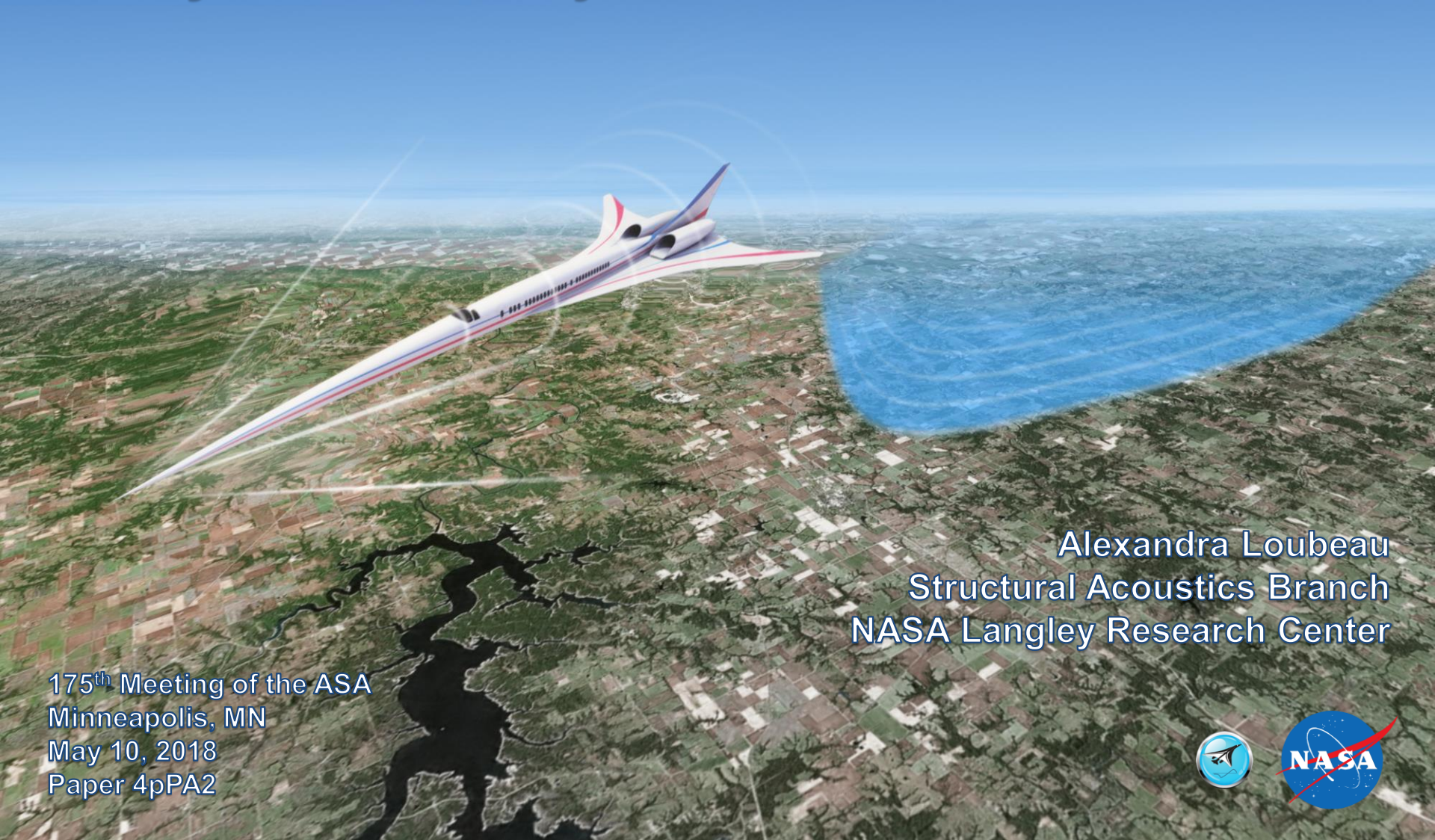
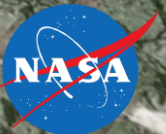


Evaluation of the effect of aircraft size on indoor annoyance caused by sonic booms and rattle noise



Alexandra Loubeau
Structural Acoustics Branch
NASA Langley Research Center

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Introduction



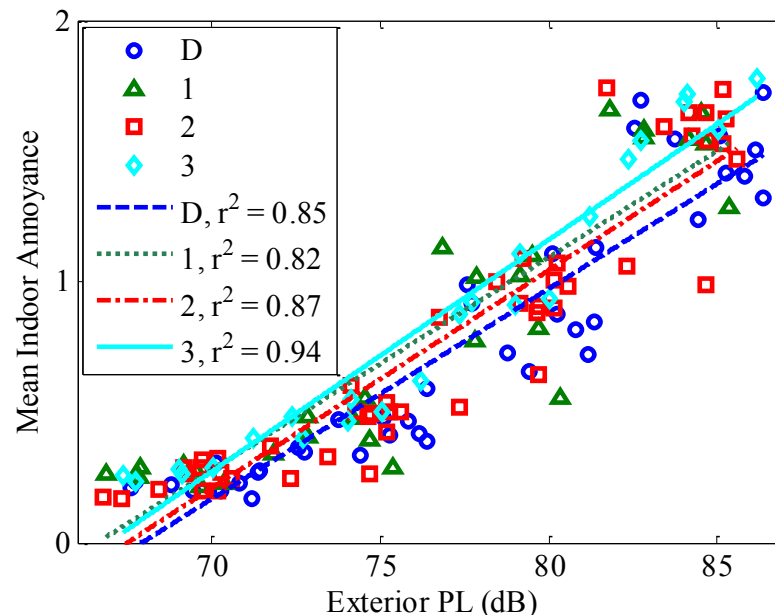
- NASA goal to enable development of noise-based standard for commercial supersonic aircraft
- NASA quiet supersonic research aircraft
 - Plan for studies of impact on community residents
- To keep costs down, demonstrator aircraft will be small (sub-scale)
- Smaller size and weight create a shorter sonic boom with less low-frequency energy than commercial airliner
 - Expect different spectral characteristics of sonic boom



Sonic Booms from Sub-Scale Aircraft



- Previous study¹ examined people's perception of sonic booms predicted for sub-scale and full-scale supersonic aircraft
 - For a given exterior PL, annoyance to sub-scale aircraft booms is not significantly different from that for a full-scale aircraft boom



D

Demonstrators



1

Business Jets



2

Small Supersonic
Airliners



3

Larger Multi-Mach
Aircraft



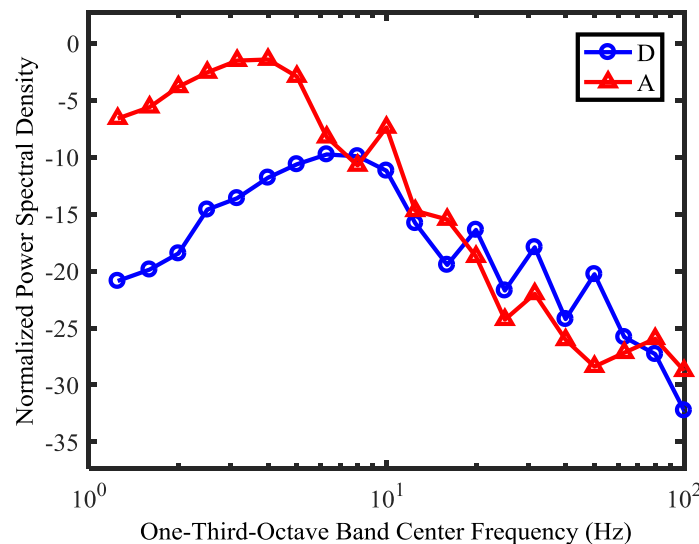
- Provided clear set of results for justifying plans to use demonstrator for community response studies (to inform noise certification standard process)
- Limitation: sonic booms presented without secondary rattle noise

¹A. Loubeau, JASA, 136(4): 2223, 2014.

Boom and Rattle Study



- Follow-on study of effect of rattle on perception of booms from sub-scale aircraft vs. full-scale aircraft
 - Conducted in NASA Langley Interior Effects Room (IER)
 - Included demonstrator (D) and small airliner (A) booms
 - Created a more realistic indoor boom environment with window rattles
- First IER test with rattle sounds matched to booms (see 4pPA1, Jake Klos)
- Primary objective
 - Compare to baseline: Does rattle change the conclusion?



Preparation for Boom and Rattle Study

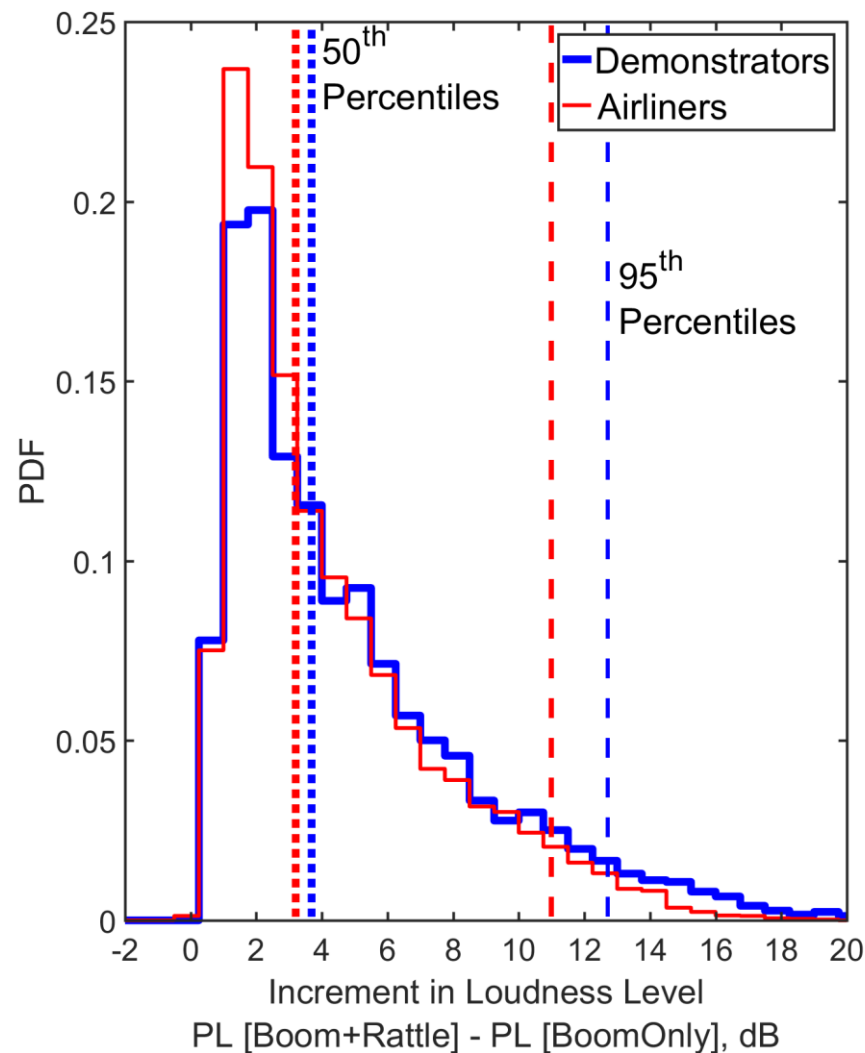
- (Details described in 4pPA1, Jake Klos)
- Sonic boom-induced window rattle sounds measured in the IER
 - Four windows and four sun catchers mounted to windows
 - Indoor boom+rattle waveform was measured at several listener locations
 - Signal processing removed the boom from the boom+rattle waveform
 - “Rattle only” signal used for objective analysis and in subjective testing
- Database of rattle sounds and levels that are matched to specific boom signatures and levels



Rattle Sound Selection



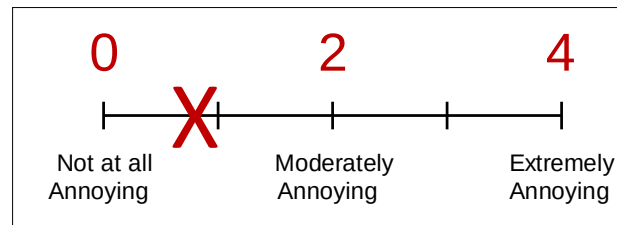
- Eight rattle conditions chosen from database
 - Variety of windows and suncatchers
 - Chosen to span a range of loudness levels
- Ninth rattle condition is no rattle



Boom and Rattle Study Details

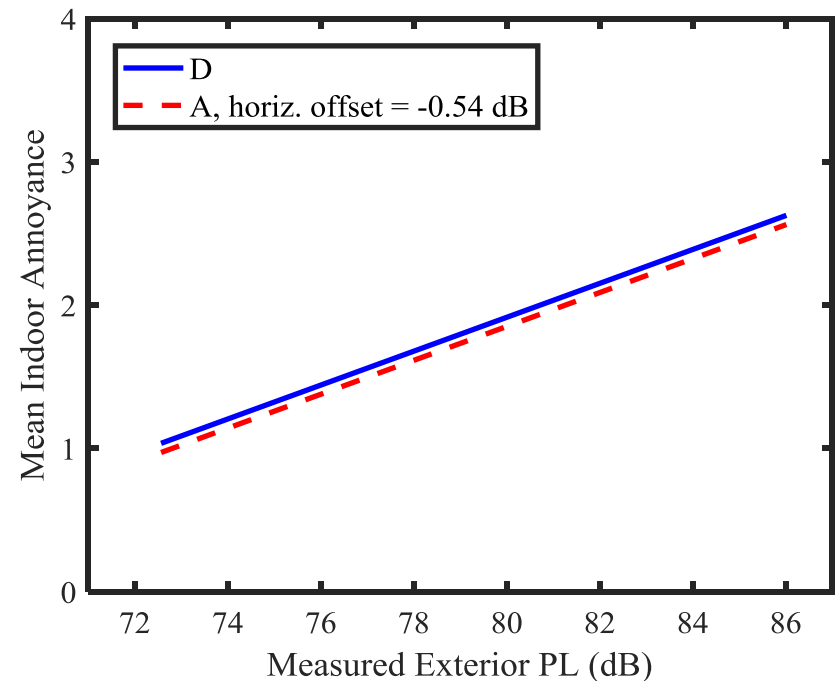
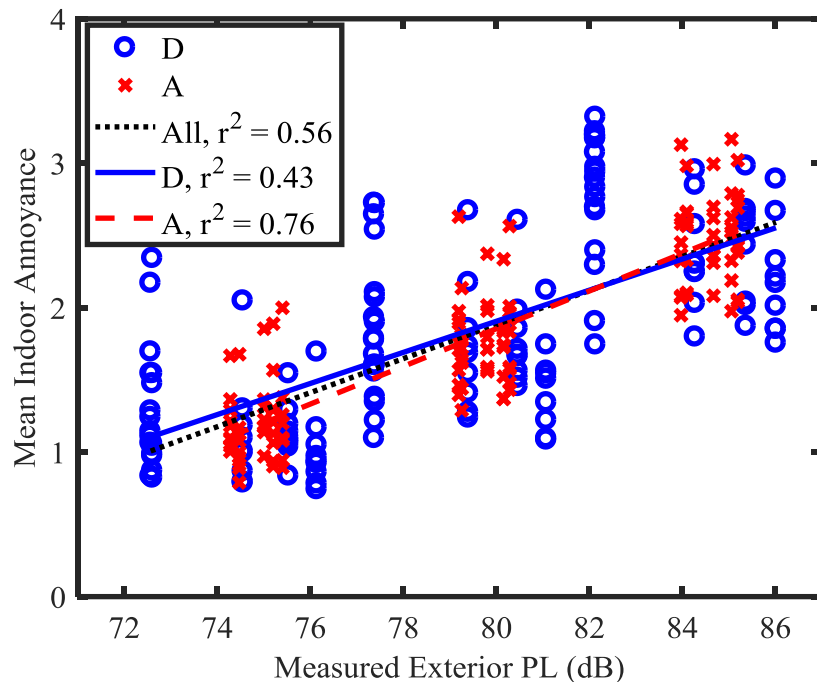


- Audio playback
 - Reproduced exterior boom with two loudspeaker arrays
 - Measured window rattle sounds were presented using small interior speaker below window
- Test details
 - 32 test subjects recruited from region of Hampton Roads, Virginia, USA
 - 270 sounds: 5 D and 5 A booms, 9 rattle conditions
 - Each boom at exterior PL of approx. [75, 80, 85] dB
 - Subjects rated annoyance to each boom/rattle experience
 - Metrics computed on outdoor booms
 - Metrics do not account for presence of indoor rattle
 - Approximates situation during community testing



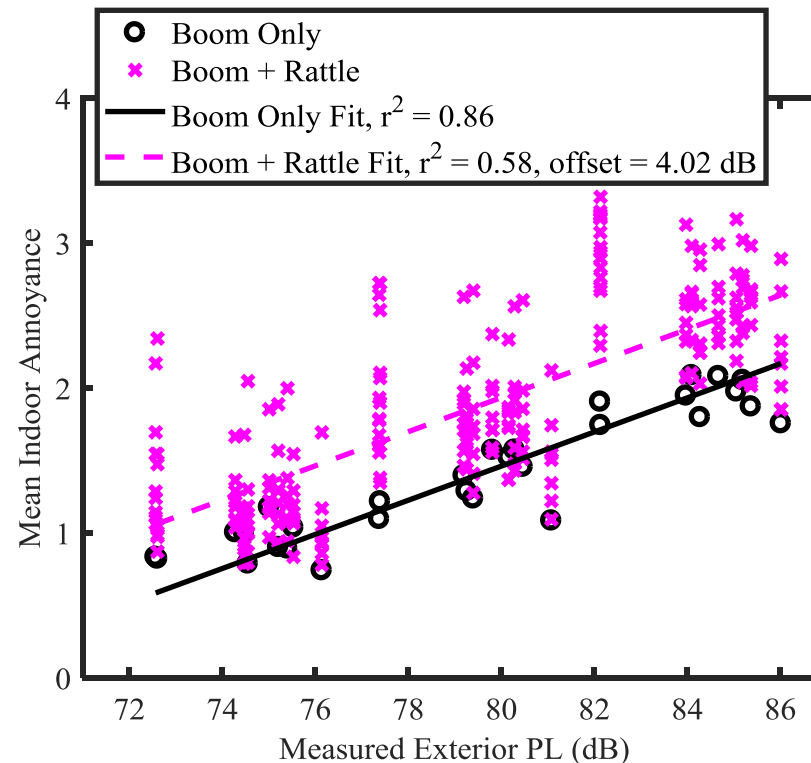
Effect of Aircraft Size

- No significant effect of aircraft size on annoyance is observed when rattles are introduced
 - Variation in annoyance can be greater for demonstrator booms
 - Regression line slopes are not significantly different
 - Confirms conclusions from previous study without rattle



Rattle Offset

- Presence of rattle increases annoyance
- Range of annoyance due to range of rattle sounds
- On average, increase in annoyance due to rattle is equivalent to increase in exterior boom PL of 4 dB
 - 4 dB “rattle penalty” is in agreement with previous rattle study (4-9 dB)³



³A. Loubeau et al., NASA/TM-2013-217975, 2013.



Noise Metrics Evaluation

- Since aircraft class is not significant
 - Combine data for 2 aircraft categories
 - Allows for additional evaluation of noise metrics
 - Calculated metrics on exterior signal
 - Range of loudness metrics on the order of 15 dB
- Metrics have lower correlations with indoor annoyance when rattle is present
 - DSEL and ISBAP have highest correlations

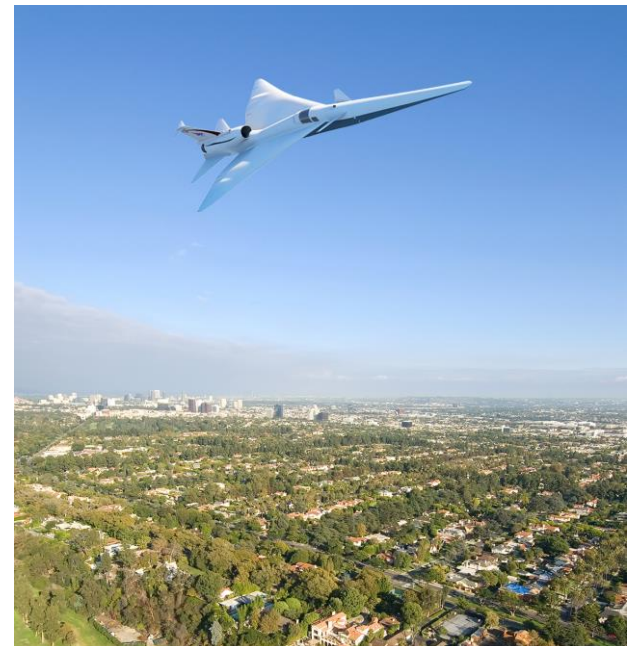
Metric	Exterior r^2	
	With rattle	Without rattle (2014)
DSEL	0.69	0.87
ISBAP	0.67	0.89
CSEL	0.66	0.84
LLZ	0.66	0.87
LCSmax	0.66	0.83
BSEL	0.63	0.86
LCFmax	0.62	0.81
ESEL	0.60	0.85
PL	0.57	0.84
ASEL	0.53	0.82
LASmax	0.53	0.82
LAFmax	0.53	0.77
PNL	0.48	0.76

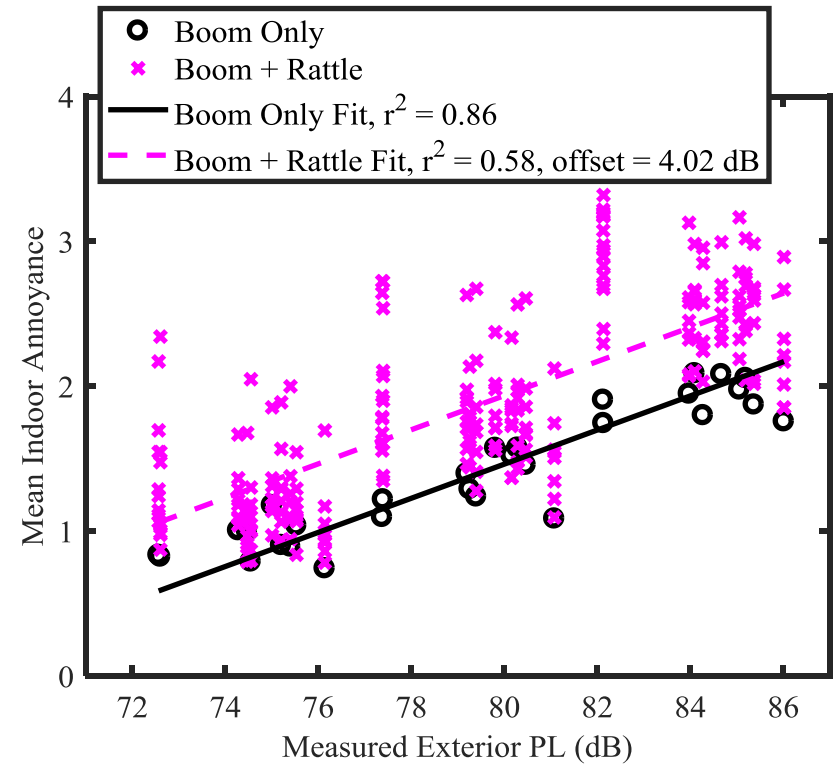
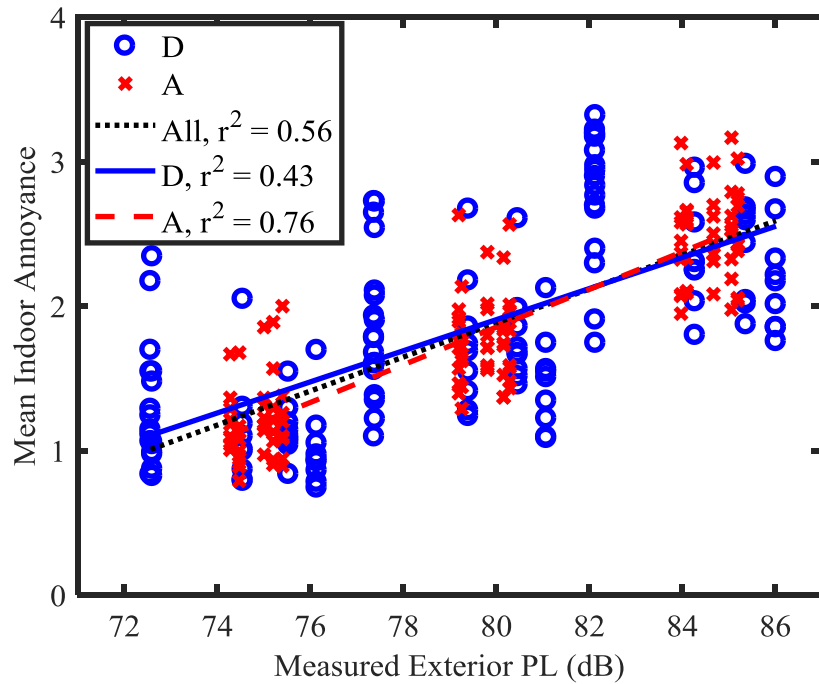
$$\text{ISBAP} = \text{PL} + 0.4201 * (\text{CSEL} - \text{ASEL})$$

Summary and Conclusions



- Laboratory study of annoyance to sonic booms from sub- and full-scale aircraft
 - Additionally included secondary rattle sounds matched to booms to create a more realistic indoor boom environment
 - For a given PL, low effect of aircraft size confirms conclusions from previous study without rattle
 - Results help justify relevance of demonstrator aircraft for use in community studies
 - To aid in development of new noise certification standards for supersonic aircraft
 - Confirmation that exterior metrics can be used to evaluate supersonic aircraft designs, regardless of size
- Metrics evaluated for studies with and without rattle
 - Exterior metrics have lower correlations with indoor annoyance when rattle is present
 - Lower correlations approximate expected situation during community testing





Alexandra Loubeau
a.loubeau@nasa.gov