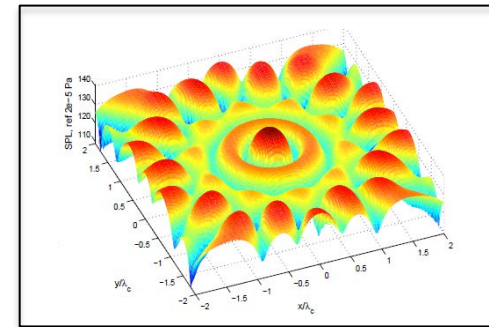
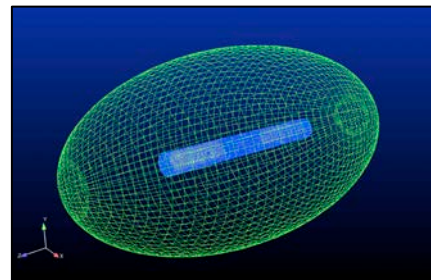
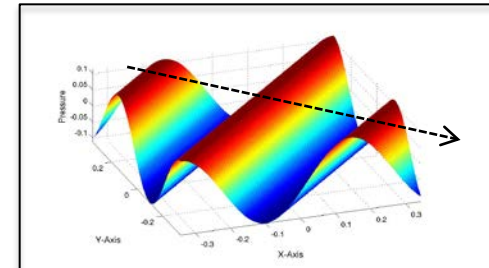


Structural-Acoustic Analysis and Test Design

Greg Tipton
Engineering Sciences Center

*Exceptional service
in the national interest*



Flight environments are driving us to develop new ground-testing and modeling techniques



Captive-carry

Acoustic noise from the engines

Turbulent flow over the weapon surface

Structural vibration at attachments to the plane

Affects how we design our components

Affects how we demonstrate our components are qualified for a particular application

Affects our modeling and testing techniques

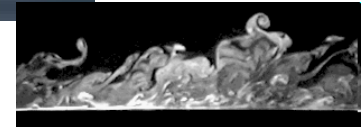
We need to understand the shock and vibration environments for our components within these weapon systems

We have a hard time mimicking these environments in lab tests

These environments are challenging to model



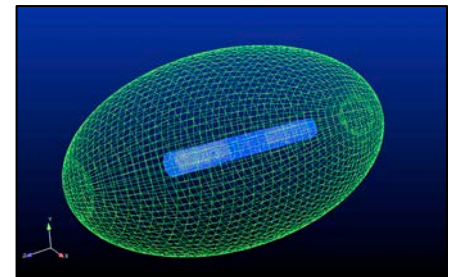
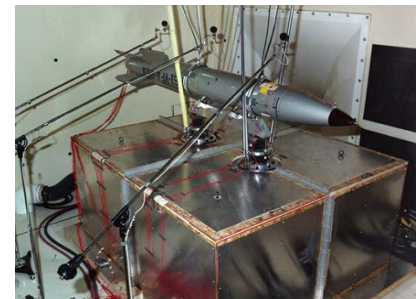
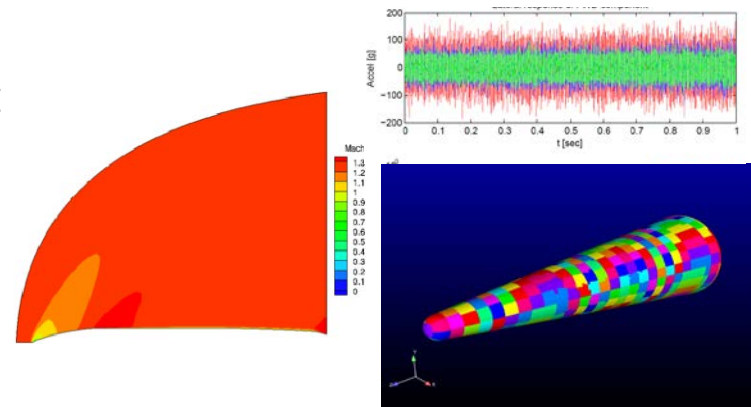
Turbulent flow over the weapon surface



Heating and ablation

Variety of testing and analysis techniques available

- Direct simulation of the actual environment
 - We are working on this for a variety of environments
 - Computationally challenging, coupled simulations
 - Limited validation opportunities
- Vibro-acoustic testing and analysis
 - Gives us a relatively straight forward ground testing technique
 - Model validation, design, and qualification
 - All the physics aren't quite right
 - Can't reach flight levels in all cases
 - But the load path is right (spatially distributed, fluctuating pressure load over the body)
 - Hope is we can extrapolate to flight conditions if needed



We have two acoustic test techniques available to us

Reverberant Acoustic Field Test (Reverb Chamber)



- Testing performed in a reverb chamber
- Idea is to setup a diffuse field throughout the chamber
- Requires you to bring your test object to the chamber

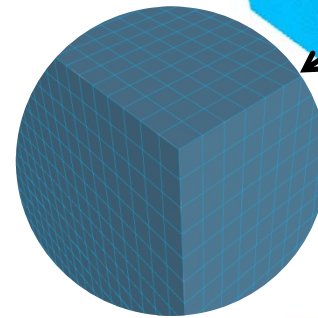
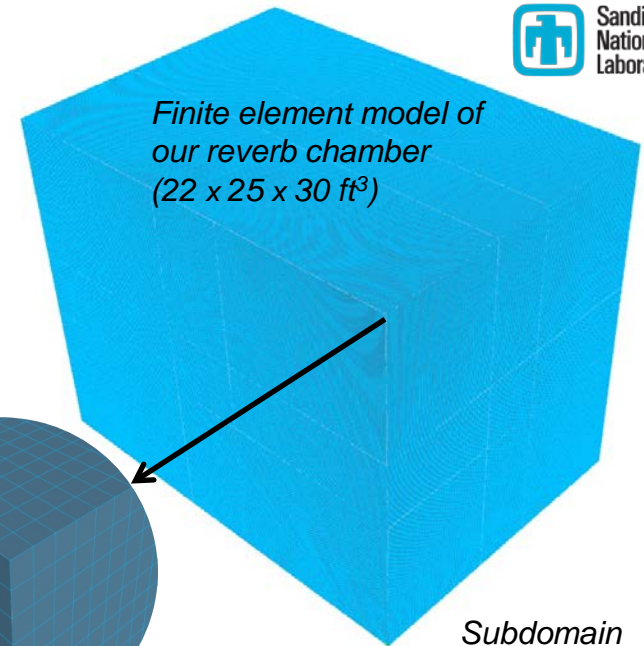
Direct Acoustic Field Test (DFAT)



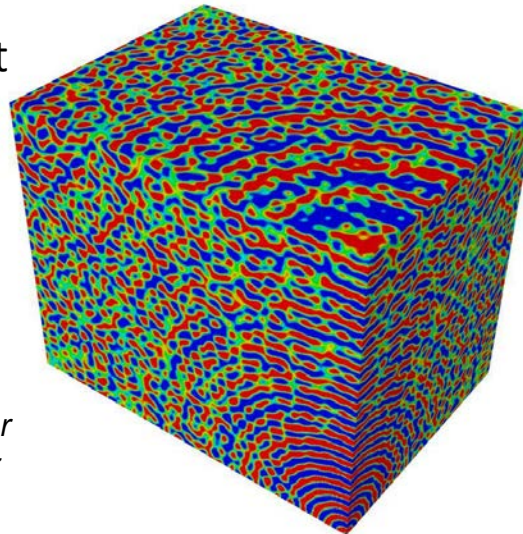
- Testing is performed in a high-bay or open room
- Bring the speakers to the test item
- No walls to provide reflected energy
- Speakers provide direct excitation to the structure
 - Probably not a diffuse field

Our in-house code suite provides coupled structural-acoustic modeling capability (Sierra Mechanics)

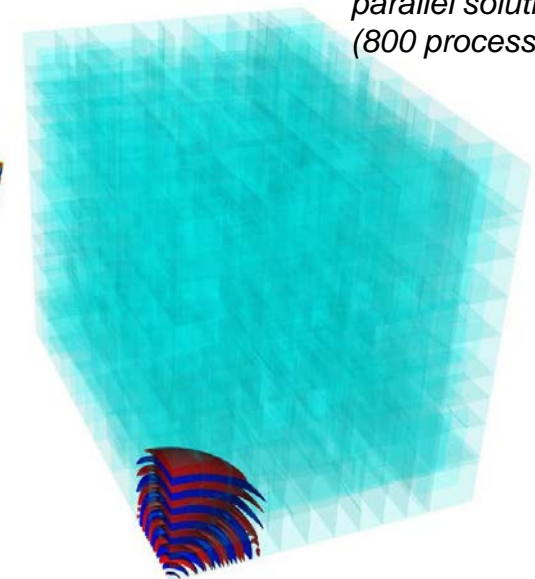
- Eigenvalue problems
- Quadratic eigenvalue problems
 - Coupled structural-acoustics
 - Absorbing boundaries
- Modal based frequency response
 - Real or imaginary valued modes
- Direct frequency response
- Time domain implicit transient



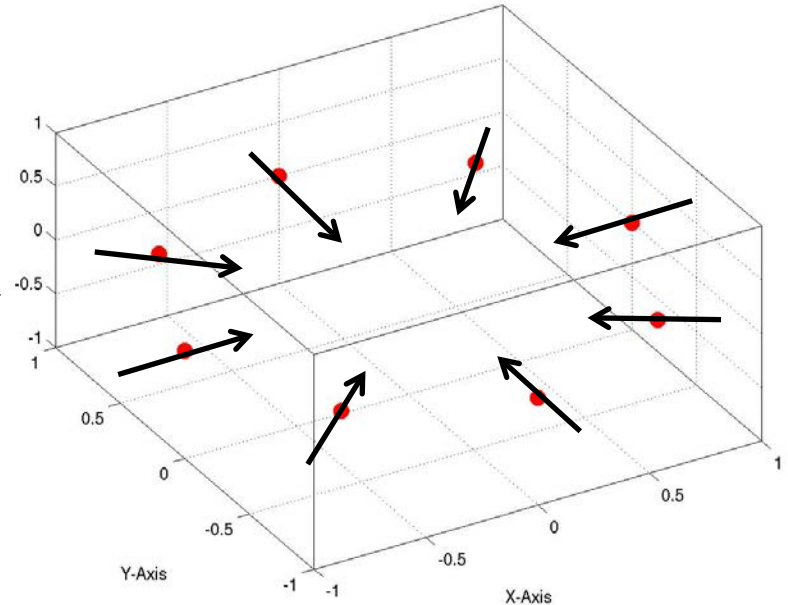
Subdomain decomposition for parallel solution (800 processors)



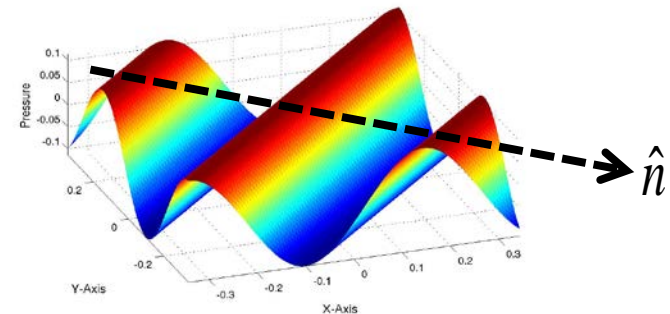
Pressure field in the chamber after 10 ms of excitation with a 1000Hz source in one corner



Recent experiences have shown us the need to fully characterize the acoustic field



- This is more of a concern for direct field testing
- You can get vary different pressure fields depending on how you control the test
- You need to characterize and control the field to understand how you are loading your test article

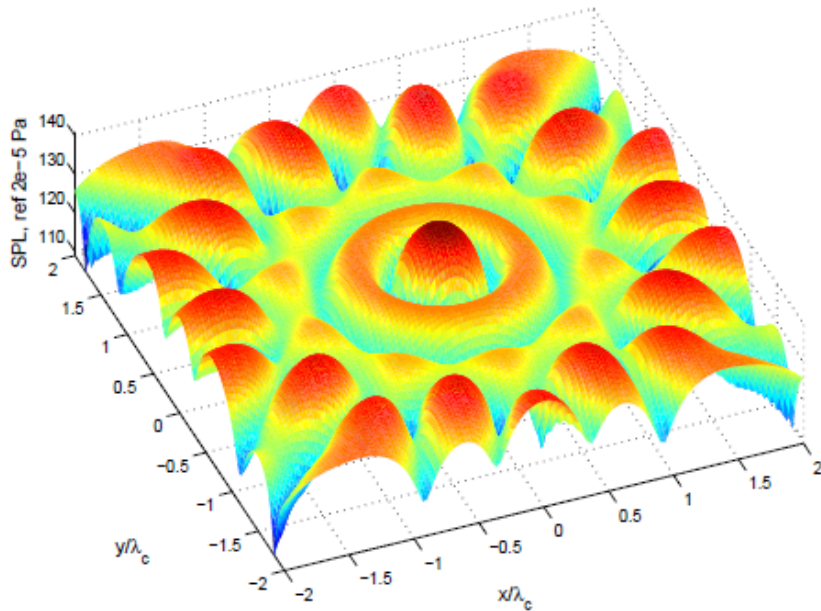


You can get very different fields depending on the phase relationships between the incoming waves

A broadband diffuse field is relatively more isotropic

DFT Sound Pressure Level:

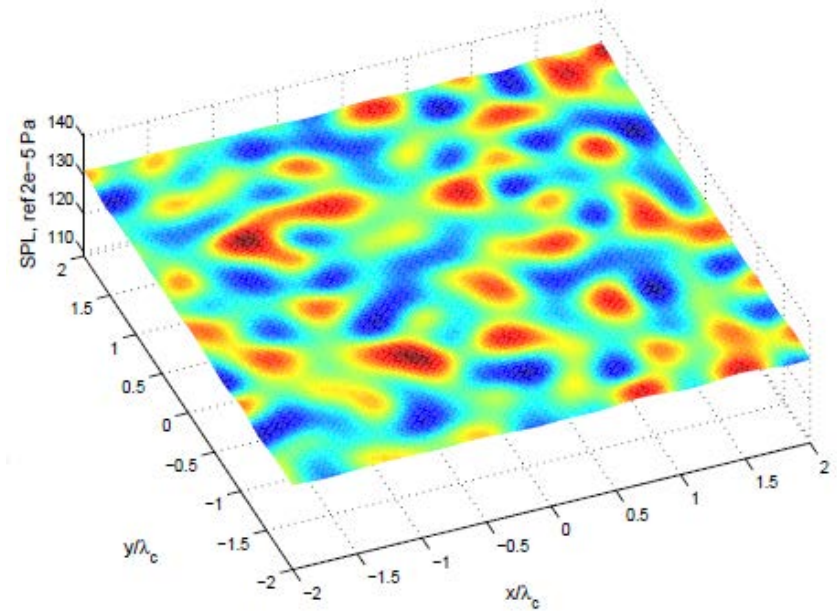
Min=109 dB, Max=141 dB, Mean=131.3 dB, Std. Dev.=4.756 dB
Number of Plane Waves=10, Number of Freqs=250



Spatial
Std. Dev. = 4.75 dB

Diffuse Sound Pressure Level:

Min=130.3 dB, Max=131.7 dB, Mean=131 dB, Std. Dev.=0.265 dB
Number of Plane Waves=10, Number of Freqs=250

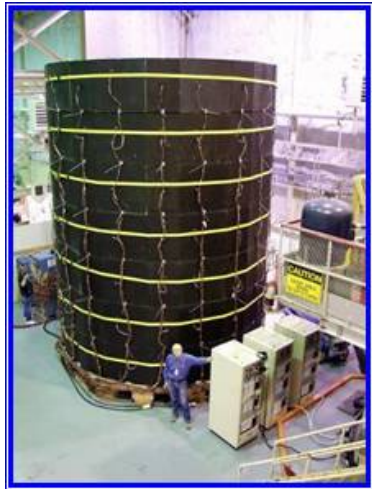


Spatial
Std. Dev. = 0.265 dB

Isophase vs. random phase
among plane waves

We are working on multi-input control techniques to obtain a diffuse field during testing

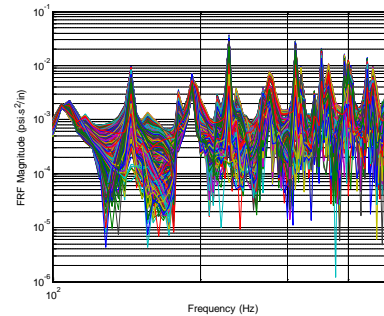
Example of a direct field acoustic test on a reentry system (simulated reentry environment)



DFAT setup

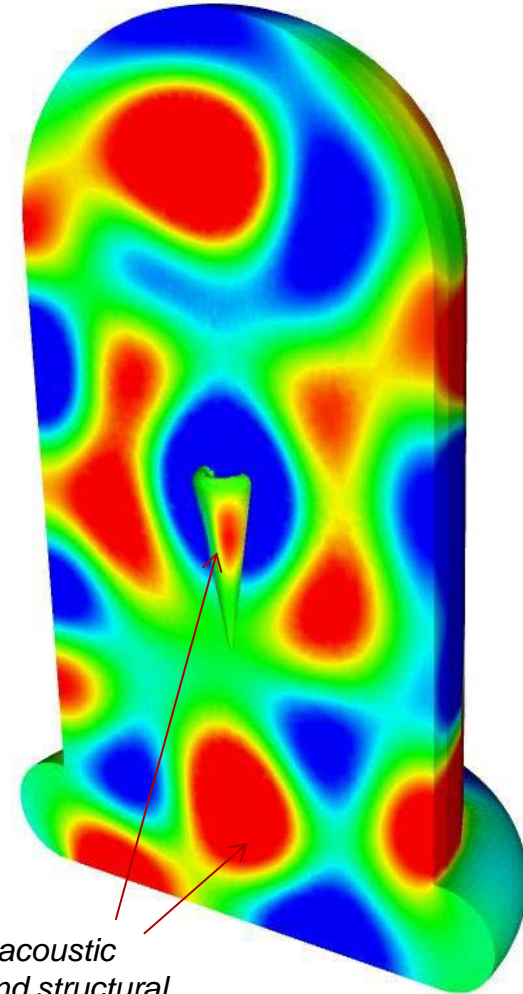


FE model of air in and around speaker stack



Frequency response functions from one set of speakers to the structure surface

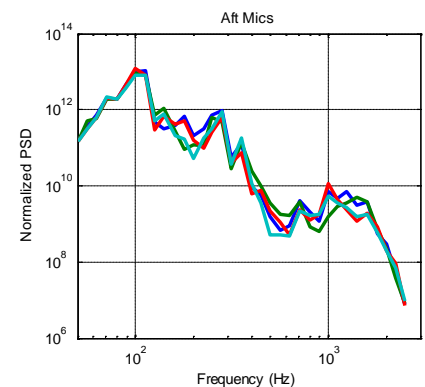
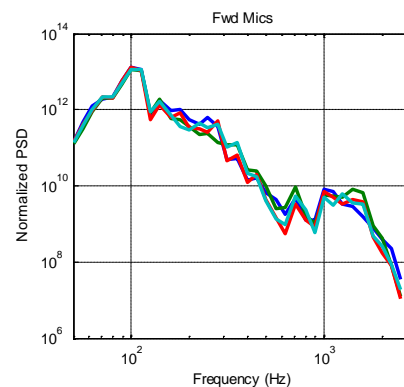
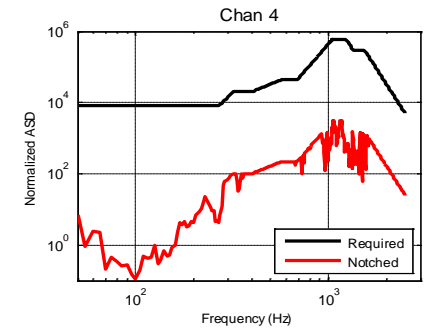
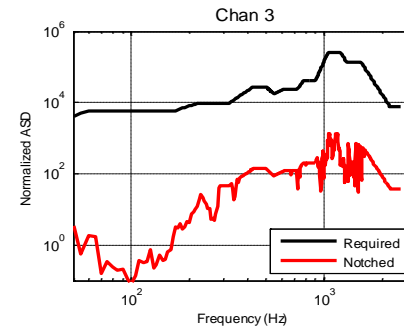
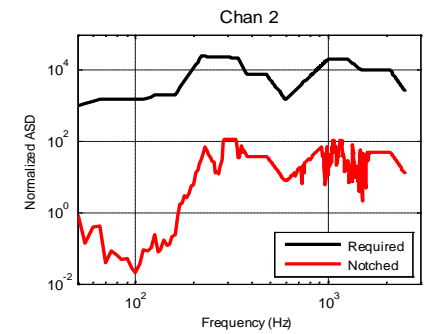
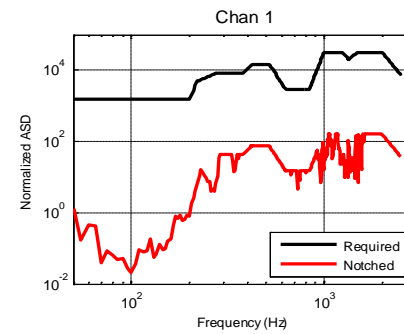
- Created a model of the test setup
 - Understand and characterize the field
 - Design test inputs/control scheme
- Computed transfer functions from the speaker stacks (12 independent inputs) to response points in the structure
- Solved the inverse problem to determine the test inputs to give desired structural responses



Computed acoustic pressure and structural displacement 200 Hz

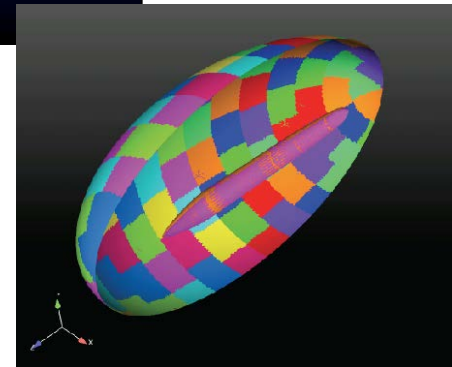
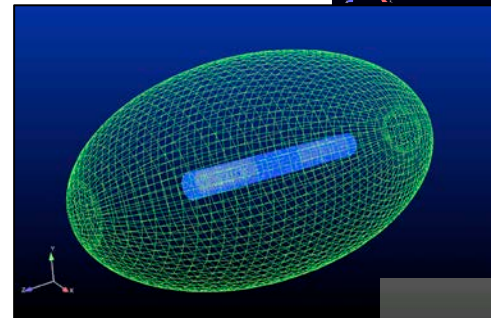
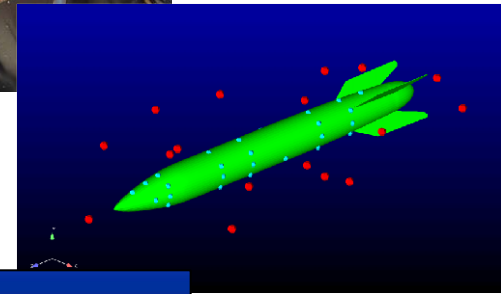
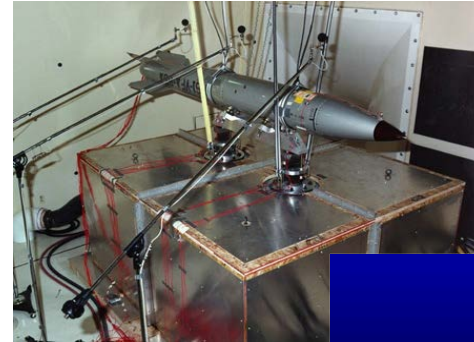
Results from direct field test

- We matched the flight response spectrum but not the levels
 - Inverse problem gave speaker voltage/current not achievable by the system (we expected this going into the test)
 - Spectrum was notched to give the highest-level test achievable
- Randomizing the phase of the 12 independent speaker stacks gave a reasonably diffuse field
 - We wanted some assurance that we were exciting the entire structure the same, everywhere
- Now in the process of comparing model responses to the test responses
- Updated model will allow us to scale up to the flight levels and simulate other environments



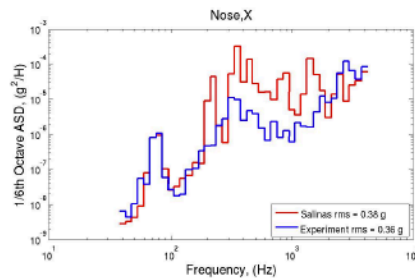
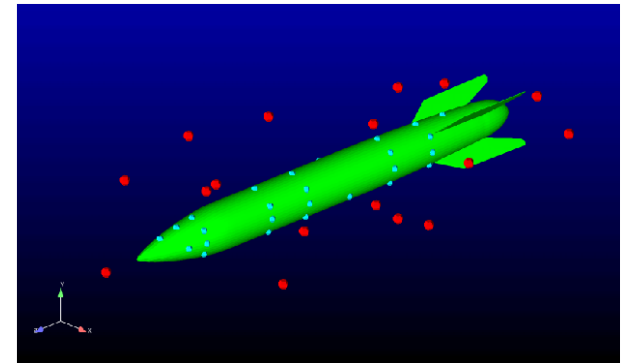
Example reverb chamber test simulating a captive-carry environment

- Acoustic test of the system in a reverb chamber
- Microphones around the system used to control the test and characterize the field
- Unlike the previous example, the entire chamber, including the speakers was not modeled
 - Model consists of a mesh of the structure surrounded by an ellipsoid of air
- Makes modeling the input harder
 - Assume we achieved a diffuse field
 - Drive patches around the ellipse with input that replicates the field
 - Like the previous example, an inverse problem was used to derive patch inputs

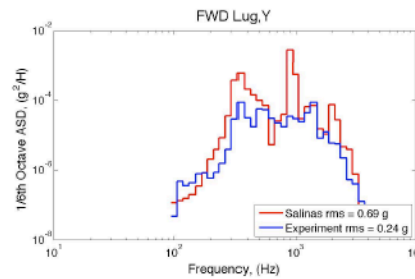


Reverb Chamber Example

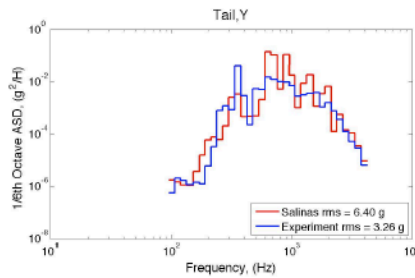
- 8 surrounding control microphones in the test (17 total microphone measurements)
- The derived model input provides an acoustic field that matches the test data fairly well
 - Tapers off at higher-frequencies due we think to nonlinear effects
- Acceleration predictions on the structure are also reasonable for a first model-test comparison



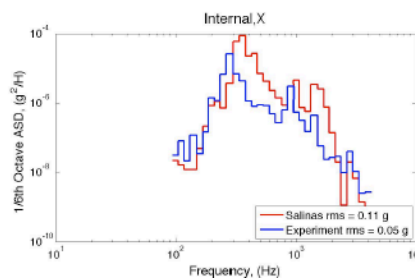
(a) Nose of Store



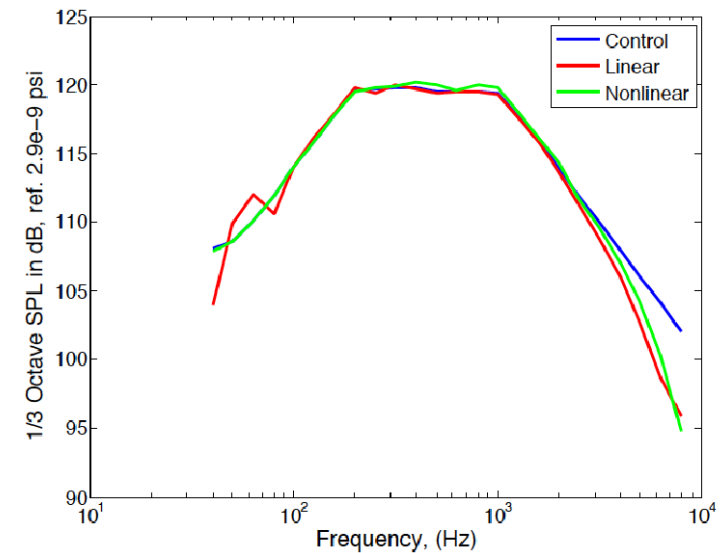
(b) Near Center of Store



(c) Tail of Store



(d) Internal Component



Next Steps and Conclusions

- Structural-acoustic modeling and testing provides us with a way to access the performance of our designs to flight environments
- We are using structural-acoustic models to design and characterize tests
- We are using the test data to update the models
- We are then using the models to predict responses at locations we can't instrument in tests and/or to environments we can't test
- We will continue to refine our techniques in the coming years