



Fundamental Aeronautics Program

Supersonics Project, Sonic Boom Modeling

Measurement of Low-Amplitude Sonic Booms In and Around Large Buildings

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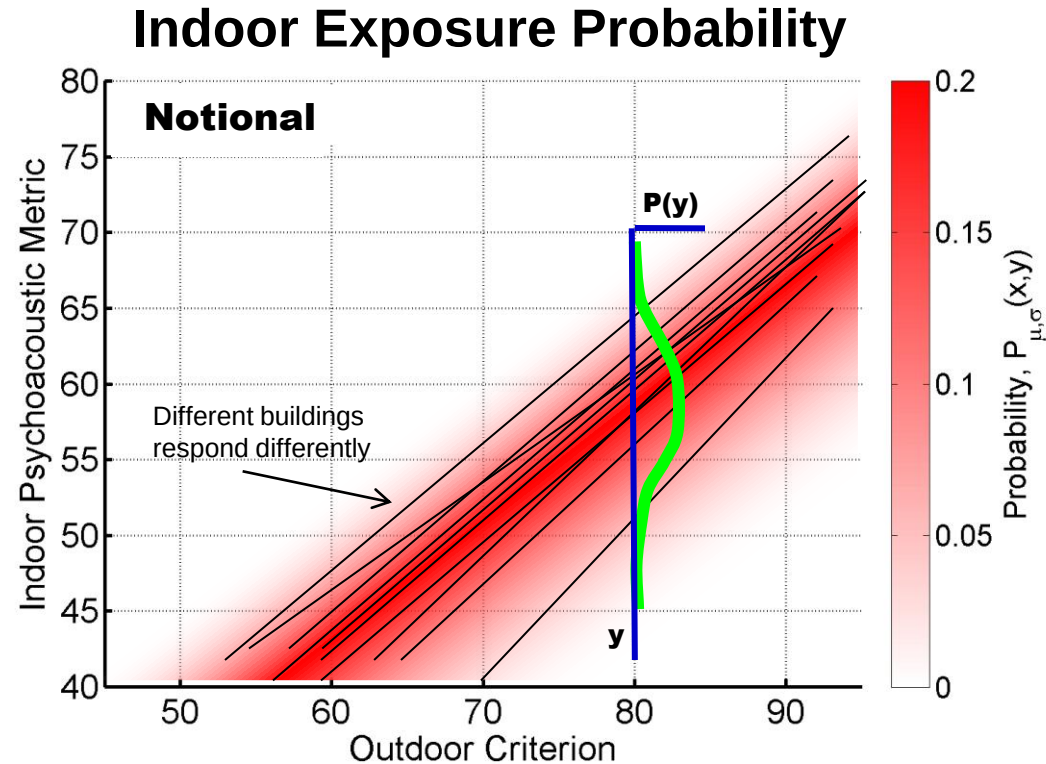
Acknowledgements



- NASA Langley
 - Alexandra Loubeau, Jonathan Rathsam
- NASA Dryden
 - Lots of folks, but in particular Edward Haering, Larry Cliatt
- Edwards Air Force Base
- Gulfstream Aerospace Corporation
- The Pennsylvania State University
- Purdue University

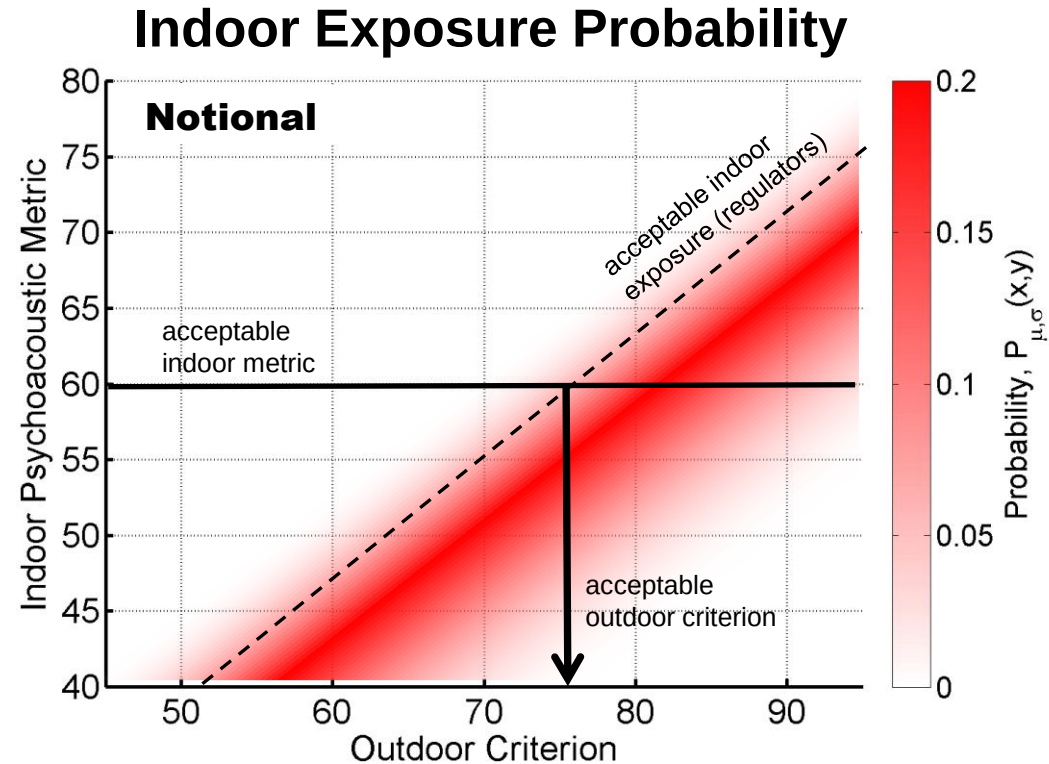
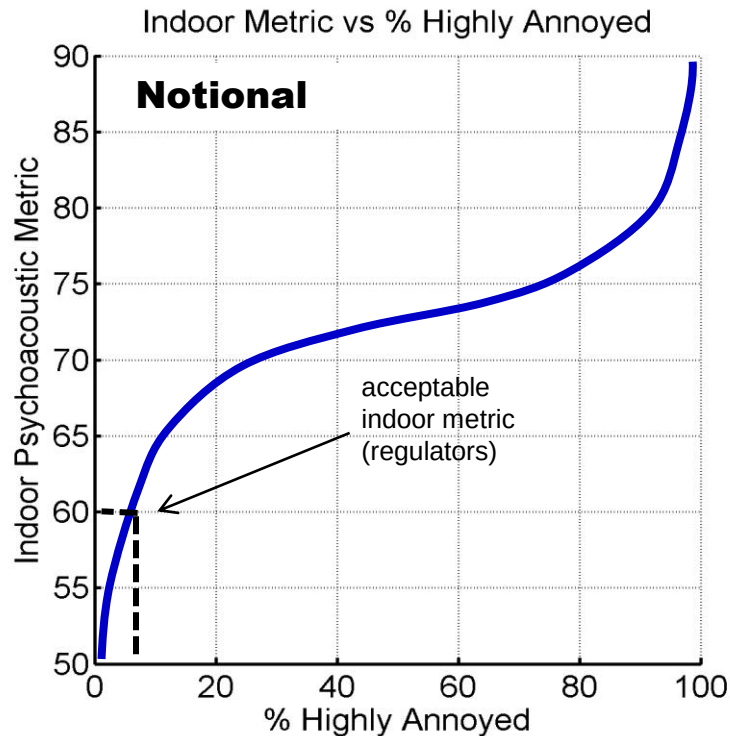
Motivation (Regulation Change)

- Need an outdoor criterion
- May need to consider indoor sound exposure
- Causes of variance:
 - Range of buildings
 - Types
 - Construction
 - Range of aircraft ops and configurations
 - Rattle
- Probability density function relates indoors to outdoors



Motivation (Regulation Change)

Connecting the dots... relating indoors to outdoors:



Going from indoors to outdoors:

- | | | |
|-------------------|---|--|
| NASA | { | Defining exposure probability density function (structural acoustic problem) |
| | | Defining indoor (and outdoor) metrics (psychoacoustic problem) |
| Regulators | { | Defining an acceptable indoor level |
| | | Defining an acceptable indoor exposure probability |

Research Goal



Develop prediction tools and create an appropriate probability density function from simulations of different indoor environments

Presentation Overview



- SonicBOBS and HouseVIBES overview
- Observed behavior:
 - Around buildings (atmospheric effects)
 - Around buildings (reflection and diffraction)
 - Inside buildings (attenuation and reverberation)
- Modeling considerations
 - Generate distributions numerically
- Rattle
- Concluding remarks

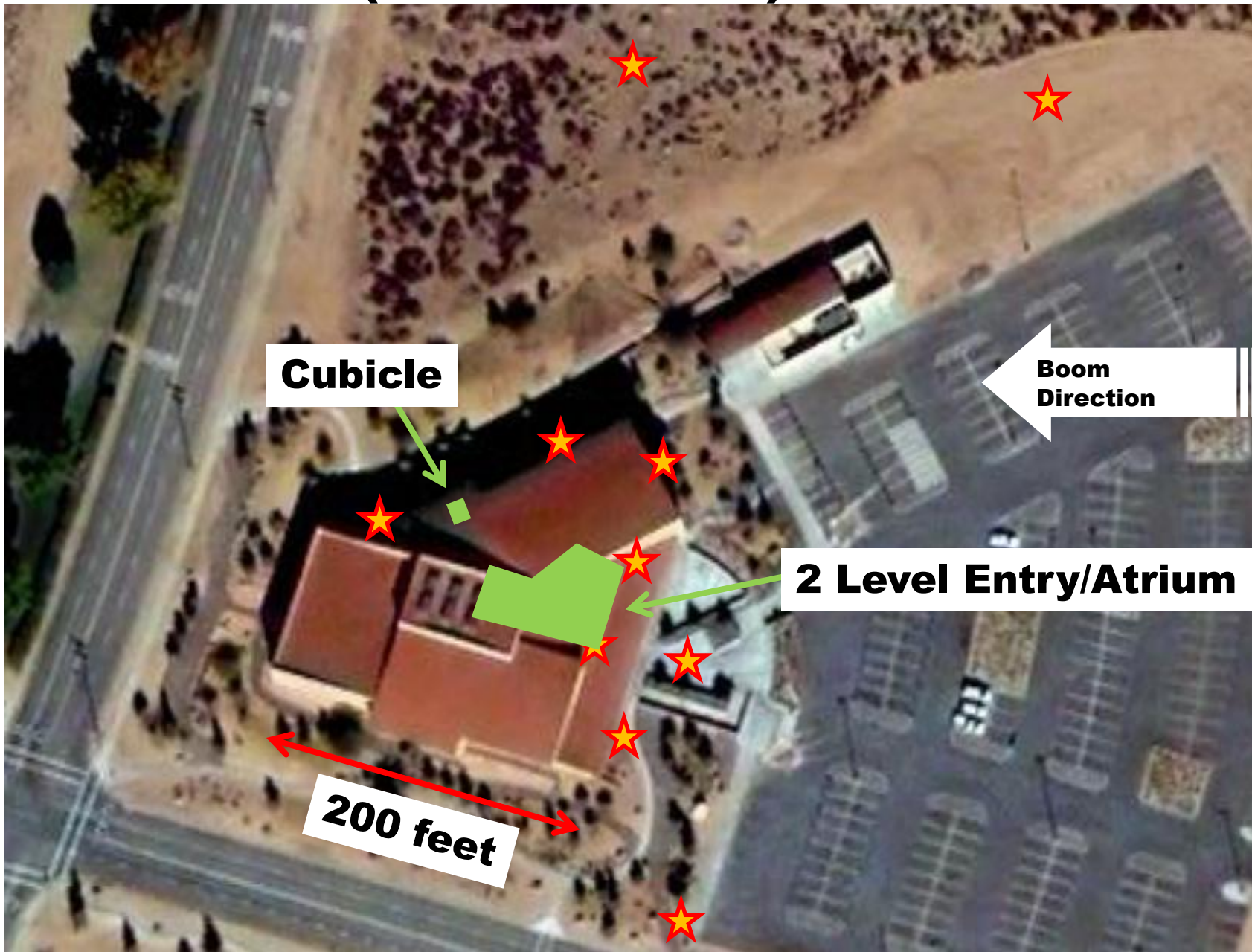


SONICBOBS AND HOUSEVIBES

SonicBOBS (Office Building)



SonicBOBS (Measurements)



Cubicle

**Boom
Direction**

2 Level Entry/Atrium

200 feet

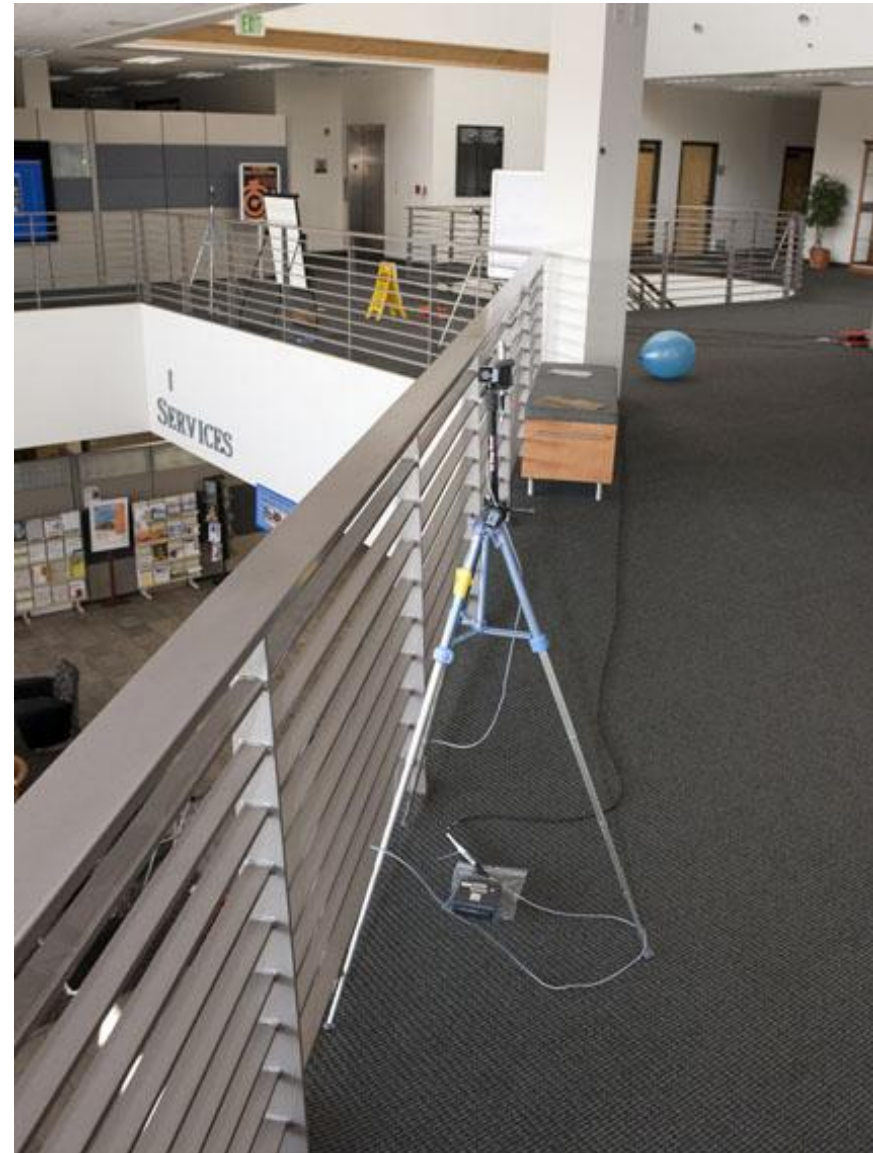
SonicBOBS (Indoor Atrium)



Entry/Atrium First Floor



Entry/Atrium Second Floor



SonicBOBS (Entryway Glass Façade)



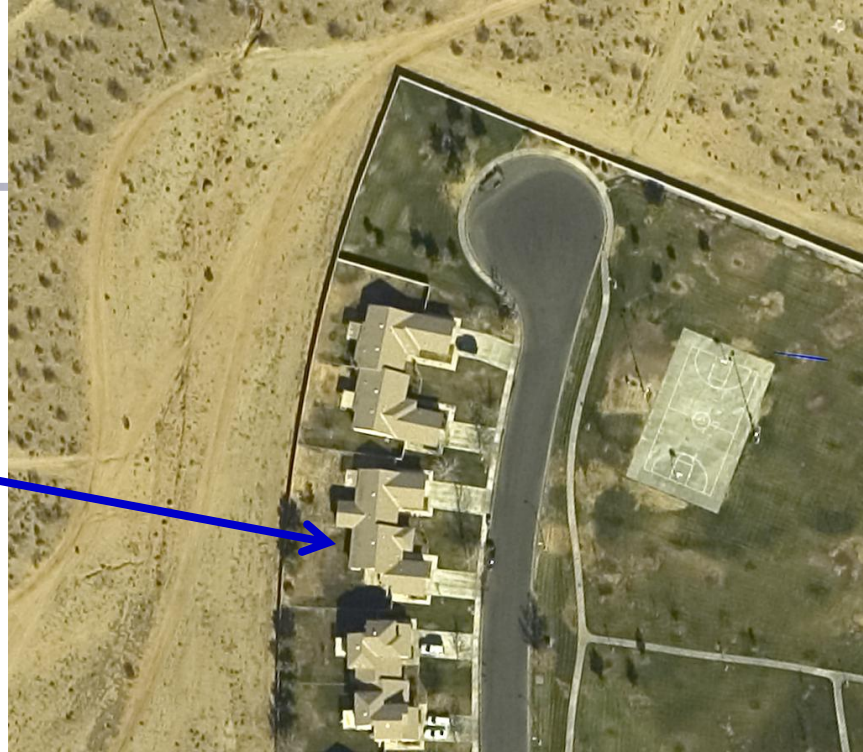
SonicBOBS (Office)



HouseVIBES



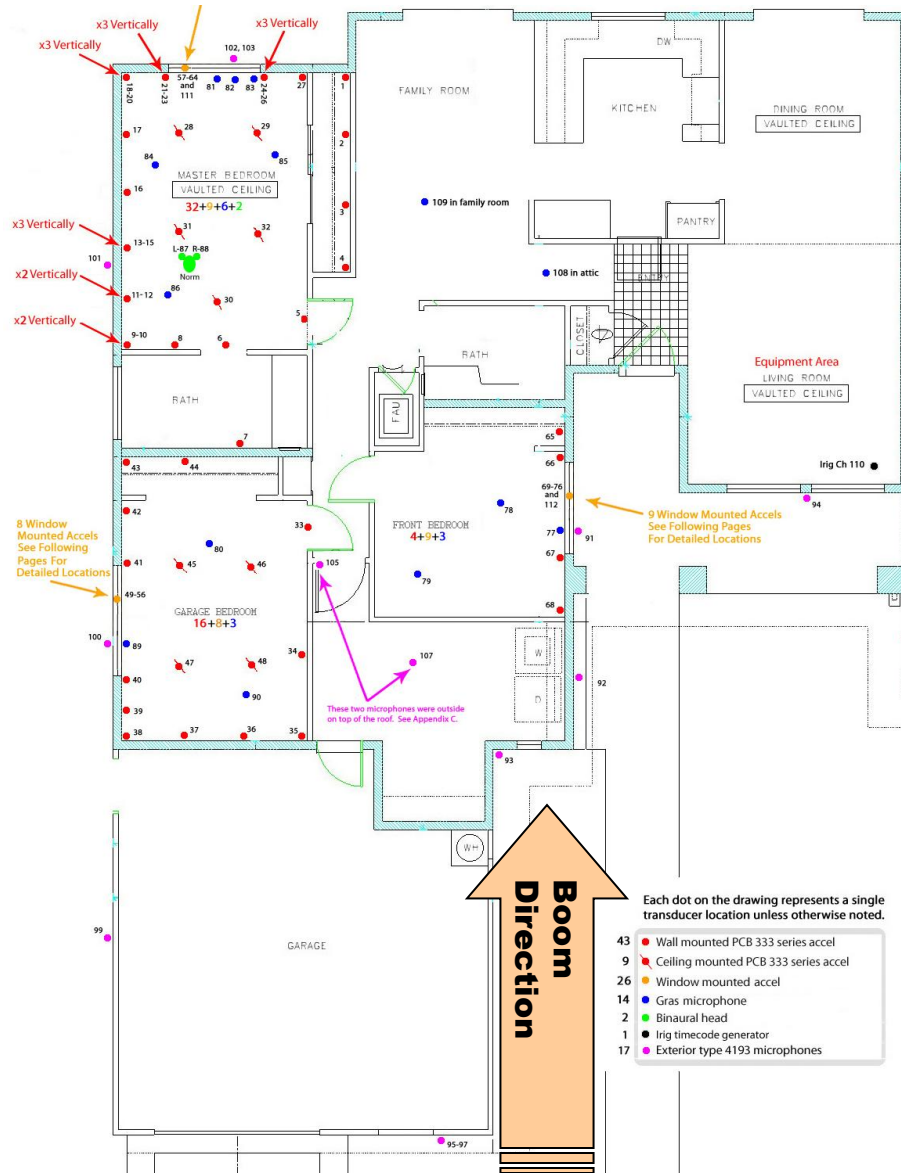
Instrumented
Townhouse



HouseVIBES (Measurements)



Floor plan (half of townhouse)



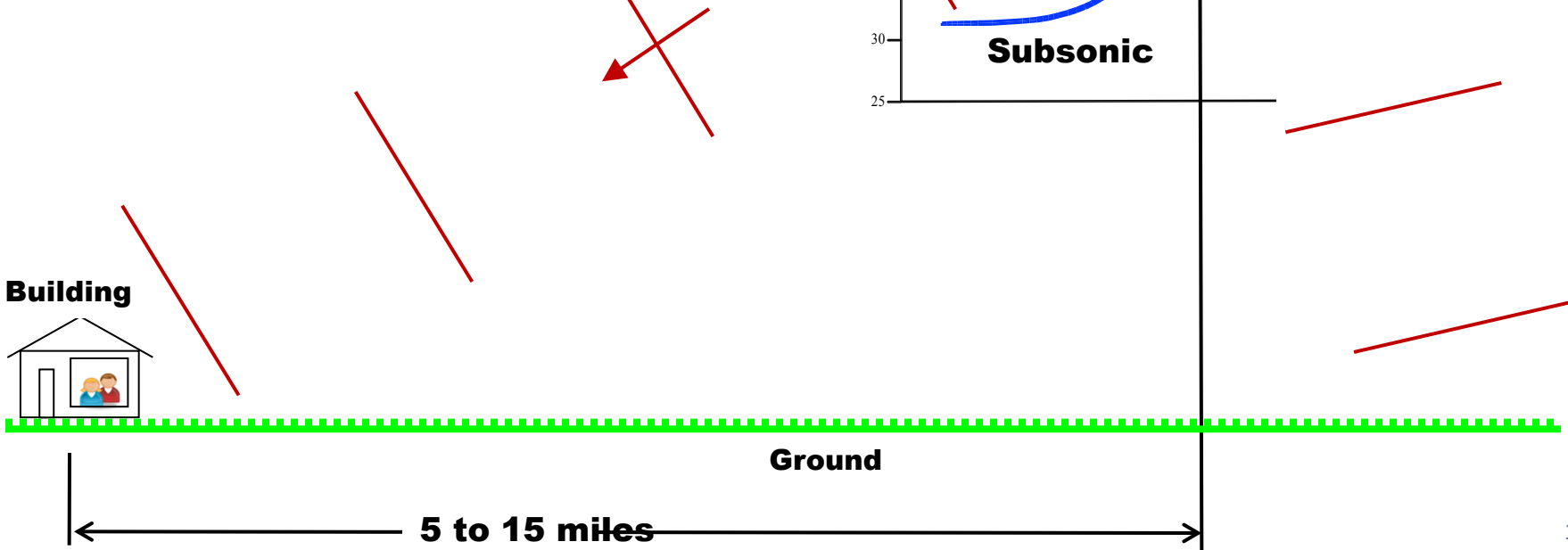
An instrumented bedroom



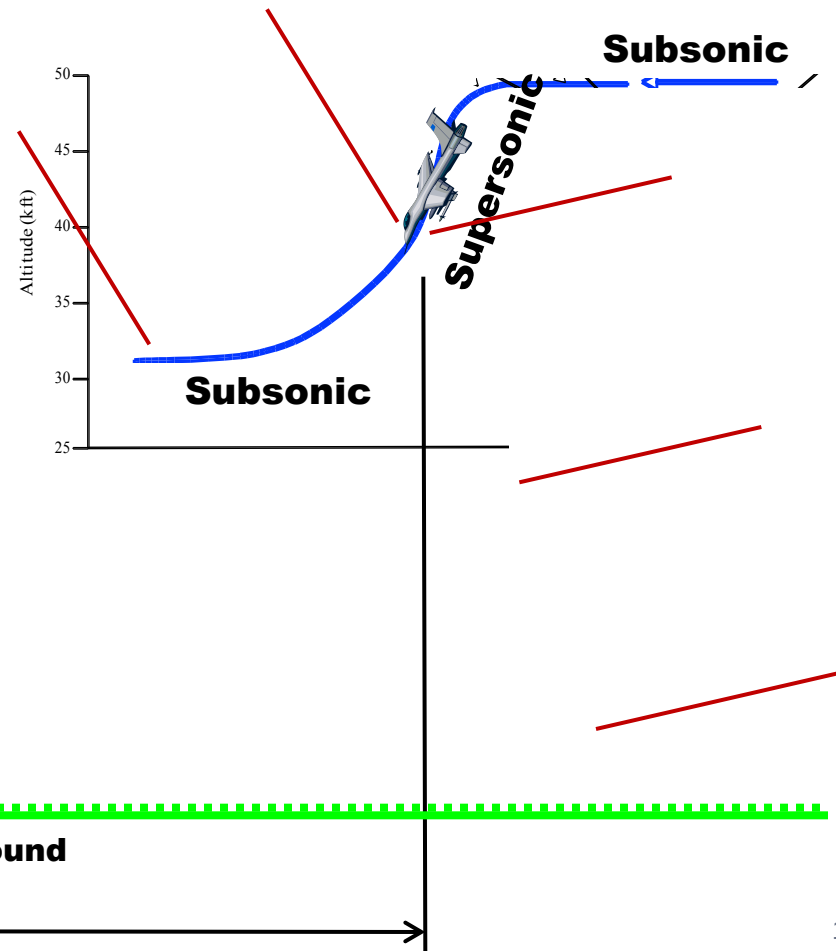
Low Boom Dive Maneuver



- Current aircraft cannot generate low booms during straight and level flight
- Sonic boom is generated during supersonic dive of an F/A 18 aircraft (Dryden operated)
- Boom propagates very far, attenuating before reaching the building
- Boom amplitude is adjusted by moving dive location relative to the building



NASA Dryden low boom maneuver



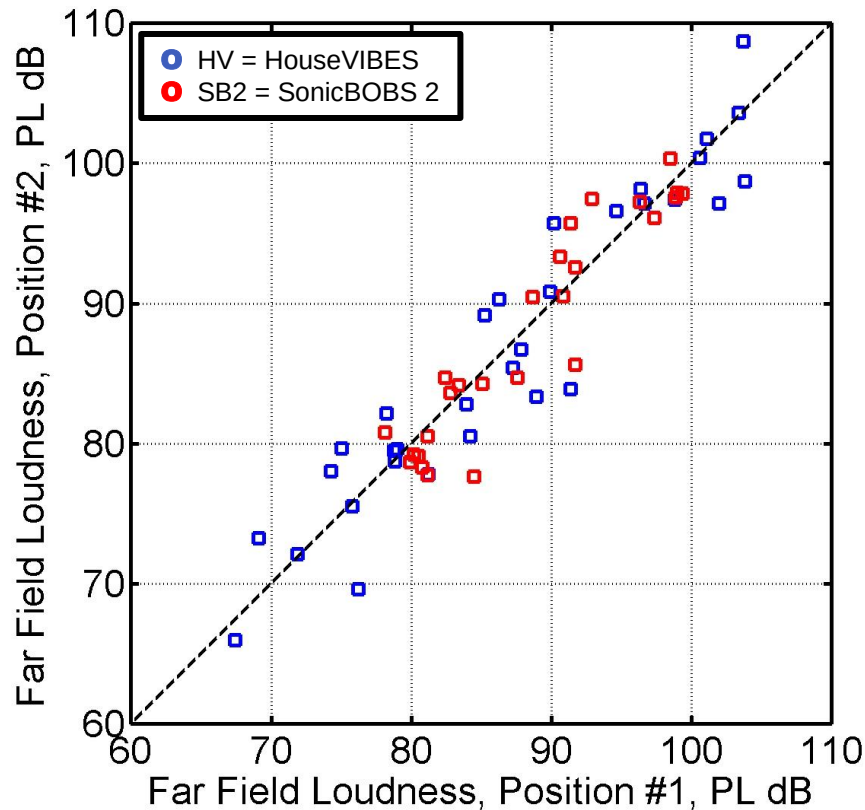


OBSERVED OUTDOOR BEHAVIOR

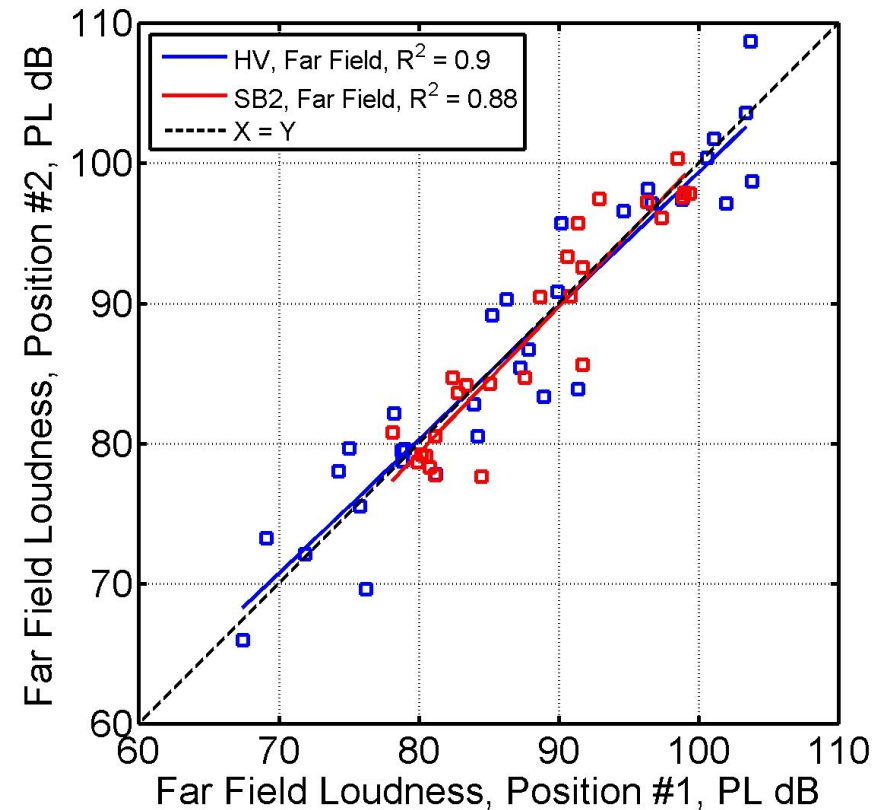
Introduction to Metric Vs. Metric Plots



Raw Data



Linear Regression

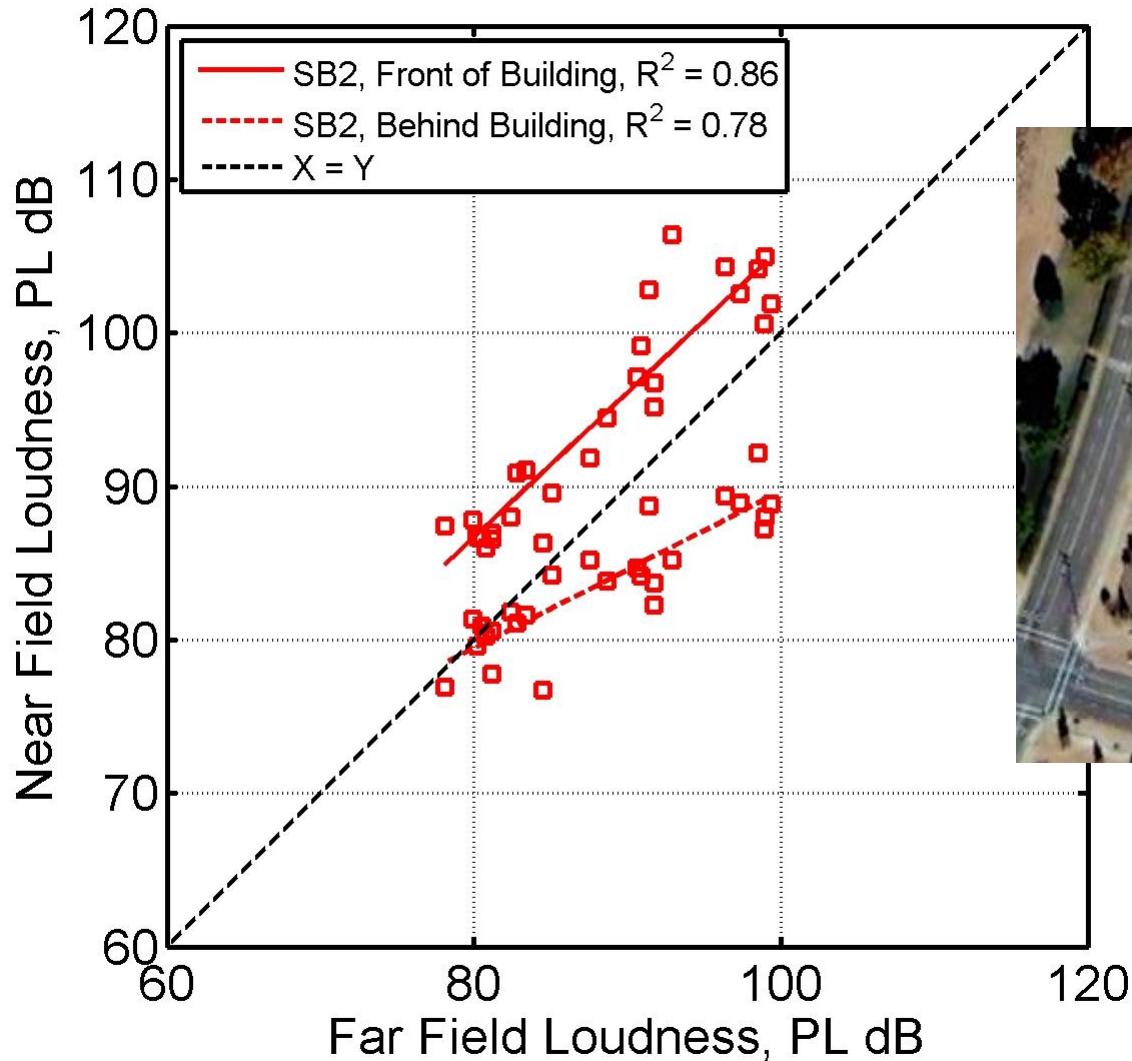


- Outdoor loudness (PL dB) at two far field positions(~400 ft apart)
- Dots represents the observed loudness for one sonic boom
- Spread is a result of atmospheric variability
- Curve fits of observed data behave as expected

Diffraction/Reflection Effects



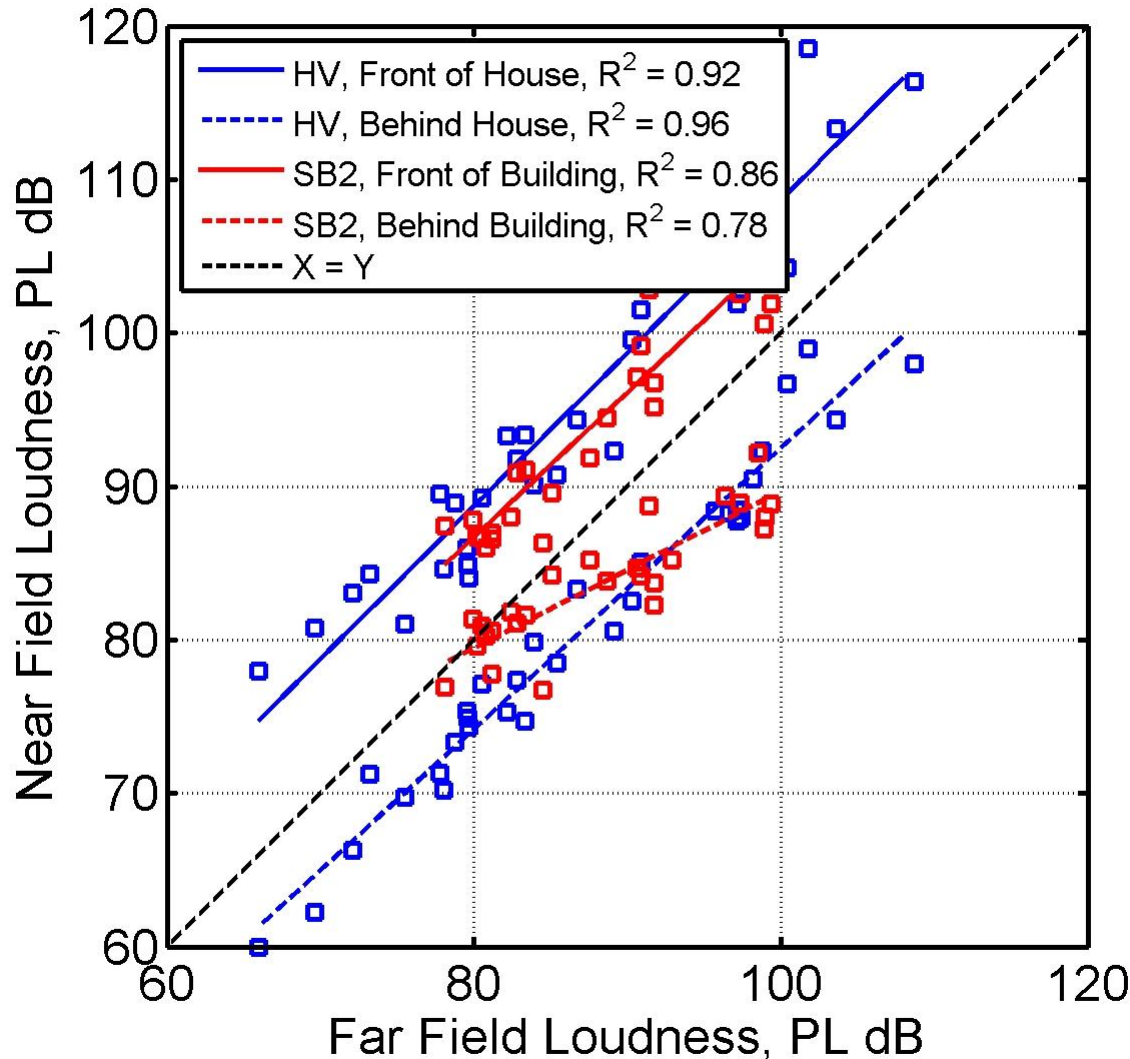
Far Field Mic Loudness



Diffraction/Reflection Effects

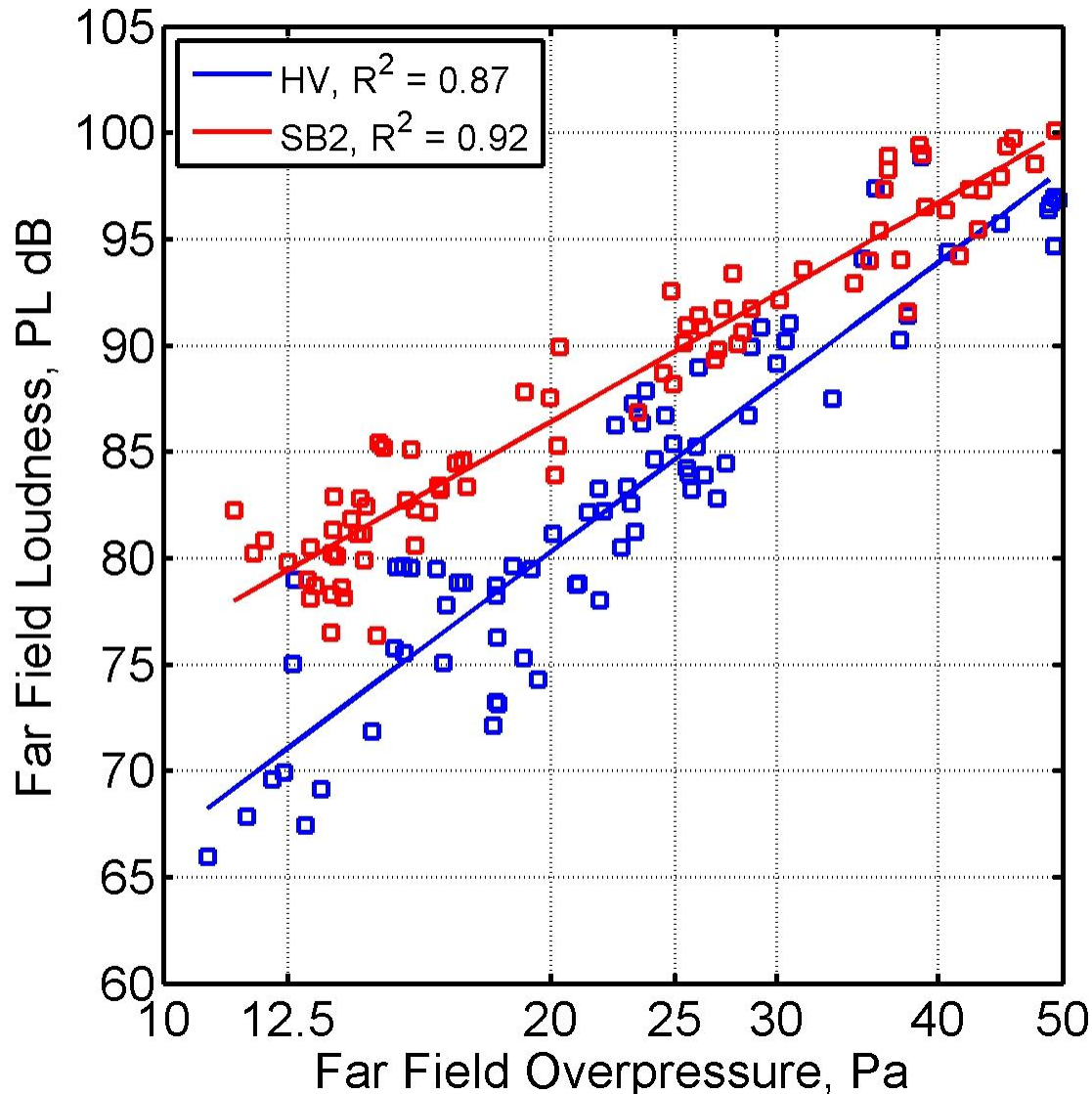


Far Field Mic Loudness



- HouseVIBES and SonicBOBS comparison
- Amplification and attenuation of boom
 - Won't change mean of a particular building or indoor space
 - May increase the variance of the distribution function
- Sang Cho (PSU) will talk about modeling diffraction

Far Field Overpressure vs. PL

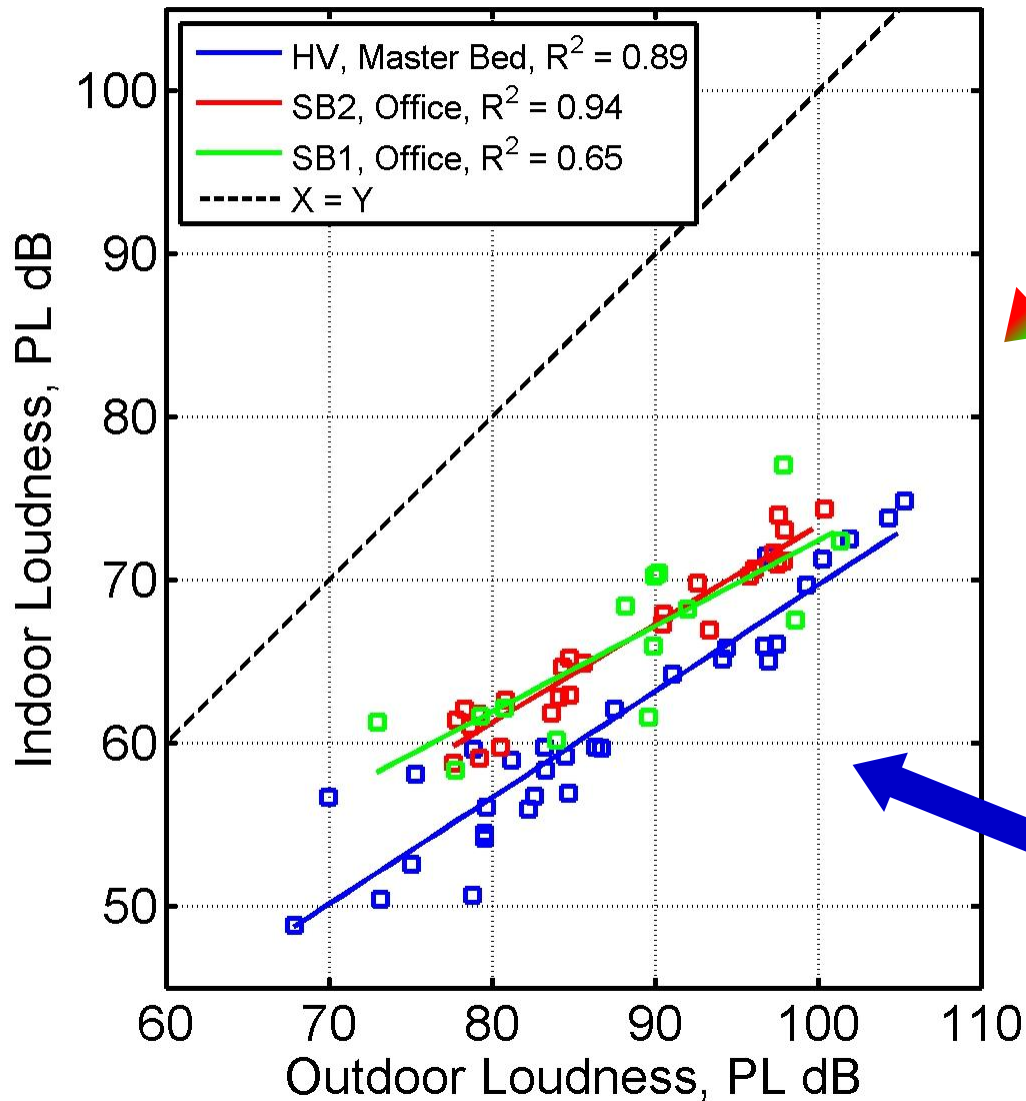


- Humidity was higher during SonicBOBS 2
 - Decreased atmospheric absorption (less attenuation)
 - 12.5 Pa (0.25 psf) booms are about 8 PL louder
- These were low boom dives
- Long propagation distances are involved
 - Especially for the lower amplitude signatures
 - 5 to 15 miles



OBSERVED INDOOR BEHAVIOR

Outdoor Vs. Indoor Loudness



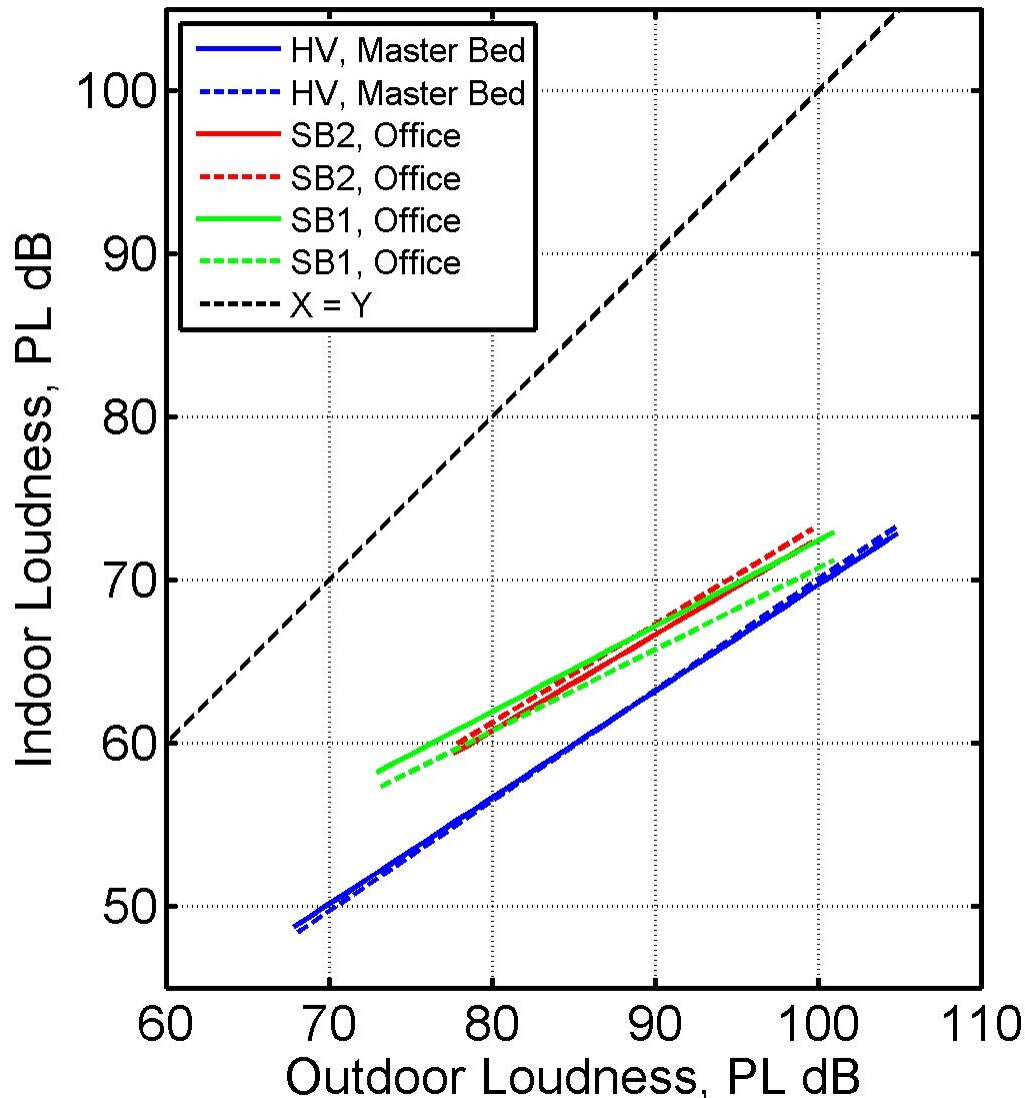
SonicBOBS Office



HouseVIBES Bedroom

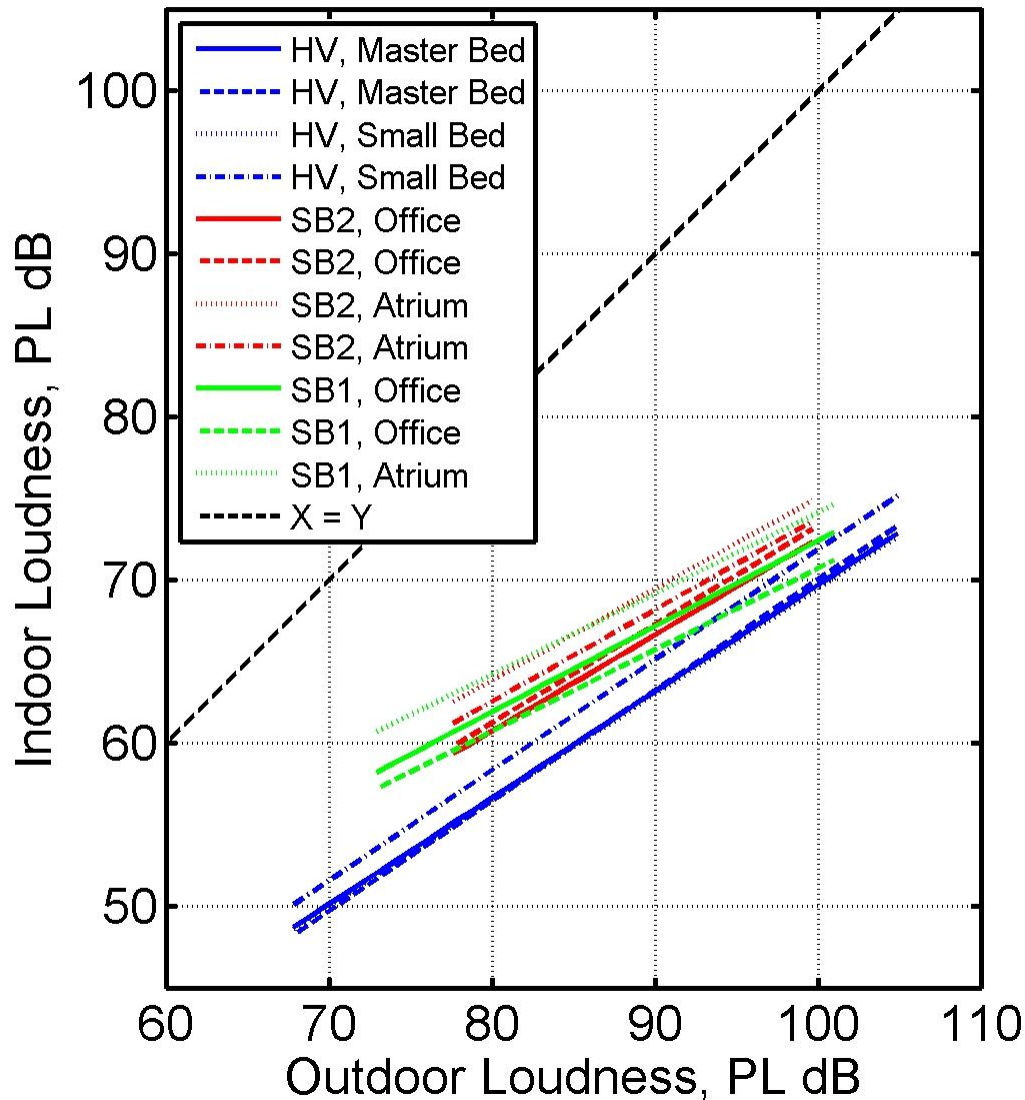


Different Positions in Same Room

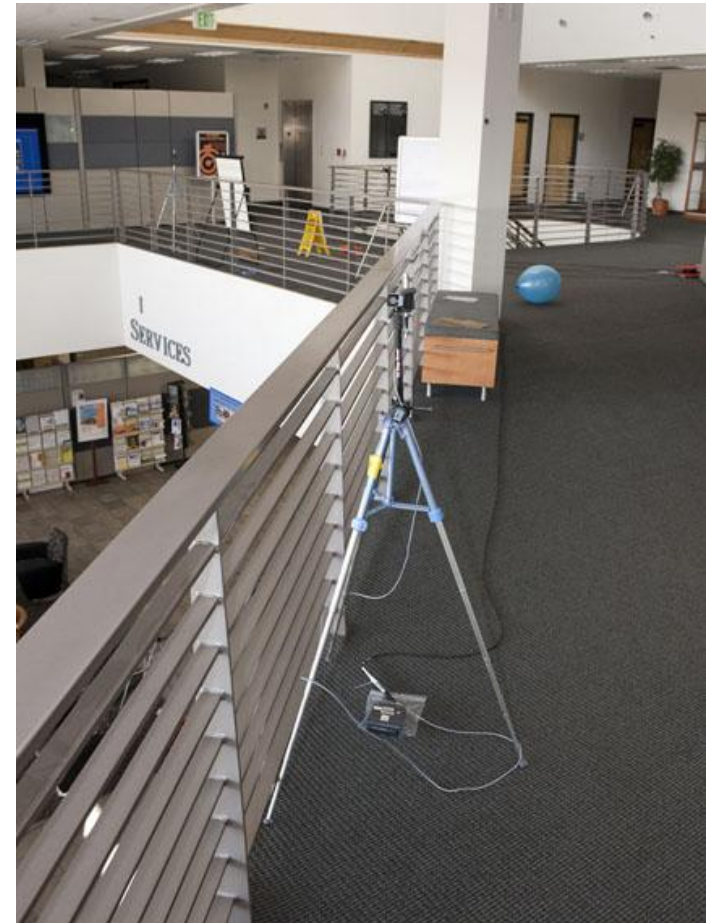


- Rattle was not prominent in these locations
- Position within a particular environment does not matter much
- The large office building and residence are quite similar (offset of about 5 PLdB)
- Sound transmission loss
 - Loudness reduction
 - Attenuation is greater for louder booms

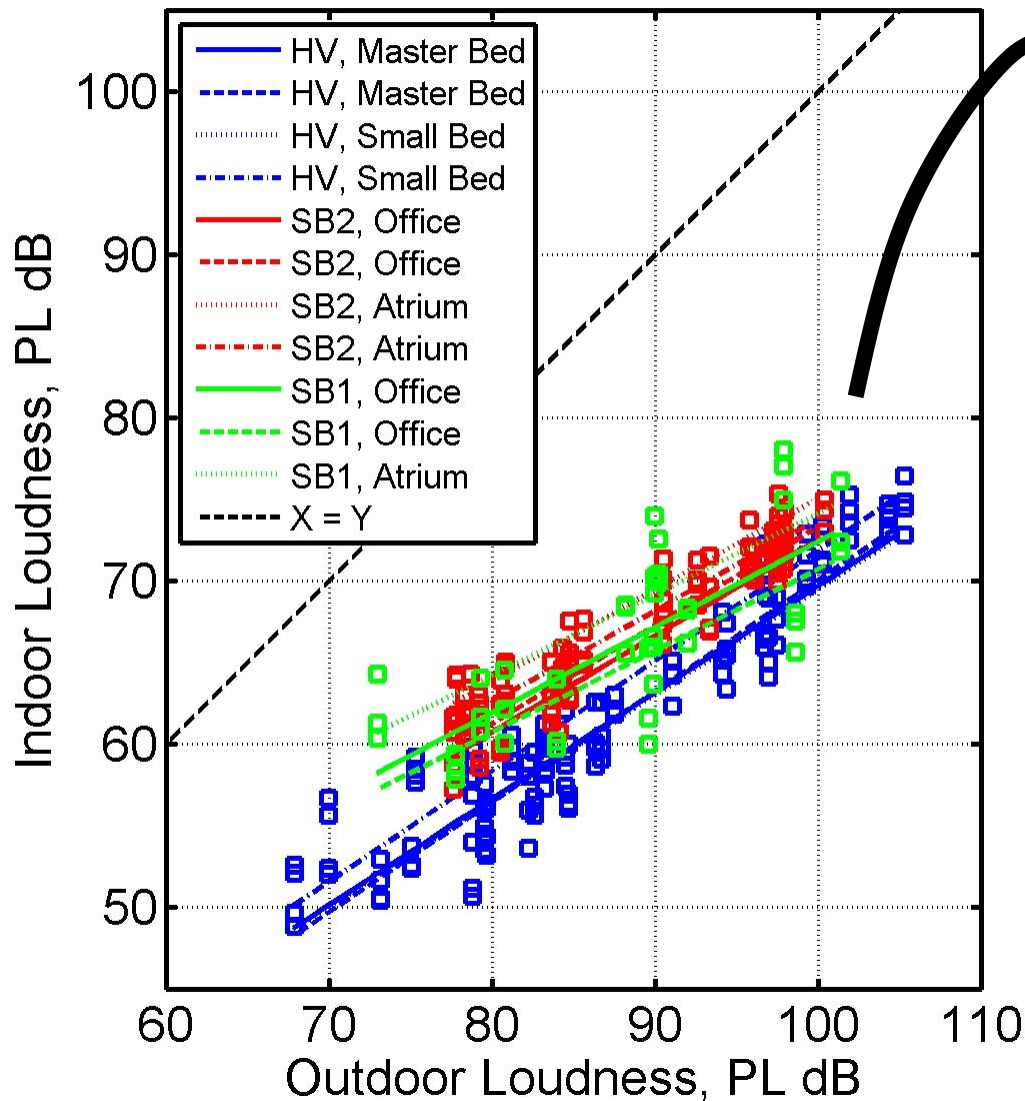
SonicBOBS Atrium + HouseVIBES Bedroom



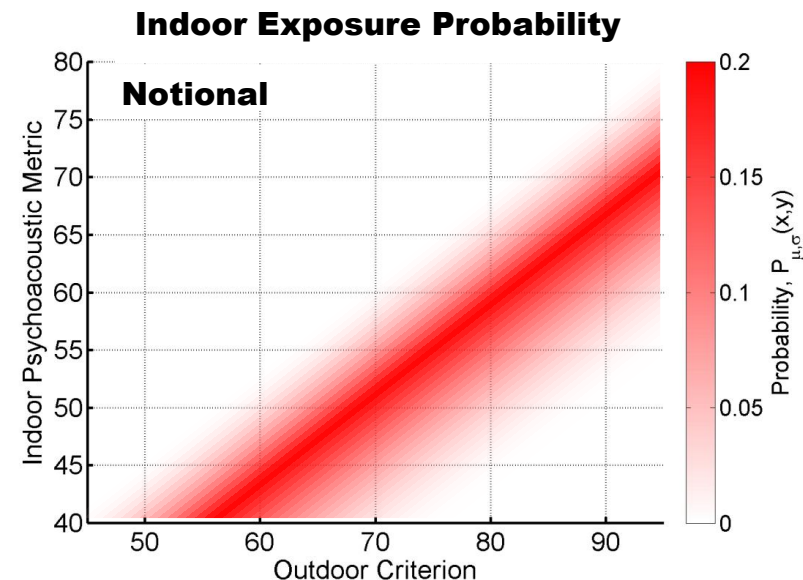
Data from atrium added to plot



Future Research Direction



- Use validated numerical tools to simulate indoor acoustics
- Compute indoor metrics from simulated data
- Estimate probability distribution for a range of “typical” buildings

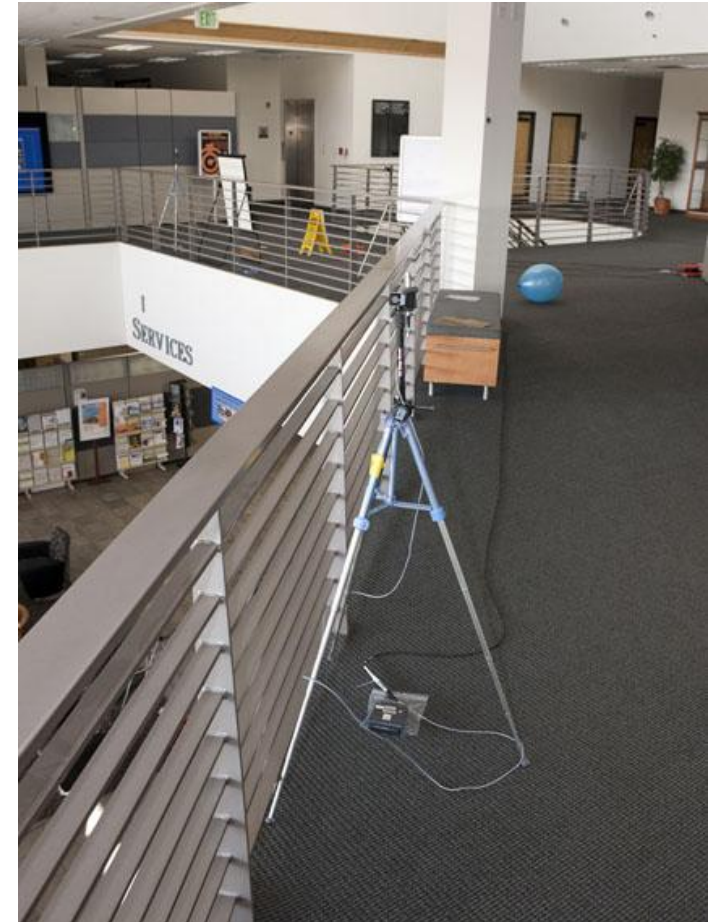
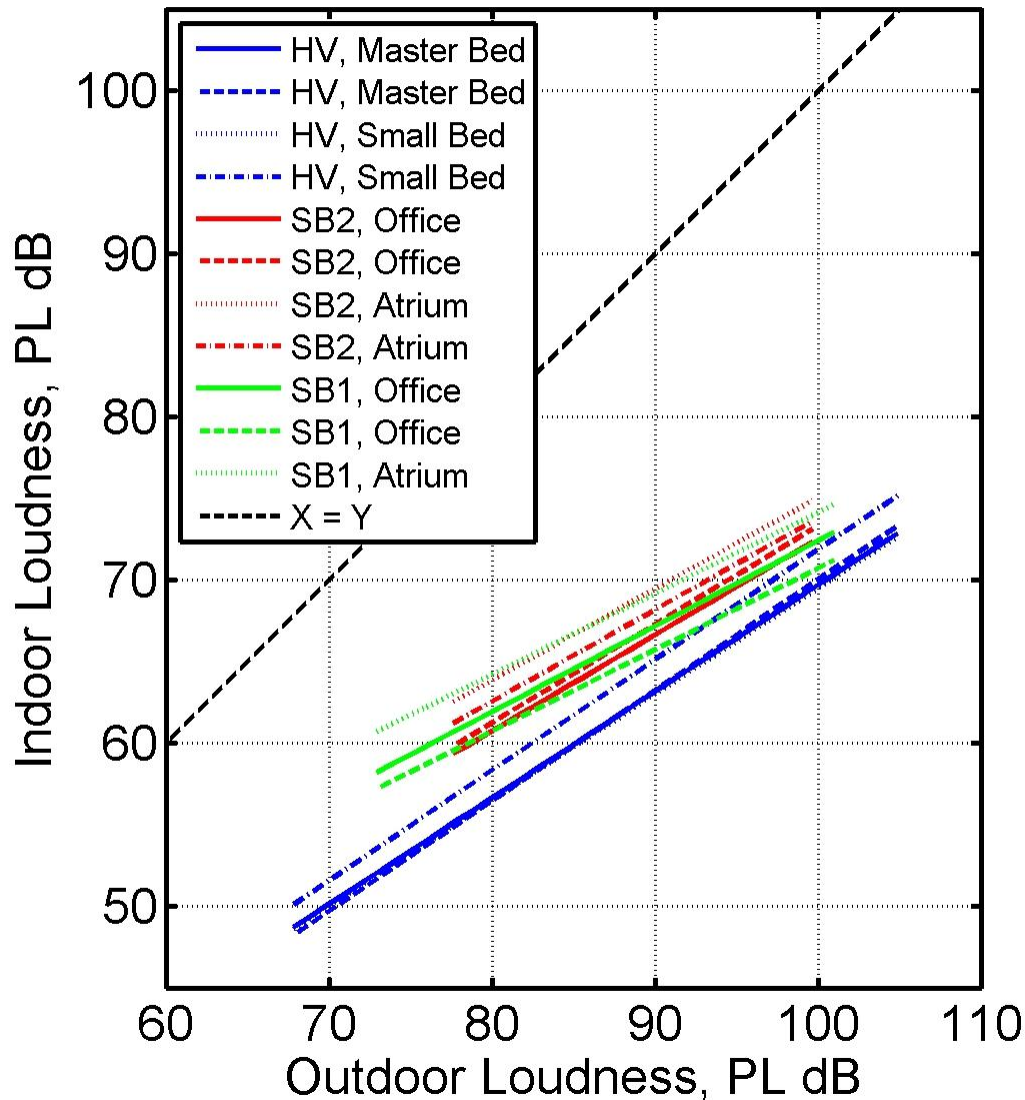


Future Research Direction

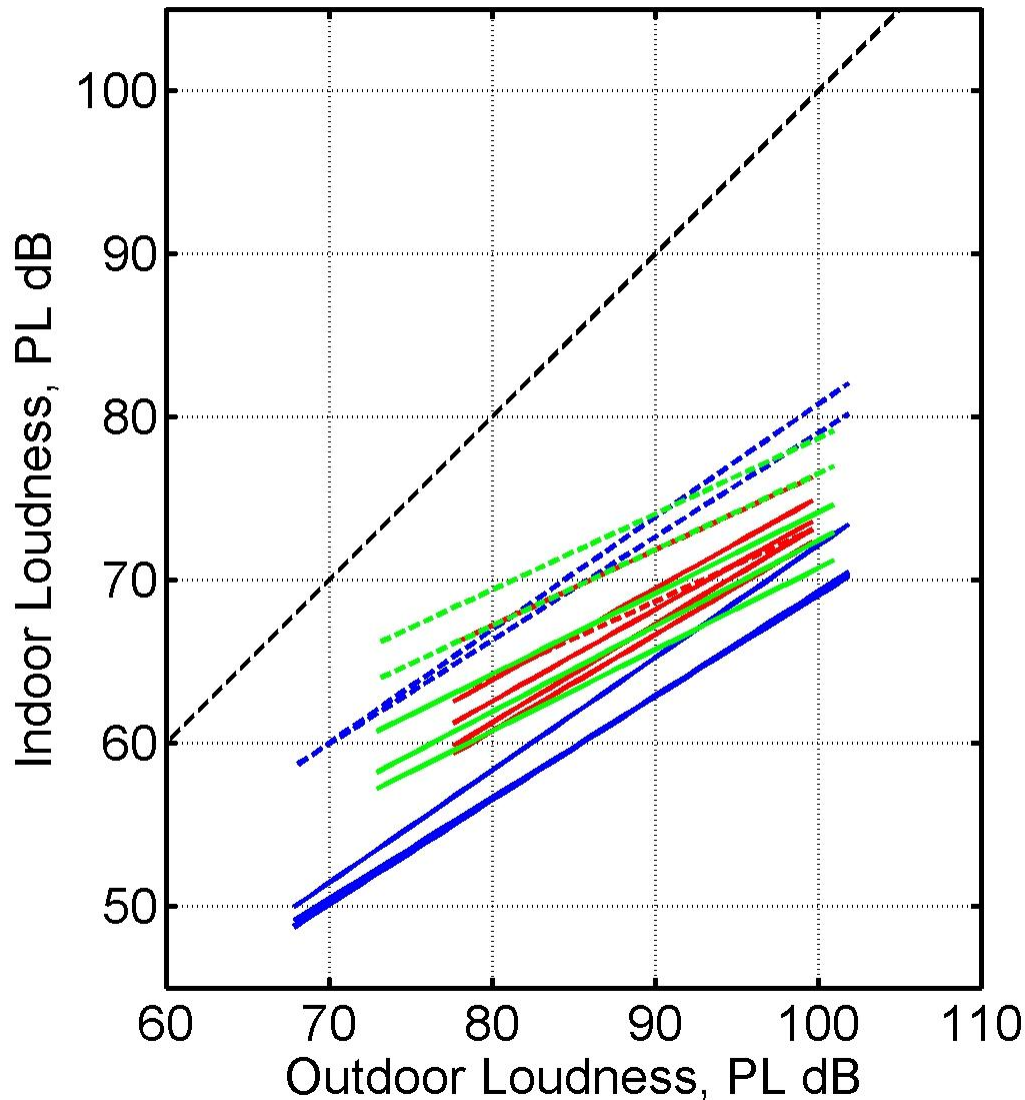


- Tool requirements:
 - Simulate realistic excitation field (PSU)
 - Low frequency transmission and re-radiation (VA Tech, Wyle, PSU)
 - High frequency indoor simulation (VA Tech)
 - Psychoacoustic metric computation
 - Define “typical” structures
 - Building types
 - Construction types
 - Number of people inhabiting these spaces
- Assemble distribution function relating indoor and outdoor criteria
- What about rattle?

Environments Without Significant Rattle



Including Environments With Rattle

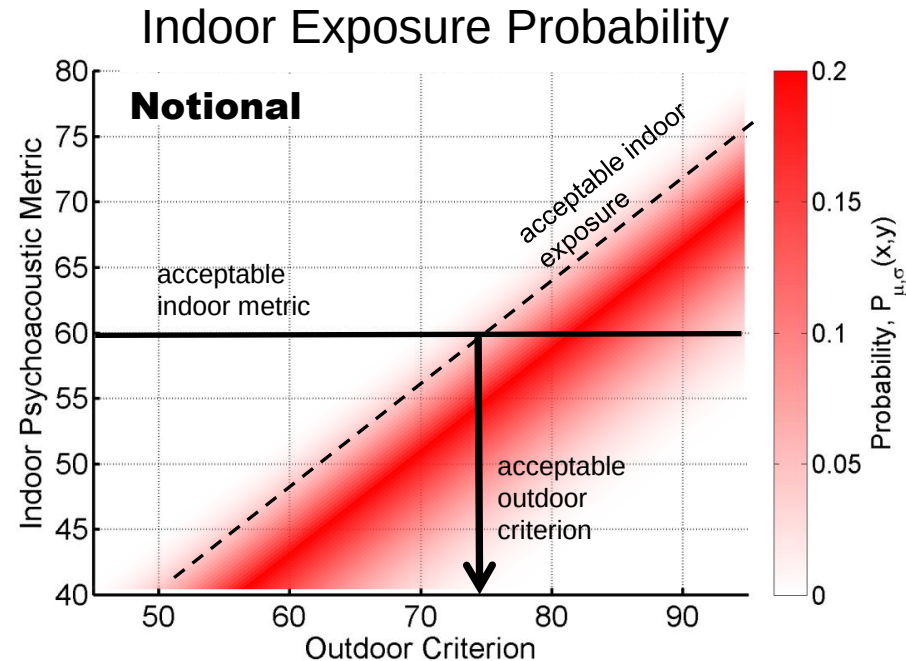


- Areas without prominent rattle (solid lines)
- Areas with prominent rattle (dashed lines)
- **HouseVIBES**
- **SonicBOBS 1**
- **SonicBOBS 2**
- Rattle will increase the variance in the probability density function

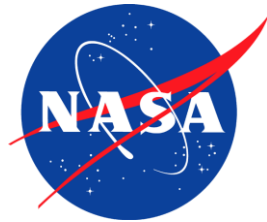
Concluding Remarks



- Comparison of HouseVIBES and SonicBOBS
 - Illustrates behavior of outdoor vs. indoor loudness
 - Demonstrates a path for developing an outdoor criterion from indoor exposure
 - Generate probability distribution from simulated environments
- Tools status
 - Diffraction tool has been developed and validated (PSU)
 - Low frequency transmission tools for small buildings have been developed and validated (VA Tech, Wyle, PSU)
 - Mid to high frequency transmission tool is under development (VA Tech)
- Need time domain methods to include effects of rattle





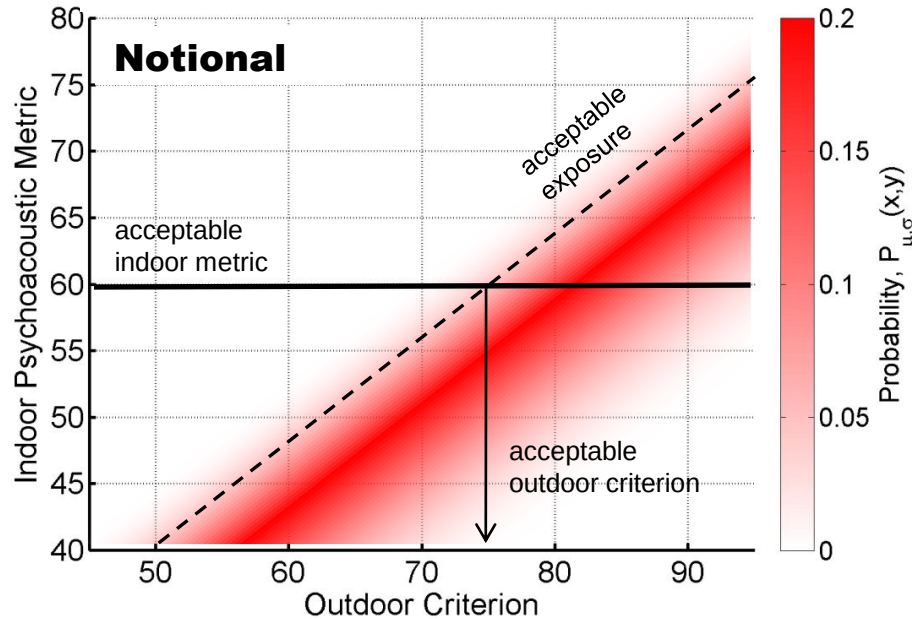




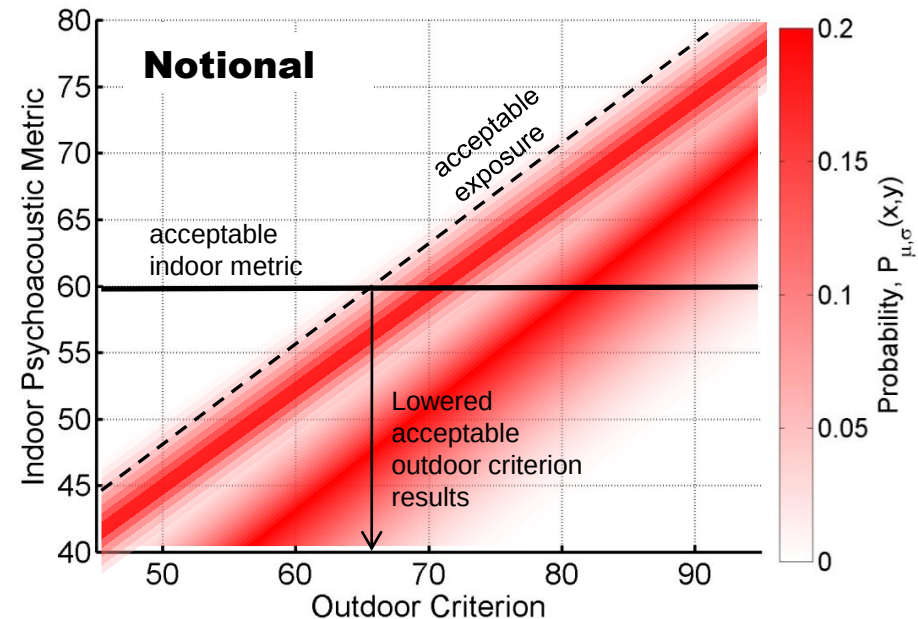
BACKUP SLIDES

Rattle Augmented Environments

Environments Without Rattle



Environments Both With and Without Rattle



Going from indoors to outdoors:

- | | | |
|-------------------|---|--|
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