Multi-Disciplinary Integration of ModSim for Navy Applications

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System Integration – Credible Solution

Our mission statement ..... 

Develop and deliver engineering-mechanics simulation applications & expertise for **credible** National Security decision making.
What we offer

SIERRA offers a wide range of simulation capabilities

- Solid mechanics
- Structural dynamics
- Acoustics
- Thermal analysis
- Fluid dynamics
- Aerodynamics

All built on common infrastructure

- Sierra also couples with other Sandia tools
  - Pre and post processing (Cubit, Paraview, SAW)
  - Design and optimization (Dakota)
  - Other computational simulation capabilities (CTH, Alegra, ITS)

Distinguishing strengths are

- Robustness: production code (SQE)
- Performance: parallel scalability, focus on NGP
- Credible: V&V, UQ, QMU
- Multi-scale and multi-physics
- Access controlled code for support of National Security Mission
Our customers
Nuclear Weapons Program & Analysts

- NW Program is the principal driver for Sandia’s Computational Simulation efforts

SNL Engineering Codes are positioned to support the engineering needs of the complex
Navy Enhanced Sierra Mechanics (NESM) Acoustics

- 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
- Parallel and scalable
**Overview - NEMO**

**Navy Enhanced Sierra Mechanics (NESM)**
- Massively Parallel, Enhanced, Physics Based M&S Suite For Prediction Of Ship Shock Response & Damage Due To Weapon Engagements
- Modern Software Engineering Designed For Evolution
- Developed To Address Validation Of The Integrated Ship System Shock Hardness IAW OPNAVINST 9072.2A As Well As Live Fire Test & Evaluation (LFT&E) Needs
- Leverages DOE-ASC Investment In Sierra Mechanics
- Leverages ONR Investment In The Implosion Program

**Emphasis on Validation for Both Shock Response & Ship Damage Compared to Physical Testing**
Organized into several SCRUM-Teams, each developing and support a set or products

1) Structural Dynamics (Linear)
2) Solid Mechanics (Nonlinear)
3) Thermal Fluids
4) Toolkit
5) Meshing
6) Dev Ops
7) Topology Optimization
8) Verification & Validation
Computational Structural Dynamics

**Structural Dynamics** – Linear, static, implicit dynamic & modal response

**Shared mechanics capabilities**
- small deformations, small-strain linear material behavior
- solid & structural elements, constraint elements
- transient–modal–modal transient solution switching, multi-sequence analyses
- non-linear pre-load transfer from Sierra/SM

**Time domain, statics & transients**
- parallel scalable domain decomposition solver with many constraints
- joint models with dissipation
- material property inversion
- stochastic material (elastic) properties

**Frequency domain**
- Helmholtz solver, performance

**Acoustics** – linear
- absorbing boundaries
- acoustic pressure source inversion
- monolithic coupling with structural response
Capabilities Applicable to DoD Needs

- Full Support for Structural Dynamics
  - Full element library, materials.
  - Modal, Transient Dynamics, Frequency Response. Superelements.
  - SRS, random vibration
  - Quadratic Eigen Value Analysis
  - Geometric and joint-type nonlinearities

- Full Support for Acoustics and Structural Acoustics
  - Mesh tying, infinite elements, PML, mild nonlinearity
  - QEV, Transient, Frequency Domain

- Inverse Methods Capability

- Coupled Physics
  - Fluids: nemo, aero and sigma
  - Thermal (unidirection): fuego
  - Nonlinear Mechanics
Full Support for Structural Dynamics

- Modal, modal superposition
- Frf
- Transient Dynamics
- Superelements
Solid Mechanics – Quasi-static, implicit & explicit transient dynamic response

**Shared capabilities**
- large deformations, large-strain nonlinear material behavior
- implicit-explicit solution switching, multi-sequence analyses
- continuum & structural finite elements, particle methods
- parallel scalable accurate frictional contact
- common & unique material models: 50+
- geometric and temporal multi-scale methods

**Implicit Solid Mechanics**
- coupled thermal-mechanical modeling, with failure
- preloads
- encapsulation & cure, incompressible material behavior

**Explicit Solid Mechanics**
- energy-dependent material models
- fracture & failure modeling (cohesive zones, XFEM, remeshing)
- empirical blast pressure loads (CONWEP)
- coupled to CTH shock-hydro, Alegra EM
Sierra/SM Capabilities
Recent developments

- New XFEM fracture and fragmentation capabilities
- Now production-izing 3D XFEM capabilities (2D in place)

SM brittle fracture modeling

loading (pressurization) rate 1x, 2x, 3.5x, 5x

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Sierra/SM Capabilities

Recent developments

- **SM preload effects in SD**
  - Improve accuracy of SD direct transient or modal analyses by including the MPCs (thru file) generated from an SM preload
Sierra/SM Capabilities

Recent developments

- Large deformation remeshing/remapping in SM
  Tensor preserving mapping

SM material parameter calibration

Global $L_2$-projection transfer

w/ adaptive remeshing

no remeshing
SQE Practices – Test Driven Development (TDD)

Develop Scalable, Maintainable Software

1. Write a failing test
   ▪ Known Solution
2. Make Test Pass
   ▪ Smallest amount of code possible
3. Refactor
   ▪ Improve code quality
SQE Practices – Scrum / Agile

- React to changing requirements to meet customer needs
Sync Release/Sprint

Requirements

▪ Coordinate effort.
▪ Allow rapid testing of features.
▪ Avoid unnecessary cost.

Approach

▪ Use the same Agile sprint boundary.
▪ Sync code-base at end of sprint.
▪ Adjust to use the same release cycle.
▪ Communications and data transfer throughout.

The Key is a collaborative partnership relationship.
Flexible Coupling Approaches

- There are many coupling algorithms. For example, iteration may or may not be required on each advance.
- Focus on a flexible strategy that permits evaluation of these algorithms.
- Use standard verification methods to ensure proper accuracy.

Coupler has unit tested capability for each of the steps of the coupling. Surrogate drivers permit integration testing independent of the region.
Sierra DevOps team enables development and distribution of the Sierra suite of applications.

- Tools and configurations for:
  - Build system
  - Test harness
  - Automated testing processes management
  - Testing dashboard
- Configuration & testing for a wide range of compilers and platforms
- Licensing management, packaging tools, internal & external delivery
- Software quality engineering & assurance testing (coverage, memory, static analysis)
- Build, installation, and execution support
- Management of software component & library integration and coupling
- Release branch creation, testing, and maintenance
Integration – Verification Tests

- Small verification tests are performed at Sandia and Document
- Verification tests are run before every sprint and full release
  - Verified and serial and parallel
- Verification document is built from passing tests
- Navy also verifies capability
Integration - Surrogates

- Mock executables demonstrating Sierra and Nemo were created to facilitate development efforts
- Surrogates run as executables, but with empty data structures and without solves
- Allow separation between “coupling” error, and “physics” errors
Verification: 1d acoustic piston

**Goal:** test loosely coupled algorithms to assess temporal accuracy

**Structure displacement**

\[ u_s(t) = e^{-dt} (a \cos \omega t + b \sin \omega t) + \nu(t - \beta) \]

**Fluid solution**

\[ v_a(t) = \dot{u}_s(t - x/c_a) H(t - x/c_a) \]
\[ p_a(t) = p_\infty + \rho_a c_a v_a(t) \]
User Support Model

Requirements

▪ Avoid overload of developers.
▪ Provide Support as near customer as possible.
▪ Build a sustainable system.

Approach

▪ First Line Support at NSWC/CD.
▪ CD forwards triaged issues to SNL development.
▪ Support tickets are maintained and tracked at relevant sites.
Applications
Questions?