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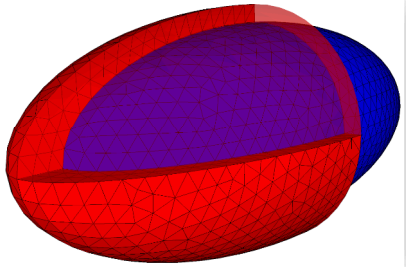

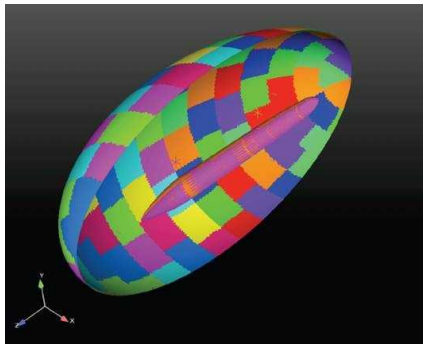
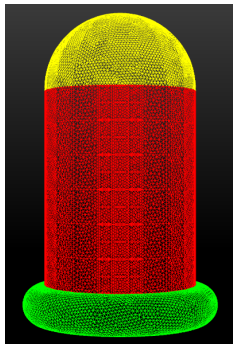
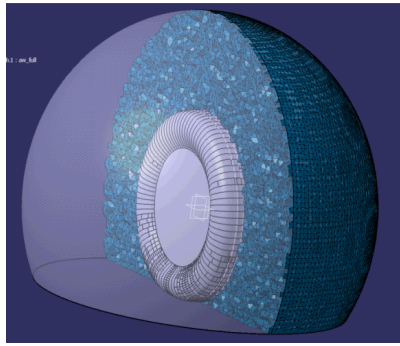

11/19/2013

Structural Acoustic Modeling Capabilities in Sierra-SD

Sierra-SD Team

U.S. DEPARTMENT OF ENERGY | NNSA

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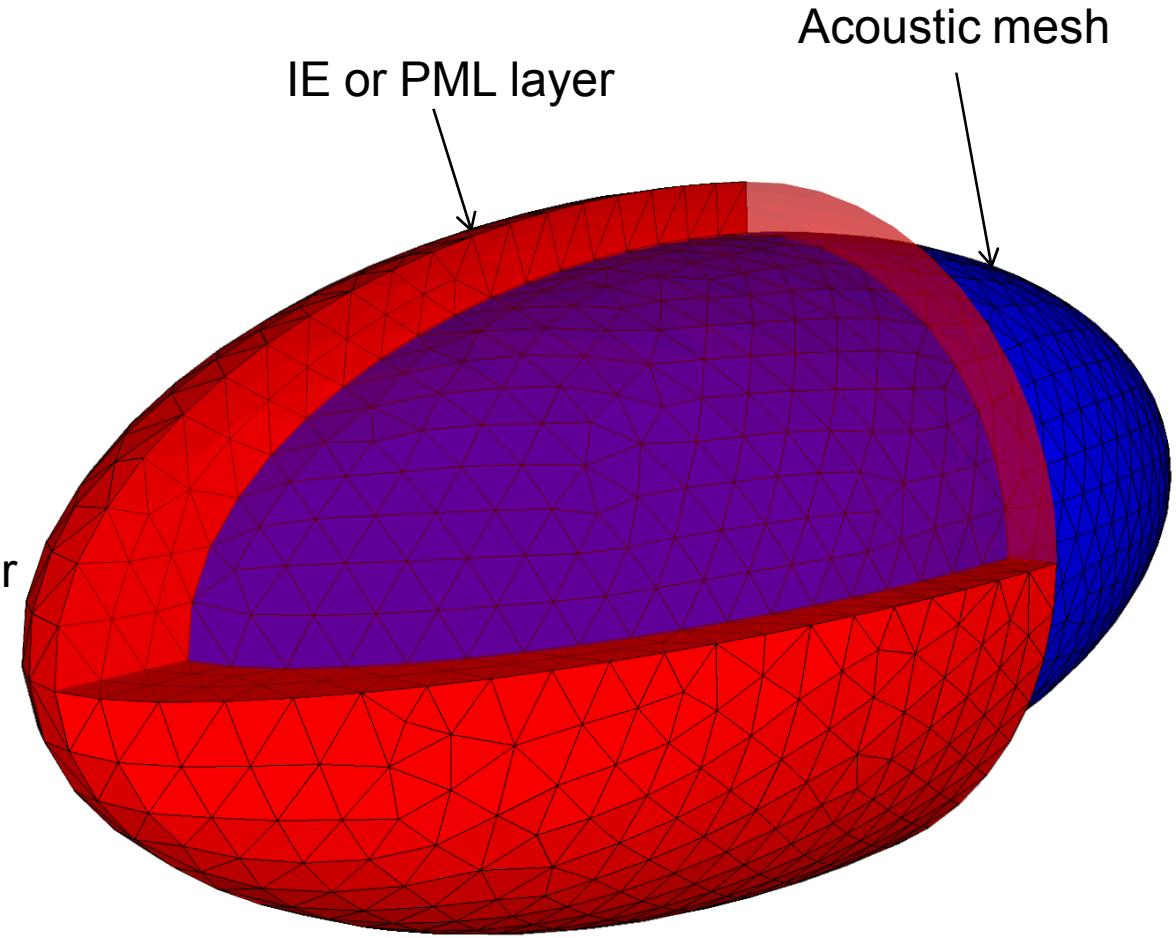
Overview of Sierra-SD Structural Acoustic Capabilities

- Hex, wedge, tet acoustic elements
- Acoustic coupling with both 3D and shell (2D) structural elements
- Linear and nonlinear acoustics
- Allows for mismatched acoustic/solid meshes
  - Mortar or multi-point constraints (MPC)'s
- Infinite elements and Perfectly Matched Layers (PML)
- Scattering (split-field) and direct (unsplit) formulations
  - Various UNDEX loadings: plane/spherical step waves, spherically spreading source, Hick's bubble
- Solution procedures:
  - Frequency response (frequency-domain)
  - Transient (time-domain)
  - Eigenvalue (modal) analysis
    - Linear and quadratic (complex modes)

Exterior Boundary Conditions

Infinite Elements (IE) and Perfectly Matched Layers (PML) for exterior problems

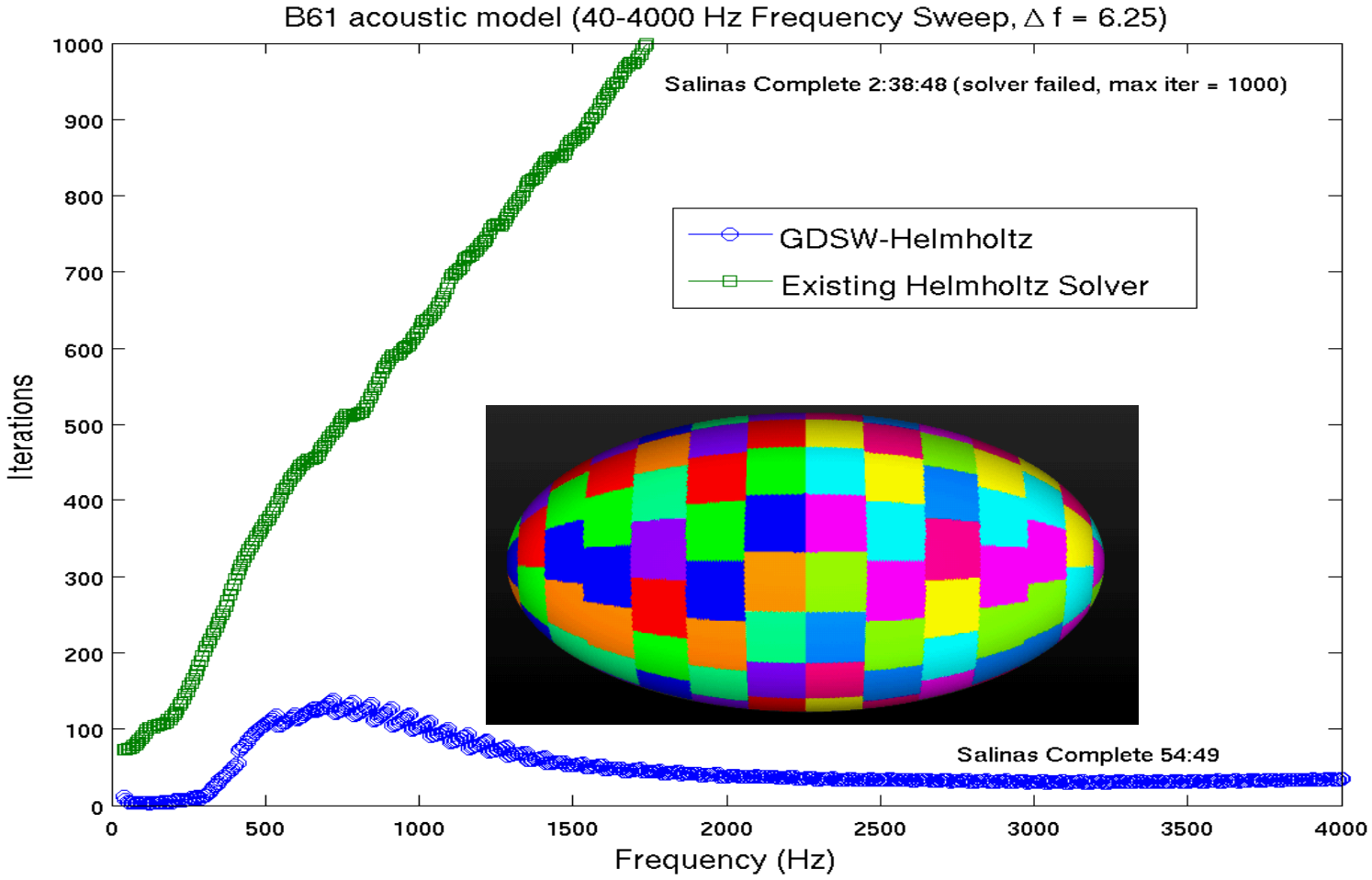
- PML and IE elements extruded automatically in Sierra-SD from surface normal on ellipsoidal acoustic mesh
  - User only needs to specify the exterior acoustic surface
- User-specified damping functions for PML and order for IE
- IE available for both time and frequency domain analysis
- PML only available for frequency domain



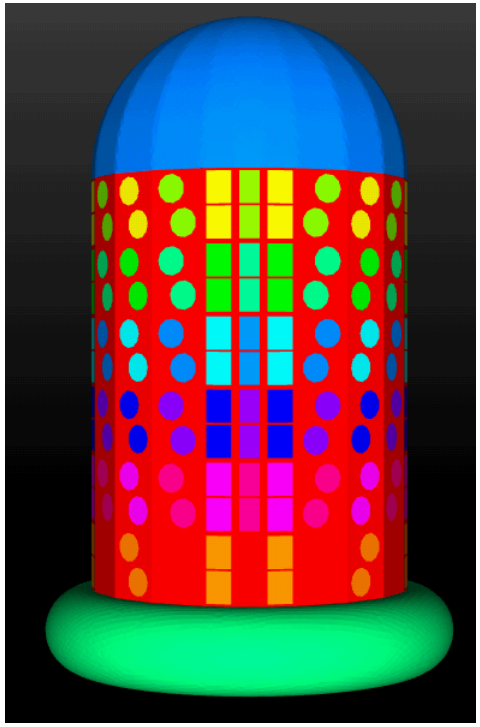
Helmholtz Solver Development

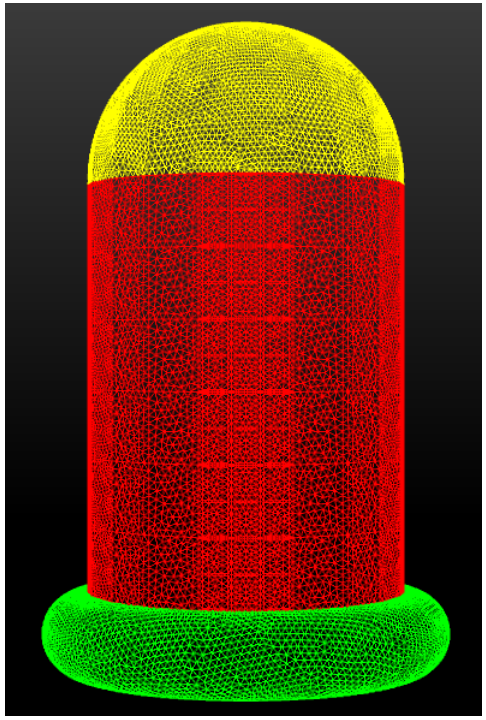
- Background:
  - In final year of research project begun in FY12
  - New solver in code base and tested nightly (beta release)
  - Additional development and testing ongoing
- Some Details:
  - Frequency domain analysis:
    - acoustic and coupled structural-acoustic problems
    - models with wide variety of element types
    - models with large numbers of constraint equations
  - Initial Applications:
    - acoustic inverse problems (source identification)
    - direct field acoustic test analysis for structural-acoustic model

Helmholtz Solver Development



Helmholtz Solver Development





- New solver in development applied to smaller DFAT structural-acoustics model
- This model representative of anticipated complexities (multiple element types, side sets, constraint equations, …)
- Parallel research effort (CSAR)
- Can already solve problems we could not before, e.g. models with infinite elements, but work ongoing (performance, reliability, alternative preconditioners, …)

1. Solved problem existing solver could not
2. Ongoing numerical studies invaluable to parallel research efforts

Inverse Problems in Sierra-SD - Motivation

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- Characterizing energy sources from experimental measurements is a common need in structural acoustics
- Determining unknown material properties from measurements is a common need in model calibration
- For applications that involve complex geometries and/or sources, finite element modeling is needed for an accurate solution of the forward problem.
- Goal: leverage existing massively parallel finite element technology developed for forward problems to solve the inverse problem.

Source Inversion Methodology in Sierra-SD

- PDE-constrained optimization approach
  - Offers flexibility and extensibility
  - Applicable to time-domain, frequency-domain, and nonlinear problems.
  - Applicable to large numbers of design variables.
- Massively parallel finite element code Sierra-SD is used for solving the forward and adjoint problems.
- Optimization code ROL/PEOpt is used for solving the optimization problem.

Examples of Structural Acoustics in Sierra-SD

- Acoustic source inversion
- Navy-Enhanced Sierra Mechanics (NESM)
- Tire noise and vibration modeling

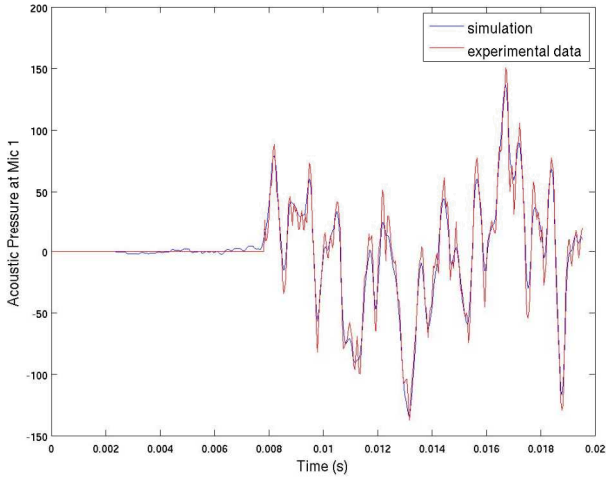
Structural Acoustics in Sierra-SD

Acoustic source inversion

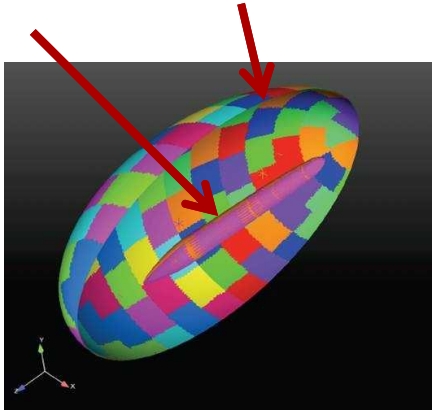
Goal:

Solve inverse problem to obtain acoustic patch inputs that produce the given microphone measurements. 2 approaches:

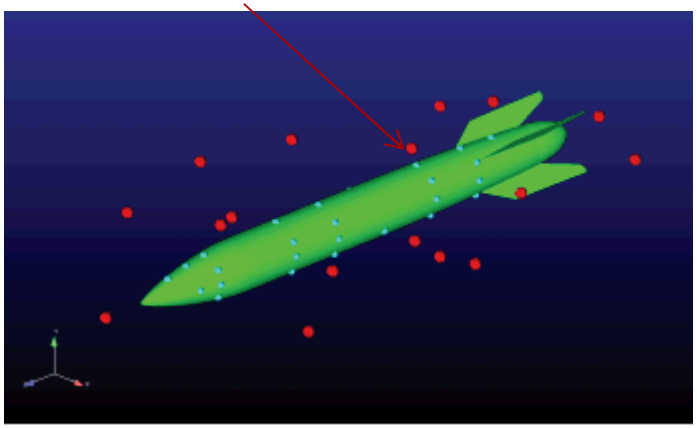
1. Frequency domain
   - broadband frequency sweep
2. Time domain
   - implicit time integration



Surface patches for sources



Microphone locations

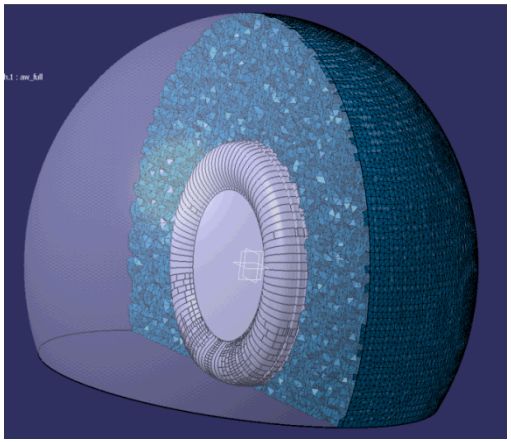


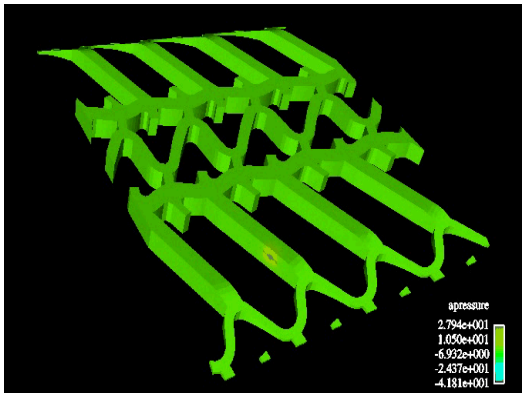
Structural Acoustics in Sierra-SD

Tire Noise Modeling with Sierra Mechanics

Large-scale computational approach for tire noise modeling

- Infinite elements
- Exterior meshing around tire surface
- Far-field acoustic calculations





Navy Enhanced Sierra Mechanics (NESM)

- NESM Capability for transient acoustic loading
  - Acoustic approximation of UNDEX loading
  - Scattering (split-field) formulation to allow for easy specification of sources
  - Various sources: plane/spherical step wave, spherically spreading source, Hicks Bubble.
  - Ellipsoidal infinite elements for far-field boundary condition
    - Allows large aspect ratio ellipsoids for slender structures

CVN-78 is the new Gerald R. Ford class of carriers being launched starting in 2015