

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

# **Pilot Study on Aircraft Noise and Sleep**

## Project 17

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Opinions, findings, conclusions and recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of ASCENT sponsor organizations.



- Field studies need to be conducted in the US to acquire current data on sleep disturbance relative to varying degrees of noise exposure to inform policy
- A methodology of using actigraphy and electrocardiography (ECG) has previously been found to provide a sensitive measure of awakenings
- ECG + Actigraphy is non-invasive, self-administration of electrodes is possible, with lower methodological cost than polysomnography
- Pilot field studies using this methodology are being conducted to evaluate the feasibility of its use and to inform the design of future studies

- Long term
  - Develop models relating the indoor maximum noise level ( $L_{Amax}$ ) to awakenings
  - Examine how individual variables (e.g. age, gender), situational variables (e.g. elapsed sleep time) and acoustical variables (e.g. spectral content, rise time) moderate the relationship between  $L_{Amax}$  and probability of awakening
- Near term
  - Complete data analysis for pilot study conducted around Philadelphia International Airport
  - Refine a study methodology for examining the effects of aircraft noise on sleep based on lessons learned from pilot field studies

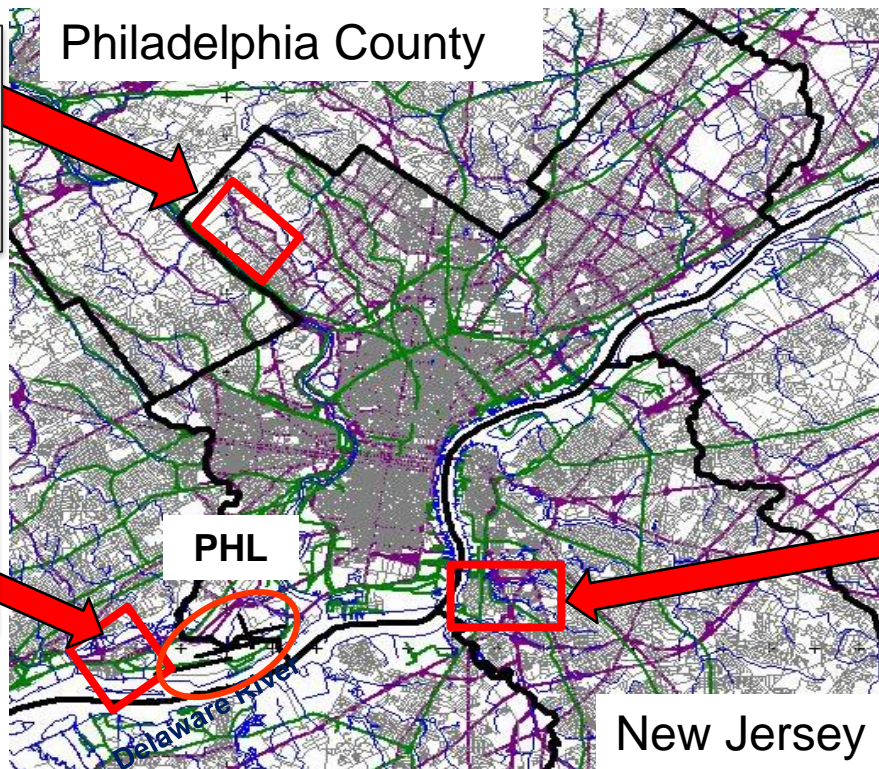
- Outcomes
  - An inexpensive yet sound study methodology for obtaining objective measures of sleep and noise
- Practical applications
  - Collaboration with the German Aerospace Center and other researchers could lead to the development of a common methodological approach which will allow comparisons between studies and data pooling

# Schedule and Status: Philadelphia Airport Sleep Study



Period	Tasks	Status
<b>Subject Recruitment and Data Collection</b>		
7/2014-7/2015	<ul style="list-style-type: none"> <li>Data collection for 3 nights for each subject, for a total of 80 subjects</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>Measurements Completed 7/2/2015</b></li> </ul>
<b>Data Analysis</b>		
5/2015-9/2016	<ul style="list-style-type: none"> <li>Calculate single aircraft event noise metrics and cumulative nighttime noise levels</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>8/15: Obtained flight data from FAA to identify aircraft events</b></li> </ul>
		<ul style="list-style-type: none"> <li>✓ <b>11/15: Completed program to identify aircraft events in sound recordings based on airport flight operations data</b></li> </ul>
		<ul style="list-style-type: none"> <li>✓ <b>1/16: Identified aircraft events for all subjects</b></li> </ul>
	<ul style="list-style-type: none"> <li>Identify awakenings using ECG and actigraphy data</li> </ul>	<ul style="list-style-type: none"> <li>○ <b>In progress: Identifying and marking artifacts in heart rate measurements</b></li> </ul>
	<ul style="list-style-type: none"> <li>Compare sleep fragmentation and subjective results between control and aircraft noise exposed subjects</li> </ul>	
	<ul style="list-style-type: none"> <li>Calculate models relating awakenings to single event aircraft noise metrics</li> <li>Compare results to the NORAH sleep study conducted around Frankfurt Airport</li> </ul>	

# Philadelphia Airport Sleep Study: Study Population Demographics



40 Participants  
52% Female  
Average Age: 32  
(Age Range: 22-68)

23 Participants  
70% Female  
Average Age: 48  
(Age Range: 23-77)

17 Participants  
41% Female  
Average Age: 42  
(Age Range: 22- 62)

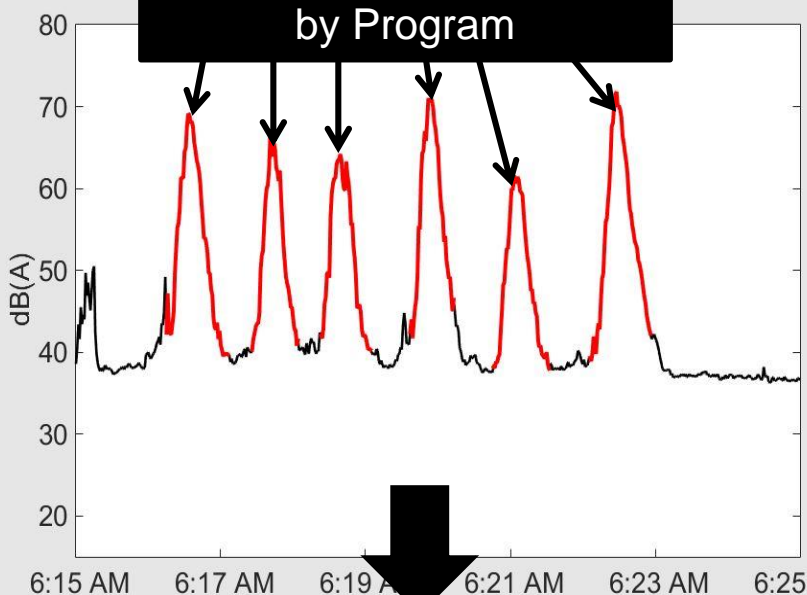
	Airport	Control
Education Level (had at least some college)	67%	90%
Duration of Residence (median)	8 years	2 years
Percent with Sound Proofing	30%	0%
Percent Highly Noise Sensitive	13%	10%

# Philadelphia Airport Sleep Study: Acoustic Analysis Procedure

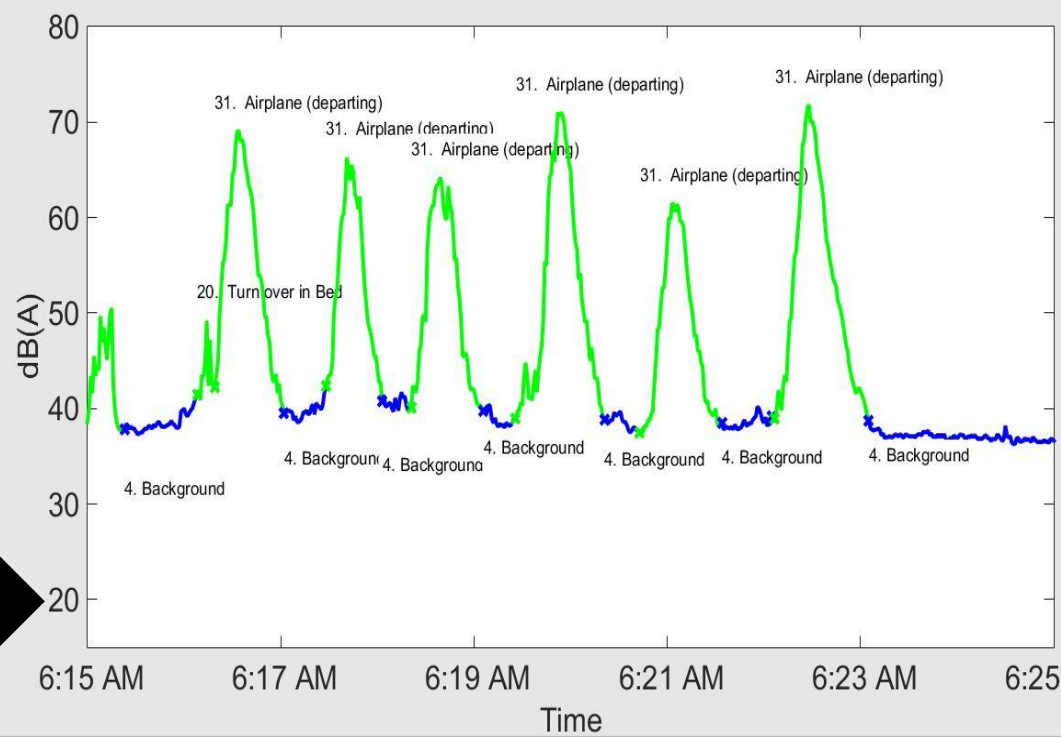


- Developed program for identifying aircraft events based on flight operations data (PDARS data obtained from FAA):
  - Geocoded participants' addresses
  - Calculated distance between aircraft flight path and geocoded address
  - Identified aircraft events in sound recordings based on level above background noise and calculated distance

## Aircraft Events Identified by Program



- Program increases rate at which acoustic files can be scored



- Identified aircraft were verified by listening to recordings
- 2 minutes before and after each aircraft event was also scored

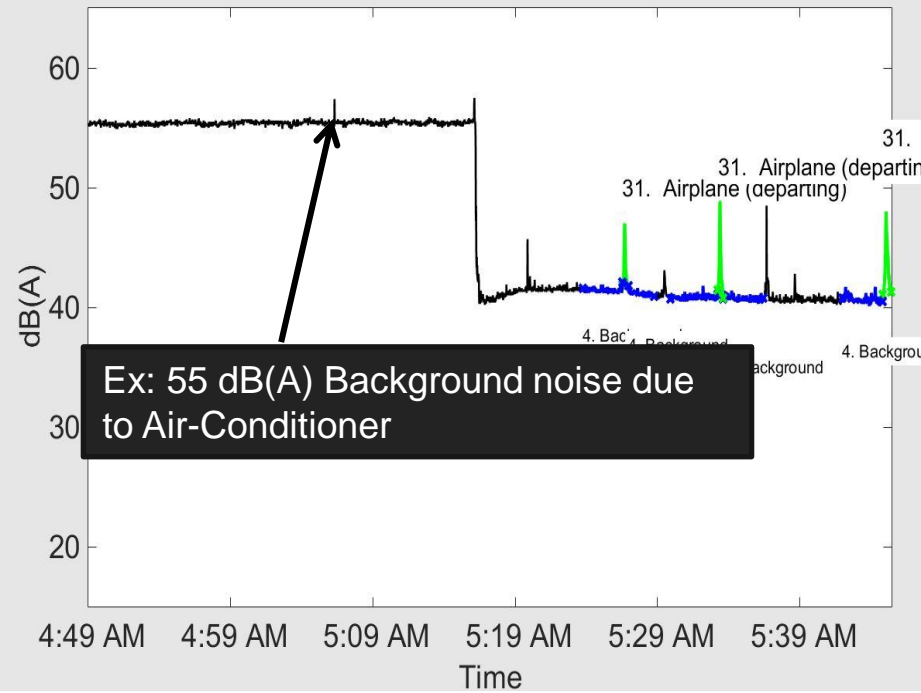
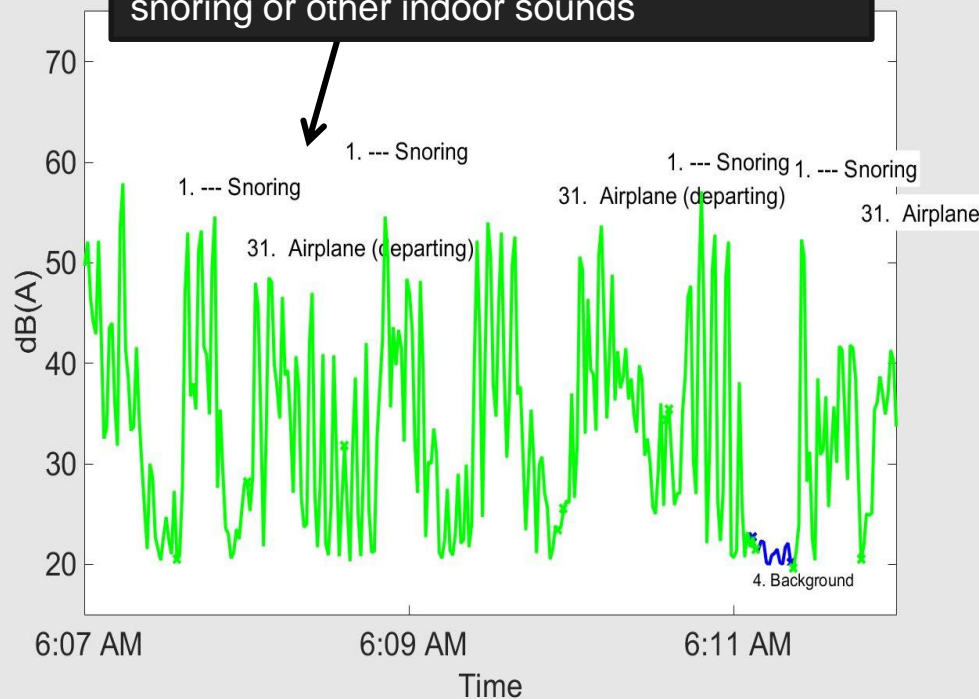


# Philadelphia Airport Sleep Study: Acoustic Analysis (Challenges)

- Additional outdoor and indoor noise events can overlap with aircraft events
- Snoring for example can contaminate an event making it difficult to identify the noise level of overlapping aircraft events
- Methodology for including or excluding these disturbed aircraft events is being developed

- Participants were asked not to sleep with tvs, radios, or music on
- Participants could sleep with fans and air conditioners, pets could remain in room
- Periods of high indoor background levels > 40 dB(A) were observed for 46% of participants by the airport
- A method for handling these background levels in the data analysis is being determined

Ex: Aircraft Events disturbed by high snoring or other indoor sounds



Ex: 55 dB(A) Background noise due to Air-Conditioner



# Philadelphia Airport Sleep Study: Lessons Learned



Recruitment Procedure	<p>Going door to door to recruit participants resulted in only 10 participants</p> <ul style="list-style-type: none"><li>• Individuals reluctant to answer door</li><li>• Many individuals not home at time</li><li>• Expensive due to time of staff in the field</li></ul> <p>Mailing letters resulted in recruitment of remaining 70 participants however response rate was still low &lt; 10%</p>
Participant Retention	<p>Individuals reluctant to allow unknown individuals in their home</p> <ul style="list-style-type: none"><li>• A website with information on the study was created</li><li>• A link to the website was on mailed flyers</li><li>• Website allows participants to verify study and study team</li></ul>
Study Protocol	<ul style="list-style-type: none"><li>• Participants were able to follow the protocol unattended</li><li>• We obtained full physiological and noise measurements for &gt; 90% of the 230 nights of measurements</li></ul>
Study Equipment	<ul style="list-style-type: none"><li>• Surveys completed on tablets, allowed real-time monitoring of participant compliance</li><li>• Heart rate devices were easy to use</li><li>• Equipment should require minimal setup by participants</li><li>• Space in many bedrooms was limited</li></ul>
Study Team	<ul style="list-style-type: none"><li>• Need to be available after normal work hours for enrolling subjects due to participants' work schedules</li><li>• Need to be available 24 hours, by study cell-phone, to address questions at night or first thing in the morning</li></ul>

# Approach: Year 2 Sleep Study

Further simplify the study methodology by eliminating staff in the field

- **Mail Survey**

- Brief recruitment survey: Primary purpose is to determine eligibility for physiological measurements
- Compensation for completing the survey will be an Amazon gift card with an amount of \$2.00, \$5.00 or \$10.00
- Target Enrollment Goal: 1000 Completed surveys

- **In-Home Study**

- 5 nights of sleep and noise measurements
- Equipment will be mailed to subjects' homes
- Target Enrollment Goal: 200 Participants

- **Outcomes**

- Determine response rates for both the mail and in-home study
- Identify inexpensive and reliable equipment
- Assess feasibility of mailing equipment
- Evaluate quality of data obtained



Combined cost of equipment to be mailed out:

**\$1,130**

# Current Status

## Year 2: Sleep Study



Period	Tasks	Status
<b>Study Preparation:</b>		
10/2015-4/2016	<ul style="list-style-type: none"> <li>Design recruitment questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>Completed 10/15</b></li> </ul>
	<ul style="list-style-type: none"> <li>Developed study protocol and obtained IRB approval</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>Completed 11/15</b></li> </ul>
	<ul style="list-style-type: none"> <li>Identified and tested low cost sound recording equipment</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>Completed 2/16</b></li> </ul>
	<ul style="list-style-type: none"> <li>Created videos on how to use equipment, prepared information content for website</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>Completed 4/16</b></li> </ul>
	<ul style="list-style-type: none"> <li>Purchased study related materials</li> </ul>	<ul style="list-style-type: none"> <li>✓ <b>Completed 4/16</b></li> </ul>
	<ul style="list-style-type: none"> <li>Determine airport and obtain flight operations, predict <math>L_{night}</math> levels and number of overflights, identify sampling regions based on predictions</li> </ul>	<ul style="list-style-type: none"> <li>○ <b>Ongoing</b></li> </ul>
<b>Data Acquisition:</b>		
5/2016-9/2016	<ul style="list-style-type: none"> <li>Mail out recruitment questionnaires</li> </ul>	<ul style="list-style-type: none"> <li>○ <b>Start date: TBD</b></li> </ul>
	<ul style="list-style-type: none"> <li>Mail out equipment for in-depth field study</li> </ul>	
	<ul style="list-style-type: none"> <li>Develop procedures for data analysis</li> </ul>	

- External

Collaborations: German Aerospace Center (DLR)

- With DLR we developed and validated an algorithm for identifying awakenings based on ECG and actigraphy data using data from year 1 and 2 of the NORAH sleep study
- Year 3 of the NORAH sleep study: Used similar methodology as PHL study
  - 3 nights of ECG and actigraphy and indoor sound level measurements
  - Similar ECG and actigraphy equipment used as PHL study
  - Equipment was dropped off on first night of the study and collected after the third night
- Results from the PHL study and the second pilot study will be compared to results of the NORAH sleep study

- Within ASCENT

Volpe National Transportation Systems Center: Provided the sound recording equipment used for the indoor measurements in the Philadelphia Sleep Study

- Summary statement:
  - Data analysis for the Philadelphia Airport study is ongoing
  - Preparations for the Year 2 study is almost complete with data collection anticipated to begin end of spring.
- Next steps
  - Philadelphia Sleep Study**
    - Calculate models relating awakenings, identified based on heart rate and actigraphy data, to indoor aircraft noise levels
  - Year 2: Sleep Study**
    - Complete nighttime noise predictions for airport
    - Select sampling regions
    - Obtain address list and mail recruitment surveys

# References

- Basner M. Design for a US field study on the effects of aircraft noise on sleep. Cambridge, MA: Partnership for Air Transportation Noise and Emissions Reduction (PARTNER), 2012. Report No.: PARTNER-COE-2012-003.
- Basner M, Griefahn B, Müller U, Plath G, Samel A. An ECG-based algorithm for the automatic identification of autonomic activations associated with cortical arousal. *Sleep* 2007; 30(10): 1349-61.
- Basner M, Müller U, Elmenhorst E-M, Kluge G, Griefahn B. Aircraft noise effects on sleep: a systematic comparison of EEG awakenings and automatically detected cardiac activations. *Physiological Measurement* 2008; 29(9): 1089-1103.

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