Research Center will use its fleet of F-18 aircraft to carry out a study that will commence this fall to gather data from base residents on their attitudes towards aircraft noise, specifically sonic booms. (Courtesy photo)

# DESERT WINGS

Serving the community of Edwards Air Force Base, California

Volume 59, Number 49

[www.edwards.af.mil](http://www.edwards.af.mil) – [www.facebook.com/edwardsairforcebase](http://www.facebook.com/edwardsairforcebase)

June 24, 2011

## Dryden asks residents to lend ear for sonic boom study

by Kate Blais  
Staff Writer

The NASA Dryden Flight Research Center is calling upon base residents to lend a keen ear to the skies above Edwards and participate in an upcoming sonic boom research study.

Commencing this fall, the NASA-sponsored study will gather data on individuals' attitudes toward aircraft noise, specifically sonic booms. The data collected will contribute to the design of quieter supersonic aircraft.

Those who participate will help engineers understand how individuals experience sonic booms.

"We need residents' help to understand how individuals experience this noise in their homes and neighborhoods in order to advance the necessary technologies for commercial supersonic transportation," said Larry Cliatt, an aerospace engineer at Dryden and principal investigator for the study.

"The testing phase will consist of produc-

ing a varying number of sonic booms per day, while collecting participant response data from the Edwards Air Force Base residential community."

Using standardized survey questions, each participant will be asked to complete a short questionnaire survey every time he or she hears any sonic boom while on base.

Surveys will be administered in paper form, a Web-based form and an application compatible with Apple mobile devices. In addition, a smartphone will be lent to some participants for the duration of the study.

Those interested in participating in the study will undergo a preliminary phone or Web interview—via the study's Web site—in order for researchers to collect more detailed information on the amount of time individuals are typically home during the day.

Participants must live on base, be at least 18 years old and be home at least part of the day during the week.

NASA is hoping to recruit at least 100 participants, 50 of whom are needed by

See B00M, Page 3



Courtesy photograph

A NASA F-18 banks left in flight over the desert. The NASA Dryden Flight Research Center will use its fleet of F-18 aircraft to carry out a study that will commence this fall to gather data from base residents on their attitudes towards aircraft noise, specifically sonic booms.

### BOOM, from 1

August 1. Each participant will receive a token of appreciation from NASA.

“Understanding residents’ responses to sonic booms is very important to NASA,” concluded Mr. Cliatt. “We are looking for at least 100 base residents during a time of high base turnover.

So, it is very important to get as many volunteers as possible.”

For more information about the research study and whether you are eligible, please call 1-800-454-5070 or e-mail Chelsea.merchant@tetrattech.com or visit www.NASABoomStudy.com.

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National Aeronautics and Space Administration

### Volunteers Needed

NASA is looking for volunteers to take part in a study about sonic boom noise in your neighborhood in the Fall 2011.

To be eligible, participants must:

- Reside on Edwards Air Force Base
- Be 18 years of age or older
- Be home at least part of the day during weekday, daytime hours

Participation is voluntary and survey responses will be confidential.

Participants will be asked to complete a brief set of questions each time they hear a sonic boom over a few months.

Please contact us at  
1-800-454-5070  
[chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)  
[www.NASABoomStudy.com](http://www.NASABoomStudy.com)

Email to those that completed to the recruitment screener

Subject: Interest in the NASA Boom Study

Dear [First Name Last Name],

Thank you! We received your on-line registration and appreciate your interest in the sonic boom research study sponsored by NASA. We will process registration information over the next several weeks and begin contacting eligible individuals in late July.

We still need many volunteers to make this research effort a success. If you have friends or neighbors who may be interested, please ask them to contact us.

[www.NASABoomStudy.com](http://www.NASABoomStudy.com)

1 (800) 454-5070

Again, to be eligible, participants must be 18 years of age or older, reside on Edwards AFB and be home at least part of the day during weekday, daytime hours.

Thank you for your help.

Kind regards,

Chelsea Merchant  
Survey Coordinator  
[chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)

Date

Dear [First Name Last Name],

National Aeronautics and Space Administration (NASA) is looking for volunteers to take part in a study about sonic boom noise in your neighborhood. The study is being conducted for research purposes and will take place in Fall 2011 at Edwards Air Force Base. To be eligible, participants must

- reside on the base
- be 18 years of age or older
- be home at least part of the day during weekday, daytime hours

If you are interested in participating in the study, please logon to the following website to see if you are eligible.

[www.NASABoomStudy.com](http://www.NASABoomStudy.com)

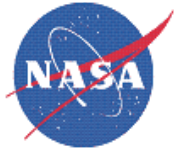
Participation is voluntary and survey responses will be confidential. The information provided will be used for statistical purposes and will not be reported in a way that would reveal individual participants.

We are working with Tetra Tech, an independent research firm, to help conduct the study. Please help us with this important research: contact us at 1 800 454 5070 or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com).

Thank you. We appreciate your help.

Sincerely,

Name  
organization  
title



Date

Dear [First Name Last Name],

Beginning this fall NASA will conduct a series of sonic boom tests to be executed by NASA Dryden Flight Research Center over Edwards AFB. These tests will record how residents experience the noise in their homes and neighborhoods. We are seeking volunteers from the Edwards community to assist with the data collection and would like you to become part of that effort.

As a volunteer you will be assigned to one of two research teams, one associated with Penn State University and the other with Fidell Associates. In that role you will be asked to complete a brief set of questions each time you hear a sonic boom over the course of a few months.

The data gathered will help researchers understand human response and attitudes to aircraft noise in their communities. This information will aid in future aircraft development and design, possibly softening noise associated with supersonic flight.

To be eligible, you must:

- Reside on Edwards Air Force Base
- Be 18 years of age or older
- Be home, at least part-time, during daytime hours during weekdays

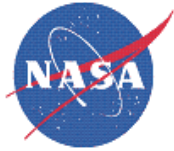
Participation is completely voluntary and survey responses will be confidential. The information provided will be used for statistical purposes and will not reveal individual identification.

NASA is working with Tetra Tech, an independent research firm, to conduct the study. If you would like to join our team and help with this important research please contact Tetra Tech toll-free at 1-800-454-5070, or email Ms. Chelsea Merchant at [Chelsea.Merchant@tetratech.com](mailto:Chelsea.Merchant@tetratech.com). Self registration is available at [www.NASABoomStudy.com](http://www.NASABoomStudy.com), and more information is provided on the reverse of this letter.

We appreciate your help and support!

Respectfully,  
Name  
organization  
title

*Please contact us at*  
**(800) 454-5070**  
**[chelsea.merchant@tetratech.com](mailto:chelsea.merchant@tetratech.com)**  
**[www.NASABoomStudy.com](http://www.NASABoomStudy.com)**



## Answers to Frequently Asked Questions

### **Who is conducting this study?**

NASA is sponsoring this research. A multi-disciplinary research team is collecting and analyzing data on sonic booms. Tetra Tech, an independent research firm, is helping us recruit eligible residents of Edwards Air Force Base.

### **Why is this study being done?**

Data from this research study will help NASA understand the impact of sonic booms on people. We want to understand people's experiences with these sounds in their homes. This information will be used by scientists, engineers and researchers to design quieter supersonic aircraft.

### **When will the study be done?**

The study will be conducted in Fall 2011. It may begin as early as August or September.

### **What will participants be asked to do?**

Some individuals will be asked to answer a few questions each time they hear a sonic boom over approximately a three-month period. Other individuals will be asked to participate for several weeks by answering a few questions each time they hear a sonic boom. They will also complete a brief summary questionnaire at the end of each day. In a short telephone interview, we will ask questions about social and demographic characteristics so that we can accurately describe the group of participants.

### **Will I receive anything for participating?**

Yes. Individuals who are eligible will be asked to complete a brief survey each time they notice a sonic boom over a period of several weeks. Participants will receive a certificate of appreciation from NASA and a patch.

### **Am I eligible if I am not at home every weekday during daytime hours?**

You might be. We need individuals who are at home at least some week days during daytime hours. A more detailed screening interview to determine eligibility will be conducted by telephone or web when you contact us. If you are at home at least part of the time on weekdays, please contact us. Call us toll-free at (800) 454-5070, send email to [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com), or logon to [www.NASABoomStudy.com](http://www.NASABoomStudy.com).

### **What if I do not know if I will be living at Edwards Air Force Base in Fall 2011?**

Please contact us even if you are not sure whether you will be on base in Fall 2011. We will contact you again closer to the study period to confirm your eligibility.

### **Whom do I contact for more information about this research?**

For information about the survey and whether you are eligible, please call (800) 454-5070 or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com).

For information about the research program and how the study results will be used, please contact Larry J. Cliatt, NASA Dryden Flight Research Center at (661) 276-7617 or [larry.j.cliatt@nasa.gov](mailto:larry.j.cliatt@nasa.gov).

You may also contact Rich Heeman at 95<sup>th</sup> ABW Plans and Programs (661) 277-2667 or [richard.heeman@edwards.af.mil](mailto:richard.heeman@edwards.af.mil).



## Volunteers Needed

**NASA is looking for volunteers to take part in a study about sonic boom noise in your neighborhood in the Fall of 2011.**

**To be eligible, participants must:**

- **Reside on Edwards Air Force Base**
- **Be 18 years of age or older**
- **Be home at least part of the day during weekday, daytime hours**

**Participation is voluntary and survey responses will be confidential.**

**Participants will be asked to complete a brief set of questions each time they hear a sonic boom over a few months.**

**Please contact us at  
1-800-454-5070  
[chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)  
[www.NASABoomStudy.com](http://www.NASABoomStudy.com)**

25 July 2011

WSPR Recruit

Short “blurb” to introduce a re-post of the June 22 news article that was posted on the Edwards AFB and NASA-Dryden websites.

**For the website:**

The NASA Dryden Flight Research Center kicked-off a research study on sonic booms in late June. The NASA-sponsored team began recruiting residents of Edwards AFB who will complete short questionnaire surveys when they notice sonic booms while on base. More volunteers are needed to help make the study a success. The research, which will take place in Fall 2011, will help engineers understand how individuals experience sonic booms and will contribute valuable information to the design of supersonic aircraft. Response by Edwards AFB residents has been enthusiastic and the research team is delighted to have over 40 people register so far—about half the number of participants needed. Base residents who are at least 18 years old and at home at least part of the day during the week are encouraged to visit [www.NASABoomStudy.com](http://www.NASABoomStudy.com) to register. More information about the research is available in [this news article](#). <[hyperlink to June 22 article](#)>

**For Facebook:**

NASA welcomes over 40 Edwards residents who have registered for a research study on sonic booms in Fall 2011. More volunteers are needed to help make this study a success. Please visit [www.NASABoomStudy.com](http://www.NASABoomStudy.com) to register or [click here](#) for more information. <[hyperlink to news article](#)>



Email to those that have been selected to participant in the study  
Penn State/Wyle research team

Subject: Selected for the NASA Boom Study

Dear [First Name Last Name],

Congratulations! You have been selected to participate in the NASA Sonic Boom study at Edwards Air Force Base that will take place this Fall as part of the Penn State research team.

Over the next couple months, we will be finalizing the survey material and getting equipment in place for the study. We will contact you again in a few weeks to tell you more about how you will be recording your answers to brief survey questionnaires when you notice sonic booms. We will also ask you some questions about your neighborhood and your reaction to common neighborhood noises.

We are still seeking additional volunteers for the study. If you have friends or neighbors who might be interested, please ask them to contact us and refer them to our website [www.NASABoomStudy.com](http://www.NASABoomStudy.com). Again, eligible participants must live on Edwards AFB, be at least 18 years of age, and be at home at least part of the day during daytime hours.

Please contact us if you have any questions or concerns.

Welcome aboard!

Chelsea Merchant  
Survey Coordinator  
[chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)

1 (800) 454-5070  
[www.NASABoomStudy.com](http://www.NASABoomStudy.com)

22 Sept 2011

WSPR Recruit

Short “blurb” to introduce a re-post of the June 22 news article that was posted on the Edwards AFB and NASA-Dryden websites and introduce the incentive.

**For the website:**

The NASA Dryden Flight Research Center is still looking for volunteers to make the sonic boom study a success. *Individuals who are eligible and agree to participate will receive a \$50 gift card.* The NASA-sponsored team began recruiting residents of Edwards AFB in late June to complete short questionnaire surveys when they notice sonic booms while on base. The research, which will take place in Fall 2011, will help engineers understand how individuals experience sonic booms and will contribute valuable information to the design of supersonic aircraft. Response by Edwards AFB residents has been enthusiastic and the research team is delighted to have over 70 people register so far. Base residents who are at least 18 years old and are at home at least part of the day during the week are encouraged to visit [www.NASABoomStudy.com](http://www.NASABoomStudy.com) to register. More information about the research is available in [this news article](#). <[hyperlink to June 22 article](#)>

**For Facebook:**

NASA welcomes over 70 Edwards residents who have registered for a research study on sonic booms in Fall 2011. More volunteers are needed to help make this study a success. *Individuals who are eligible and agree to participate will receive a \$50 gift card.* Please visit [www.NASABoomStudy.com](http://www.NASABoomStudy.com) to register or [click here](#) for more information. <[hyperlink to news article](#)>

Date

Dear [First Name Last Name],

National Aeronautics and Space Administration (NASA) is continuing to look for volunteers to take part in a study about sonic boom noise in your neighborhood. *Individuals who are eligible and agree to participate will receive a \$50 gift card.*

To be eligible, participants must

- reside on Edwards AFB during Fall 2011
- be 18 years of age or older
- be home at least part of the day during weekday, daytime hours

If you are interested in participating in the study, please logon to the following website to see if you are eligible.

[www.NASABoomStudy.com](http://www.NASABoomStudy.com)

If you already registered at the website, you do not need to re-register. All persons who register, meet the eligibility criteria, and agree to participate will receive a \$50 VISA gift card. The card can be used to purchase goods or services wherever VISA is accepted.

The study is being conducted for research purposes and will take place in Fall 2011 at Edwards Air Force Base. Participation is voluntary and survey responses will be confidential. The information provided will be used for statistical purposes and will not be reported in a way that would reveal individual participants.

We are working with Tetra Tech, an independent research firm, to help conduct the study. Please help us with this important research: contact us at 1 800 454 5070 or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com).

Thank you. We appreciate your help.

Sincerely,

Name  
organization  
title

## C-12 Recruitment Screener

### Low Boom Response Pilot Program Recruitment Screening Questionnaire

[Self-administered survey of EAFB residents who volunteer to be contacted]

**INT2** Before we begin, please note that your participation is voluntary. However, we need you to answer all of the following eligibility questions. If you do not want to answer one of these questions, you may stop the survey but then you may not be able to participate in the study. The results of the study will be summarized so that the answers you provide cannot be associated with you or anyone in your household. The questions in this eligibility survey should take about 10 minutes of your time and you must be 18 years of age or older to consent to participate in this research.

If you need help completing these questions, please contact Chelsea Merchant of Tetra Tech at (800) 454-5070 or [chelsea.merchant@tetratech.com](mailto:chelsea.merchant@tetratech.com).

If you have questions about the research program and how the study results will be used, please contact Larry J. Cliatt, NASA Dryden Flight Research Center at (661) 276-7617 or [larry.j.cliatt@nasa.gov](mailto:larry.j.cliatt@nasa.gov).

(Select one)

- 1 Continue
- 2 No longer interested [skip to EX]

**Q2** Do you currently live on Edwards Air Force Base? (Select one)

- 1 Yes
- 2 No [skip to NOTQ]

**Q3A** The next questions ask about the time you personally are at home. We need to know if participants will be able to tell us about noise in their area during different times of the day.

First, we will ask about the number of weekdays that you are usually at home, and roughly how many hours each day. Then, we will ask about evenings during the week, and the number of hours you are usually at home in the evenings. There is one question about your time at home on Saturdays.

(Press "next" to continue)

**Q3** Think about the weekdays Monday through Friday between 7 o'clock in the morning and 5 o'clock in the evening. On how many weekdays are you usually at home at least part of the day during these hours?

(Enter "0" if not usually home during this time)

(Enter a whole number between 0 and 5 below; Please give your best estimate)

\_\_\_\_\_ number of days (enter number between 0 and 5)

**[IF Q3 EQ 0 SKIP TO Q6]**

**Q4** On a weekday when you are at home, how many hours are you usually at home in the morning, that is between 7 o'clock in the morning and noon?

(Select one; Please give your best estimate)

- 0 Not usually at home during this time
- 1 1 hour
- 2 2 hours
- 3 3 hours
- 4 4 hours
- 5 5 hours

**Q5** On a weekday when you are at home, how many hours are you usually at home in the afternoon, that is between noon and 5 o'clock in the evening?

(Select one; Please give your best estimate)

- 0 Not usually at home during this time
- 1 1 hour
- 2 2 hours
- 3 3 hours
- 4 4 hours
- 5 5 hours

**[ASK ALL]**

**Q6** Please tell me about Monday through Friday evenings. On how many weeknights are you usually home at least part of the time between 5 o'clock and 7 o'clock in the evening?

(Enter "0" if not usually home during this time)

(Enter a whole number between 0 and 5 below; Please give your best estimate)

\_\_\_\_\_ number of weeknights (enter number between 0 and 5)

**[IF Q6 EQ 0 SKIP TO Q8]**

**Q7** On a weeknight when you are at home, how many hours are you usually at home between 5 o'clock and 7 o'clock in the evening?

(Select one; Please give your best estimate)

- 0 Not usually at home during this time
- 1 1 hour
- 2 2 hours

**[ASK ALL]**

**Q8** Next, please think about when you are at home during daytime hours on Saturdays. Weekend schedules can be different from one week to the next. In general on Saturdays, are you usually at home less than half the day, about half the day, or more than half the day?

By "daytime hours," we mean between 7 o'clock in the morning and 5 o'clock in the evening.

(Select one)

- 0 Not usually at home on Saturdays
- 1 Less than half the day
- 2 About half the day
- 3 More than half the day

**Q8a** People often have different schedules in the fall than they do during the summer months. This study will be done during Fall 2011. To the best of your knowledge, will the time you spend at home in the fall be about the same as it is now, much less than it is now, or much more?

Please note: The study could begin in late August or early September and last through the middle of November

(Select one)

- 1 At home in the fall about the same time as now
- 2 At home in the fall much less time than now
- 3 At home in the fall much more time than now

**Q9A** Will you be living on Edwards Air Force Base at that time?

Please note: The study could begin in late August or early September and last through the middle of November

(Select one)

- 1 Yes
- 2 No
- 3 Uncertain (Specify)

**Q9** To the best of your knowledge is your hearing normal?  
(Select one)

- 1 Yes [skip to Q11A]
- 2 No

**Q10** Do you use a hearing aid?  
(Select one)

- 1 Yes
- 2 No

**Q11A** As part of the study, participants will be asked to answer a few questions each time they hear a sonic boom. The survey can be completed in different ways, and the next questions will help us understand what will work best.

(Press “next” to continue)

**Q11** Some participants may be asked to complete the short questionnaire over the Internet each time they hear a sonic boom.

Do you have access to a computer from your home? (Select one)

- 1 Yes
- 2 No [skip to Q14]

**Q12** Can you access the Internet from your home using this computer?  
(Select one)

- 1 Yes
- 2 No [skip to Q14]



**Q13** Would you be willing to use this computer to complete the questionnaire on-line as part of this study? You would not be reimbursed for any costs to use the computer or to access the Internet. (Select one)

- 1 Yes
- 2 No

**Q14** Some participants may be asked to complete the short questionnaire using their own personal SmartPhone or mobile device each time they hear a sonic boom. We will provide an application that runs on the iPhone, the iPod Touch, or the iPad.

Do you own an iPhone, iPod Touch, or iPad that is your own personal device?

If you have questions about using your own device, click here: [\[FAQ link\]](#)

(Select one)

- 1 Yes
- 2 No [\[skip to Q16\]](#)

**Q15** Would you be willing to use your iPhone, iPod Touch, or iPad as part of this study? This would be at your own expense.

If you have questions about using your own device, click here: [\[FAQ link\]](#)

(Select one)

- 1 Yes
- 2 No

**Q16** We will lend SmartPhones to some participants for the purpose of the study. Participants will receive training and technical assistance, and they will be asked to use the SmartPhones to answer survey questions. You may use the phone for personal use at no expense but must return the phone at the end of the study.

Would you be willing to participate in the study using a SmartPhone that is provided to you?

If you have questions about using a SmartPhone provided to you, click here: [SmartPhone FAQ]

(Select one)

- 1 Yes
- 2 No [skip to Q20]

**Q17** The SmartPhones that we lend participants have Global Positioning System capability, or GPS. The GPS will be used to check the quality of data- that is, are participants at home, or away from home when they answer questions about the noise they hear. The GPS will **not** be used to track participants throughout the day.

Would you be willing to answer survey questions with a SmartPhone that uses this GPS capability?

If you have questions about using a SmartPhone provided to you, click here: [SmartPhone FAQ]

(Select one)

- 1 Yes
- 2 No [skip to Q20]

**Q18** The SmartPhones we lend to participants may be used to make telephone calls, send text messages, or browse the Internet at no cost to you. You will be asked to use the SmartPhone to answer questions about noise that you hear over approximately a three-month period.

Are you willing to answer survey questions over a three-month period using a SmartPhone provided by us?

If you have questions about using a SmartPhone provided to you, click here:  
[SmartPhone FAQ]

(Select one)

- 1 Yes
- 2 No

**Q20** It's helpful to know how people find out about this research. How did you learn about this study? (Select all that apply)

- 1 A letter or email from Edwards Air Force Base or from NASA
- 2 Poster in community area
- 3 Announcement at meeting or workshop
- 4 Social networking site (Facebook, Twitter)
- 5 Public service TV announcement
- 6 Newspaper article
- 7 From a neighbor/friend
- 8 Other (specify)

**Q21A** Thank you. We will contact you again before the study begins. To make sure that we can reach you, would you please tell us your...

- Full Name:
- Q21B** Full Street Address:
- Q21C** Primary Phone: [Example: "1112223333"]
- Q21D** Alternate Phone number: [Example: "1112223333"]
- Q21E** Email:

**INT99** Thank you. Do you have any comments to add? (Select one)

- 1 No, continue
- 2 Yes, enter comments below

**Q22** Those are all of our questions. We will be contacting individuals who are eligible for the study in about a month.

Please press "next" to submit your answers.

**NOTQ** Unfortunately only individuals who live in housing on Edwards Air Force Base are eligible to participate in this study. Thank you. We appreciate your interest.

**EX** Thank you for your time and consideration. Feel free to contact us with any questions or concerns or if you decide to participate in the survey:

Phone: (800) 454-5070

E-mail: [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)

(Press "next" to exit survey)



# Appendices

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## Appendix D

**D-1: Email Instructions for Apple, 26 October 2011**

**D-2: Email Instructions for Web, 26 October 2011**

**D-3: Mail Instructions, 19 October 2011**

**D-4: Field Study FAQ, 19 October 2011**

Dear <name>,

Thank you for participating in NASA’s sonic boom study. This email describes what you will do during the study and how to contact us if you have questions.

The dates of the study are **Friday, November 4 to Tuesday, November 22.**

On the morning of Friday, November 4, we will kick off the study around 10:00 AM with a loud boom followed by a series of booms. The loud boom marks the start of the study. Please begin to fill out the survey forms at that time and continue until the study ends on November 22. We will notify you if the study ends early.

Please complete two types of response forms using your Apple device. A member of the research team should have already installed the application on your device.

### **Single Boom response form**

Each time you notice a sonic boom, complete a “Single Boom” response form. Complete the form as soon as possible after you notice the sonic boom and answer each question as best you can.

- Complete a separate form for each sonic boom heard throughout the day.
- Some sonic booms may have a “double boom” sound (e.g. “boom-boom, boom-boom”). Count this as a single sonic boom and record it only once.
- We want to know about all sonic booms you notice. Complete the form not matter how loud or soft the boom and even if you notice the effects of the sonic boom but do not hear the boom itself.

### **Daily Summary response form**

At the end of the day, complete one “Daily Summary” response form. The questions on this form are similar, but not identical, to the Single Boom response form.

- Complete one Daily Summary response form each day –every day of the week—even if you did not hear any sonic booms or were not at home.
- Complete the Daily Summary response form after 6:00 PM each day.

### **Other important instructions:**

- Several questions ask “while you were at home.” By “at home” we mean, inside your home, in your yard or the immediate vicinity.
- Please go about your normal daily activities and report booms you notice when at home. You do not need to carry forms or materials to the store, in the car, or other places where you might notice sonic booms.
- Neighbors and friends may be participating in the study as well. We are interested in your personal reactions and experiences with each sonic boom you hear. We ask that you record your reactions to the sonic booms before discussing the details with anyone, including members of your household.

You will also receive paper survey forms via FedEx. These materials can be used as a back-up if the Apple application fails. The FedEx shipment includes two days’ of material and instructions for completing and returning the paper forms. Please contact us if you have questions or if you need more supplies.

**Research team follow-up during and after the study**

- If you have any questions, please contact us by telephone or email. We may call you after the study begins to check-in.
- We may conduct a brief follow-up telephone interview. This will help us understand what worked well and what did not, the wording of survey questions, and clarity of instructions, among other similar things.

If you have questions, please contact me by telephone (608.316.3681) or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com). If you need technical assistance with the Apple application, please contact Clif Wilmer at [clifton.wilmer@wyle.com](mailto:clifton.wilmer@wyle.com) or 703-599-3985.

Regards,  
Chelsea

<signature>

Dear <name>,

Thank you for participating in NASA’s sonic boom study. This email describes what you will do during the study and how to contact us if you have questions.

The dates of the study are **Friday, November 4 to Tuesday, November 22.**

On the morning of Friday, November 4, we will kick off the study around 10:00 AM with a loud boom followed by a series of booms. The loud boom marks the start of the study. Please begin to fill out the survey forms at that time and continue until the study ends on November 22. We will notify you if the study ends early.

Please complete two types of response forms using your computer. Log on at [www.ReportNASABoom.com](http://www.ReportNASABoom.com) to complete the forms. Your ID code is JE9865 (your initials of first and last name plus the last four digits of primary phone number).

### **Single Boom response form**

Each time you notice a sonic boom, complete a “Single Boom” response form. Complete the form as soon as possible after you notice the sonic boom and answer each question as best you can.

- Complete a separate form for each sonic boom heard throughout the day.
- Some sonic booms may have a “double boom” sound (e.g. “boom-boom, boom-boom”). Count this as a single sonic boom and record it only once.
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- We may conduct a brief follow-up telephone interview. This will help us understand what worked well and what did not, the wording of survey questions, and clarity of instructions, among other similar things.

If you have questions, please contact me by telephone (608.316.3681) or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com).

Regards,

Chelsea Merchant  
Survey Coordinator  
[chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)



## NASA SONIC BOOM STUDY INSTRUCTIONS

Thank you for participating in NASA's sonic boom study. This is a quick reference guide on the materials enclosed and how to complete them. **We will contact you in a few days to review the instructions and answer any questions. If your schedule has changed or if you have moved off base, please contact Chelsea Merchant at 608.316.3681.**

Study materials included in your FedEx package:

- **Instructions** – This document.
- **Frequently asked questions** – Yellow document with answers to questions you might have.
- **Post-it note with your personal ID number** – Please write this ID on each survey form you complete. The ID is the initials of your first and last name, followed by the last four digits of your primary phone number.
- **Expanding pocket envelope** – Contains the survey forms you will complete, organized into daily packets. Each packet contains 1 Daily Summary Response Form and 10 Single Boom Response Forms. The daily packet is also a return mailer: Use this envelope to mail each day's completed survey forms to Tetra Tech.
- **Extra forms** – One tear-off pad with extra Single Boom Response Forms.
- **Chelsea Merchant's business card** – Please contact her directly if you have questions.

### Study Dates

**Friday, November 4 through Tuesday, November 22**

If the study period changes or ends early, you will be notified by the research team.

### **Study Kick-off**

On the morning of Friday, November 4, we will kick off the study. Around 10:00 AM, there will be a loud boom followed by a series of booms. The loud boom marks the start of the study. Please begin to fill out the survey forms at that time and continue until the study ends on November 22.

**INSTRUCTIONS ON COMPLETING SURVEY FORMS ON REVERSE SIDE**



### **Single Boom Response Form (white)**

Each time you notice a sonic boom, complete a “Single Boom” response form. Complete the form as soon as possible after you notice the sonic boom and answer each question as best you can.

- Complete a separate form for each sonic boom heard throughout the day.
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- We want to know about all sonic booms you notice. Complete the form no matter how loud or soft the boom, and even if you notice the effects of the sonic boom but do not hear the boom itself.

### **Daily Summary Response Form (blue)**

At the end of the day, complete one “Daily Summary” response form. The questions on this form are similar, but not identical, to the Single Boom response form.

- Complete one Daily Summary response form each day, every day of the week, even if you did not hear any sonic booms or were not at home.
- Complete the Daily Summary response form after 6:00 PM each day.

### **Other important instructions:**

- Please include your ID on all completed Single Boom and Daily Summary response forms. (ID is initials of first and last name + last four digits of primary phone number.)
- Several questions ask “while you were at home.” By “at home” we mean, inside your home, in your yard or the immediate vicinity.
- Please go about your normal daily activities and report booms you notice when at home. You do not need to carry forms or materials to the store, in the car, or other places where you might notice sonic booms.
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- We will call to inform you when the study ends; it may end prior to November 22<sup>nd</sup>.
- We may conduct a brief follow-up telephone interview. This will help us understand what worked well and what did not in terms of the methods of data collection, the wording of survey questions or response categories, and clarity of instructions, among other similar things.

### **Questions and Technical Assistance**

If you have questions or need technical assistance, please contact Chelsea Merchant by telephone (608.316.3681) or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com).



## NASA SONIC BOOM STUDY INSTRUCTIONS

Thank you for participating in NASA's sonic boom study. **Although you will be participating in the study by a web-based or Apple application we are providing you with back-up paper/pencil forms to use if Internet or cell service is unavailable.** This is a quick reference guide on the materials enclosed and how to complete them. We will contact you in a few days to review the instructions and answer any questions. If your schedule has changed or if you have moved off base, please contact Chelsea Merchant at 608.316.3681.

Study materials included in your FedEx package:

- **Instructions** – This document.
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- **Chelsea Merchant's business card** – Please contact her directly if you have questions.

### Study Dates

**Friday, November 4 through Tuesday, November 22**

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- Complete the Daily Summary response form after 6:00 PM each day.

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If you have questions or need technical assistance, please contact Chelsea Merchant by telephone (608.316.3681) or email [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com).

## Frequently Asked Questions and Answers

### ***Study information***

#### **Who is conducting this study?**

NASA is sponsoring this research. A multi-disciplinary research team is collecting and analyzing data on sonic booms. Tetra Tech, an independent research firm, is helping conduct the study.

#### **How many people are participating in the study?**

110 residents of Edwards Air Force Base have been selected to participate in the study.

#### **How will the results be used?**

The results of the study will help engineers understand how individuals experience sonic booms and will contribute valuable information to the design of supersonic aircraft.

#### **When will I get my gift card?**

Participants in the study will receive a \$50 VISA gift card a few weeks after the study ends.

#### **What if I'm no longer eligible (moving off base)?**

Notify the research team by emailing [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com) or by telephone at (800) 454-5070.

### ***Contact information***

#### **Who do I contact if I have problems with the Apple application?**

Feel free to contact Clif Wilmer at [clifton.wilmer@wyle.com](mailto:clifton.wilmer@wyle.com) or by telephone at 703-599-3985.

#### **What if I'm no longer interested in participating in the study?**

Notify the research team by emailing [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com) or by telephone at (800) 454-5070.

## **Study details**

### **What do I do if I'm going to be out of town for a few days? What if I'm going to be on vacation one of the weeks during the study?**

Complete the Daily Summary forms for the days you will be away indicating you were not at home. Please send Chelsea Merchant an email ([chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com)) if you will be away for more than 4 days during the study period. If you will be out of town the week of Thanksgiving and participating using the paper method, please mail in your forms prior to leaving town.

### **Can someone else in the household complete these forms?**

Only the person who has been selected to participate in the study should complete the forms. It is important that we get information from the same person throughout the study period. We are interested in your personal reactions and experiences with each sonic boom you hear. We ask that you record your reactions to the sonic booms before discussing the details with anyone, including members of your household.

### **I lost my forms; what do I do? What if I need more forms?**

You can make copies of the forms from a different daily folder. If additional materials are needed, notify the research team by emailing [chelsea.merchant@tetrattech.com](mailto:chelsea.merchant@tetrattech.com) or by phone at (800) 454-5070.

### **I can't remember my ID code.**

The ID is the initials of your first and last name, followed by the last four digits of your primary phone number.

### **What if I am not sure if the noise I heard was a sonic boom?**

Record the information you heard and you can enter a comment at the end of the survey under "additional comments" indicating that information.

### **What if I hear the effects of the sonic boom but do not hear the sonic boom itself?**

Even if you notice the effects of the sonic boom but not the sonic boom itself, complete a Single Boom survey. We want to know about all sonic booms you notice.

### **I heard a boom but I didn't have a form with me, wasn't at my computer or did not have my Apple device. What should I do?**

Make a note of the time and record the information as soon as you can. If you were not in the immediate vicinity of your home, you do not need to report the sonic boom.



# Appendices

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## Appendix E

### E-1: Sample Boom Master List



# Appendix E

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## Sample Boom Master List

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Sequence #	Primary Recorded Data				Backup / Estimated Data								
	UTC DATE	LOCAL DATE	Site Alpha Recorded Local Time	Site Alpha Peak Overpressure (psf)	SNOOPI UTC TIME	SNOOPI LOCAL TIME	SNOOPI Peak Overpressure (psf)	Estimated Local Time	Supplemental Chapel II Mic Overpressure @Array (psf)	Estimated Overpressure / Aural (psf)	Recorded On Main Array (Y)	WSPR F-18 boom? Y	Field and Processing Notes
1	11/4/2011	11/4/2011	11:22:14	0.84	18:22:18	11:22:18	1.15				Y	Y	
2	11/4/2011	11/4/2011	11:32:36	0.21	18:32:41	11:32:41	0.24				Y	Y	
3	11/4/2011	11/4/2011	11:41:27	0.44	18:41:32	11:41:32	0.54				Y	Y	
4	11/4/2011	11/4/2011	11:48:55	1.17	18:49:00	11:49:00	0.86				Y	Y	
5	11/7/2011	11/7/2011	12:13:42	0.10	20:13:47	12:13:47	0.09				Y	Y	
6	11/7/2011	11/7/2011	12:23:58	0.11	20:24:03	12:24:03	0.12				Y	Y	
7	11/7/2011	11/7/2011	12:36:50	0.19	20:36:55	12:36:55	0.26				Y	Y	
8	11/7/2011	11/7/2011	12:56:03	0.09	20:56:08	12:56:08	0.11				Y	Y	
9	11/7/2011	11/7/2011	15:18:42	0.66	22:33:44	14:33:44	1.51				N	N	
10	11/7/2011	11/7/2011	15:32:10	0.29	23:18:48	15:18:48	0.22				Y	Y	
11	11/7/2011	11/7/2011	15:43:47	0.38	23:32:15	15:32:15	0.28				Y	Y	
12	11/7/2011	11/7/2011	16:03:56	0.55	23:43:53	15:43:53	0.44				Y	Y	
13	11/8/2011	11/7/2011	16:03:56	0.55	00:04:00	16:04:00	0.46				Y	Y	
14	11/8/2011	11/8/2011	07:30:56	0.16	15:31:01	07:31:01	0.18				Y	Y	
15	11/8/2011	11/8/2011	07:43:05	0.16	15:43:10	07:43:10	0.17				Y	Y	
16	11/8/2011	11/8/2011	07:59:35	0.49	15:59:39	07:59:39	0.58				Y	Y	
17	11/8/2011	11/8/2011	08:11:43	0.37	16:11:48	08:11:48	0.42		0.19		Y	Y	
18	11/8/2011	11/8/2011	08:22:48	0.17	16:22:44	08:22:44					Y	Y	SNOOPI: too low, no autotrigger. Missed call, no manual trigger
19	11/8/2011	11/8/2011	08:34:11	0.15	16:34:16	08:34:16	0.22				Y	Y	
20	11/8/2011	11/8/2011	08:43:18	0.39	16:43:23	08:43:23	0.41				Y	Y	
21	11/8/2011	11/8/2011	09:02:50	0.54	17:02:55	09:02:55	0.60				Y	Y	
22	11/8/2011	11/8/2011						13:28:00		0.35	N	N	Aural Estimation
23	11/8/2011	11/8/2011	14:13:06	0.39	22:13:12	14:13:12	0.34				Y	Y	
24	11/8/2011	11/8/2011	14:23:34	0.61	22:23:38	14:23:38	0.52				Y	Y	
25	11/8/2011	11/8/2011	14:37:55	0.40	22:37:59	14:37:59	0.43				Y	Y	
26	11/8/2011	11/8/2011			22:50:35	14:50:35	0.86				N	Y	Site M (manually triggered) also recorded the boom
27	11/9/2011	11/9/2011	11:22:01	0.68	19:22:05	11:22:05	1.06				Y	Y	
28	11/9/2011	11/9/2011	11:33:57	0.47	19:34:02	11:34:02	0.50				Y	Y	
29	11/9/2011	11/9/2011	11:43:36	0.55	19:43:41	11:43:41	0.71				Y	Y	
30	11/9/2011	11/9/2011	12:04:58	0.52	20:05:02	12:05:02	0.54				Y	Y	
31	11/9/2011	11/9/2011	14:16:02	0.66	22:16:06	14:16:06	0.68				Y	Y	
32	11/9/2011	11/9/2011	14:28:22	0.47	22:28:26	14:28:26	0.50				Y	Y	
33	11/9/2011	11/9/2011	14:47:49	0.38	22:47:54	14:47:54	0.30				Y	Y	
34	11/9/2011	11/9/2011	14:58:25	0.35	22:58:29	14:58:29	0.34				Y	Y	
35	11/9/2011	11/9/2011	15:26:07	0.7	23:26:11	15:26:11	0.78				Y	Y	
36	11/9/2011	11/9/2011	15:41:11	0.66	23:41:15	15:41:15	0.73				Y	Y	
37	11/9/2011	11/9/2011	15:51:14	0.34	23:51:18	15:51:18	0.49				Y	Y	
38	11/10/2011	11/9/2011	16:11:07	0.36	00:11:11	16:11:11	0.42				Y	Y	
39	11/10/2011	11/10/2011	11:28:15	0.41	19:28:20	11:28:20	0.36				Y	Y	
40	11/10/2011	11/10/2011	11:38:44	0.35	19:38:48	11:38:48	0.33				Y	Y	
41	11/10/2011	11/10/2011	11:51:13	0.25	19:51:17	11:51:17	0.33				Y	Y	
42	11/10/2011	11/10/2011	12:09:51	0.38	20:09:55	12:09:55	0.34				Y	Y	
43	11/14/2011	11/14/2011	08:21:25	0.17	16:21:30	08:21:30	0.19				Y	Y	
44	11/14/2011	11/14/2011	08:31:34	0.36	16:31:38	08:31:38	0.37				Y	Y	
45	11/14/2011	11/14/2011	08:41:21	0.3	16:41:26	08:41:26	0.21				Y	Y	
46	11/14/2011	11/14/2011	08:54:50	0.33	16:54:55	08:54:55	0.34				Y	Y	
47	11/14/2011	11/14/2011	09:04:18	0.1	17:04:21	09:04:21	0.12				Y	Y	
48	11/14/2011	11/14/2011	09:49:22	1.65	17:49:22	09:49:22	1.85				Y	Y	
49	11/14/2011	11/14/2011	14:12:14	0.18	22:12:19	14:12:19	0.29				Y	Y	
50	11/14/2011	11/14/2011	14:25:56	0.53	22:26:01	14:26:01	0.35				Y	Y	
51	11/14/2011	11/14/2011	14:44:54	0.51	22:44:58	14:44:58	0.62				Y	Y	
52	11/14/2011	11/14/2011	14:53:30	0.48	22:53:35	14:53:35	0.48				Y	Y	
53	11/14/2011	11/14/2011	15:23:02	0.61	23:23:06	15:23:06	0.66				Y	Y	
54	11/14/2011	11/14/2011	15:37:45	0.4	23:37:50	15:37:50	0.38				Y	Y	
55	11/14/2011	11/14/2011	15:47:41	0.89	23:47:45	15:47:45	0.77				Y	Y	
56	11/15/2011	11/14/2011	16:07:27	0.38	00:07:32	16:07:32	0.32				Y	Y	

Sequence #	Primary Recorded Data				Backup / Estimated Data						Recorded On Main Array (?)	WSPR F-18 boom?	Field and Processing Notes
	UTC DATE	LOCAL DATE	Site Alpha Recorded Local Time	Site Alpha Peak Overpressure (psf)	SNOOPI UTC TIME	SNOOPI LOCAL TIME	SNOOPI Peak Overpressure (psf)	Estimated Local Time	Supplemental Chapel II Mic Overpressure @Array (psf)	Estimated Overpressure / Aural (psf)			
57	11/15/2011	11/15/2011	10:26:32	0.35	18:26:37	10:26:37	0.30				Y	Y	
58	11/15/2011	11/15/2011	10:38:19	0.17	18:38:24	10:38:24	0.14				Y	Y	
59	11/15/2011	11/15/2011	10:47:34	0.29	18:47:39	10:47:39	0.20				Y	Y	
60	11/15/2011	11/15/2011	10:58:36	0.16	18:58:41	10:58:41	0.14				Y	Y	
61	11/15/2011	11/15/2011	11:08:24	0.14	19:08:29	11:08:29	0.17				Y	Y	
62	11/15/2011	11/15/2011	13:25:06	0.89	21:25:10	13:25:10	0.62				Y	Y	
63	11/15/2011	11/15/2011	13:33:44	0.74	21:33:48	13:33:48	0.82				Y	Y	
64	11/15/2011	11/15/2011	13:46:14	0.59	21:46:19	13:46:19	0.46				Y	Y	
65	11/15/2011	11/15/2011	13:56:19	0.42	21:56:24	13:56:24	0.59				Y	Y	
66	11/15/2011	11/15/2011	14:07:07	0.31	22:07:09	14:07:09		0.46			Y	Y	No SNOOPI
67	11/15/2011	11/15/2011	15:29:47	0.59	23:29:52	15:29:52	1.19				Y	Y	
68	11/15/2011	11/15/2011	15:36:24	1.1	23:36:29	15:36:29	1.43				Y	Y	
69	11/15/2011	11/15/2011	15:44:24	1.11	23:44:29	15:44:29	1.30				Y	Y	
70	11/15/2011	11/15/2011	15:50:21	1.08	23:50:26	15:50:26	1.35				Y	Y	
71	11/16/2011	11/16/2011	09:03:23	0.3	17:03:29	09:03:29	0.25				Y	Y	SNOOPI: missed bow shock, est. from tail shock. 0.0913 (0.25?)
72	11/16/2011	11/16/2011	09:15:52	0.25	17:15:56	09:15:56	0.23				Y	Y	
73	11/16/2011	11/16/2011	09:26:03	0.2	17:26:08	09:26:08	0.17				Y	Y	
74	11/16/2011	11/16/2011	09:39:43	0.16	17:39:48	09:39:48	0.21				Y	Y	
75	11/16/2011	11/16/2011	09:51:54	0.23	17:51:59	09:51:59	0.22				Y	Y	
76	11/16/2011	11/16/2011	13:47:50	1.76	21:47:50	13:47:50	1.66				Y	N	Non-WSPR SNOOPI caught the first of two big booms at 13:47 local.
77	11/16/2011	11/16/2011	13:47:58	1.69		13:47:58		1.61			Y	N	Non-WSPR. The array auto recorded both as being 8 seconds apart.
78	11/16/2011	11/16/2011						2.04	13:48:39		Y	N	Non-WSPR. Plane-Only recorded at Golf at 2.04 psf
79	11/16/2011	11/16/2011						1.11	13:48:48		Y	N	Non-WSPR. Plane-Only recorded at Golf at 2.04 psf
80	11/16/2011	11/16/2011			22:31:54	14:31:54	1.65		0.25		N	N	Non-WSPR Low Boom
81	11/16/2011	11/16/2011			22:40:46	14:40:46	0.87				N	N	Heard two big booms. Assume 10 sec separation, equal amplitude
82	11/16/2011	11/16/2011			22:41:17	14:41:17	0.56			1.65	N	N	Array was not set to autotrigger. Recorded at Chapel 2.
83	11/16/2011	11/16/2011									N	N	Array was not set to autotrigger. Recorded at Chapel 2.
84	11/16/2011	11/16/2011									N	N	Chapel 2 captured two big booms and the little boom
85	11/16/2011	11/16/2011			23:18:57	15:18:57	1.77			1.60	N	N	
86	11/16/2011	11/16/2011			23:19:01	15:19:01				0.28	N	N	
87	11/16/2011	11/16/2011			23:27:35	15:27:35	1.49				N	N	
88	11/16/2011	11/16/2011			23:28:01	15:28:01	0.63				N	N	
89	11/16/2011	11/16/2011			23:39:05	15:39:05	0.29				Y	Y	
90	11/16/2011	11/16/2011	15:39:00	0.28	23:39:05	15:39:05	0.29				Y	Y	
91	11/16/2011	11/16/2011	15:53:19	0.39	23:53:24	15:53:24	0.40				Y	Y	
92	11/16/2011	11/16/2011			23:59:25	15:59:25	1.98				N	N	
93	11/16/2011	11/16/2011				15:59:35			0.43		N	N	
94	11/17/2011	11/16/2011			00:08:12	16:08:12	1.37				N	N	
95	11/17/2011	11/16/2011			00:08:54	16:08:54	1.56				N	N	
96	11/17/2011	11/16/2011	16:13:58	0.31	00:14:03	16:14:03	0.35				Y	Y	
97	11/17/2011	11/16/2011	16:23:58	0.26	00:24:03	16:24:03	0.30				Y	Y	
98	11/17/2011	11/17/2011	10:00:51	0.2	18:00:57	10:00:57	0.19				Y	Y	
99	11/17/2011	11/17/2011	10:10:24	0.17	18:10:29	10:10:29	0.17				Y	Y	
100	11/17/2011	11/17/2011	10:32:43	0.22	18:32:48	10:32:48	0.24				Y	Y	
101	11/17/2011	11/17/2011	10:49:24	0.21	18:49:29	10:49:29	0.23				Y	Y	
102	11/17/2011	11/17/2011	11:03:43	0.22	19:03:48	11:03:48	0.23				Y	Y	
103	11/17/2011	11/17/2011	11:19:05	0.1	19:19:10	11:19:10	0.09				Y	Y	
104	11/17/2011	11/17/2011	11:39:07	0.08	19:39:12	11:39:12	0.08				Y	Y	
105	11/17/2011	11/17/2011	12:09:17	0.1	20:09:22	12:09:22	0.12				Y	Y	
106	11/18/2011	11/18/2011	07:20:32	0.17	15:20:37	07:20:37	0.20				Y	Y	
107	11/18/2011	11/18/2011	07:28:16	0.12	15:28:20	07:28:20	0.11				Y	Y	
108	11/18/2011	11/18/2011	07:42:00	0.08	15:42:05	07:42:05	0.12				Y	Y	
109	11/18/2011	11/18/2011	07:50:53	0.28	15:50:58	07:50:58	0.24				Y	Y	
110	11/18/2011	11/18/2011	08:03:23	0.12	16:03:27	08:03:27	0.14				Y	Y	



# Appendices

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## Appendix F

**F-1: Measured Sonic Booms across the Housing Area**

**(Applicable to all Appendix F Figures)**

## Appendix F

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### Measured Sonic Booms across the Housing Area

*Applicable to all Appendix F Figures*

Sonic Boom measured signatures (psf) are shown in white for all available measurement locations superimposed on a satellite image of the study area. The first letter of each measurement site name is indicated at each geo-referenced microphone location (a-m). The data for site m (dormitory area) is grouped closer to the primary housing area cluster to facilitate photo cropping. Computed loudness levels (PL in dB) are indicated in grey for a 650 ms duration as described in Section 4.1.3. Instances where a -13.0 dB appears indicates that the 1dB minimum A-weighted SEL signal-to-noise ambient threshold was not met and the booms were not included in the metric interpolation to the resident households. The boom event numbers in each figure title correspond with those indicated in the WSPR Sonic Boom Master List (Tables 16 and 17).



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Boom 001





Boom 002





Boom 003





Boom 004





Boom 005





Boom 006





**Boom 007**





Boom 008





**Boom 010**





**Boom 011**





**Boom 012**





Boom 013





Boom 014





**Boom 015**





**Boom 016**





Boom 017









Boom 019





Boom 020





Boom 021





**Boom 023**





**Boom 024**





Boom 025





Boom 026





Boom 027





Boom 028





Boom 029





**Boom 030**





Boom 031





Boom 032





**Boom 033**





Boom 034





Boom 035





**Boom 036**





**Boom 037**





Boom 038





**Boom 039**





**Boom 040**





**Boom 041**





Boom 042





**Boom 043**





Boom 044





Boom 045





Boom 046





Boom 047





**Boom 048**





**Boom 049**





**Boom 050**





**Boom 051**





**Boom 052**





Boom 053





Boom 054





**Boom 055**





Boom 056









Boom 058









Boom 060





Boom 061





**Boom 062**





**Boom 063**





**Boom 064**





Boom 065





Boom 066









**Boom 068**





**Boom 069**





Boom 070





Boom 071





**Boom 072**





Boom 073





**Boom 074**





**Boom 075**





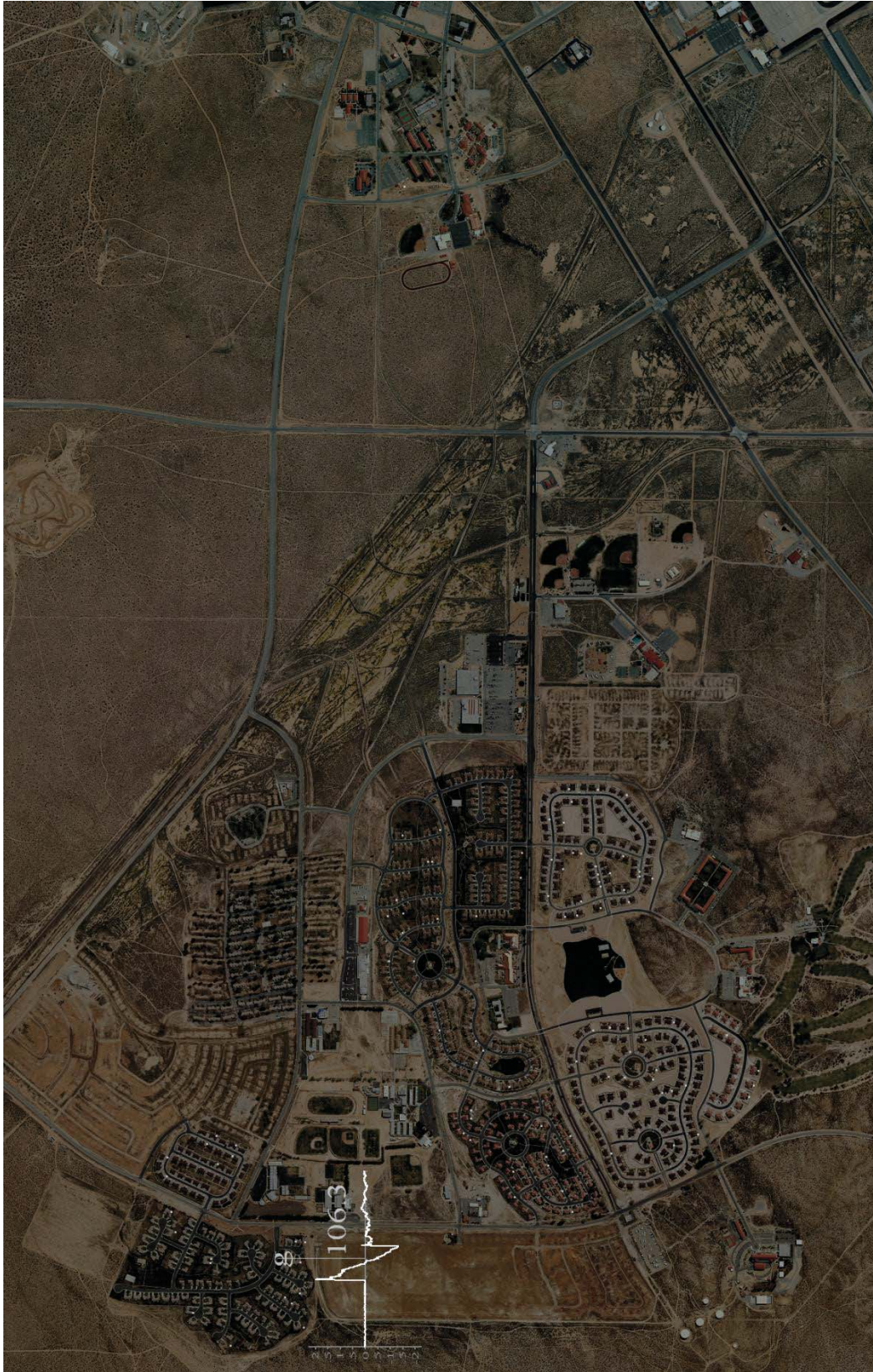
**Boom 076**





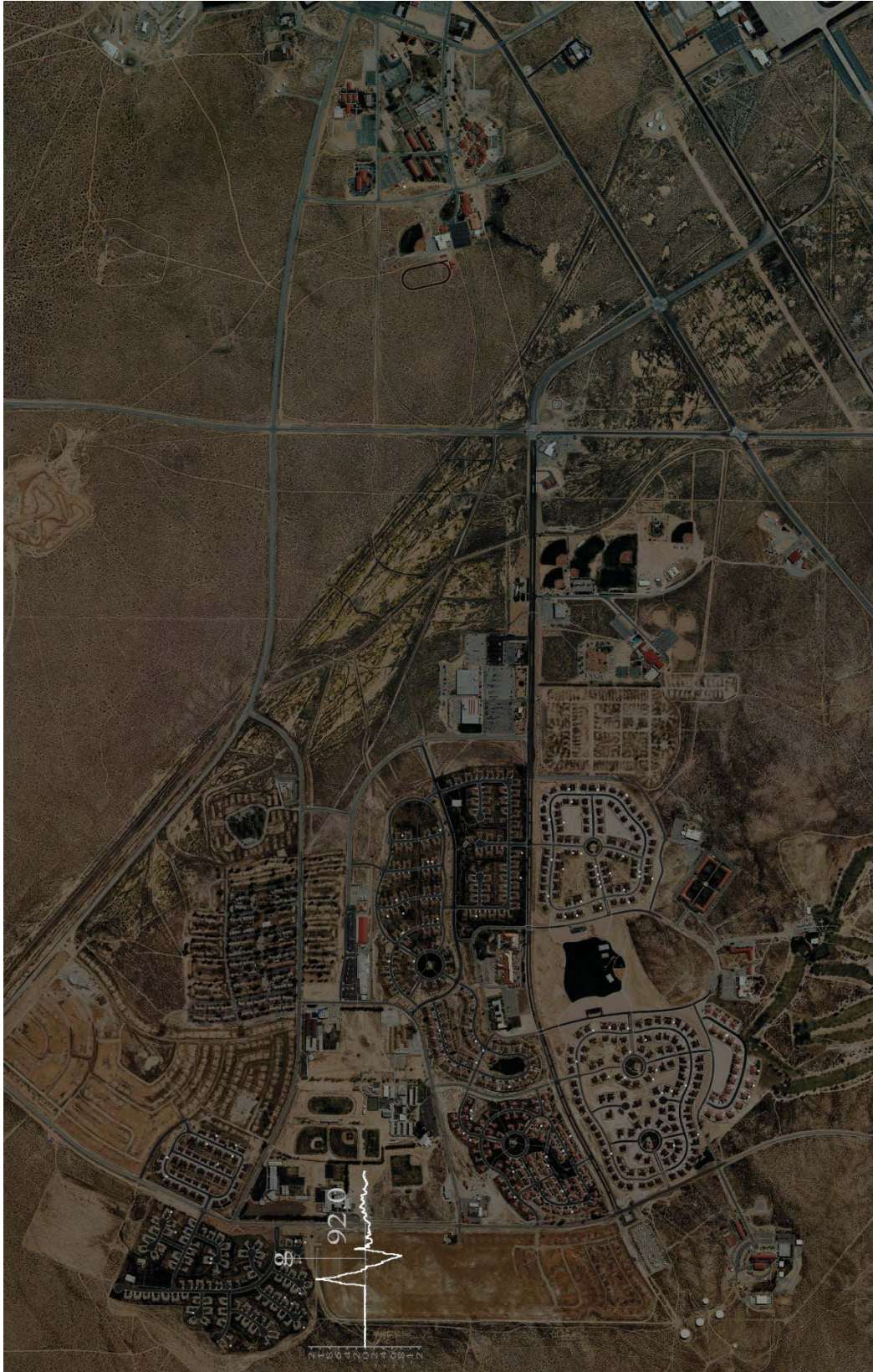
**Boom 077**





**Boom 078**





Boom 079





**Boom 090**





**Boom 091**





Boom 096





Boom 097





**Boom 098**





**Boom 099**





**Boom 100**





**Boom 101**





Boom 102





Boom 103





Boom 104





Boom 105





**Boom 106**





Boom 107









Boom 109







# Appendices

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## Appendix G

### G-1: WSPR Data Preparation and Cleaning Steps





## Appendix G

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### WSPR Data Preparation and Cleaning Steps

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## Appendix: WSPR Data Preparation and Cleaning Steps

The following is a summary of data cleaning and preparation steps that were used in the WSPR NASA study. These steps were documented in various sections of the report.

### *Data preparation: Survey Format and Questions*

The first task is to read in and organize the data. The survey format and questions were summarized. Throughout all the variables, the value -9 is used to indicate a missing response, and -6 is used to indicate a question that was not asked.

#### First two questions

SAS variable name	Excel Name	Variable	Question
<b>ID</b>	caseID		This is the unique identifier associated with each respondent for the entire study.
<b>Type</b>	Entype		Indicates whether the survey responses are for 1 A single boom 2 A daily summary

There is a slightly different set of questions that is asked for the two survey types, the Single Event (type 1) vs. the Daily Summary (type 2).

#### Single Event Per boom survey response (Answered only when type =1)

SAS variable name	Excel Name	Variable	Question
<b>E_month</b>	E1a		What month? NOTE: this question always has the answer 11, since the test took place in November
<b>E_day</b>	E1b		What date did the boom occur?
<b>Time</b>	E2		What time did the boom occur? (military time)
<b>Location</b>	E3		When the boom occurred were you... 1 indoors at home 2 indoors somewhere else 3 outdoors at home 4 outdoors somewhere else
<b>Annoy</b>	E4		How much did the boom bother disturb or annoy you? (response is 0-10)
<b>Loud</b>	E5		How loud was the boom? (response is 0-10)
<b>Interfere</b>	E6		How much did the boom interfere with your activity? (response is 0-10)
<b>Startle</b>	E7		How much did the sonic boom startle you or make you jump? (response is 0-10)
<b>Vibrate</b>	E8		How much vibration from the boom did you see or feel in your home? (response is 0-10)
<b>rattle</b>	E9		How much rattle from the boom did you experience in your home? (response is 0-10)



If type=1, the questions above are answered, and all the questions in the table below are skipped. In the spreadsheet, this 'skipping' is indicated by a -6 in all the associated cells. If type=2, then the questions above are skipped and the associated cells are filled with -6 and the survey jumps straight to the below questions.

### Daily Survey response (Answered only when type=2)

SAS variable name	Excel Name	Variable	Question
<b>A_month</b>	A1a		What month? NOTE: this question always has the answer 11, since the test took place in November
<b>A_day</b>	A1b		What date did the boom occur?
<b>Morning</b>	A2c1		Were you home for at least one hour in the morning? (0=no,1=yes)
<b>Afternoon</b>	A2c2		``...in the afternoon? (0=no,1=yes)
<b>Evening</b>	A2c3		``... in the evening? (0=no,1=yes)
<b>Not_home</b>	A2c4		Were you at gone from the house all day?(0=no,1=yes) NOTE: if answer here is yes, the rest of this table is skipped.
<b>Num_booms</b>	A3		During the time you were home today, how many sonic booms did you hear? NOTE: data problems here: -3 means 4-6, -4 means at least 6 -5 means 6 or more
<b>Day_annoy</b>	A4		How much did the booms bother, disturb, or annoy you? (0-10)
<b>Dat_cat_annoy</b>	A5		Which of the following categories best describes how much the sonic booms bothered, disturbed or annoyed you? 1 Not at all 2 Slightly 3 Moderately 4 Very 5 Extremely
<b>Day_loud</b>	A6		How loud were the sonic booms? (0-10)
<b>Day_interfere</b>	A7		How much did the booms interfere with your activities? (0-10)
<b>Day_vibrate</b>	A8		How much vibration from the sonic booms did you see or feel in your home today? (0-10)
<b>Day_rattle</b>	A9		How much rattle from the booms did you experience in your home today? (0-10)
<b>Windows</b>	A10		During the time you home today, were windows closed or open most of the time? (1=closed, 2=open)
<b>Unsure</b>	A11		Did you hear any noises today that might have been booms but you are not sure? (1=yes, 2=no)
<b>(Not included)</b>	O_A12		Describe what the noise sounded like
<b>(Not included)</b>	A13		Additional Comments
<b>(not included)</b>	O_A13		More comments

At this point, the information from the respondents has all been accounted for, but there are additional covariates that are

included in the data set, as well as some bookkeeping variables for errors. For all of the samples, the following variables are included:

SAS variable name	Excel Name	Variable	Explanation
<b>Mode</b>	Mode		How the respondent entered answers: Apple (Smartphone) Web Paper (pen and paper)
<b>Reminder</b>	Reminder_signup1		Date the participant signed up for reminder text or emails. 0 if they did not sign up.

Additionally, there are time stamps for the web and apple specific variables. These are not used in the SAS file yet, so they aren't summarized yet.

The last group of variables exists for the purpose of flagging data issues. For all of these, a 0 means no problem, and a 1 means that the observation has been flagged.

Flag Number	Explanation
<b>Flag1</b>	Respondent submitted two daily summaries on the same day.
<b>Flag2</b>	Respondent submitted two single boom forms at the same time on the same day.
<b>Flag3</b>	Illogical boom times (before 7 am or after 6 pm)
<b>Flag4</b>	Invalid number of booms per day on daily form
<b>Flag5</b>	Circled multiple responses for scaled questions
<b>Flag6</b>	Answered questions when shouldn't have.
<b>Flag7</b>	Skipped questions that should have been answered ( - 9 entered in data set)
<b>Flag8</b>	Entered invalid ID code
<b>Flag9</b>	Respondent put times for 8 sonic booms on one event form
<b>Flag_ds</b>	Flags the entries that are duplicate daily forms
<b>Flag_sb</b>	Flags the entries that are duplicate single boom forms.

## Flags and variables in SAS

The first step was to eliminate the variables that SAS wouldn't read in properly, such as replaced all the -9 (missing value) with '.', and saved the file as a .csv. SAS reads the data in fine, and the next step is work with the flagged observations.

Here is a summary of how many observations are flagged, both in total and by response method.

Flag Number	# Flagged (total)	# Flagged (apple)	# Flagged (Paper)	# Flagged (Web)
Flag1	26	14	4	8
Flag2	48	20	18	10
Flag3	14	1	13	0
Flag4	3	0	3	0
Flag5	2	0	2	0
Flag6	3	1	2	0
Flag7	63	5	58	0
Flag8	23	0	0	23
Flag9	8	0	8	0
Flag_ds	NA	NA	NA	NA
Flag_sb	NA	NA	NA	NA

As a way to reduce the number of flagged responses, there is one extra step: eliminate all the surveys where the respondent was either not home all day (not\_home=1). These responses don't give us any information, so I eliminate them. The data included people that actually gave a number response for daily annoyance and those that heard no booms all day (num\_booms=0). The 'daily annoyance' rating for these observations who reported hearing no booms is -6: missing. This is not a valid number for the analysis we are doing (someone can't be negatively annoyed) so all these -6's were replaced with 0's.

### Flag1: duplicate daily responses

There are a total of 18 duplicate responses. That is, a total of 8 pairs of duplicates, and 2 responses that are flagged but no longer have a pair (the pairs got eliminated in the step above). The different respondents / duplicate pairs seem to be in error for different reasons. We looked directly at the excel file in order to resolve these cases.

**The first 3 pairs** of duplicates are from the same respondent: 2707. This respondent filled out separate forms for the morning and afternoon. The data is different for each of these values, and the entries appear to be intentional. I am keeping all of these forms and using them separately, as they offer different information.

**The pair of duplicates from 2331**, the first entry was done just after midnight on the 18<sup>th</sup>, and the second was done the evening of the 17<sup>th</sup>. It appears that the first entry was in fact for the 17<sup>th</sup>, and the second was for the 18<sup>th</sup>. There is no entry for this respondent for the 17<sup>th</sup>. The SAS code now replaces the first 18 with 17.

**The second pair from 2602** (on Nov 17) seems to be a result of apple device not transmitting right away, and the respondent re-answering the questions and submitting again. In this case, the first response corresponds to the second taking of the survey, and thus this will be the one we keep. The SAS code now does this.

**The first pair from 2602 (on the 10<sup>th</sup>), and the pair from 2326** (on the 16<sup>th</sup>) looks like an 'update' situation, where the respondent filled out the daily form, and then heard more booms and sent in another. In this case, we'll keep only the last form. The sas code takes care of this.



**The pair of from 2742:** This pair of responses is exactly the same; therefore we simply eliminate one of them. This is resolved by a no duplicates statement in the code.

**The single flagged response from 2421** is an update scenario, so we'll keep it. Resolved in SAS.

**The single flagged response from 2594 is suspicious.** It's a paper submission of maximum annoyance. The other duplicate response said they were not home, so it got eliminated. The paper submission was kept. This issue was resolved in SAS.

### **Flag 2: Duplicate single boom forms (43)**

The response to this is to eliminate the first response and keep the 'updated' response in each case.

### **Flag 3: Illogical boom times (14)**

These are boom times when no testing was underway: at night, or very early in the morning. These were kept in the data set; because maybe when we get the objective data is added in we'll see that there were in fact noises (from the base or from the neighborhood) that the respondents actually did hear.

### **Flag 4: Invalid number of booms on daily sheet (3)**

There are only three here:

-3 (which means 4-6 booms). I am replacing the -3 with 5.

-4 (which means 'at least 6' booms).

-5 (which means 'more than 6' booms).

For both -4 and -5 we replaced the negative number with the (rounded up) mean number of booms reported for that day by other respondents. The days under consideration are days 8 and 14, with means 7.28 and 7.88 respectively. Thus, the -4 and -5 will both be replaced by the number 8.

### **Flag 5: Circled multiple responses for scaled questions (2)**

Here, the circled responses are -7. There is no indication as to which responses were circled, or else we could just take the mean value. We replaced the -7 with -9 and treat them as missing.

### **Flag 6: Answered questions when shouldn't have (0)**

All of these flagged entries were due to 'heard no sonic booms' and 'was not at home today' responses.

### **Flag 7: Skipped questions they should have answered (59)**

There is no fix for this, so it was treated as missing data.

### **Flag 8: Invalid ID code (23)**

These were left in the data set, since they give us good information. We won't be able to use them when we have the sound metrics, since we won't be able to figure out where they are, but at least we'll be able to use the information in the first part of the analysis.

## **Flag 9: Respondent put times for 8 sonic booms on one event form (8)**

We deleted all of these, we have no idea which boom the responses are referencing, and so we can't get much from this in the grand scheme.

After the flags (except flag 2) have been resolved, we have a total of 2,911 responses. Next, we split them up into DAILY and PER\_BOOM data sets for separate consideration.

### **Daily data set**

The daily data set has 385 responses.

### **Single Event (per boom)**

After eliminating any duplicate entries (and keeping any 'update' entries), we get 2518 responses.

## *Data cleaning for processing*

### **Subjective dataset (Daily Summaries and Per-boom reports)**

The following Data Inspection and Cleaning steps were used:

- 1) Flags removed, and any duplicate records.
- 2) No-flight days removed.
- 3) False id's (3000 series) removed. These IDs in the 3000s are the survey responses that they could not attach to a unique subject due to a problem with the Web ID entries.

There was an early discrepancy wherein we had n=51 vs. n=52 for the Subjective only data. This resulted from a step deleting num\_booms=0. That deletion code was subsequently eliminated, data for which num\_booms=0 was then included, and 52 participants were retained in the analysis.

### **Objective dataset**

The following additional Data Inspection and Cleaning steps were used:

- 1) Three ID's records were removed: ID2440, ID2481, and ID2569. ID2481 and ID2569 were web respondents that did not submit any survey forms, and ID2440 was an iPod for which data could not be retrieved.

The boom id values obtained from combining all the objective data files (one for each respondent) yielded a list of booms that did not match exactly with the WSPR monitor results. The WSPR list contained 110 documented booms, whereas the respondent boom list contained only 109 booms. This discrepancy was evidently a result two booms occurring extremely close together at 13:48 on day 16. An additional boom needed to be recognized in the respondent boom list and this was assigned a time of 1348.5 to locate it between 13:48 and 13:49. See the addition of boom at 13:48 in the respondent list (boom id #78).

Table 1. Comparison of Boom Lists

Day	Time	Boom id	WSPR sequence	WSPR date	WSPR time
4	1122	1	1	110411	112218
4	1132	2	2	110411	113241
4	1141	3	3	110411	114132
4	1149	4	4	110411	114900
7	1214	5	5	110711	121347
7	1223	6	6	110711	122403
7	1237	7	7	110711	123655
7	1256	8	8	110711	125608
7	1433	9	9	110711	143344
7	1518	10	10	110711	151848
7	1532	11	11	110711	153215
7	1543	12	12	110711	154353
7	1604	13	13	110711	160400
8	731	14	14	110811	73101
8	743	15	15	110811	74310
8	759	16	16	110811	75939
8	811	17	17	110811	81148
8	822	18	18	110811	82244
8	834	19	19	110811	83416
8	843	20	20	110811	84323
8	903	21	21	110811	90255
8	1328	22	22	110811	132800
8	1413	23	23	110811	141312
8	1423	24	24	110811	142338
8	1438	25	25	110811	143759
8	1450	26	26	110811	145035
9	1122	27	27	110911	112205
9	1133	28	28	110911	113402
9	1143	29	29	110911	114341
9	1205	30	30	110911	120502
9	1416	31	31	110911	141606
9	1428	32	32	110911	142826
9	1447	33	33	110911	144754
9	1458	34	34	110911	145829
9	1526	35	35	110911	152611
9	1541	36	36	110911	154115
9	1551	37	37	110911	155118
9	1611	38	38	110911	161111



Day	Time	Boom id	WSPR sequence	WSPR date	WSPR time
10	1128	39	39	111011	112820
10	1138	40	40	111011	113848
10	1151	41	41	111011	115117
10	1209	42	42	111011	120955
14	821	43	43	111411	82130
14	831	44	44	111411	83138
14	841	45	45	111411	84126
14	855	46	46	111411	85455
14	904	47	47	111411	90421
14	949	48	48	111411	94922
14	1412	49	49	111411	141219
14	1426	50	50	111411	142601
14	1445	51	51	111411	144458
14	1453	52	52	111411	145335
15	1026	53	53	111411	152306
15	1038	54	54	111411	153750
15	1047	55	55	111411	154745
15	1058	56	56	111411	160732
15	1108	57	57	111511	102637
15	1325	58	58	111511	103824
15	1333	59	59	111511	104739
15	1346	60	60	111511	105841
15	1356	61	61	111511	110829
15	1407	62	62	111511	132510
15	1523	63	63	111511	133348
15	1529	64	64	111511	134619
15	1536	65	65	111511	135624
15	1538	66	66	111511	140709
15	1544	67	67	111511	152952
15	1547	68	68	111511	153629
15	1550	69	69	111511	154429
15	1607	70	70	111511	155026
16	903	71	71	111611	90329
16	915	72	72	111611	91556
16	926	73	73	111611	92608
16	939	74	74	111611	93948
16	951	75	75	111611	95159
16	1347	76	76	111611	134750
16	1348	77	77	111611	134758

Day	Time	Boom id	WSPR sequence	WSPR date	WSPR time
16	1348.5	78	78	111611	134839
16	1349	79	79	111611	134848
16	1357	80	80	111611	135700
16	1431	81	81	111611	143154
16	1432	82	82	111611	143204
16	1440	83	83	111611	144046
16	1441	84	84	111611	144117
16	1518	85	85	111611	151849
16	1519	86	86	111611	151857
16	1520	87	87	111611	151901
16	1527	88	88	111611	152735
16	1528	89	89	111611	152801
16	1529	90	90	111611	153905
16	1553	91	91	111611	155324
16	1559	92	92	111611	155925
16	1600	93	93	111611	155935
16	1608	94	94	111611	160812
16	1609	95	95	111611	160854
16	1612	96	96	111611	161403
16	1623	97	97	111611	162403
17	1000	98	98	111711	100057
17	1010	99	99	111711	101029
17	1032	100	100	111711	103248
17	1049	101	101	111711	104929
17	1103	102	102	111711	110348
17	1119	103	103	111711	111910
17	1139	104	104	111711	113912
17	1209	105	105	111711	120922
18	720	106	106	111811	72037
18	728	107	107	111811	72820
18	742	108	108	111811	74205
18	750	109	109	111811	75058
18	803	110	110	111811	80327

The following three tables summarizing the cleaning steps, including number of responses removed at each step, and the total number under consideration.

**Table 2. Cleaning Steps for Full Data**

Data Step (Full data)	Number removed	Total number
Read in file from Excel	-	3251
Eliminate full duplicate entries	8	3243
Eliminate responses where respondent was not home all day, or num_booms was missing	77	3166
Eliminate duplicate daily responses (dealt with individually). Case IDs 2602 and 2326, eliminate responses with flag 9.	11	3155
Eliminate responses with no respondent ID	17	3138

**Table 3. Cleaning Steps for Daily Summary Data**

Data Step (Daily Data)	Number removed	Total number
Extract Daily responses from full subjective data set	-	626
Eliminate responses from non-boom days and responses where the day is not specified	195	431

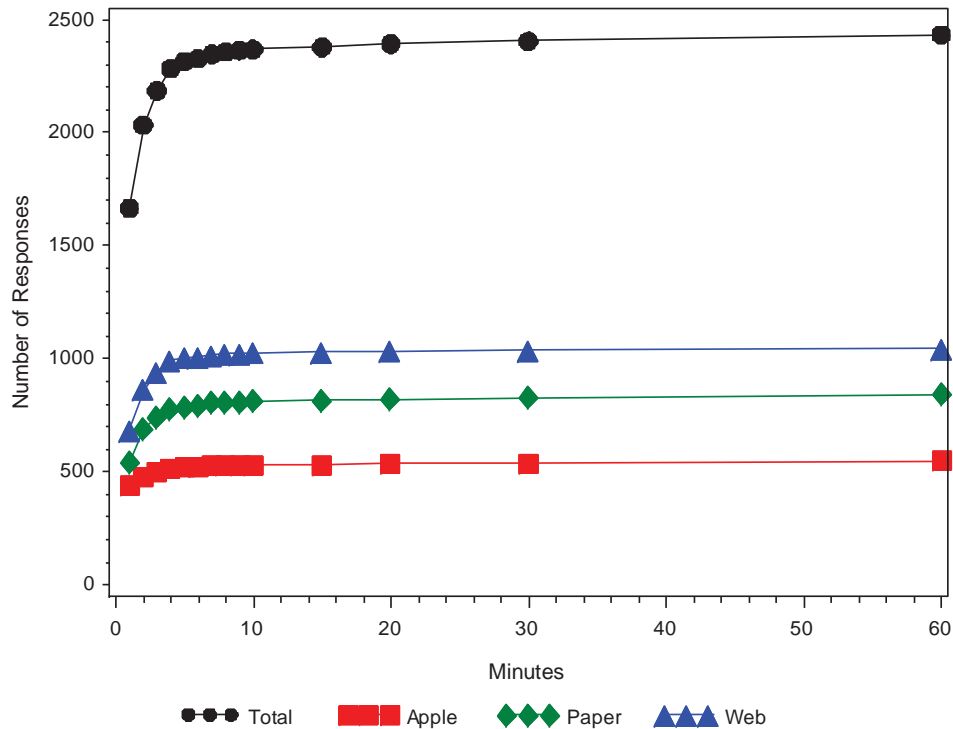
**Table 4. Cleaning Steps for Per Boom Data**

Data Step (Per boom Data)	Number removed	Total number
Extract Per Boom responses	-	2512
Eliminate ID #s 3000 - 3005	6	2506
Match each response to closest boom time (within 10 minutes on either side)	137	2369

Once the boom list was complete, we used the SAS code to match up booms reported by the participants with those appearing in the WSPR monitor output. This is an essential step to connect the information provided by the surveys with the sound metrics recorded at the monitors. The match-up process required setting a ‘window’ within which a reported boom could be associated with a monitor (actual) boom. Because participant recollection of boom times could be off by either direction (reported time different by being minutes before or after the actual time), we used  $\pm$  various intervals. In using smaller windows (e.g.  $\pm 10$  minutes vs.  $\pm 30$  minutes) the sample size was diminished because fewer of the reported times matched up with the actual times. By employing various windows, we generated the graph below:



## Response Rate by Time Window



The final window used for further analysis was the  $\pm 10$ -minute window. Although using more stringent criteria (a smaller window) is expected to improve the quality of the data in terms of confidence that reported booms were linked to actual booms, we noted in the report that there are still concerns with this process when booms are spaced closely together.

The subjective response data contained 566, 892, and 1,084 per boom surveys from Apple, Paper, and Web modes respectively. This indicates a total of 2,542 responses. After the initial data cleaning sets on the entire data set, there were 2,512 per boom responses eligible for matching. This means that 30 surveys were eliminated because of duplication, missing IDs, flags, and participants being absent from their home during the day. After eliminating ID numbers 3000 to 3005, which do not have any corresponding objective data, 2,506 per boom responses are eligible for matching. Finally, 137 responses were not within 10 minutes of an observed boom, and thus are eliminated.

Ultimately, 2,369 responses are included in the merged data set. This means that a total of 173 responses were eliminated, or about 7% of all per boom responses. If we narrow the window of acceptable booms from 10 minutes on either side of the responses to 5 minutes, then the number of matched pairs is 2,316. This is an elimination of about 8%. Reduction of the window to 3 minutes on either side results in a loss of 13% of data. This window length would prevent ambiguity in booms in a way that the 10 minute window does not given the spacing of the as-flown WSPR sonic booms.

### Data Preparation for Quadratic Regression Line Fit

For each metric the data was separated into defined bins for processing. An attempt was made to define between 9 and 11 bins of equal width according to the metric. Alternatively, the bin width could have been chosen based on number of responses in that bin. These bins are then used to define Percent HA. The SAS software calculated the percent highly annoyed (HA) for each bin, and then fit a quadratic regression line. The approach followed requires the definition of bins for



the noise metrics. The bins are then used to define Percent HA. This means that the results of the analysis are dependent upon choice of bin.

### **Data Preparation for Logistic Regression Analysis of Moore and Glasberg and Inside Metric**

A slight modification was made to address the booms that were within a minute of each other (#78 on previous list). The time and date listed in the second column of each file was used to record the date and time of each boom. In the previous analysis, these boom times were rounded to the nearest full minute; however this analysis included the full time using minutes and seconds. This time was used for matching of subjective responses to the objective boom data. Because the boom times used in matching were slightly different (less than 30 seconds) between this analysis and the last, the number of matched observations is also slightly different. Specifically, there are 68 fewer in this analysis than in the last. The matching process and all data steps are identical as before. However this change eliminated the need to account for two booms within the same minute, as including second counts clearly separates these two booms. An attempt was made in both methods to match each response with the proper boom. This slight change may be a minor improvement because it clearly separates booms within the same minute.



# Appendices

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## Appendix H

### H-1: WSPR Single Event vs. Daily Summary Responses for Test Day 10





## Appendix H

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### WSPR Single Event vs. Daily Summary Responses for Test Day 10



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## Appendix H: WSPR Single Event vs. Daily Summary Responses for Test Day 10

The noise design was balanced to provide a distribution of sonic booms that resulted in DNL levels across the range that has been investigated previously, and provided sufficient data points to compare to previous findings. The design was varied each day to facilitate weather and flight logistics, and to adjust for the presence of non-WSPR booms that the community was exposed to from other sources.

The lowest low booms are the most sensitive to weather changes, so the lowest booms were reassigned to days with better weather. The various adjustment factors resulted in the days with the lowest DNL falling on the last two days of the test. This was not part of the original noise design, but was a result of other variables.

Single-event response rates were consistently highest among subjects using paper (58 percent), followed by Web (50 percent), and Apple (45 percent). Declines in response over time, and particularly the final two days of the test, were exhibited across all three modes and to approximately the same extent (8 to 10 percentage points week 1 to week 2; 18 to 22 points the final two days). While there was an observed decrease in single event response rate on the final day, the findings suggest that this was not due to response fatigue, but because the lowest booms weren't heard. The responses on the last test day were tabulated to demonstrate this trend in the data. It was suspected that the drop in response was due to a drop in the number of respondents who heard the booms.

There was a slight drop in overall response rate, and a much larger drop in number of responses that reported that they actually heard booms. For more details, consider Table 1 detailing number of responses for each day that booms occurred along with the number of responses indicating no booms were heard. The percentages have been rounded to the nearest whole number.

**Table 1. Summary of Daily Responses for All Test Days**

Test Day	Test Date	Total Responses	Responses indicating num_booms=0	Percent of responses with num_booms=0
1	11/4	40	6	15%
2	11/7	46	6	13%
3	11/8	48	2	4%
4	11/9	47	4	9%
5	11/10	41	6	15%
6	11/14	45	1	2%
7	11/15	44	1	2%
8	11/16	45	1	2%
9	11/17	40	13	33%
10	11/18	35	19	54%

The percent of the responses with num\_booms=0 for each day is given in the last column of Table 1. On the last day over half of the respondents indicated that they did not hear any booms at all. This is more than three times as much as most other days.

The number of per boom event responses and the number of daily response submitted on the last day was also evaluated. As can be seen in Table 1, on the last day a total of 35 daily responses were submitted. This is a drop, but not a huge drop, from the number of responses on previous days. Table 2 provides a summary of the number of per boom responses for each of the test days. In this case, only 28 per boom responses were submitted on the last day. This is a very large drop from the response rate of previous days, indicating that very few of the respondents heard any of the booms. The next lowest response number is 91, more than three times the number of responses for the last day. The highest number of responses was 537, nearly 20 times the number of responses on day 10.



**Table 2. Summary of Per Boom Responses for All Test Days**

Test Day	1	2	3	4	5	6	7	8	9	10
Number of per boom responses	128	212	341	336	106	371	333	537	91	28

The distribution of the number of booms heard as reported on the daily summaries on the last test day is provided in Table 3. Approximately 5% of respondents heard more than two booms, and 80% of them heard only one or none. This trend in the data supports the inference that the lowest low booms were very soft, and were simply not heard.

**Table 3. Distribution of num\_booms for Day 10**

Number of booms	Frequency	Percent of responses on day 10
0	19	54.29
1	9	25.71
2	3	8.57
3	2	5.71
4	1	2.86
5	1	2.86

Recall from Table 1 that 35 people submitted daily summaries. Of these, 15 also submitted per boom summaries. Notably, there was also one respondent (ID 2501) that submitted 2 per boom responses but no daily response. Table 4 gives the ID number of the respondents that submitted daily surveys on day 10, and the number of per boom responses they submitted. Table 5 gives another way of looking at the response rates of the participants that submitted daily surveys.

**Table 4. ID Numbers and Number of Per Boom Responses**

ID	Number of per boom responses
2571	5
2407	3
2454	3
2312	2
2419	2
2730	2
2362	1
2421	1
2460	1
2469	1
2512	1
2538	1
2646	1
2732	1
2738	1
2331	0
2333	0
2340	0
2353	0
2357	0
2398	0

ID	Number of per boom responses
2417	0
2418	0
2468	0
2470	0
2491	0
2492	0
2524	0
2625	0
2640	0
2691	0
2704	0
2707	0
2729	0
2742	0

Table 5. Summary of Daily Respondent Completion of Per Boom Surveys

Number of per boom surveys completed	Number of respondents
0	20
1	9
2	3
3	2
5	1

On the last day, 35 participants submitted daily summaries, and 15 of those 35 also submitted single event ratings. The daily summaries indicated how many booms were heard that day. About 5% of respondents heard more than two booms, and 80% of them heard only one or none. The finding cannot be definitive, as there may be a non-response component to the data. However, this trend in the data is an indication that the participants were still responding, but the decline in single event response rates was because the lowest low booms were not heard.



# Appendices

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## Appendix I

### I-1: Discussion Concerning Quadratic Regressions





## Appendix I

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### Discussion Concerning Quadratic Regressions

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## Appendix I: Discussion Concerning Quadratic Regressions

The point must be stressed that the choice of bins for the quadratic regression is more or less arbitrary and not at all scientifically motivated. In order to provide consistency with the prior body of acoustic analysis it is included here. However, even a small change in bin choice (i.e., from 8 bins to 9 bins to 11 bins), will result in different regression lines.

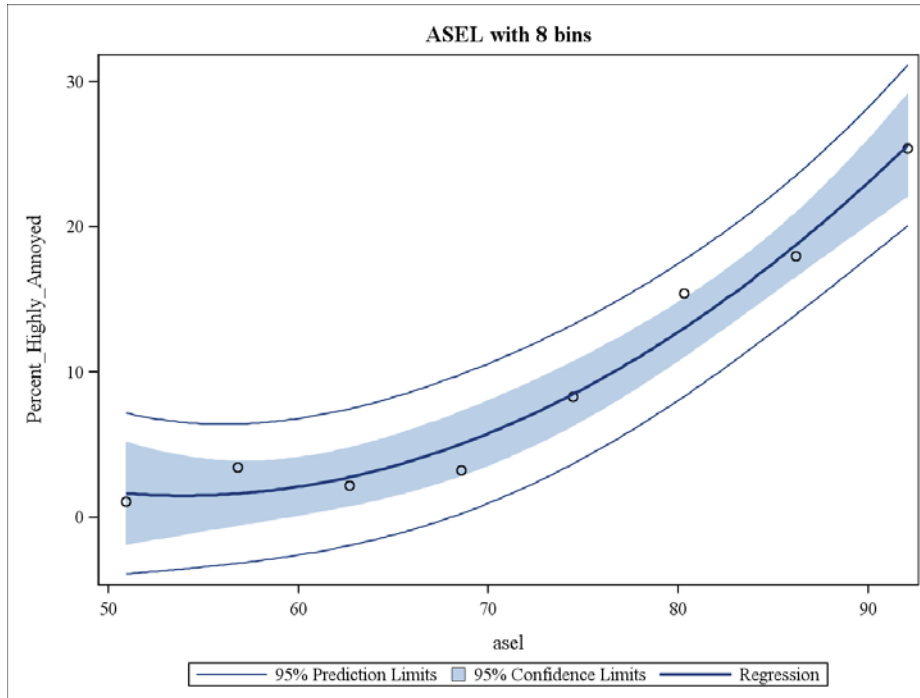


Figure I-1. ASEL with 8 bins

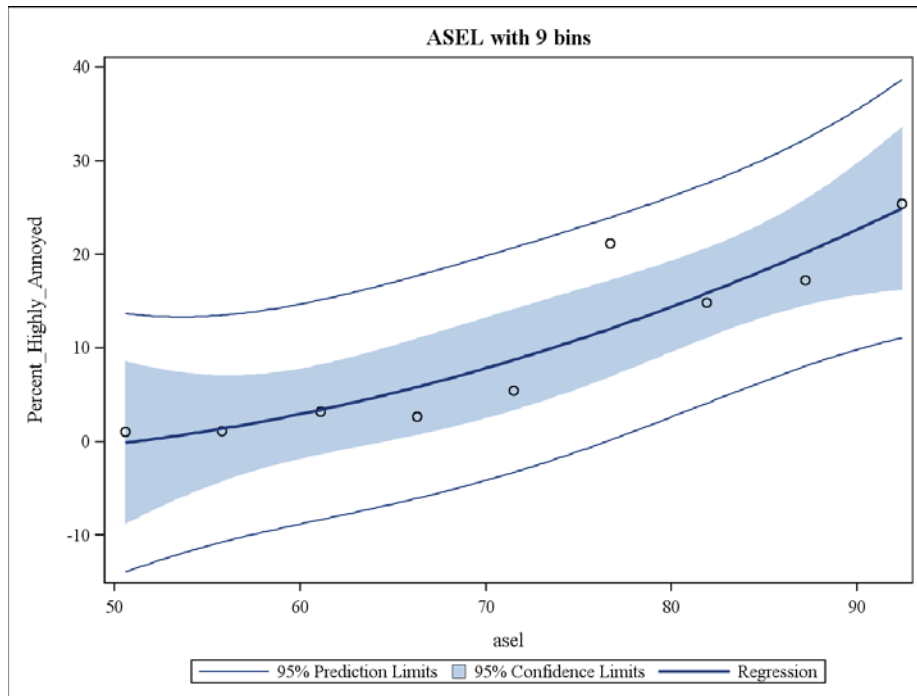
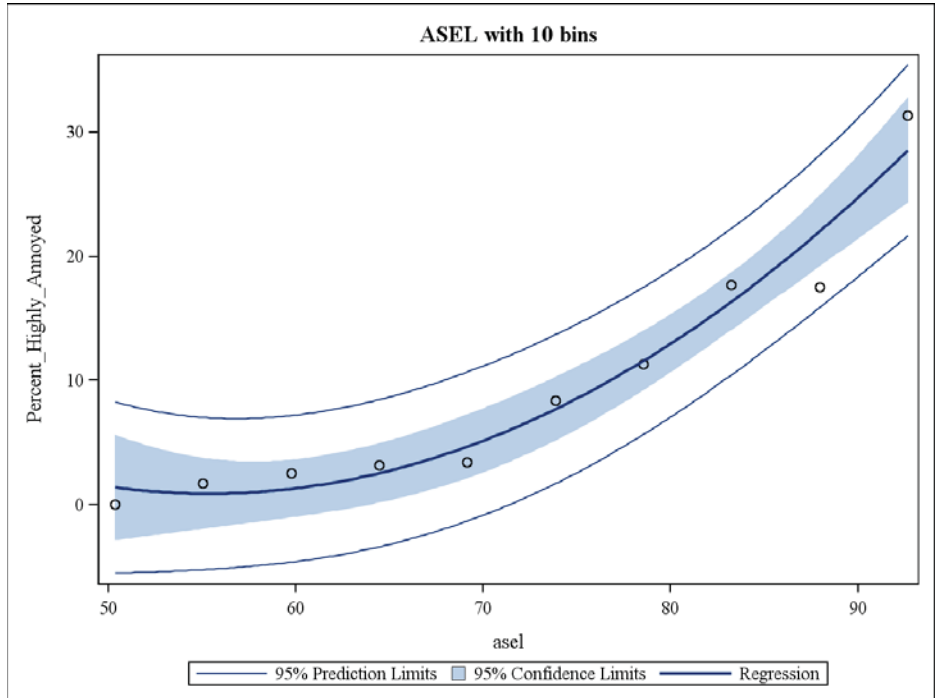
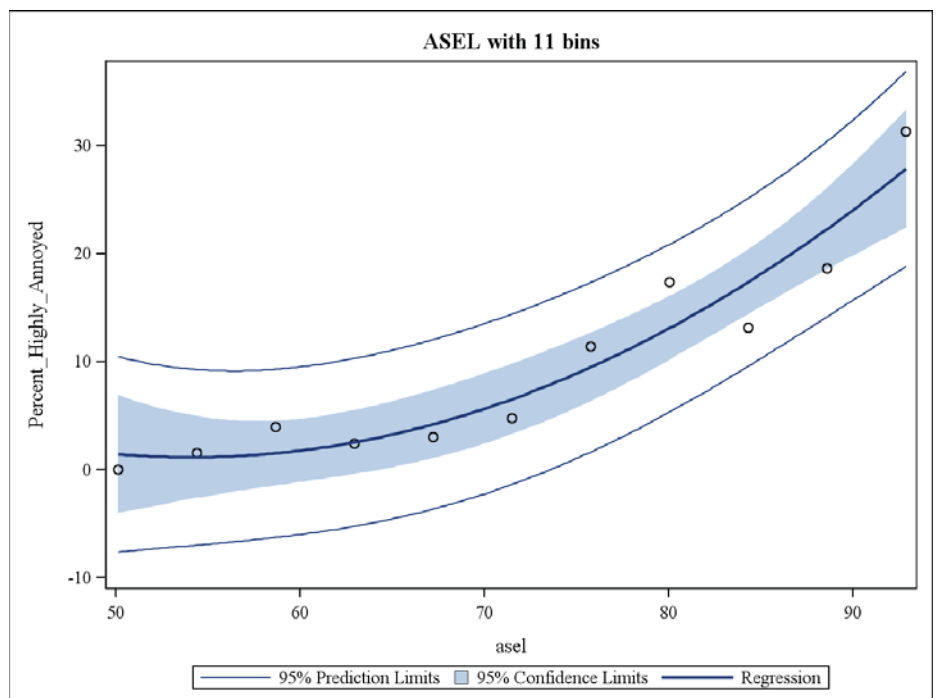


Figure I-2. ASEL with 9 bins



$$\%HA = 706.78 - 14.18*(ZSEL) + 0.07*(ZSEL)^2$$

**Figure I-3. ASEL with 10 bins**



$$\%HA = 75.64 - 2.19*(PL) + 0.02*(PL)^2$$

**Figure I-4. ASEL with 11 bins**



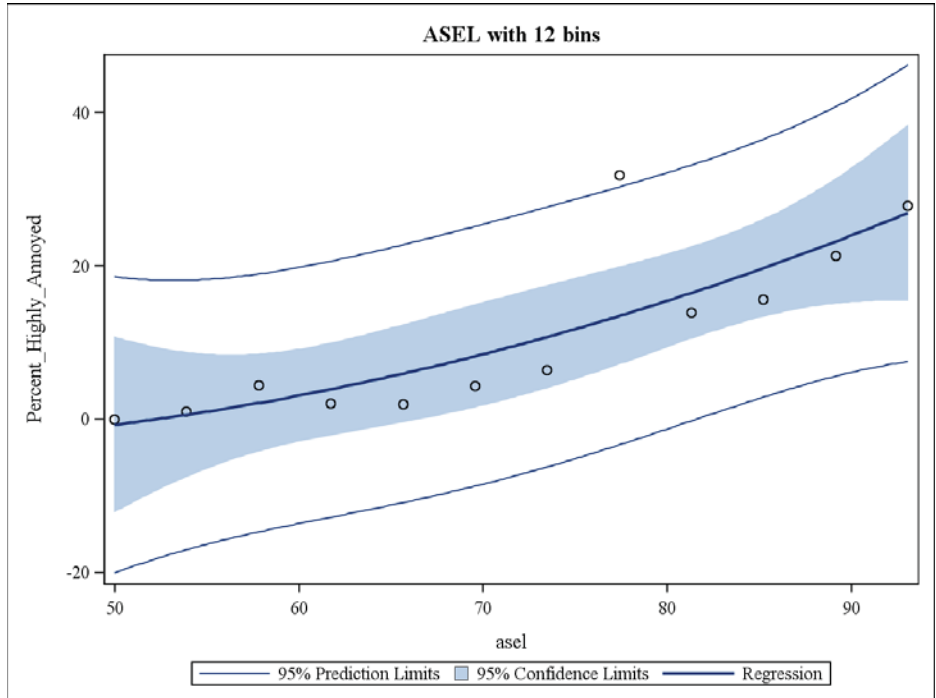


Figure I-5. ASEL with 12 bins

Table I-1. Summary of R-squared values from different bin numbers

Number of bins	R-Squared
8	0.9758
9	0.8397
10	0.9586
11	0.8963
12	0.6842

As indicated in Table I-1, choice of bins has a large effect on not only the regression line, but the R-Squared values. For this reason, it is essential that a procedure is used that is independent of bin choice, or that the choice of bins is scientifically motivated. Further, figures I-1 through I-5 indicates that the confidence bands extend into negative territory for each regression fit. Using logistic regression, the fit is restricted to only positive values and thus this problem is avoided entirely.

Section 4.3.2.3 is included in the report that readers may see something familiar, however inclusion of the quadratic regression fits under the current binning schemes is statistically inappropriate. It is strongly recommended that logistic regression fits are used for this analysis, and for future analyses with lower annoyance subjective response data, one works directly with the annoyance ratings, and not with a binary HA or not HA.

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