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Inverse Problems for NW applications in a Massively Parallel Finite Element Framework

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OBJECTIVE: Develop robust and parallelized optimization tools for NNSA's NW applications through leading-edge research in optimization.

INVERSE PROBLEM FORMULATION:

$$\underset{a}{\text{minimize}} \quad \mathcal{J}(a)$$
$$\text{s.t.} \quad c(u,p,a) = 0 \quad \text{in} \quad \Omega$$

where,

- $\mathcal{J}(a)$: Function that measures misfit between computational and experimental data
- $c(u,p,a)$: Structural-acoustics computational model
- u : Structural displacement field
- p : Acoustic pressure field
- a : Acoustic acceleration inputs
- Ω : Computational domain of interest

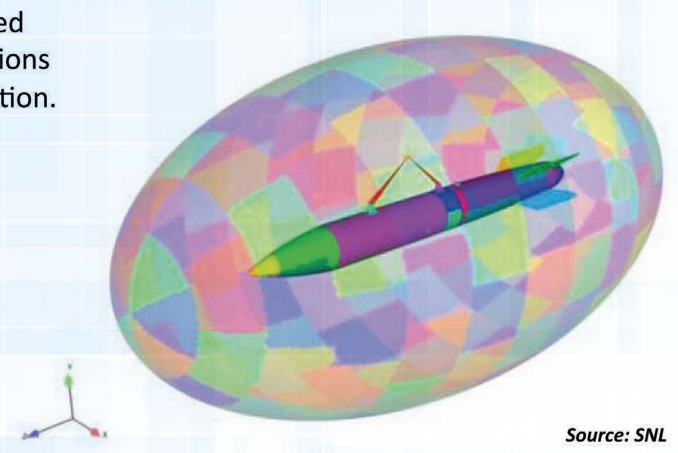


Figure 1. Acoustic mesh and structural representation of the B61.

MAIN CHALLENGES:

1. Large-scale coupled physics modeling
2. Several unknown parameters
3. Limited experimental measurements
4. Derivation of complex analytical equations

Table 1. Error between computational and experimental acoustic pressures.

Microphone	Percentage Error
1	2.23
2	6.58
3	4.43
4	2.19
5	1.77
6	5.98
7	2.18
8	4.42
9	2.24
10	2.97
11	4.23
12	6.74
13	2.32
14	5.90
15	4.41
16	2.88
17	3.76

RESULTS: Figures 5, 6 and 7 show a close match between the computational and experimental acoustic pressures at one of the control points.

The objective function for this problem was defined as

$$J(a) = \frac{1}{2\left(\sum_{i=1}^{N}|p_i^m|^2\right)^{1/2}}\sum_{i=1}^{N}(p_i^c - p_i^m)^2$$

This error was reduced to approximately 3.8 %.

ENHANCEMENTS: We can further reduce the percentage errors shown in **Table 1** by including :

1. Analytical second-order information
2. Regularization methods

These two enhancements will minimize computational time and enable the optimization tool to solve the problem with improved accuracy.

Computational Model

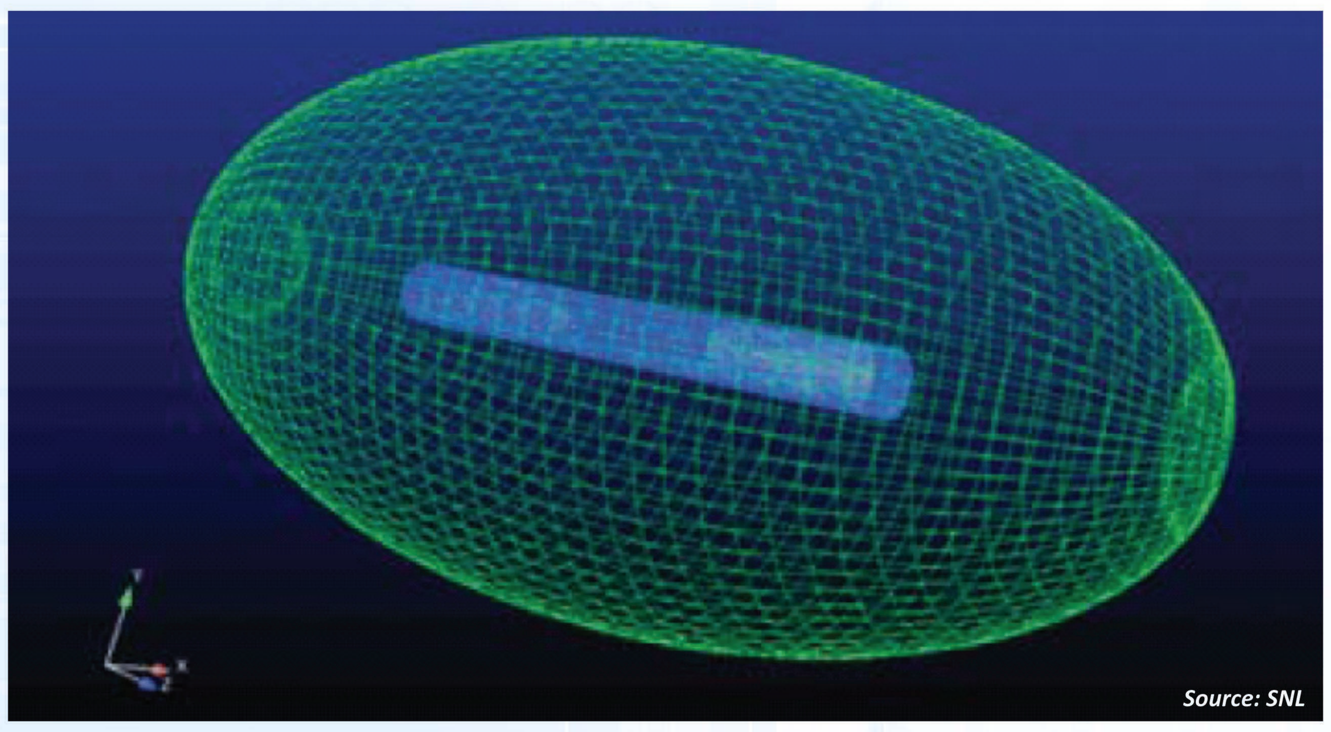


Figure 2. Structural model surrounded by a infinite element acoustic mesh.

PROBLEM DESCRIPTION: The problem consists of an ellipsoidal-shaped domain, with an outer surface that is divided into 174 patches. Acoustic acceleration inputs were calibrated at each of these patches using the inverse structural-acoustics tools in SIERRA/SD. Each of these solutions took about a half hour on 128 cores on Glory.

Control Points Location

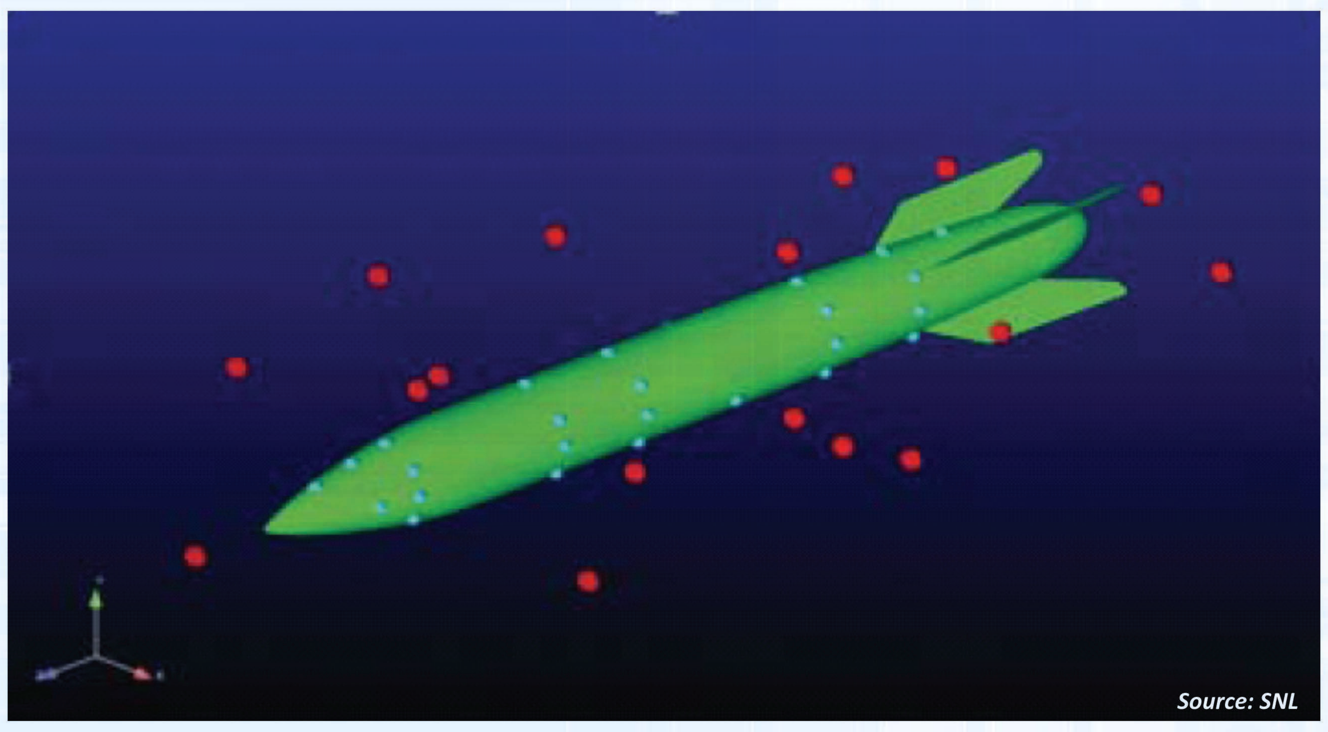


Figure 3. Control points for acoustics inverse problem.

GOAL: Calibrate a set of patch accelerations that will produce the best match possible with the experimental microphone pressures measure at seventeen control points location. The new inverse structural-acoustics computational capability in SIERRA/SD was used to inversely characterize a set of patch accelerations.

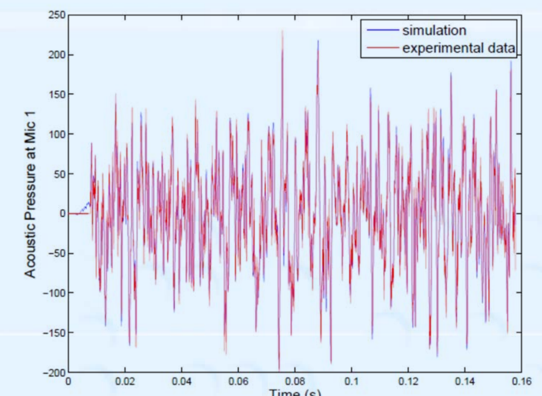


Figure 4. A comparison of measured and predicted acoustic pressures at a microphone.

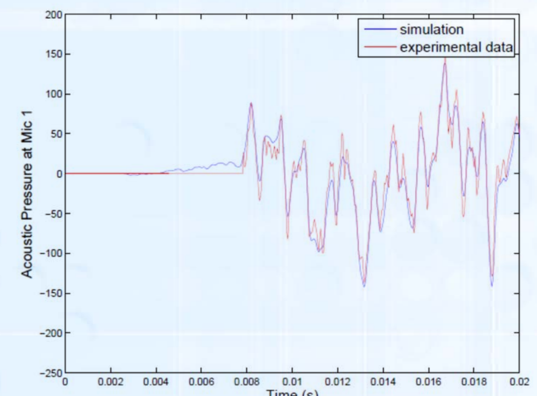


Figure 5. A close-up view of the time span from t = 0s to t = 0.02s of the experimental and predicted acoustic pressures.

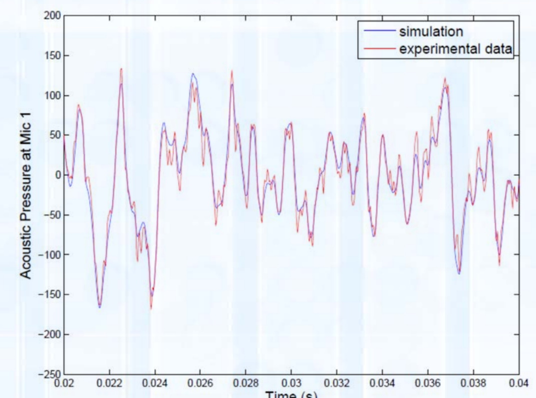


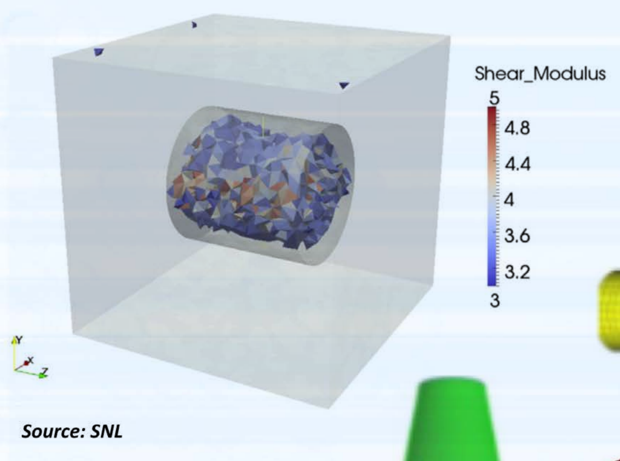
Figure 6. A close-up view of the time span from t = 0.02s to t = 0.04s of the experimental and predicted acoustic pressures.

New inverse structural-acoustics computational simulation capability

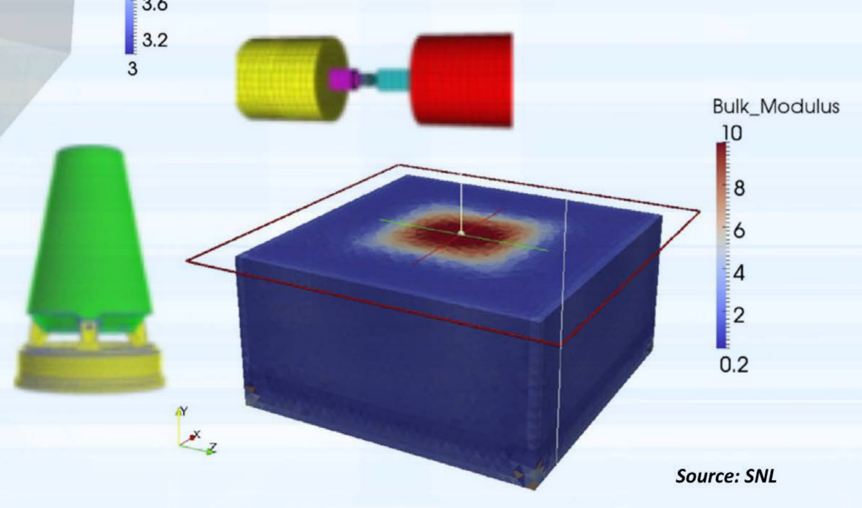
Figure 7. B61 structural-acoustics computational model.

The inverse structural acoustics capability in SIERRA/SD enables analysts to inversely estimate the desired experimental acoustic conditions of NW components. This capability can be used to characterize complex spatially varying acoustic environments in both time and frequency. This capability also represents a new paradigm for future integration of advanced computational tools and experimental measurements. This new capability constitutes a unique and powerful parallelized computational tool that supports the broad national security interests of our nation.

Further inverse computational simulation capabilities in SIERRA/SD



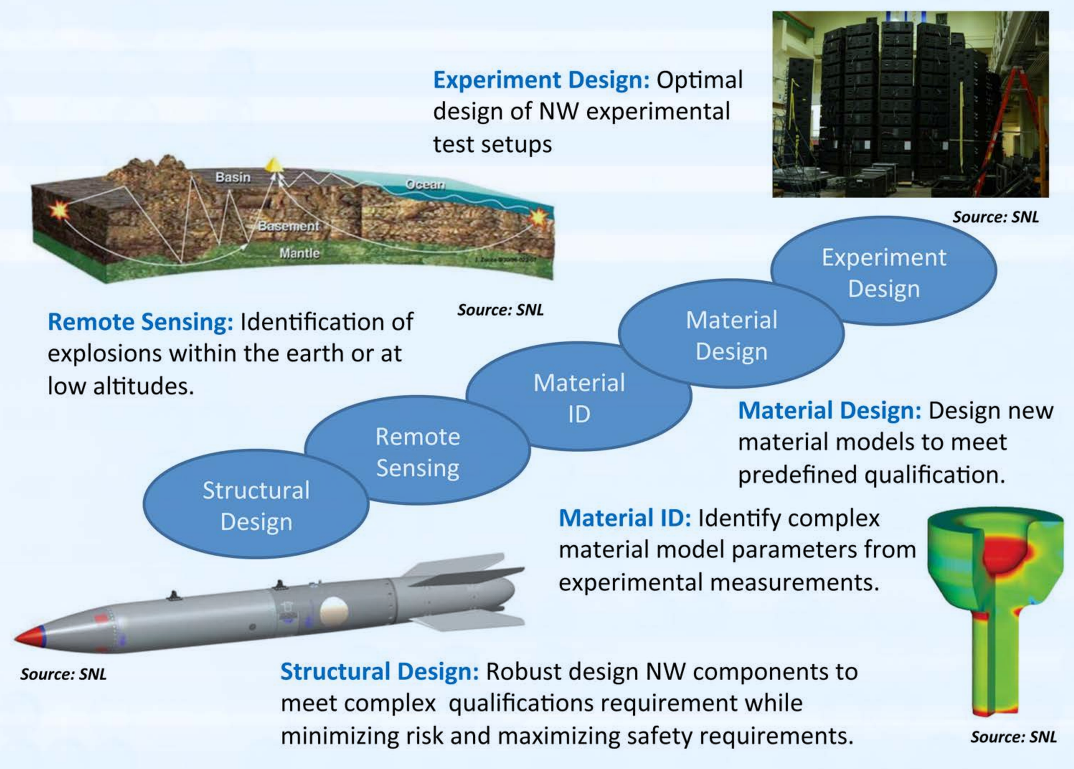
Material ID: The new material identification (ID) computational capabilities in SIERRA/SD enables analysts to inversely characterize constitutive parameters of complex constitutive material models.



Material ID Features:

1. Spatially varying and constant elastic properties.
2. Viscoelastic properties

Other NW Applications



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