Sonic Boom Community Testing

NASA Quiet Supersonic Flights 2018 (QSF18) Risk Reduction Test

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Aviation Noise and Vibration Subcommittee
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Civil Supersonic Flight

- **Civil supersonic overland flight prohibited**
- **Recent advances to significantly reduce sonic boom noise**
- **Industry interest in lifting the ban**

- **NASA is working with regulators to**
  - Provide science-based assessment and data
  - Enable development of a new noise standard
    - Noise metric, test procedures, noise limit

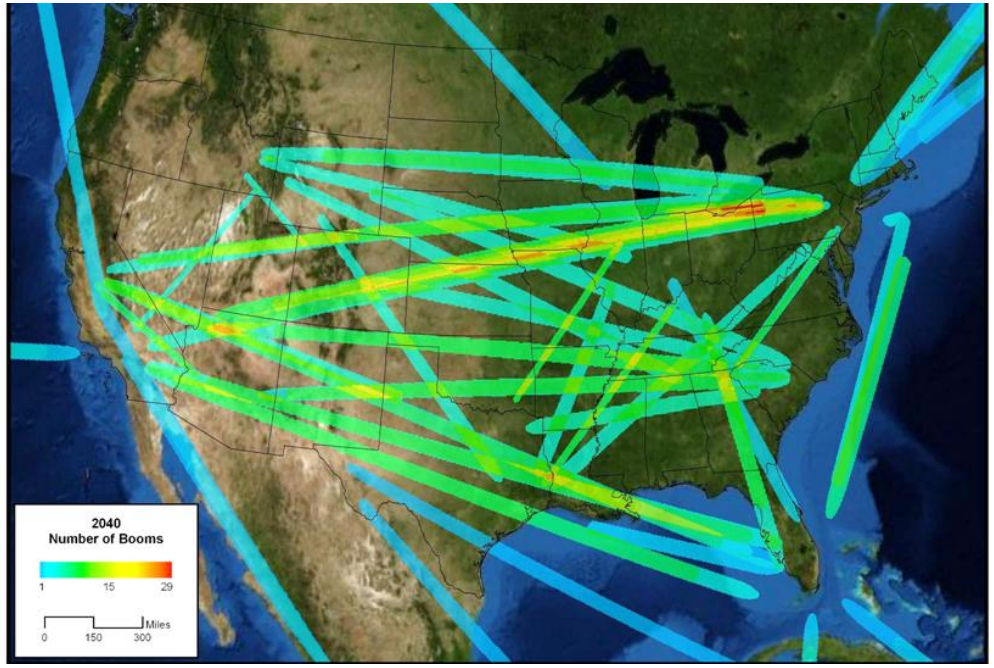
- **NASA is building the X-59 QueSST low-boom demonstrator to support standards development**
  - Prediction tool validation for shaped booms
  - Community response testing

Sonic Boom Waveforms and Spectra

Unique aspects of sonic booms

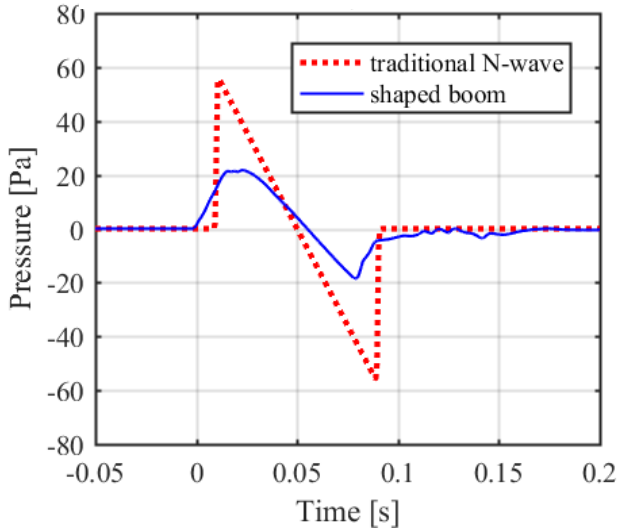
- Transient nature of sonic boom
- Low-frequency energy
- Created along entire supersonic path
- Cannot use the same methods/metrics as for subsonic aircraft

Number of booms predicted in 2040

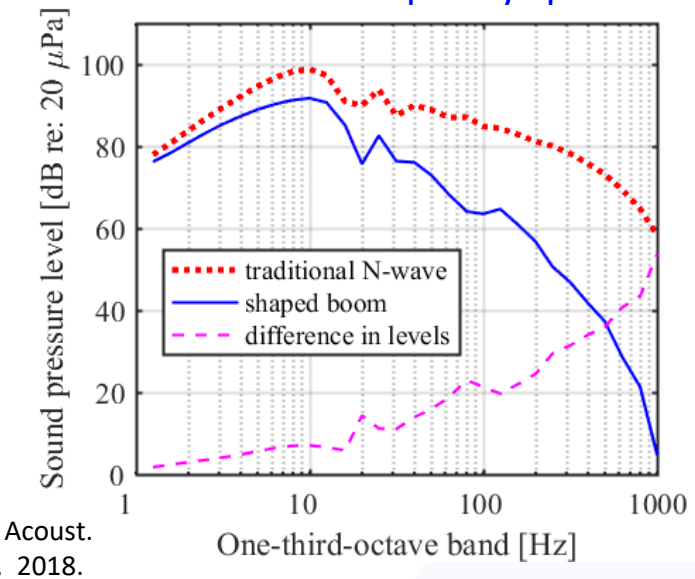


J. Rachami and J. Page. AIAA 2010-1385.

Example boom shapes



Variation in frequency spectra



J. Rathsam et al. J. Acoust. Soc. Am., 143:489, 2018.

QSF18 Risk Reduction Test Overview

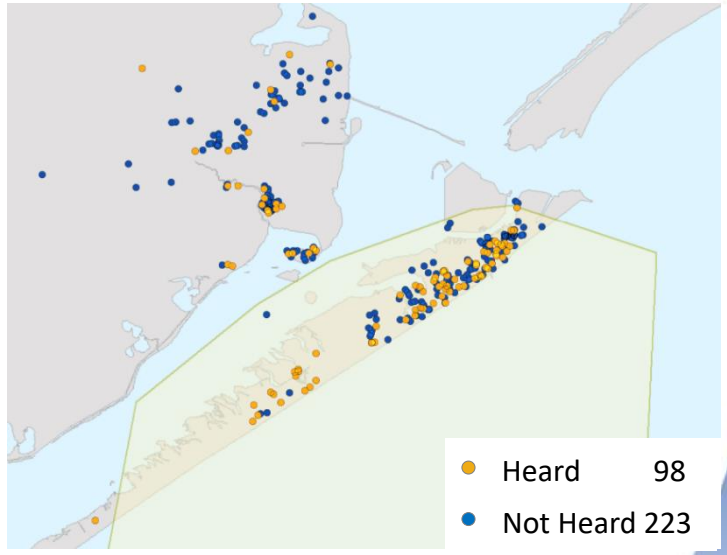
- **Before X-59 testing, tested methodologies in a city that's not used to hearing sonic booms**
- **NASA conducted supersonic research flights in Galveston, TX on November 5-15, 2018**
  - Galveston met all key selection criteria
  - Data not for supersonic aircraft regulation development
  - Also tested community engagement strategy
- **9 flight days over two weeks**
  - 22 flights with F-18 low-boom dive
  - 52 sonic thumps
- **4 - 8 sonic thumps daily, levels increased gradually**
- **500 members of the public participated in survey**
- **~20 noise monitors measured sound levels across survey area**

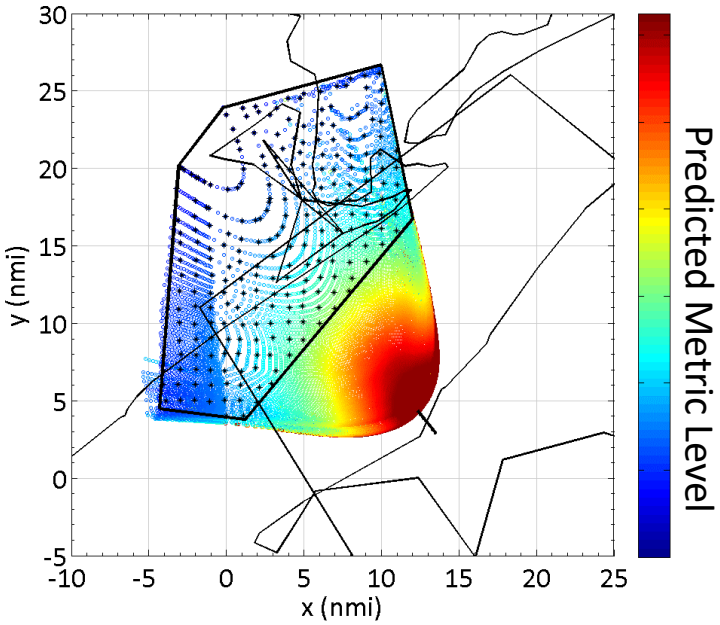
Noise Monitor Measurements

- **Primary units connected by cellular network**
  - Controlled by host station on Galveston Island
- **Sparse array with locations chosen for**
  - Cellular connectivity
  - Low ambient noise
  - Security, access, and approval
  - Placement in footprint

Predictions and Exposure Estimation

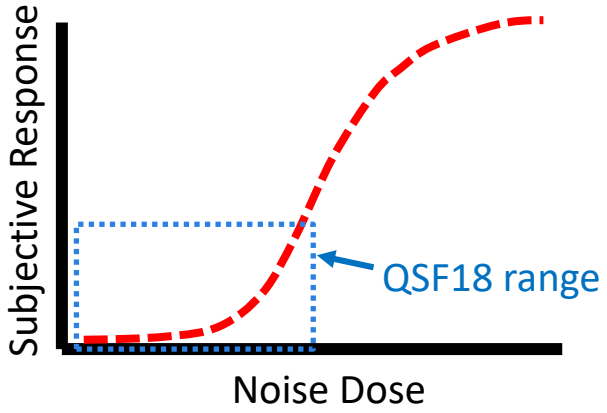
- **Geolocation of survey participants during each boom event**
  - Needed to estimate participant dose for each boom event
  - Geolocation question included in survey
  - Data cleanup was required
    - 71% of automatic geolocations were successful
- **Post-flight ground boom predictions**
- **Methods to assign participant dose**
  - Adjust prediction for participant location by delta
  - If predictions unavailable, use distance-weighted average of measurements



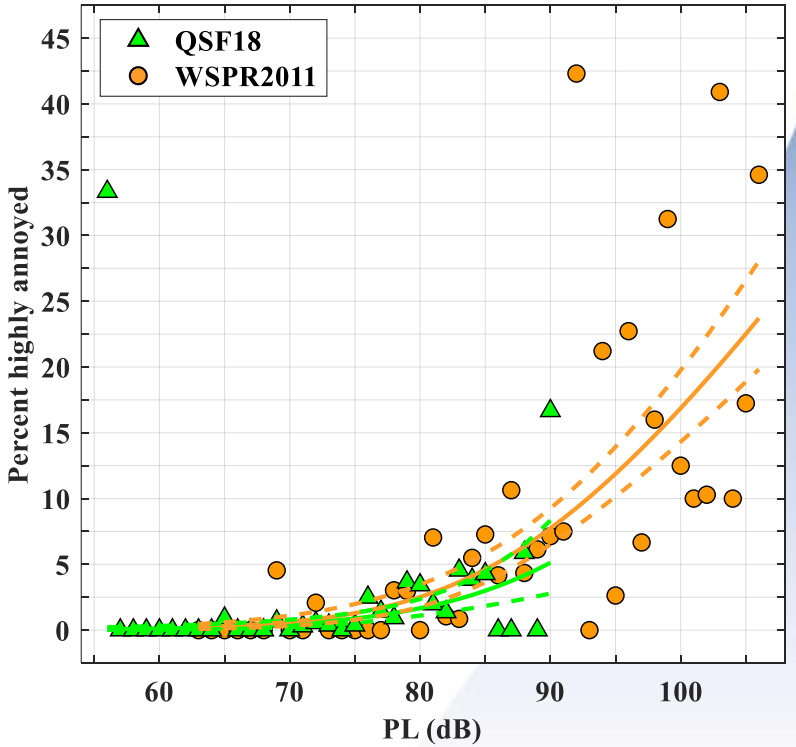


Dose-Response Summary Curves (Single Event)

- **How much did the sonic thump bother, disturb, or annoy you?**
  1. Not at all annoyed
  2. Slightly annoyed
  3. Moderately annoyed
  4. Very annoyed
  5. Extremely annoyed



- **Summary curves overlaid on binned data**
  - Curves are not best-fit lines to plotted data points
  - Each datapoint represents all noise exposures binned in 1 dB increments
- **QSF18 results compared to previous NASA WSPR2011 test**
  - QSF18 had a smaller range of boom levels
  - Similar results where levels overlap
- **Specific data not for supersonic aircraft regulation decisions**
  - Methodological development



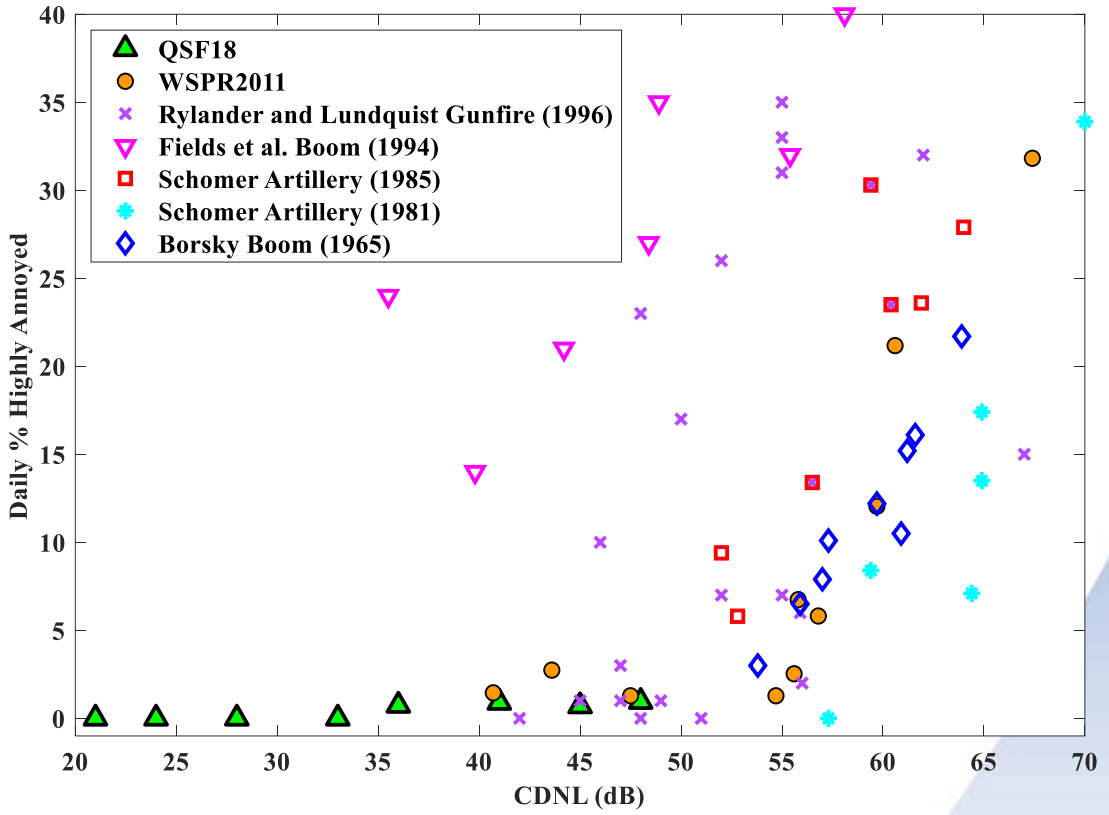
J. Lee et al. J. Acoust. Soc. Am., 147:2222, 2020.

Cumulative Dose-Response Results

- **Over the course of your day, how much did the sonic thumps bother, disturb, or annoy you?**
  1. Not at all annoyed
  2. Slightly annoyed
  3. Moderately annoyed
  4. Very annoyed
  5. Extremely annoyed

- **QSF18 results compared to previous tests**
  - QSF18 had a much lower range of CDNL
  - Daily annoyance in QSF18 is not directly comparable to long-term cumulative annoyance found in transportation noise survey literature
  - However, comparison shows similar results in area of overlap

Comparison of Impulse Noise Community Tests



S. Fidell, Community Response to High-Energy Impulsive Sounds: An Assessment of the Field Since 1981 (National Academy Press), 1996.

Summary from QSF18

Successful risk reduction test overall

- Participant recruitment goals met
- Survey worked well, though with geolocation difficulties
- Noise monitors successfully deployed and operated with dedicated field team
- Exposure estimation posed challenges
- Statistical models developed for dose-response curve

Updates to methodology required for X-59

- Key technical challenge is scaling up to enable nationally representative results
- Automation of data collection and analysis for rapid turnaround time
- Remote operation of noise monitors
- Weather-robust acoustic hardware
- Updated statistical analysis approaches

X-59 Goal: Provide nationally-representative dose-response database to ICAO of community response to quiet supersonic aircraft flight over land

Acknowledgements

Quiet Supersonic Flights 2018 Partners

- NASA sonic boom team
- Applied Physical Sciences (lead), Penn State ARL, US DOT Volpe, Gulfstream, KBRwyle, Gaugler Consulting, Eagle Aeronautics, Brigham Young University (BYU)

QSF18 Field Crew (Galveston)	QSF18 Aircraft Operations (Houston)
	

NASA Contractor Report https://ntrs.nasa.gov/citations/20200003223