Sierra SM 4.30 Release

Wednesday, October 9, 2013

(9 sprints)

SAND Number: 2013-9599 C

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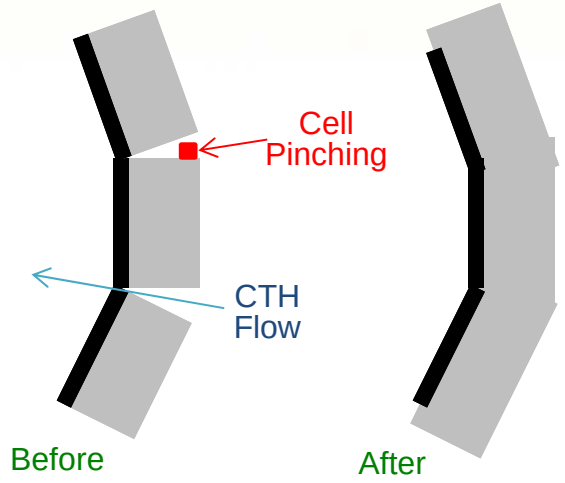
Fortissimo

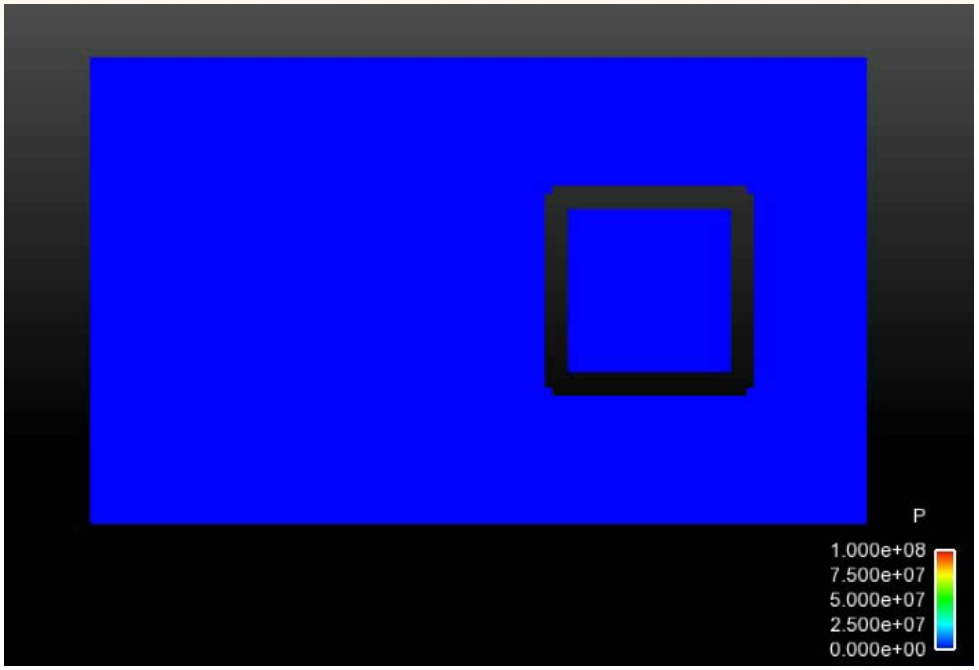
Blast-on-Structure

Sierra-SM coupled to CTH

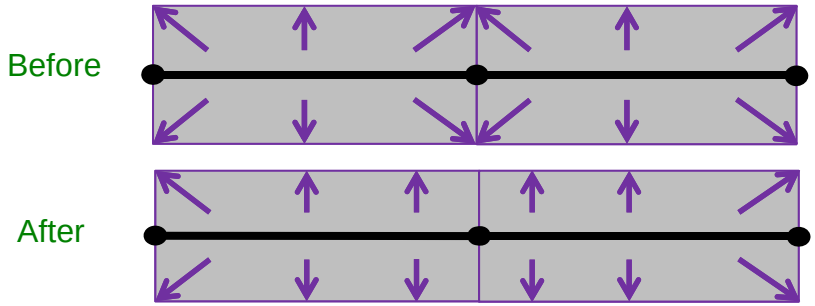
Fortissimo with Shells

1) **Expand lofted shells to close gaps in lofted geometry**





2) **More robust normal calculation**



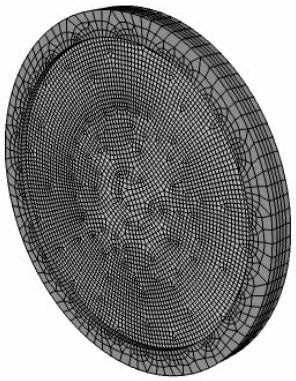
3) **Greatly expanded test coverage**

Status

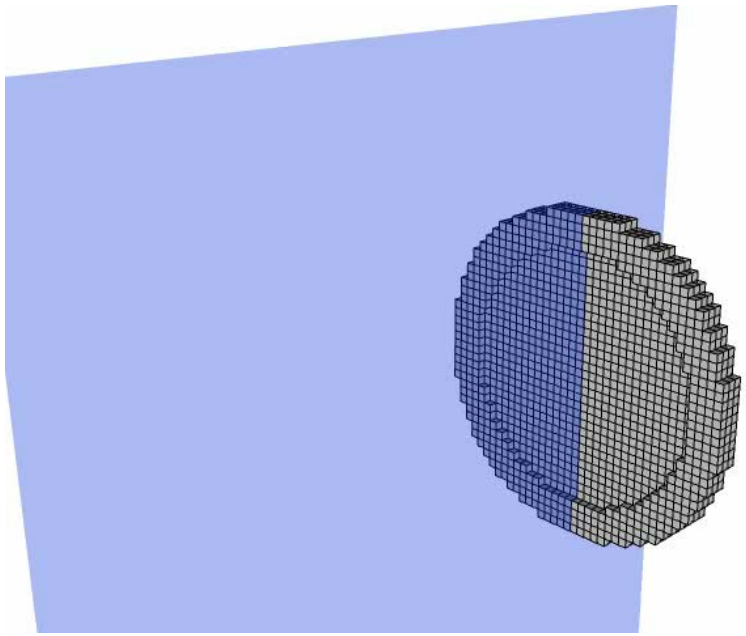
- Bleed through issue fixed
- CTH instability issues appear resolved
- Performance improved 400%
- Ready for friendly user testing

Fortissimo With Element Death

- Properly update Lagrangian boundary representation during element death
- Fix segfaults when using element death with CTH adaptive mesh refinement
- Allow particle conversion in Fortissimo (particles created in Sierra, though not inserted to CTH now)

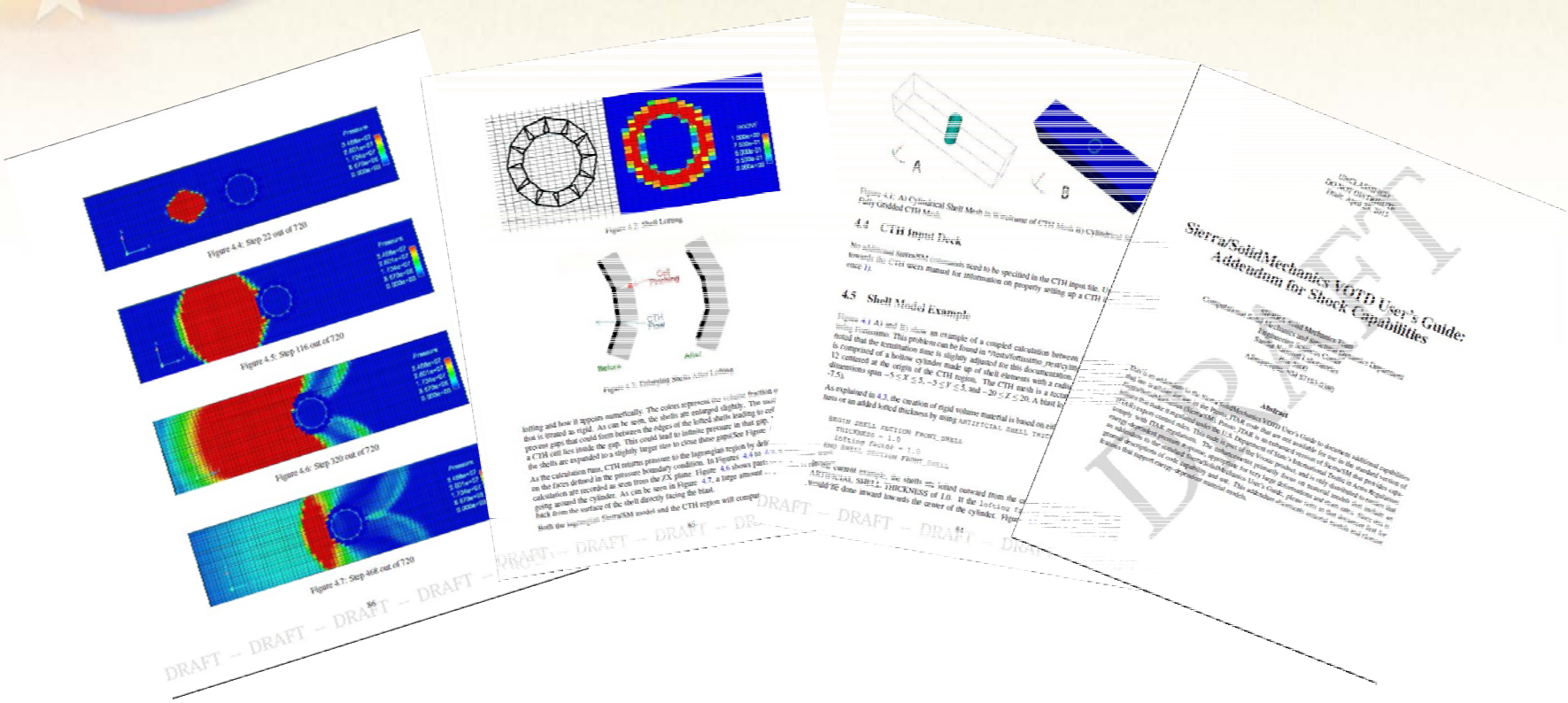


What Sierra Sees



What CTH Sees

Fortissimo Documentation



- Added documentation to **Sierra/SolidMechanics VOTD User's Guide: Addendum for Shock Capabilities.**
- Discussed coupling between Sierra and CTH using Fortissimo.
- Explained how shell lofting works
- Includes an example problem

Fortissimo Parallel Performance

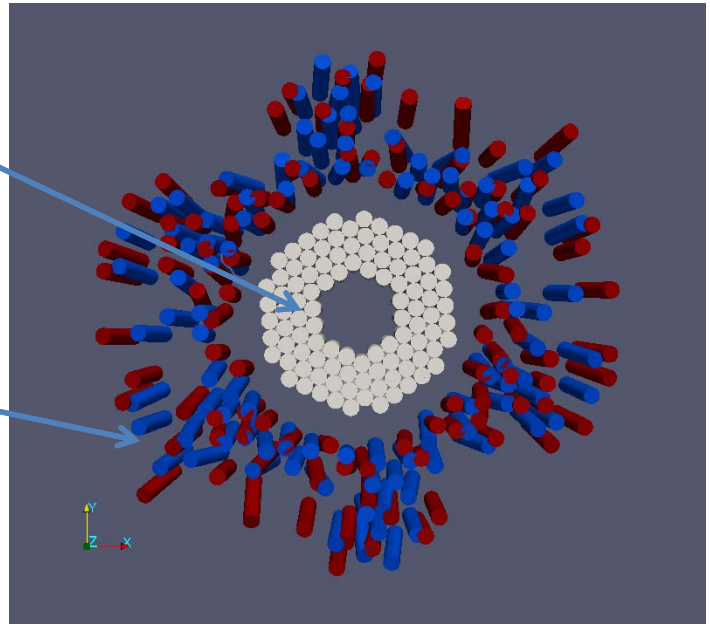
Beginning of Sprint Results

	Zapotec 1	Fortissimo
Run Time (hrs)	6.39	44.11
CTH cycles	17701	10323
Lagrangian cycles	43782	29833

Initial rod location

Rods at 3 ms
Red: fortissimo
Blue: zapotec1

Velocities look approximately the same between codes



Solutions at 3 milliseconds

(Courtesy of Arne Gullerud)

Fortissimo Performance

	4.29.7	4.29.8
Volume Insertion	**4.1**	**0.9 (4.5X)**
Pressure	**1.5**	**0.2 (7.5X)**
CTH	4.3	3.8 (*)
Presto	0.1	0.1
REDSKY (64P)	**10 Hours**	**5 Hours**

* CTH Version was updated during the sprint.

Elements & Materials

Element Energy Calculations

Following Element Quantities are now Available:

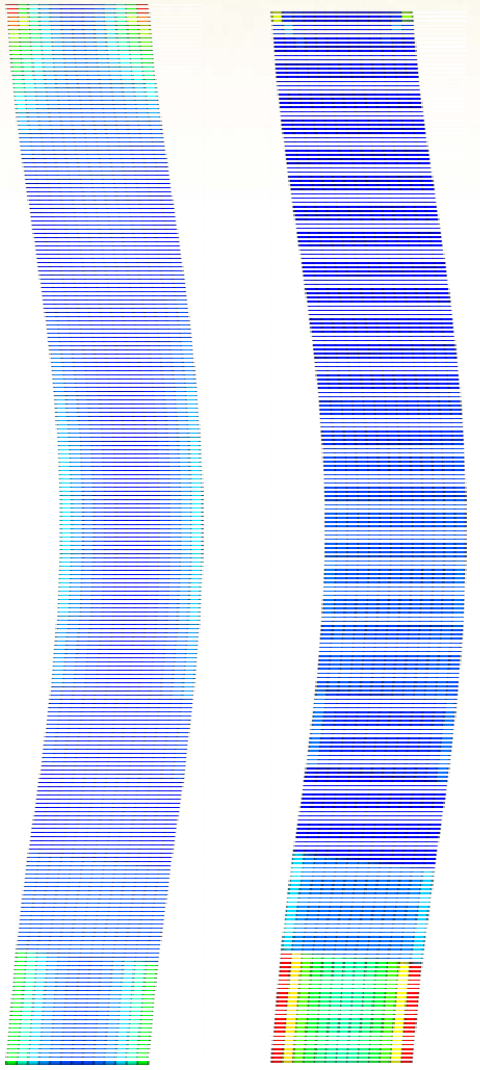
Name	Available For	Description
Internal_energy	~All Elements	Total element internal energy
Internal_energy_density	All Solid Elements	Internal_energy/volume
Hourglass_energy	~All Elements	Total element hourglass energy
Hourglass_energy_density	All Solid Elements	Hourglass_energy/volume
Derformation_energy_density	All Solid Elements	Internal_energy_density minus Hourglass_energy_density
Strain_energy_density	Single Integration Point Solid Elements	Integral of material stress dot material strain
Strain_energy	Single Integration Point Solid Elements	Strain_energy_density * volume

Note:

"*Deformation_energy_density*" should match JAS3D **"EINENG"**

"*Strain_energy_density*" should match ABAQUS **"SENER"**

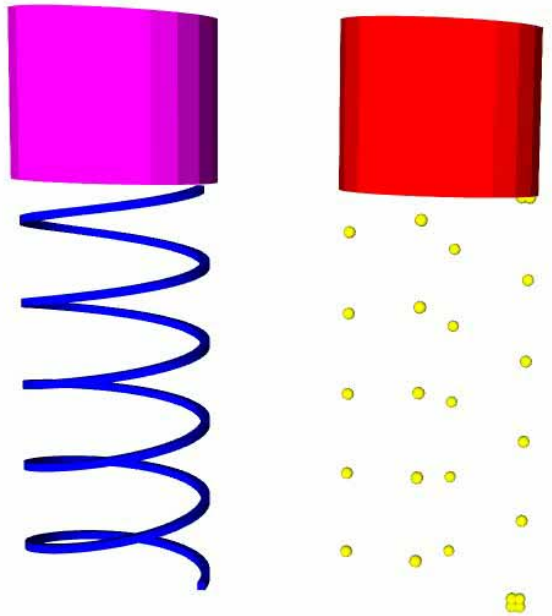
In absence of thermal strains these two quantities are identical

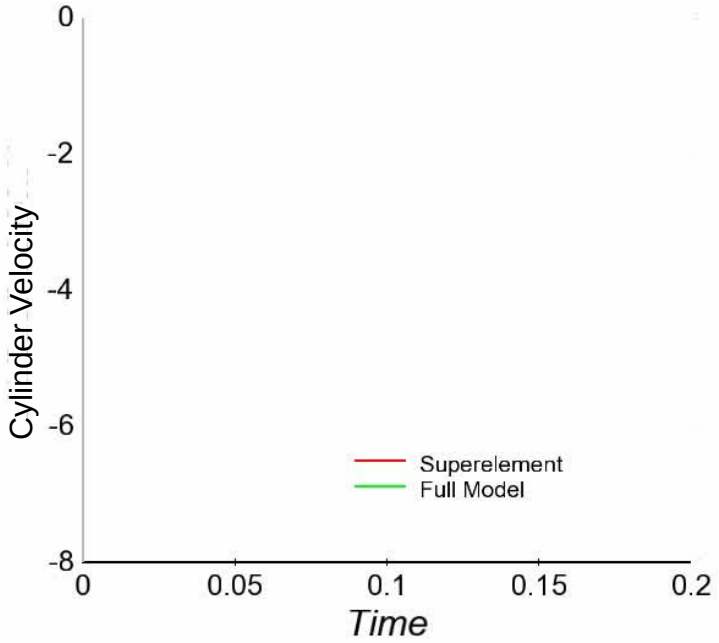


Strain Energy Density

Hourglass Energy Density

Superelement Example





Full Model

Adagio Runtime: 7 hours

Superelement Composite Model
(150 Modes)

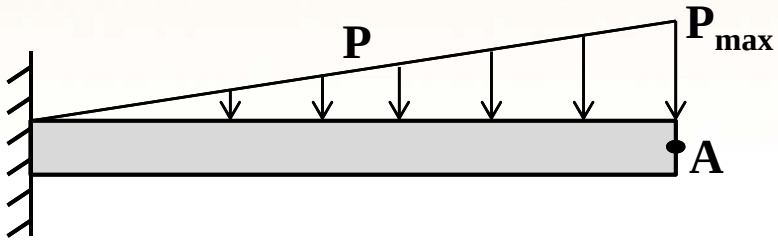
Linear Spring + Nonlinear Contact

Salinas Runtime: 2 minutes
Adagio Runtime: 3 minutes
Total Runtime: 5 minutes

Super element composite model captures most spring behavior:

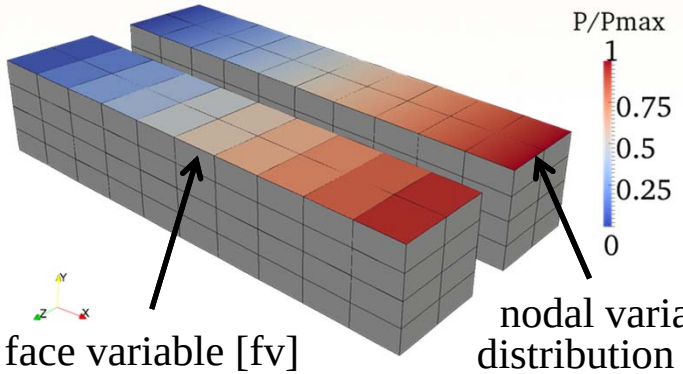
- Vertical stiffness of spring
- Lateral shift in spring due to vertical load
- Slip of spring off cylinder
- Ultimate velocity of cylinder

Element Consistent Pressure Loads



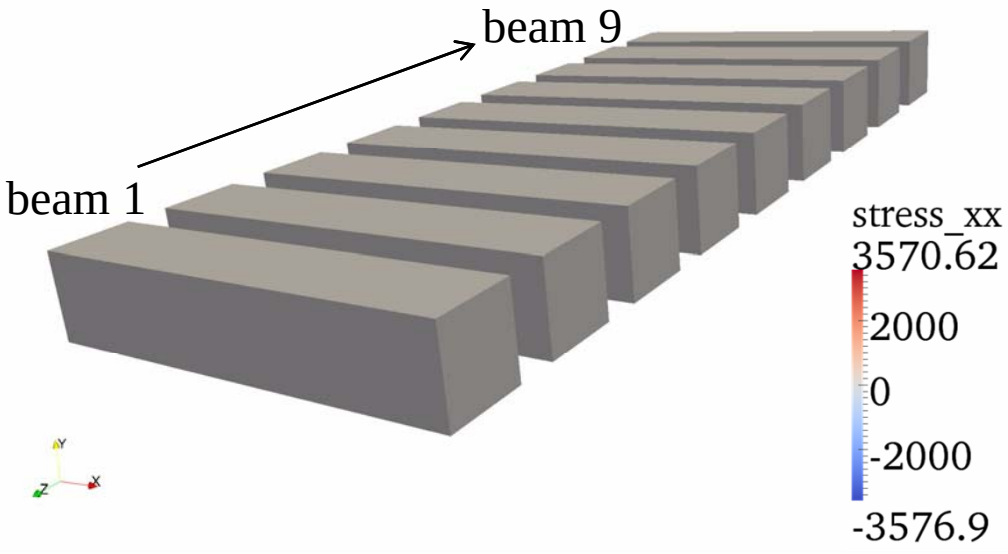
beam	elem	df|fv|df	$\Delta_{A,max}$
1	hex8	df	0.146
2	hex8	fv	0.145
3	hex8	nv	0.146
4	hex20	df	0.144
5	hex20	fv	0.143
6	hex20	nv	0.144
7	hex27	df	0.144
8	hex27	fv	0.143
9	hex27	nv	0.144
Euler-Bernouli sol'n :			**0.138**

3 Ways to Apply Spatially Varying Pressure:



face variable [fv]

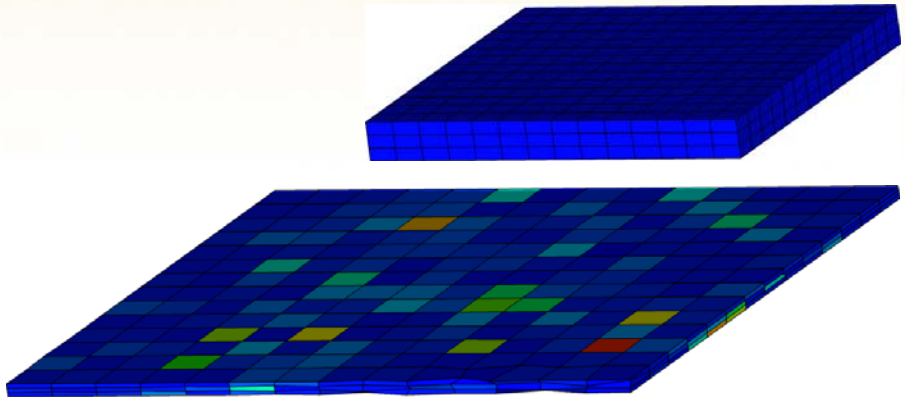
nodal variable [nv];
distribution factor [df]
(on face nodes)



Hyperfoam Modulus

Objective:

Repair instability issues in systems models using the hyperfoam material model. Hyperfoam material exhibits substantial stiffening under compression.

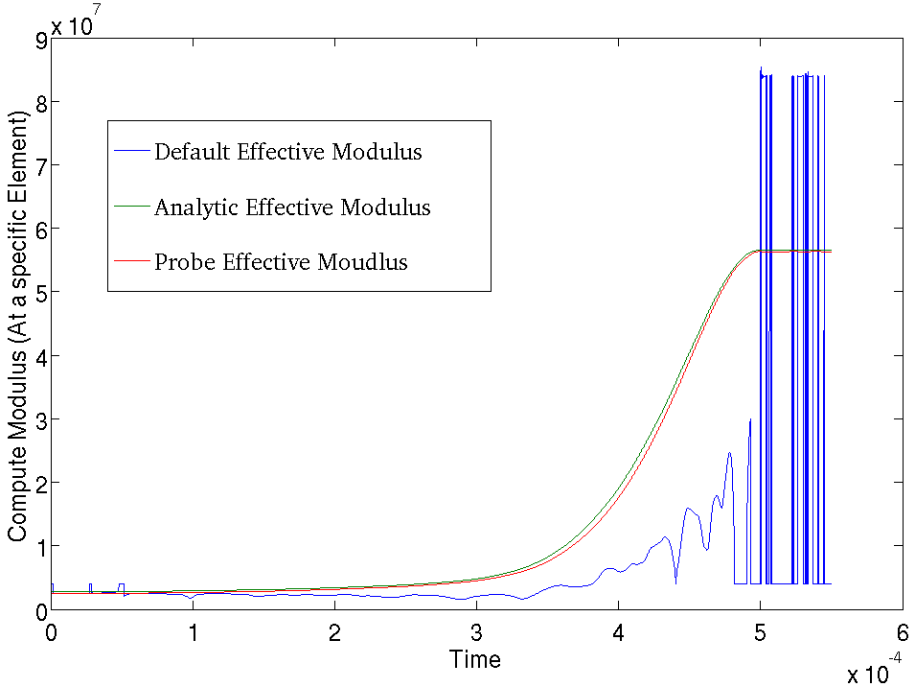


Issues Identified with Default Modulus:

- If strain increment too small default secant modulus reverts to uncompressed modulus
- Modulus can be significantly anisotropic, different strain directions yield different modulus.
- Modulus controls hourglass and time step. If wrong or volatile causes instability.

Done this Sprint:

- ✓ Implement optional PROBE effective material modulus option. Much more robust, somewhat more expensive, can be used with any material.
- ✓ Bill Scherzinger implemented analytic stiffness for hyperfoam model.



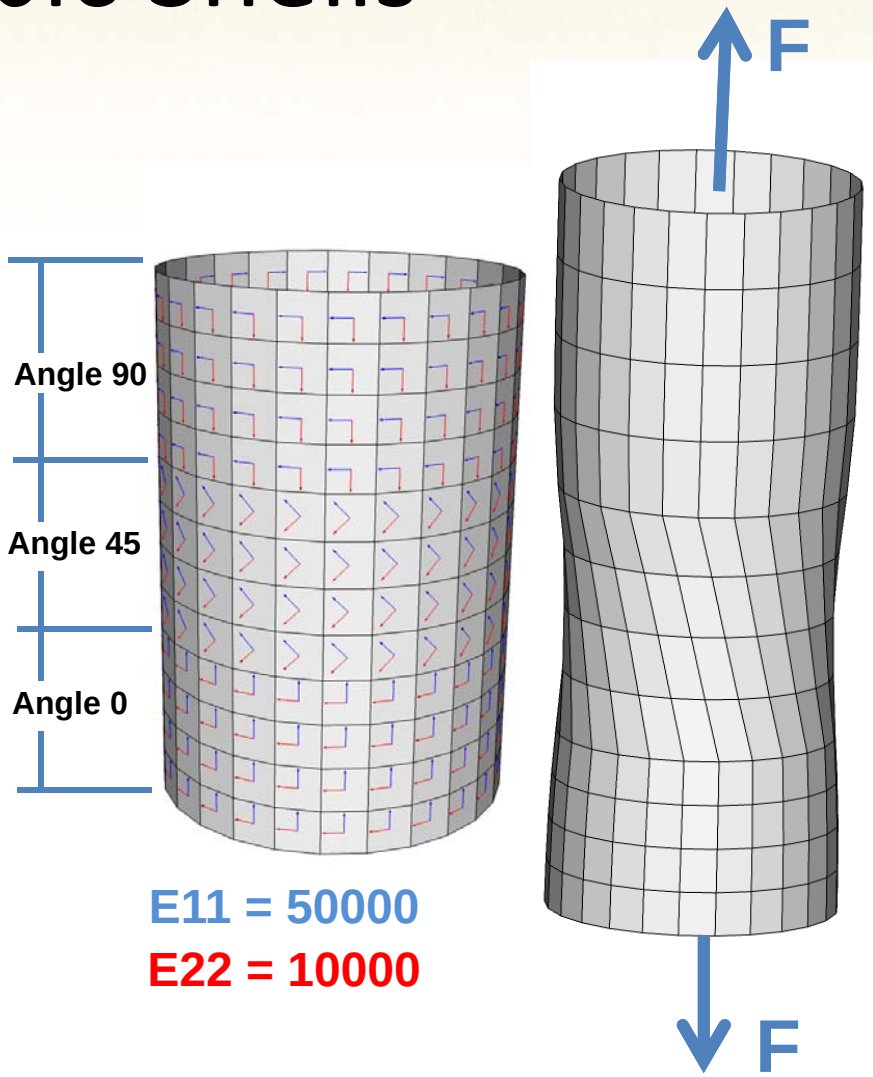
Orthotropic Shells

Objective:

Initial implementation for orthotropic shells in Sierra/SM

Done:

- ✓ Implement basic 2D orthotropic elastic shell model (six elastic constants)
- ✓ Implement syntax to read and create element local coordinate systems. Based on R vector, T vector, and orientation angle.
- ✓ Allow visualization of rotated reference frame
- ✓ Verified: Correct response for orthotropic hoop and axial strain in cylinder
- ✓ Verified: Model correctly reproduces isotropic results for isotropic inputs



XFEM

Failure modeling

2-D XFEM Example Problems

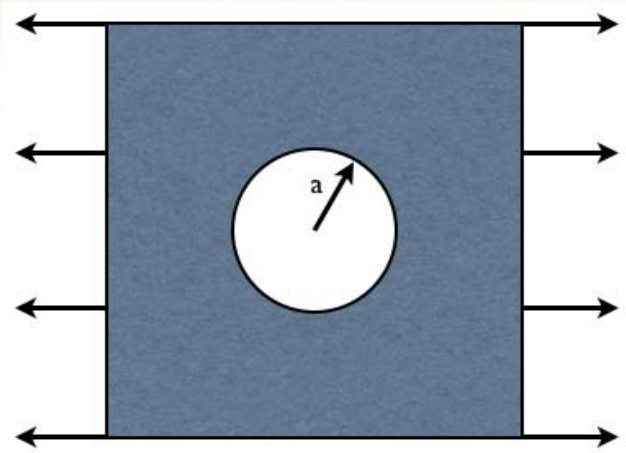
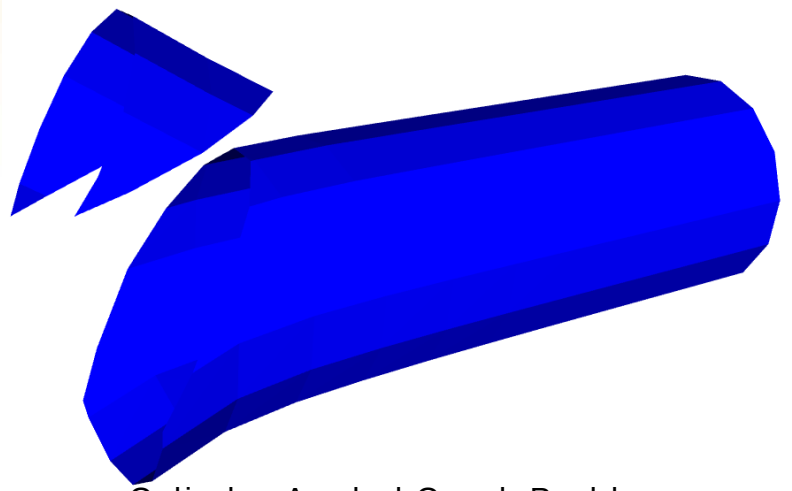


Plate with hole problem
Capabilities tested: Crack nucleation, planar crack growth, cohesive zone insertion



Cylinder Angled Crack Problem
Capabilities tested: Angled prescribed crack and planar crack growth

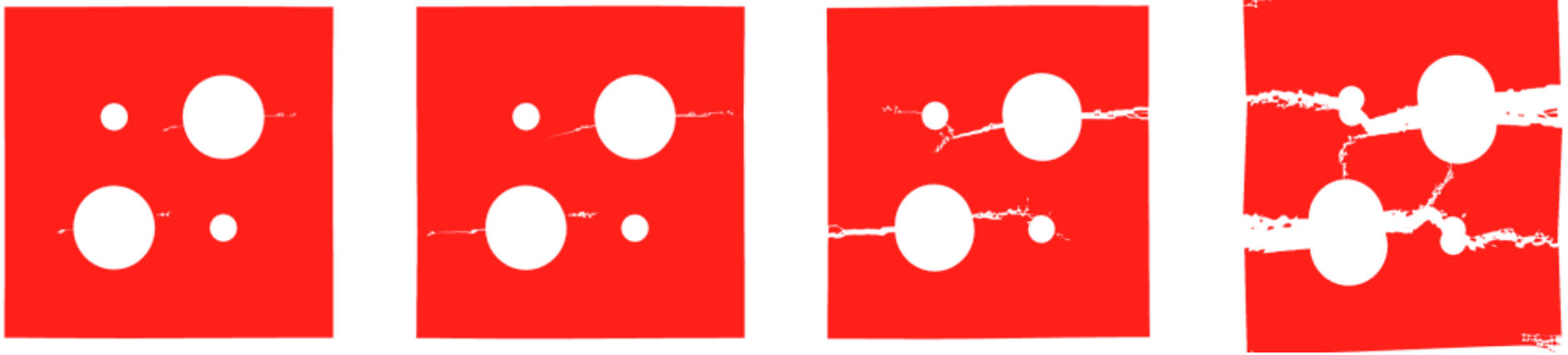
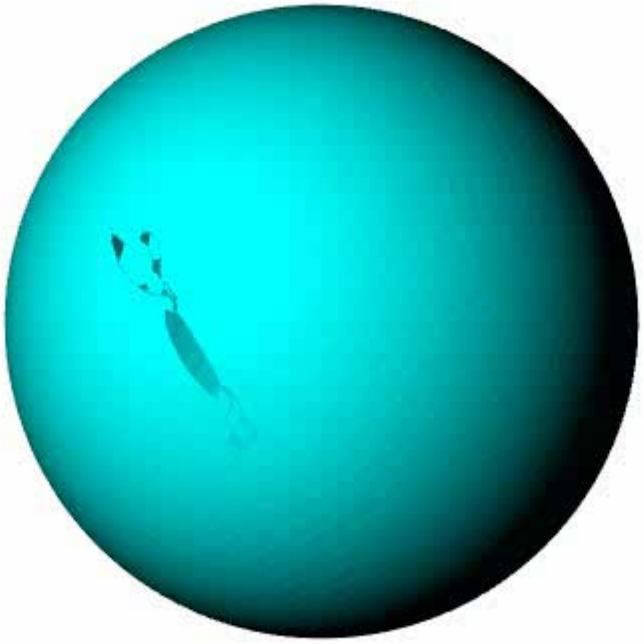


Plate with Multiple Holes Problem
Capabilities tested: Crack nucleation, branching, piecewise-linear crack growth

2D: XFEM with Element Death



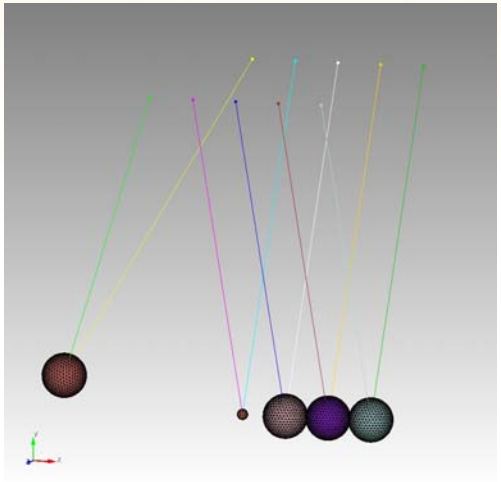
Mark Merewether's test case.

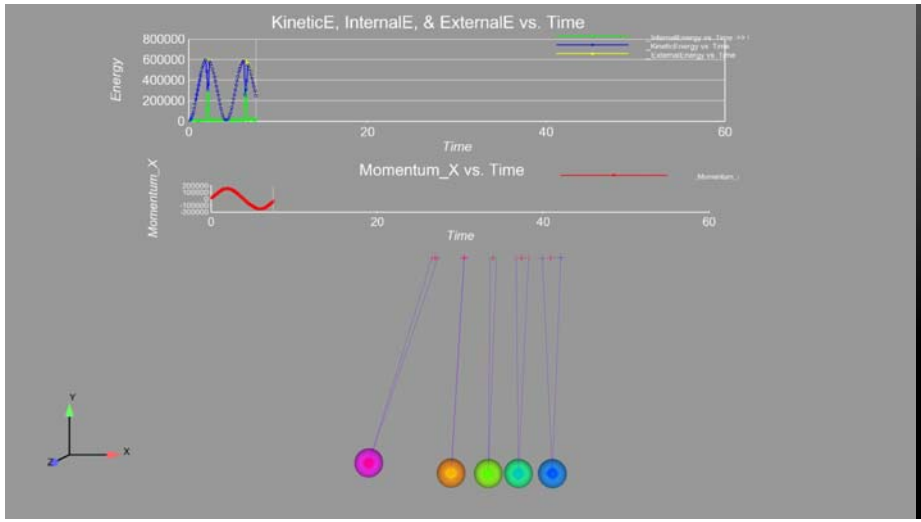
- XFEM to model initial mechanics driven cracking
- Element death to resolve complex crack intersection and remove instabilities

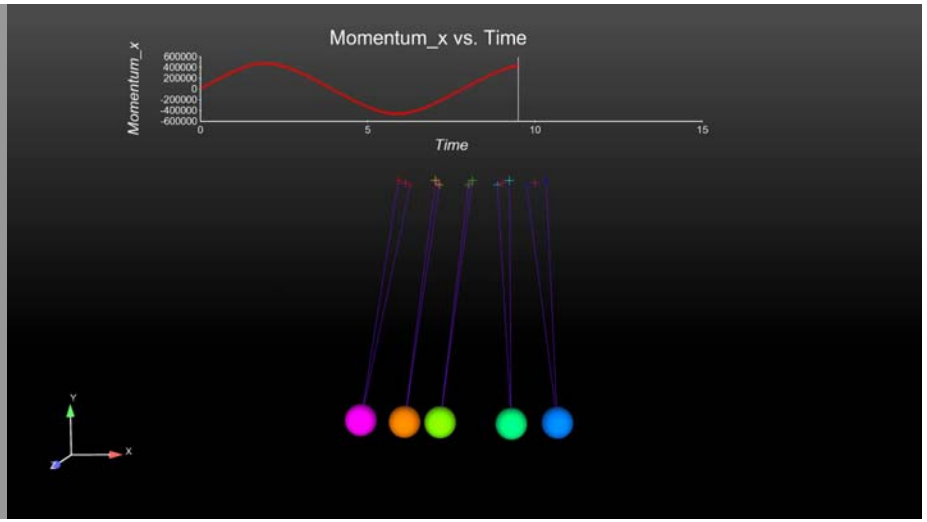
Example Problem Manual

Newton's Cradle

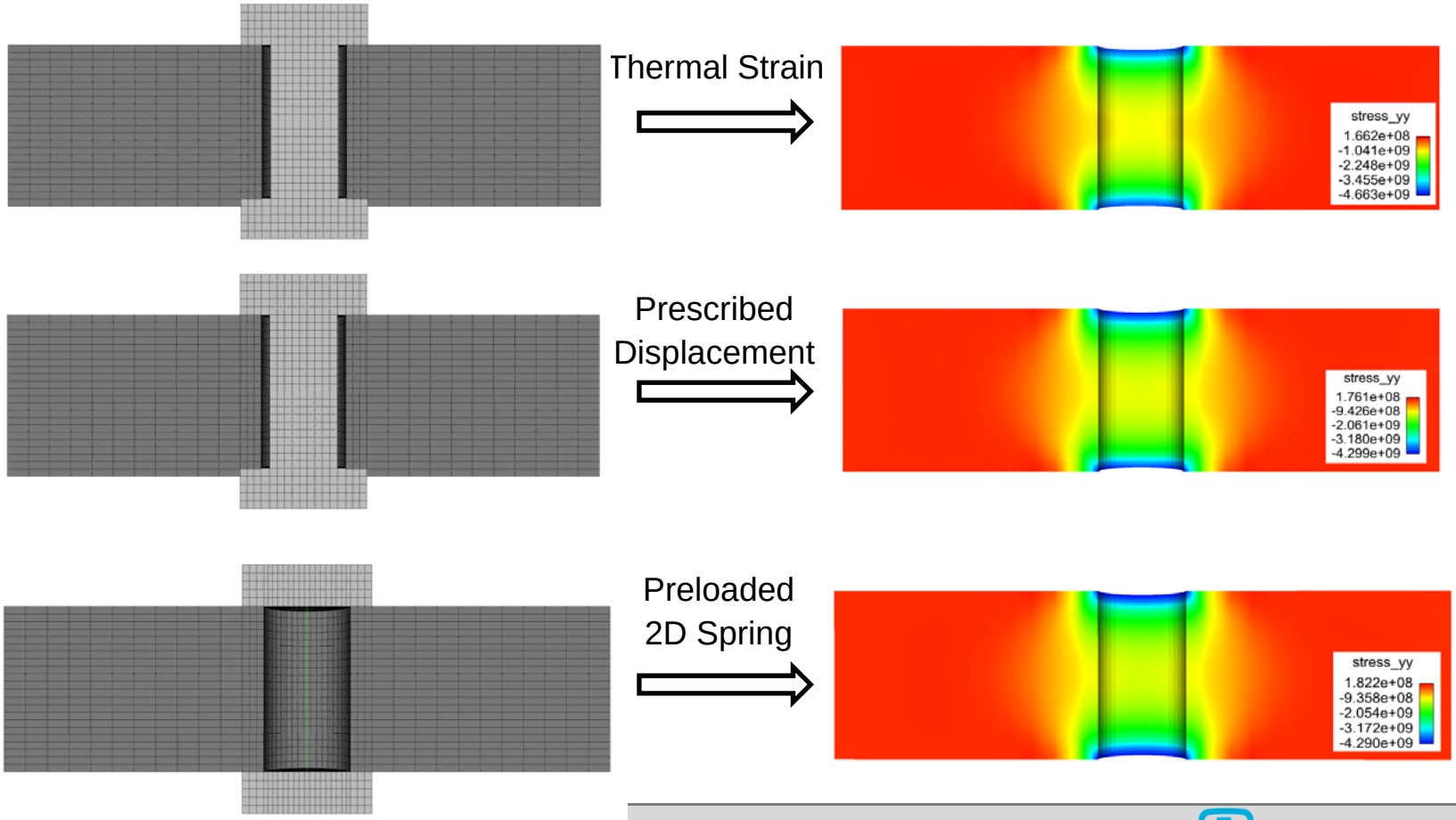
- **Rigid Bodies**
- **Truss Elements**
- **Gravity Load**
  - **Fixed Displacement: x y z**
  - **Fixed Rotation: x y**







Bolt Preload



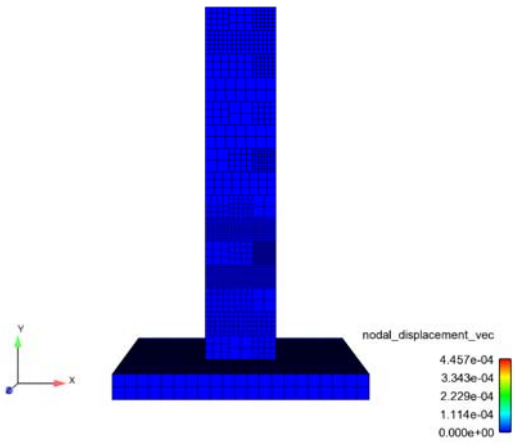
Jenga Tower

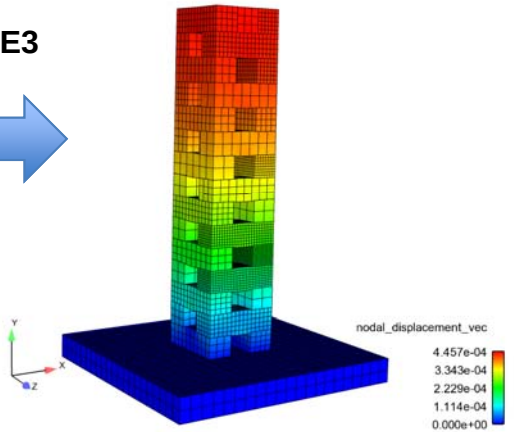
Initial Tower

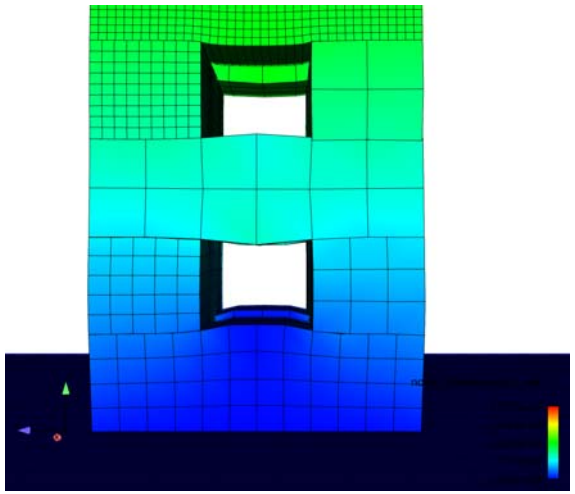
Final Tower

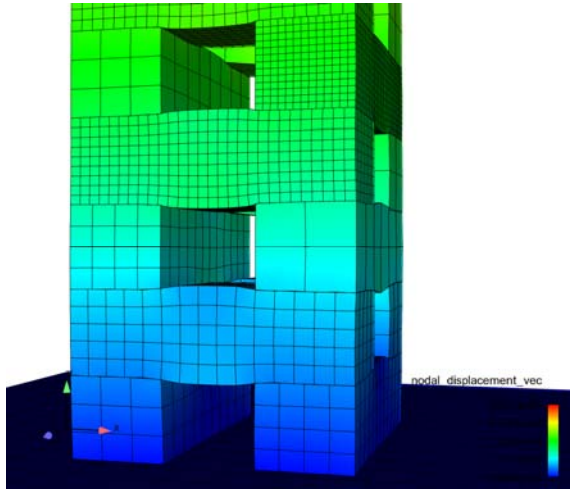
Gravity Preloaded

Displacement Factor: 2.00E3









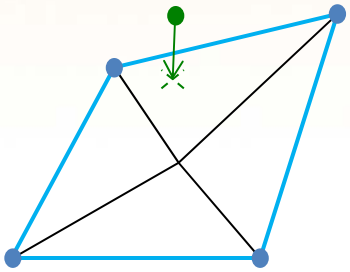
Contact

SM/SD/TF

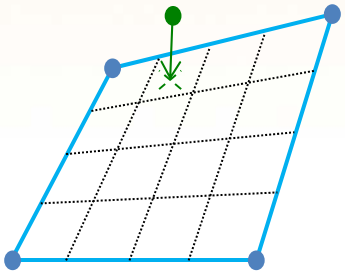
Friction Models

Marching towards default DASH

Quad Face Projection in DASH



Tri Facet Projection

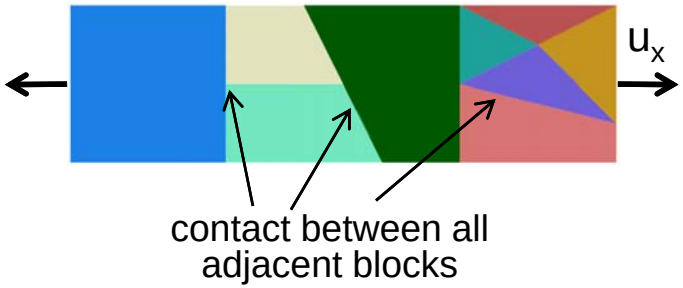


Quad Face Projection

- **Done this sprint:**
  - Enable capability in DASH
  - Not default (yet); undocumented
  - Regression tests in explicit & implicit
- **To do next:**
  - Optimization, Performance & robustness testing

Beam Tied Contact Test,
Explicit Transient Dynamics

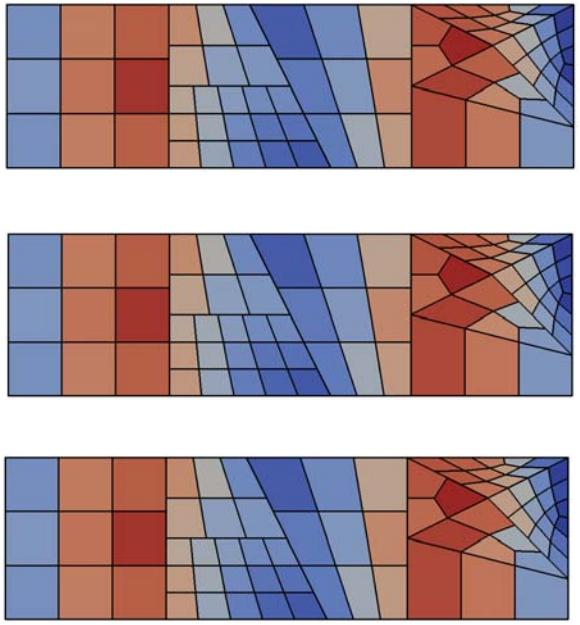
- stress_xx waves should be continuous



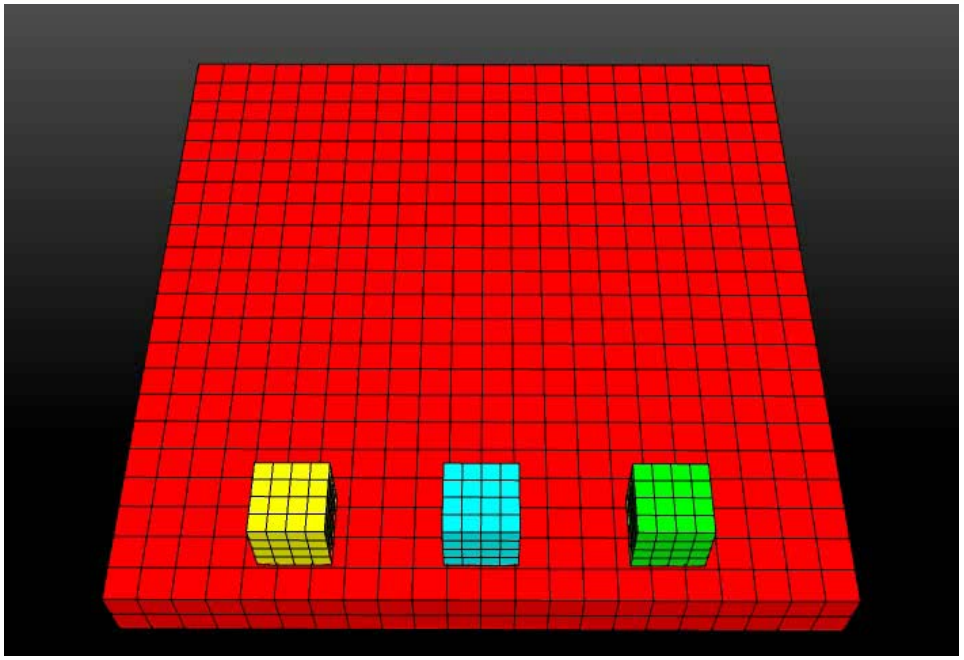
ACME -- QUAD FACE PROJECTION

DASH – QUAD FACE PROJECTION

DASH -- TRI FACET PROJECTION



Contact: Refactoring Friction Models and Add Time Varying Friction Model



- Refactored Dash friction models section of contact for easier friction model implementation
  - Moved friction model classes to individual files
  - Moved implicit calculations onto the friction model class
  - Each friction model class has implicit AND explicit functions
- Implemented a time-varying friction model
  - Refactoring of friction models allowed for 1.5 day implementation of new model

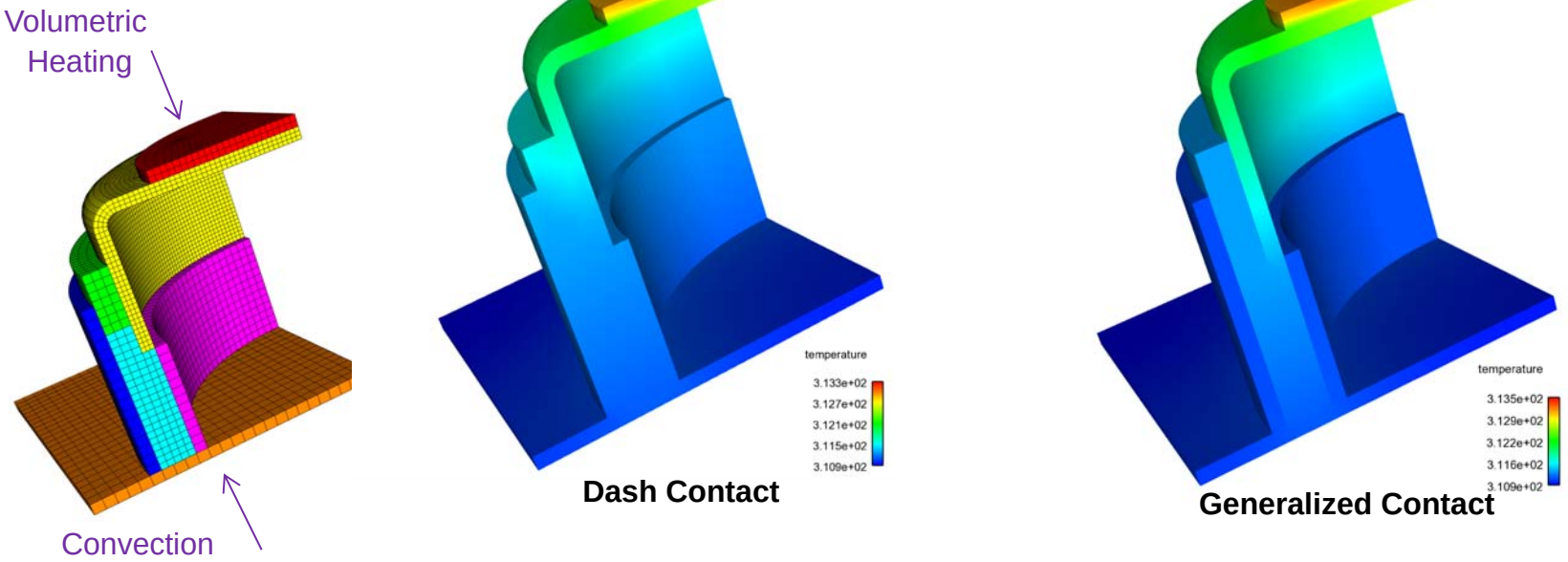
Migrate Dash Contact to Aria

What Was Done:

- Some generalizations to contact of concepts like stiffness, mass, and displacement to thermal contact
- Enable use of Dash defined contact constraints in Aria Thermal contact
- Testing, debugging, verification, and more debugging

Purpose:

- Leverage structural contact work to provide robust and efficient thermal contact
- Make a single contact definition work for both structural and thermal contact with the same options and behavior

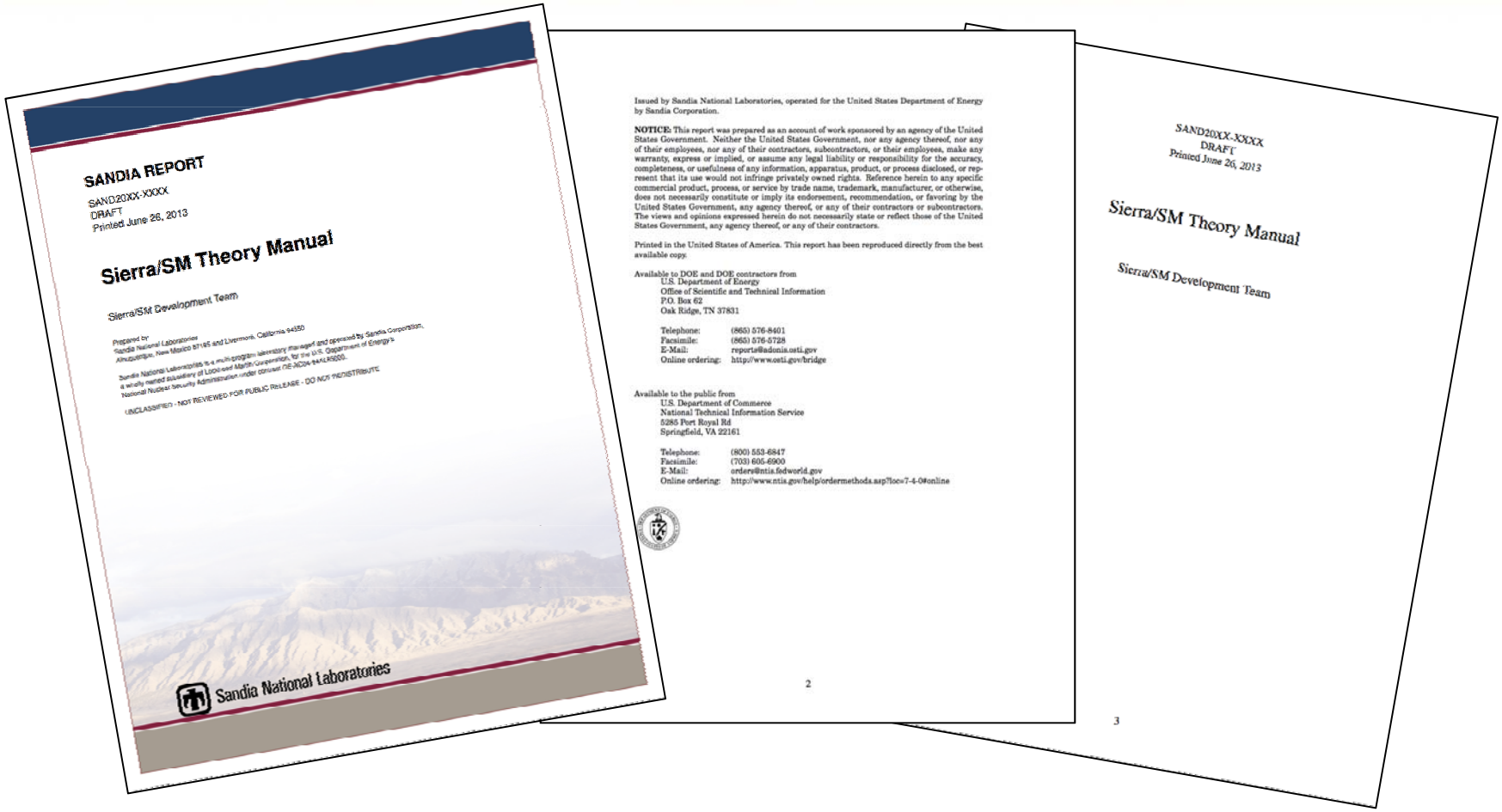


Documentation

Theory Manual

OBJECTIVE

- Get theory manual ***draft*** ready for R&A [DONE]



Updated Verification Tests Manual

SANDIA REPORT

SAND20XX-XXXX
DRAFT
Printed September 23, 2013

Sierra/SM Verification Tests Manual

Sierra/SM Development Team

Prepared by
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Sandia National Laboratories

- Manual status
  - 4.26 release (end of FY12):
    - # pages: 250
    - # nightly test runs: 38
  - 4.28 release:
    - # pages: 310
    - # nightly test runs: 78
  - 4.30 release (end of FY13):
    - # pages: 470
    - # nightly test runs: 106

180% increase during FY13

- New features in 4.30 release:
  - Significant improvements in contact feature coverage
    - Especially for implicit
  - Contact mesh convergence tests
  - Improved Introduction
    - Background
    - Discussion of verification approaches

Testing

Nightly Memory Usage Testing

Motivation:

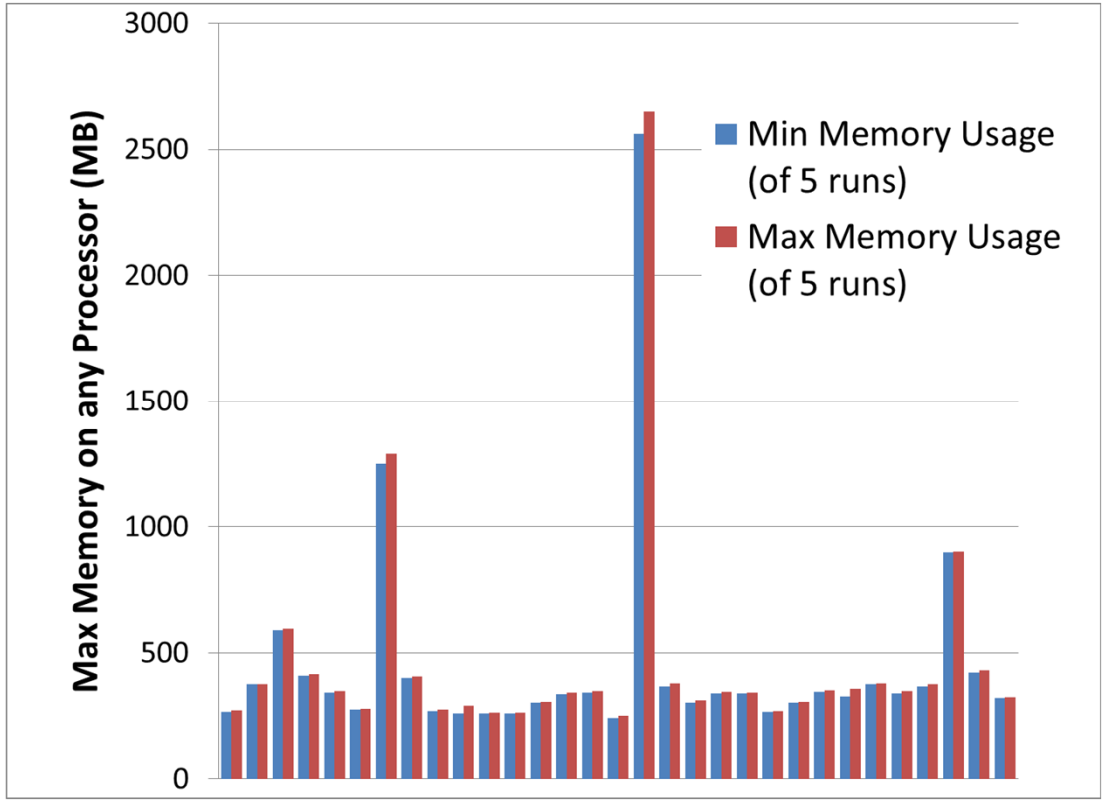
Ensure that future changes to STK mesh or other new code development does not adversely increase the memory usage of Sierra Solid Mechanics analysis runs.

What was done:

- Memory logging added to all redsky performance tests (~45 tests)
- Tests pass if memory usage is within 5% of current baseline

Lessons Learned

- Some variance night to night, but low.
- All Sierra jobs require at least 250 MB memory per processor no matter the size.



Performance Test Suite

OBJECTIVE

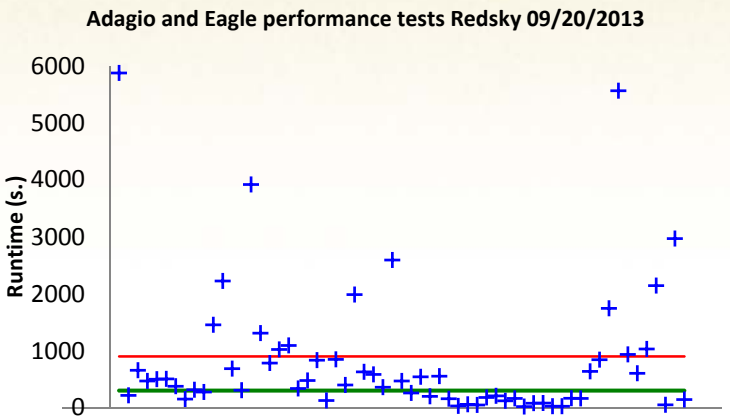
- Evaluate and start refactoring our performance tests.

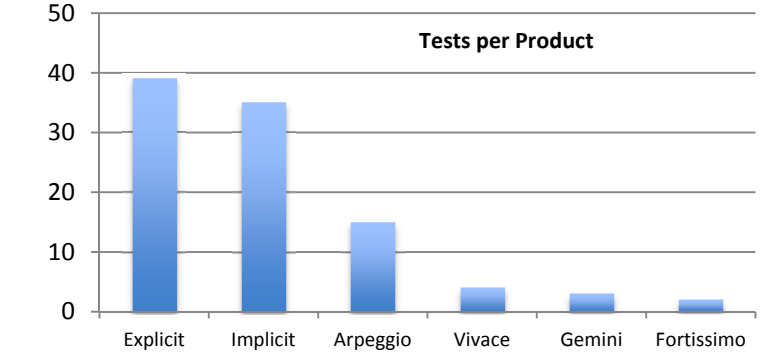
DONE this sprint

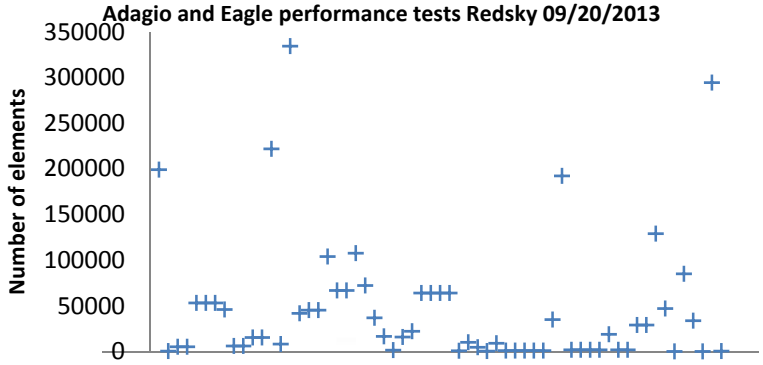
- Reorganized all performance tests under performance folders, located inside each product's test directory.
- Removed fast running performance tests by moving them out of the performance folder, and eliminating the "performance" keyword from their *.test file.
- Added missing performance checks (runtime, memory) to worthy tests with the "performance" keyword in their *.test file.
- Classify them depending on product, feature coverage, solver settings, runtime, element type and size.

Potential next steps

- A natural next step is to evaluate all data gathered during this sprint and make recommendations for improving our performance testing.
- One recommendation is to establish a weekly test suite to include performance testing of full scale analyses.







Thank You!

The Solid Mechanics Team was able to deliver these capabilities while also addressing ~25 user support tickets per sprint!

The Solid Mechanics PMs who organized the important user support and any major user requested capability development!

The Solid Mechanics Scrum Master who are invaluable in organizing the reviews, planning meetings, and daily standups!

The Solid Mechanics Users who have identified issues to fix, documentation to update, and been generous with their time in verifying user support issues.