SAND2008-5901C

SIERRA_SolidMechanics

Quasistatic, Implicit dynamics and Explicit dynamics Capabilities

Computational Solid Mechanics and Structural Dynamics Department, 1542

August, 2008

SIERRA Mechanics Modules

SIERRA_SolidMechanics

Quasistatics, Implicit dynamics and Explicit dynamics

SIERRA_SolidMechanics: Development team

Team member	Expertise
Manoj Bhardwaj	Structural Dynamics, Agile code development
Nathan Crane	NBTet remeshing, element death
Arne Gullerud (½ time)	Material models, shell contact
Jason Hales	Solvers, elements, failure modeling
Martin Heinstein	Contact, solvers, transient dynamics
Brent Perschbacher	Performance profiling, testing
Kendall Pierson	Solvers, Code architecture
Vicki Porter	Rigid body mechanics, QS←→ETD handoffs
Greg Sjaardema (½ time)	SIERRA framework/toolkit
Ben Spencer	BCs, multi-scale modeling
Joe Jung	manager 1542

SIERRA_SolidMechanics : capabilities (sampling)

index

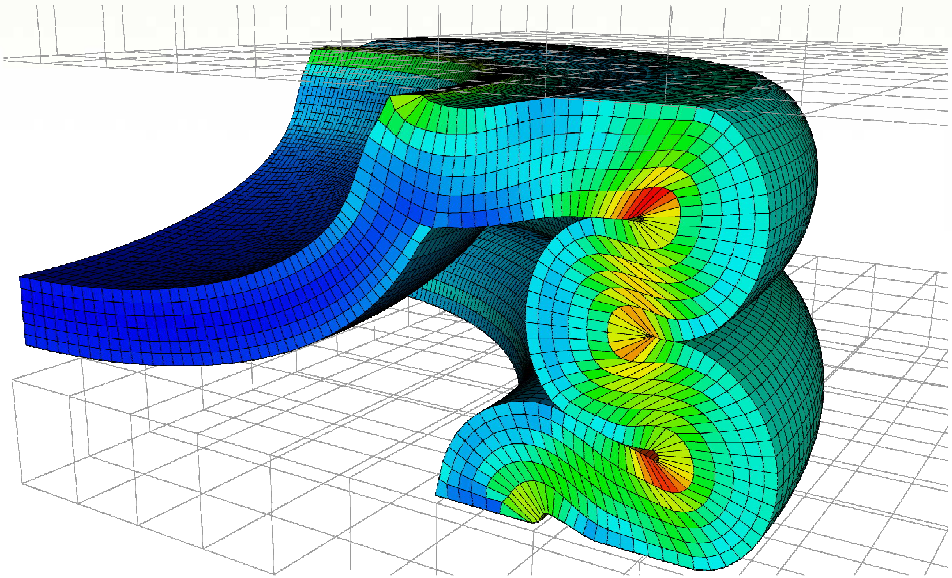
Single Physics	Nonlinear stress response (w/ multi-level solvers)	stress
	Interface problems	contact
	Energy absorbing impact (e.g. crash)	impact
	Large deformations (remeshing, particle methods)	remesh
	Failure Modeling (explicit & implicit)	GPFM
Coupled Physics	quasistatics↔transient dynamics↔structural dynamics	SM x-fer
	Thermal-structural response (e.g. residual stress)	TSR
	Fluid Structure Interaction	FSI
	Energy deposition (e.g. blast-structure, ground shock)	Shock

SIERRA_SolidMechanics :
Nonlinear stress Response

Application areas
- ✓ Mechanical stress simulation

Objective
- ✓ Kinematic and/or force driven deformation
- ✓ Material & Geometric nonlinearities

Methodology
- ✓ Parallel-scalable Implicit multi-level solvers for quasistatics (QS) and Implicit transient dynamics (ITD)
- ✓ Explicit transient dynamics (ETD)



"Energy absorbing barrier"

Multilinear elastic-plastic constitutive model

Frictional contact, geometric and material nonlinearities, parallel scalability

Quasistatic solution with multi-level solver, nonlinear CG core solver with FETI preconditioner

SIERRA_SolidMechanics :
Interface Problems

Application areas

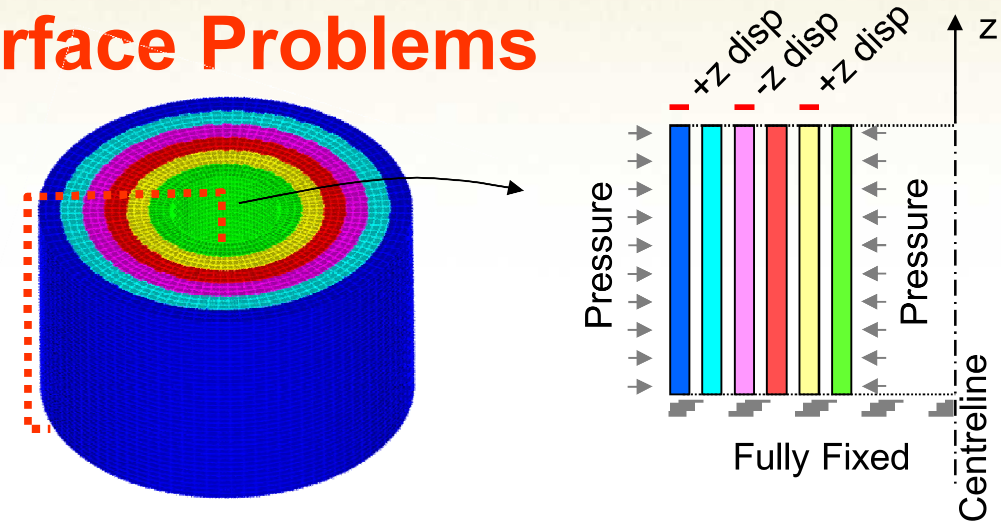
- ✓ Implicit and explicit problems w/ interfaces

Objective

- ✓ Foundational capability for modeling structural response w/ interfaces

Methodology

- ✓ Parallel-scalable contact algorithms for implicit & explicit



“concentric cylinders”

Nonlinear materials, frictional (Coulomb) contact

10^6 element hex model solution on Thunderbird (4480 Dual 3.6 GHz Intel EM64T processors, 6 GB RAM)		
# slip updates	256 Procs Min:Sec (Itr)	512 Procs Min:Sec (Itr)
1	32:28 (279)	17:18 (182)
2	27:11 (184)	14:33 (194)
3	21:14 (140)	12:10 (140)

SIERRA_SolidMechanics :
Interface Problems

Application areas

- ✓ Tire performance

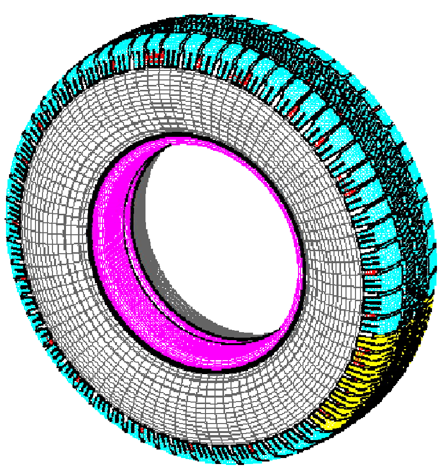
Objective

- ✓ Validated footprint prediction

Methodology

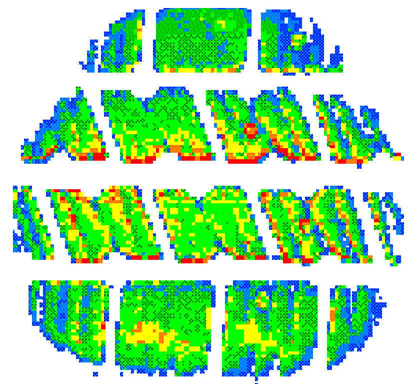
- ✓ Algorithms for frictional energy dissipation

Nonlinear incompressible materials, frictionless & frictional contact



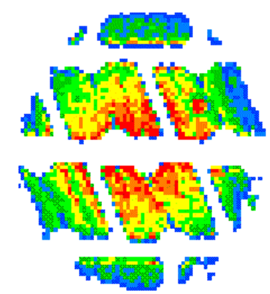
“tire footprint”

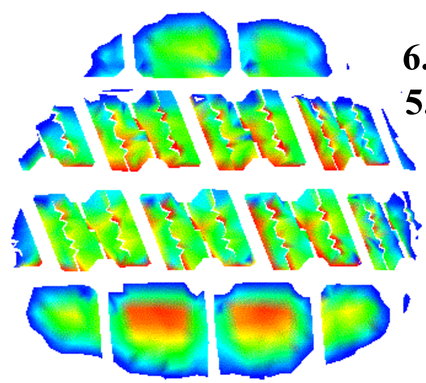
Front Tire	**Rear Tire**
50 psi / 1425 lb / 0.75° camber / 1.07° slip	80 psi / 670 lb



Experimental

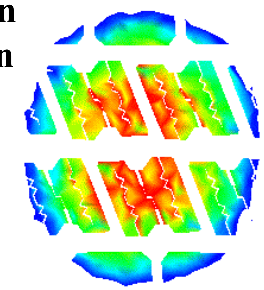
6.5 in < FL > 4.2 in
6.5 in < FW > 4.6 in
1.51 < FSF > 1.82

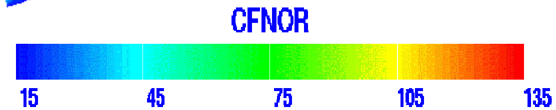




Calculated

6.69 in < FL > 3.99 in
5.97 in < FW > 4.65 in
1.49 < FSF > 1.50





SIERRA_SolidMechanics :
Energy absorbing impacts

Application areas

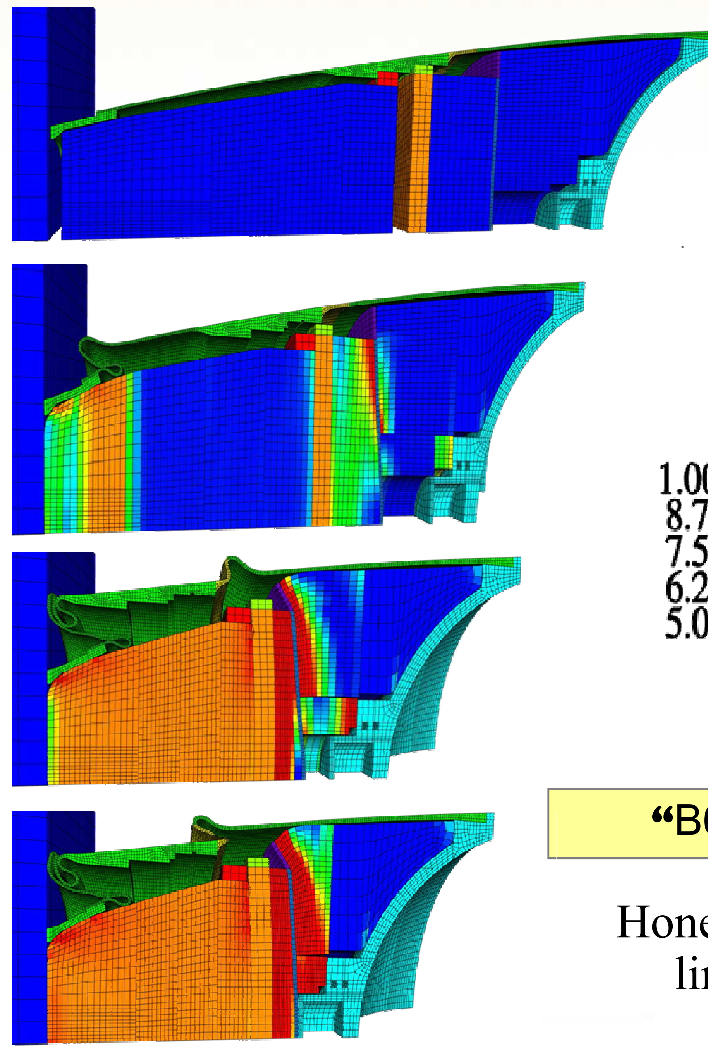
- ✓ Impact limiter design

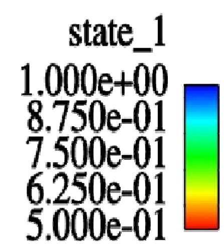
Objective

- ✓ Modeling large deformation impacts & Internal energy dissipation

Methodology

- ✓ Honeycomb plasticity model, impact, contact frictional energy





"B61 head-on"

Honeycomb impact limiter model

SIERRA_SolidMechanics : Energy absorbing impacts

Application areas

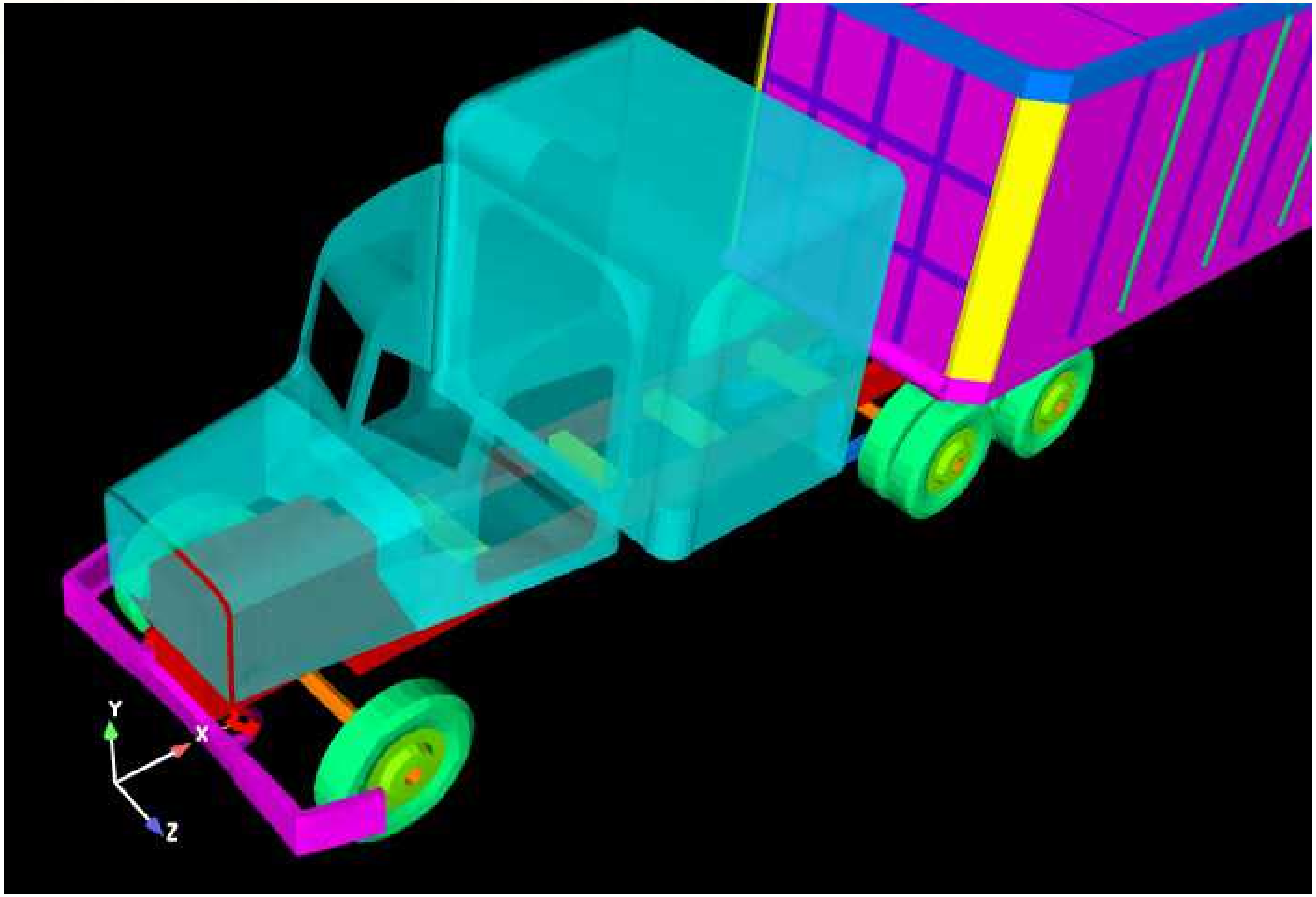
- ✓ Crash simulations

Objective

- ✓ Modeling large deformation impacts

Methodology

- ✓ Parallel scalable self-contact algorithm for shells, hexes, beams,…



“truck-trailer head-on”

Shell, hex & beam model
Impact velocity = 55 mph

SIERRA_SolidMechanics : Nodal-Tet/AutoRemeshing

Application areas

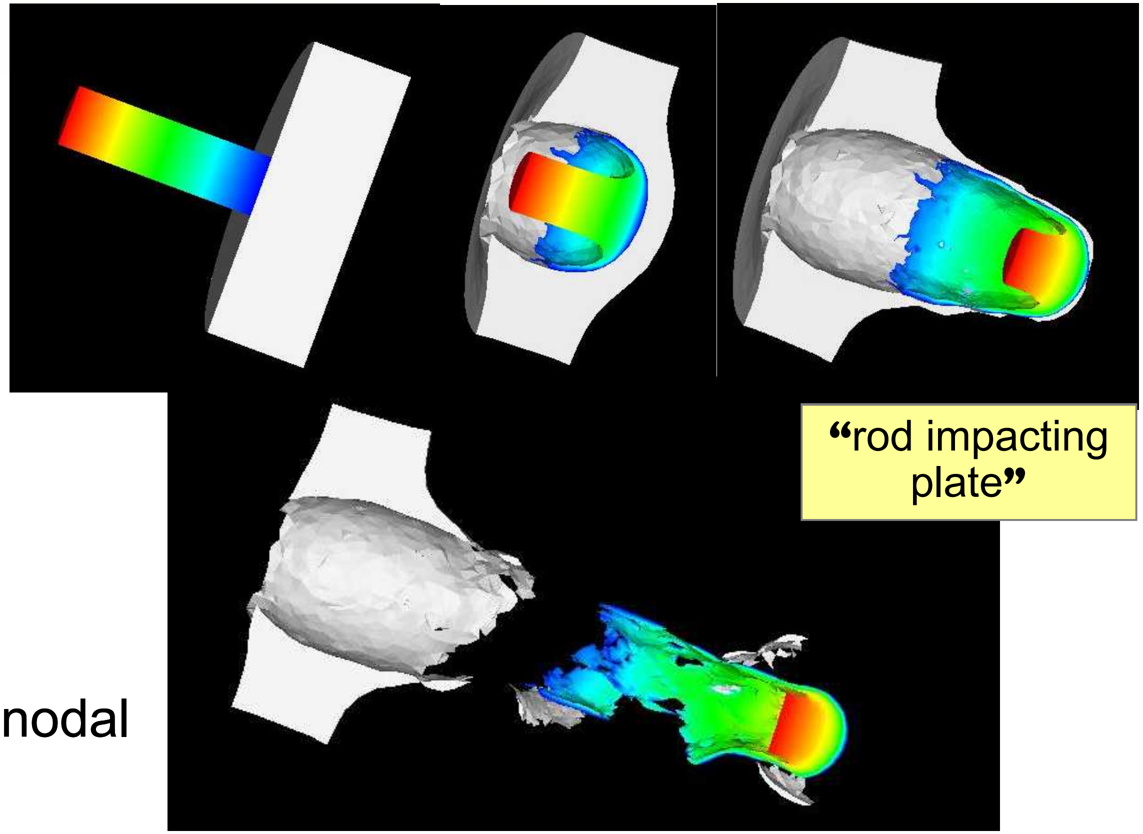
- ✓ Ballistic penetration
- ✓ Metal forming
- ✓ Snow-mud traction

Objective

- ✓ Modeling dynamic events where solid materials undergo extreme deformation with large plastic flow

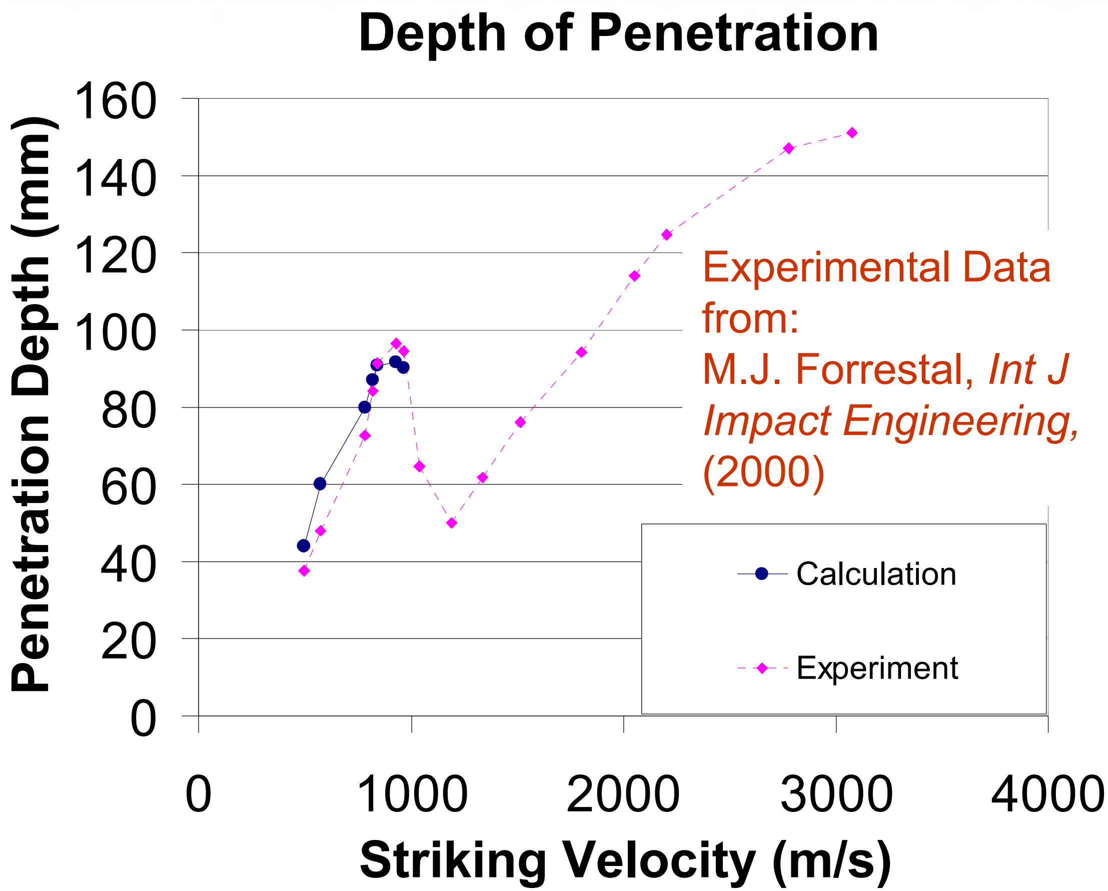
Methodology

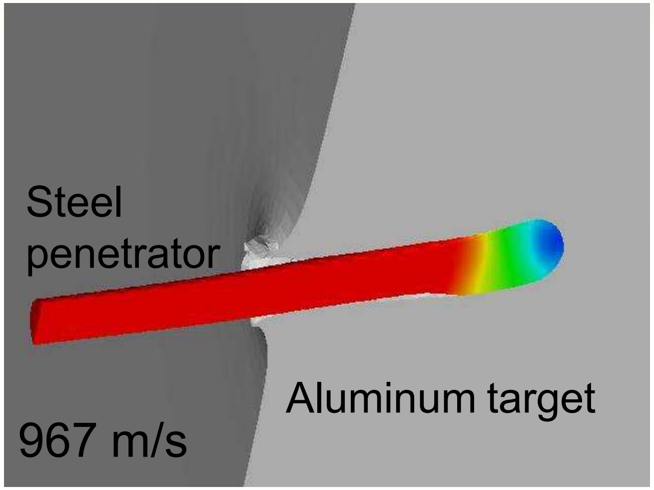
- ✓ non-locking low order nodal tetrahedral element
- ✓ Deformation induced automatic remeshing, w/ minimal state advection

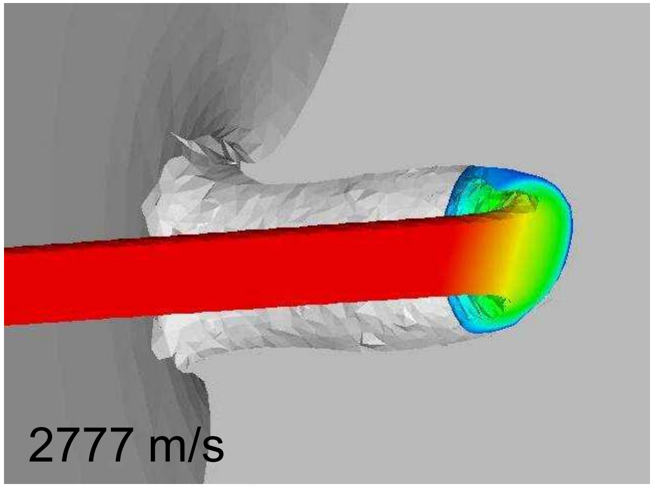


Tungsten rod, steel plate,
Impact velocity = 2500 m/s

SIERRA_SolidMechanics :
Nodal-Tet/AutoRemeshing







SIERRA_SolidMechanics : Particle methods

Application areas

- ✓ High-speed impacts, fluid dispersal

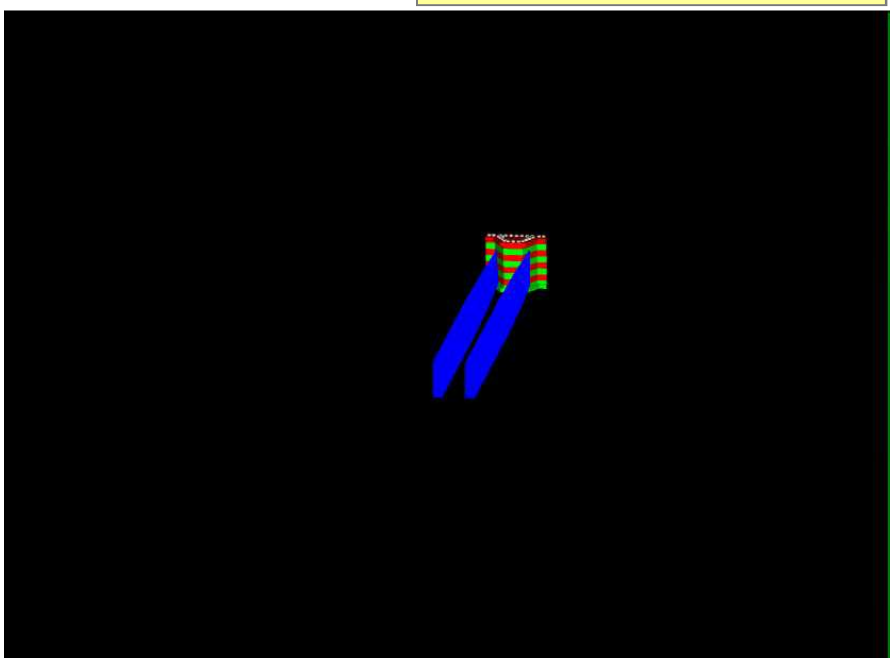
Objective

- ✓ momentum transfer to other structures

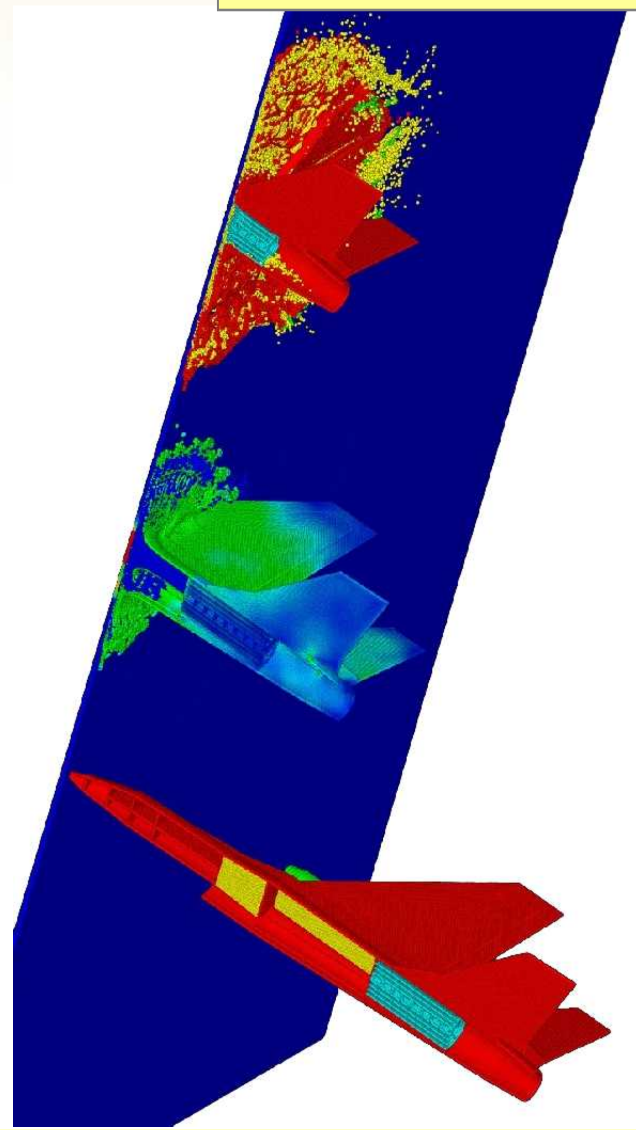
Methodology

- ✓ SPH

"water sled"

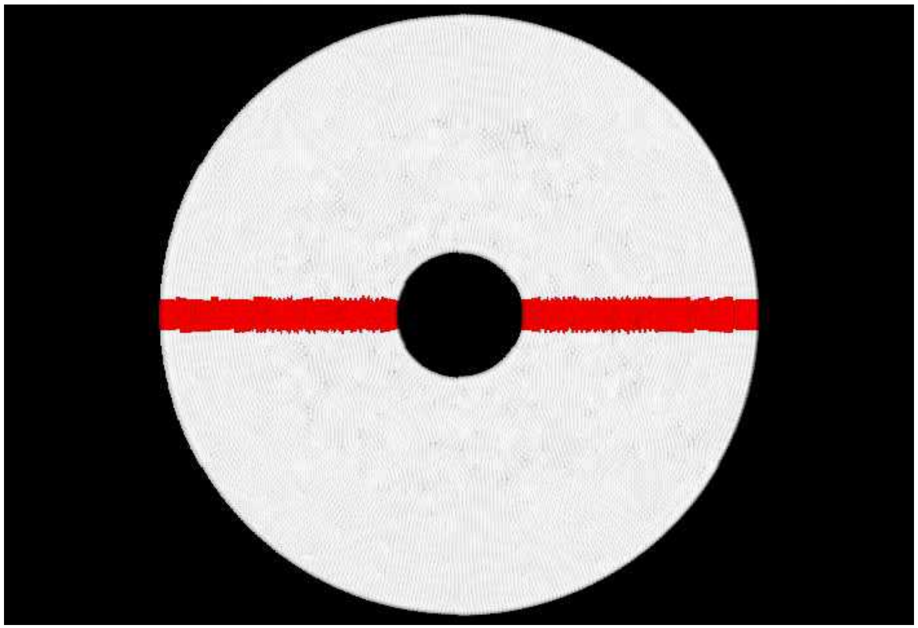


"F16-impact"

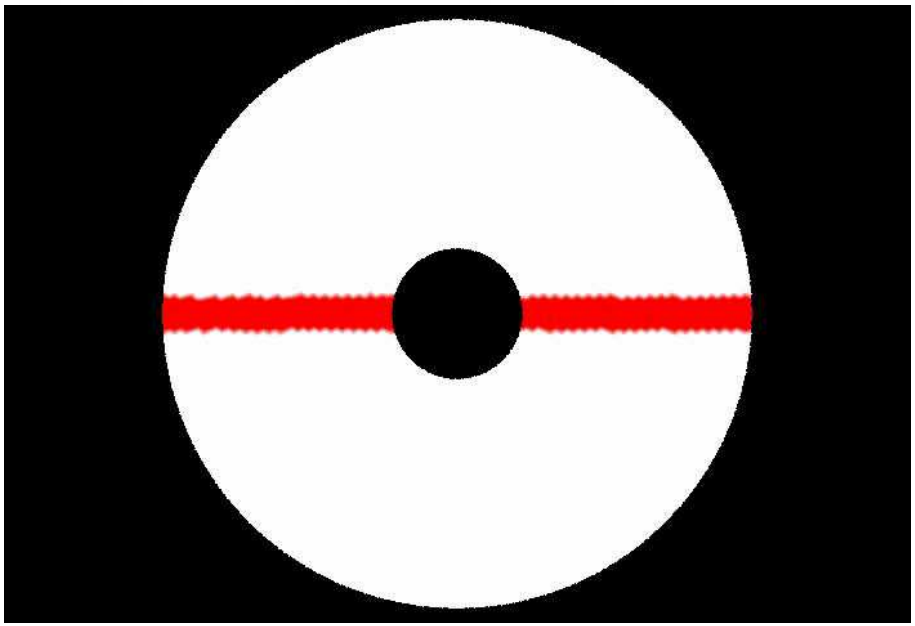


SIERRA_SolidMechanics :
Particle methods or NBTet remeshing ?

"viscous disc"



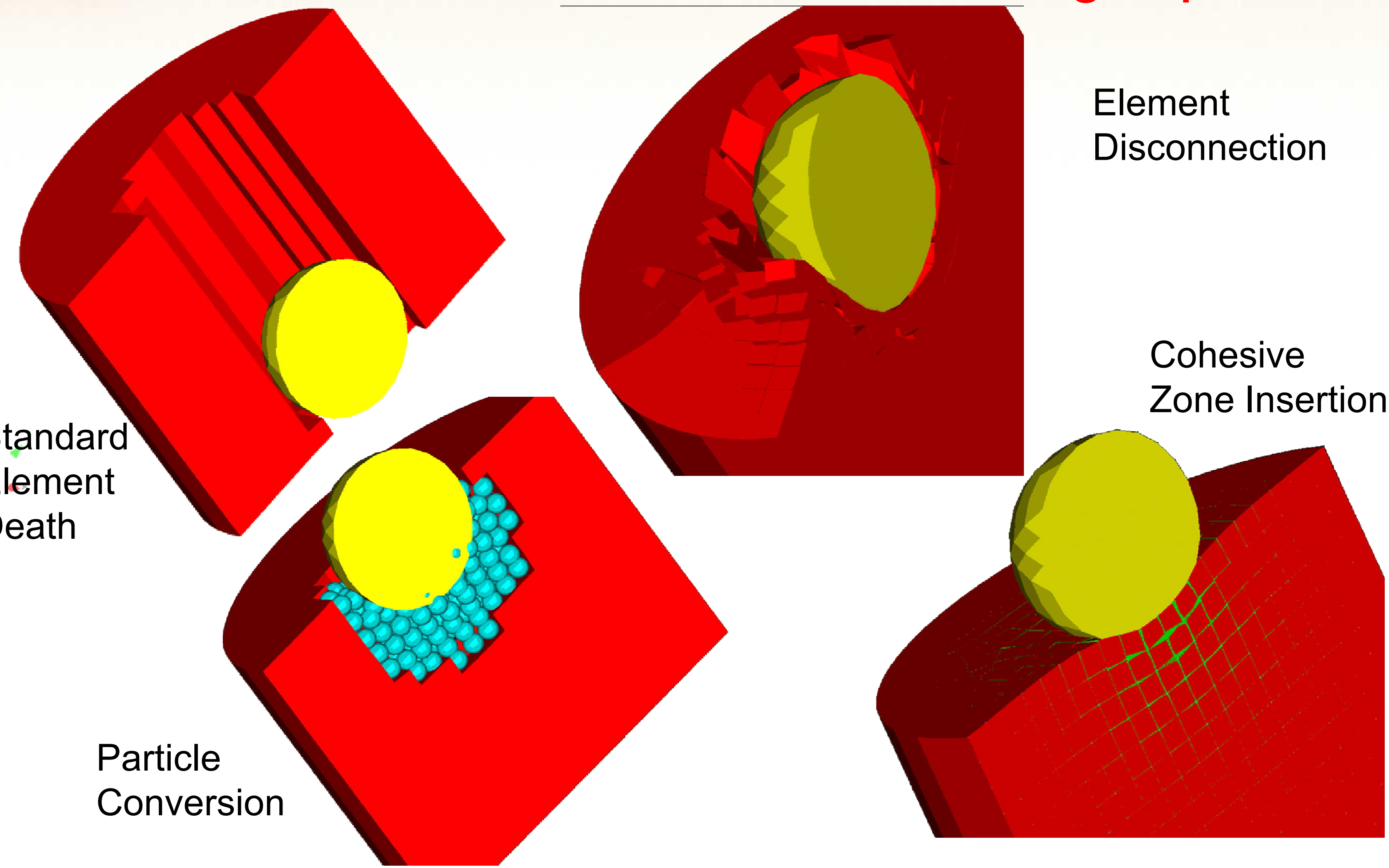
SPH



NBTet-remeshing

NBTet remeshing is preferred over SPH for large shearing deformation where material response is critical

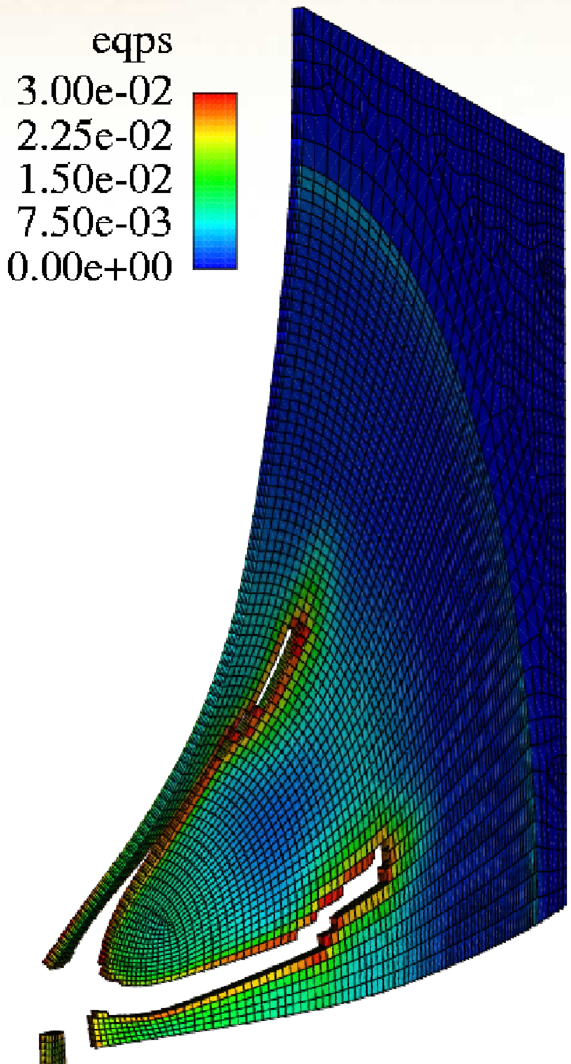
SIERRA_SolidMechanics :
General Pervasive failure modeling capabilities



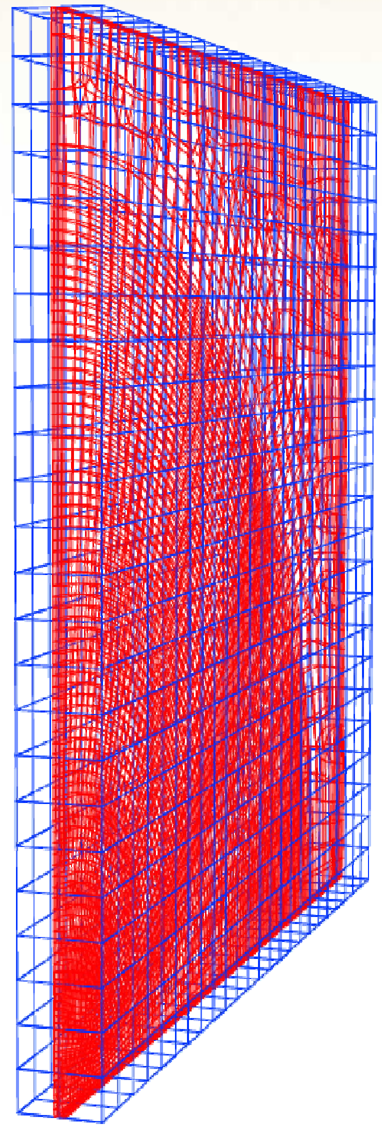
SIERRA_SolidMechanics :
Multi-scale failure modeling

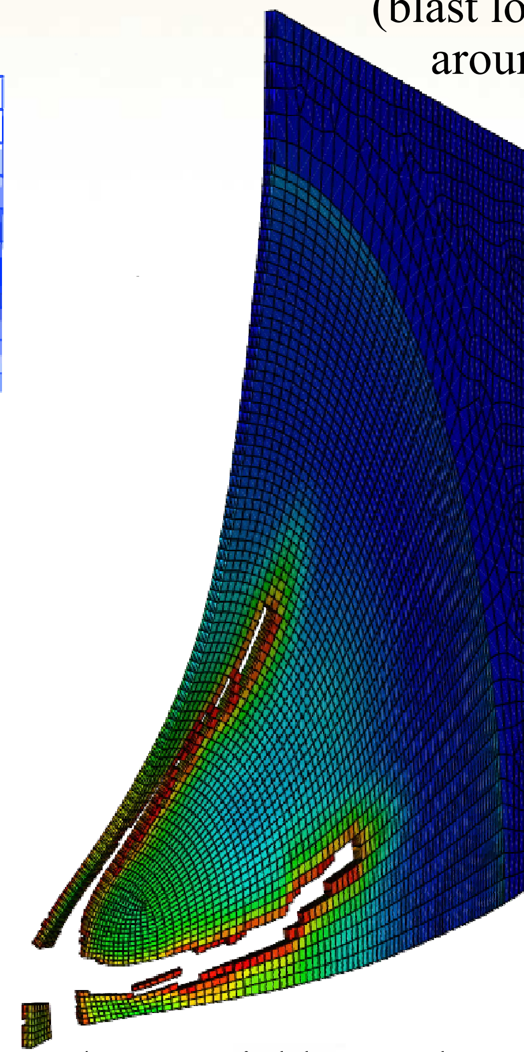
" ¼-plate "

(blast loaded, fixed around edge)



Solution w/o ECM





w/ ECM yields a 4x larger timestep

SIERRA_SolidMechanics :
Quasistatic/Implicit failure modeling

Application areas

- ✓ Brittle & ductile failure

Objective

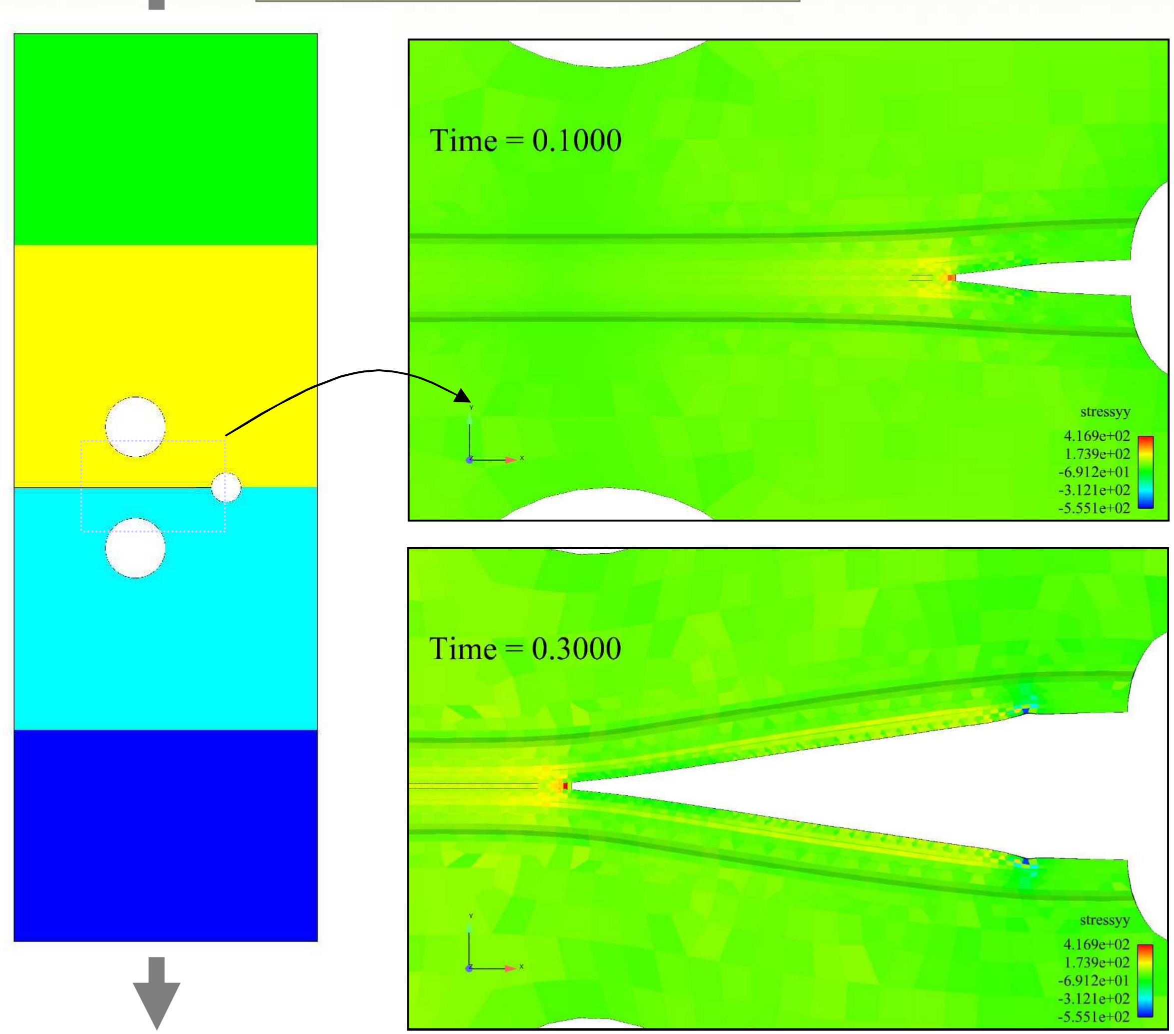
- ✓ Converged

Methodology

- ✓ Multi-level solution control (1 element death per "Newton" update)

QS loaded, Multi-linear elastic-plastic model, coupon is pre-cracked

" 3-hole tension test "

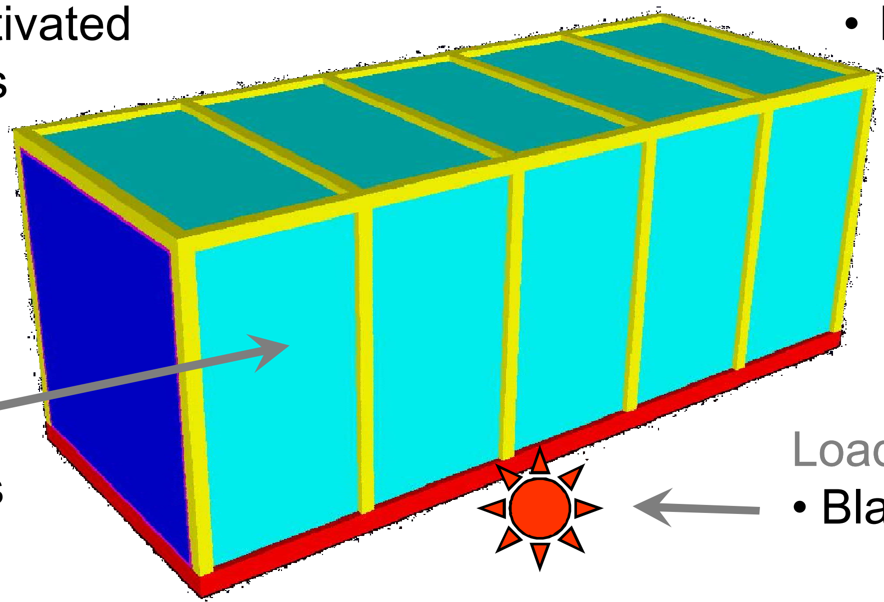


SIERRA_SolidMechanics :
General Pervasive failure modeling capabilities

“5-panel box / blast”

Fracture Methods:
- Element Death with Particle Conversion
- Dynamically Activated Cohesive Zones

Advanced Methods:
- Tet Remeshing
- Explicit Control Modes

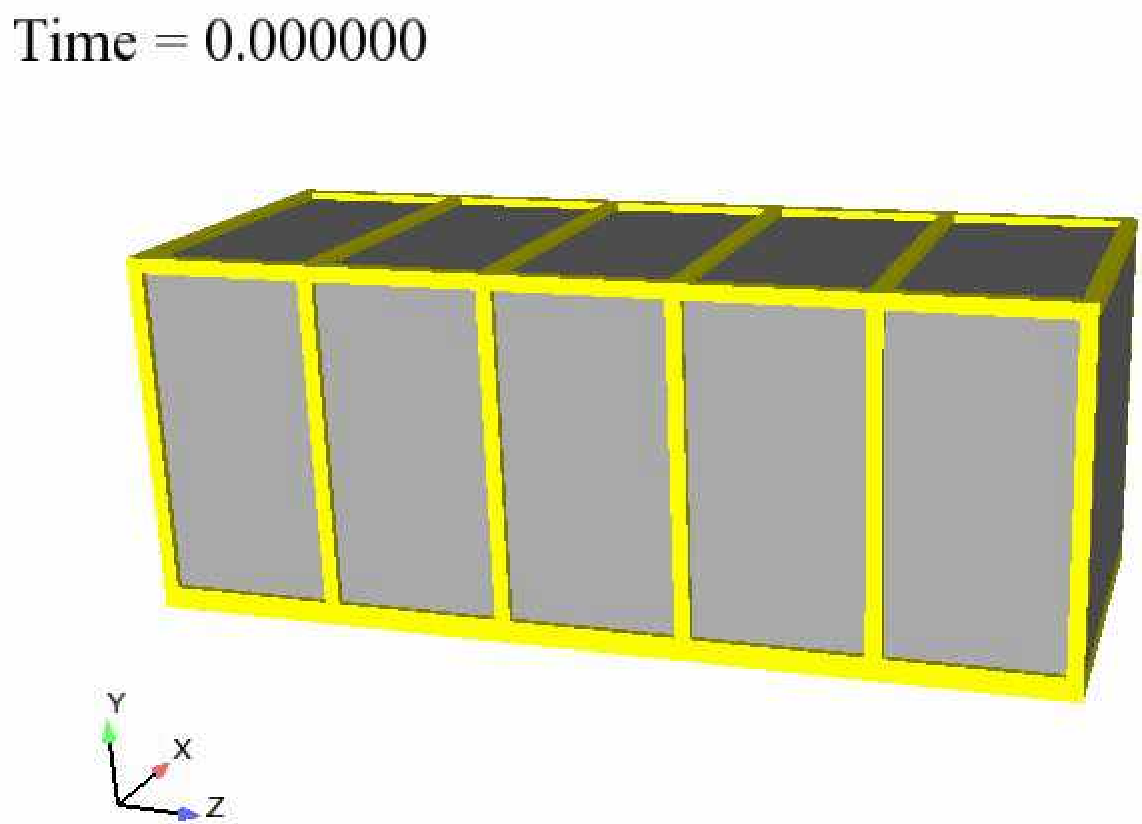


Elements:
- Hexes
- Nodal-based tets
- Shells

Loading:
- Blast Pressure (Conwep)

SIERRA_SolidMechanics :
General Pervasive failure modeling capabilities

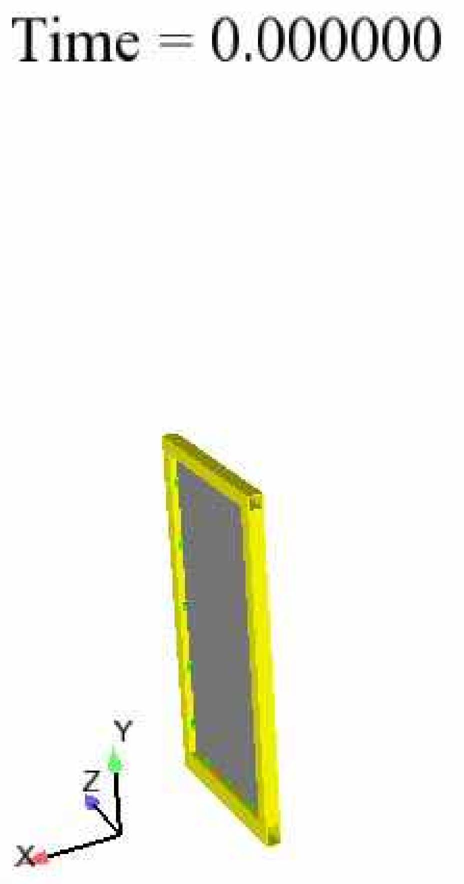
"5-panel box / blast"



SIERRA_SolidMechanics :

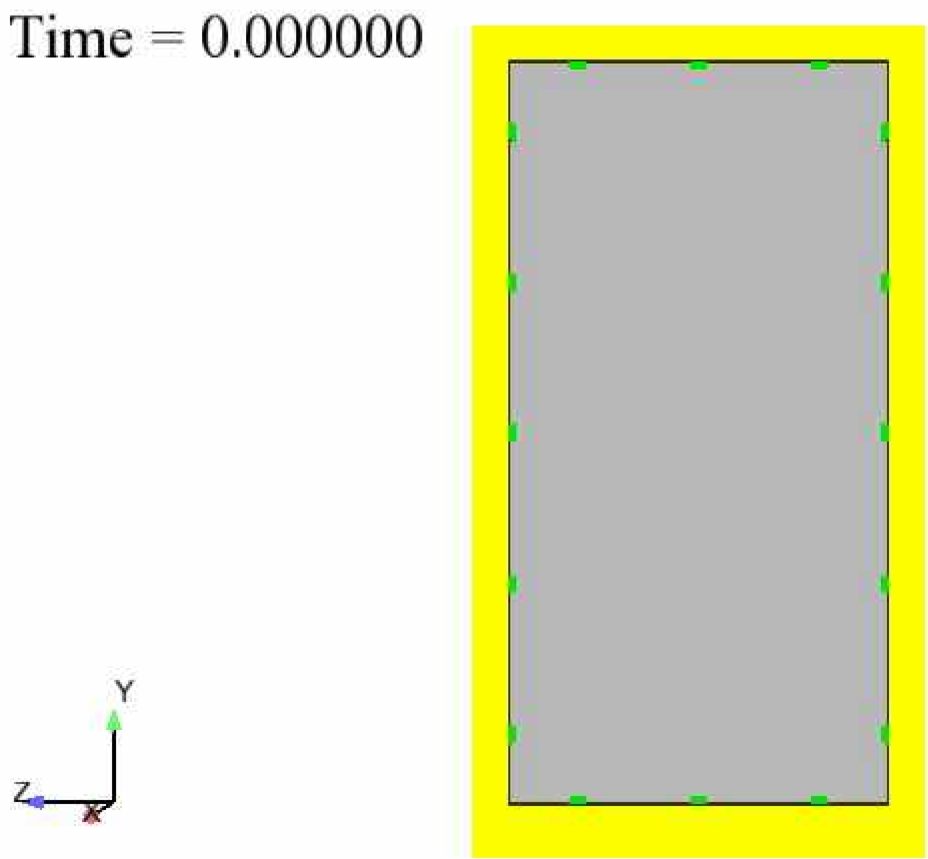
General Pervasive failure modeling capabilities

"single-panel / blast"

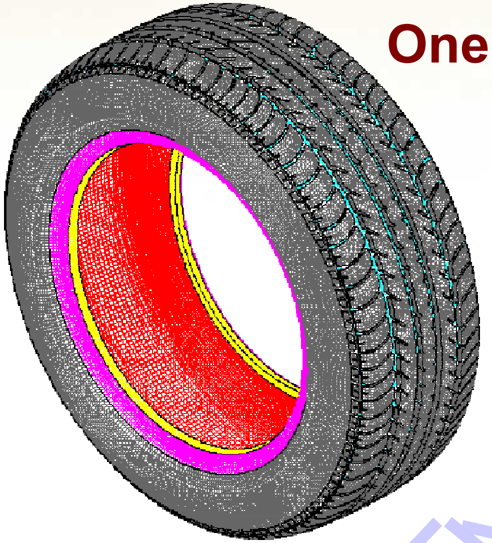


SIERRA_SolidMechanics :
General Pervasive failure modeling capabilities

"single-panel / blast"

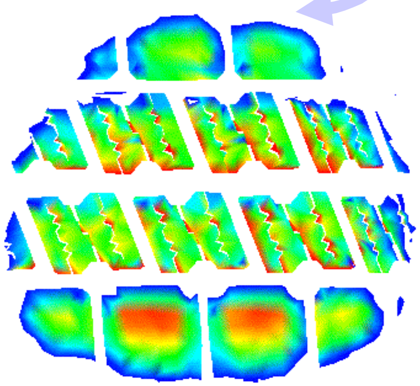


SIERRA_SolidMechanics :
SolidMechanics transfers

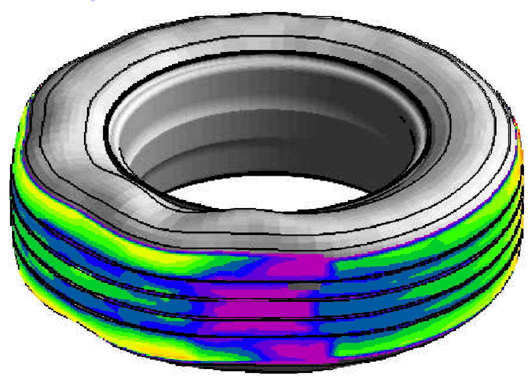


One Tire "reference" mesh
…Many analyses
(using variety of algorithms & transfer operators)

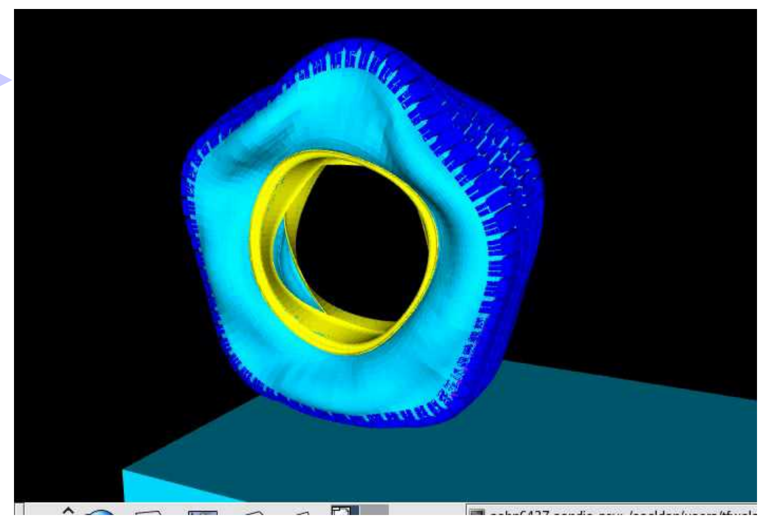
- Quasistatic Inflate-deflect (parked tire footprint)
- Steady State Rolling (handling characteristics)
- Quasistatic Rolling (wear prediction)
- High-speed Dynamic Rolling (dynamic effects)
- Modal analysis of a parked tire



QS-ID (footprint)



LHSR (frictional energy loss, standing waves)

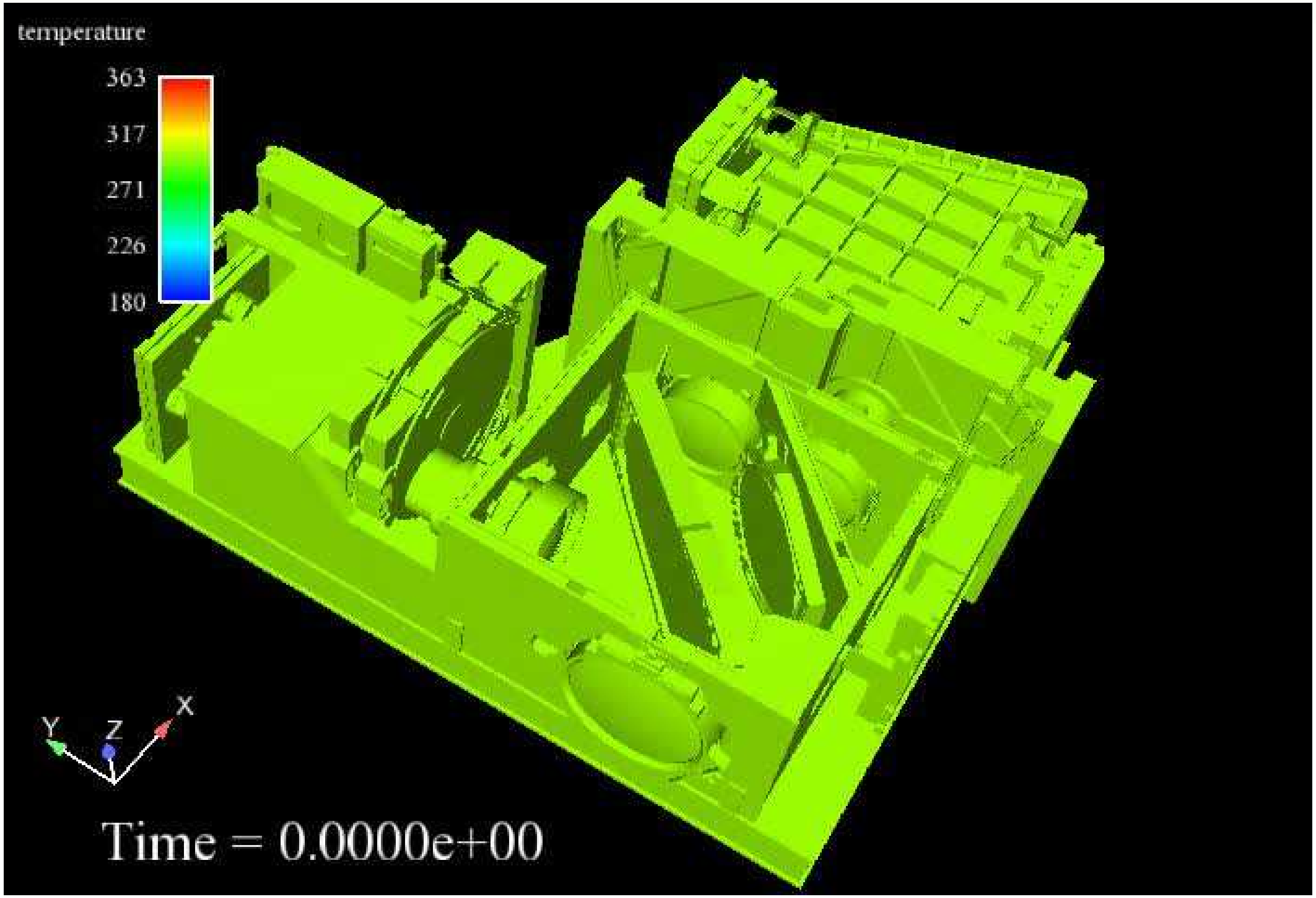


Modes (→ modal reduction)

SIERRA_SolidMechanics : Thermal Structural Response

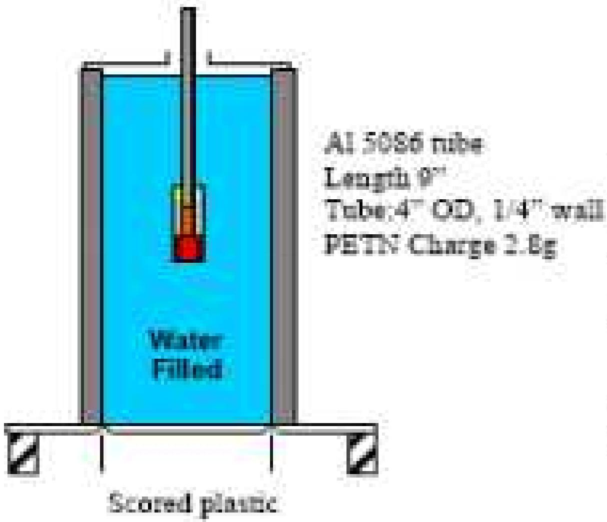
HIFES satellite in "hot" orbit

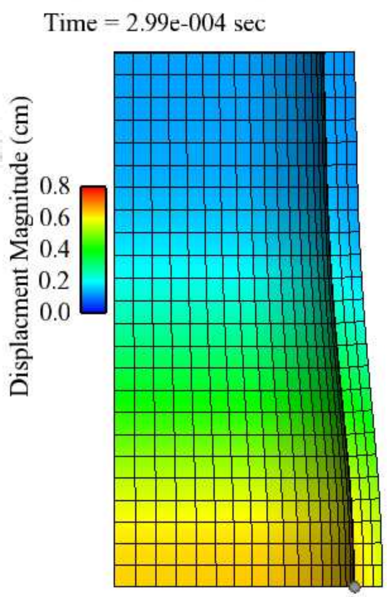
Modeled w/ NBTet



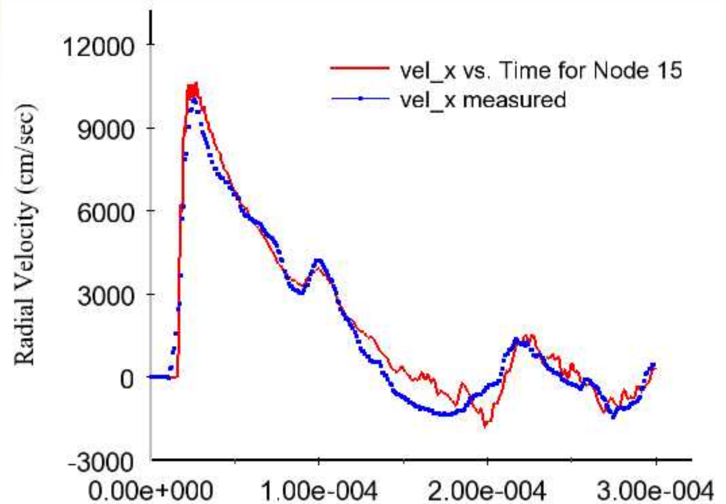
SIERRA_SolidMechanics :
Fluid Structure Interaction

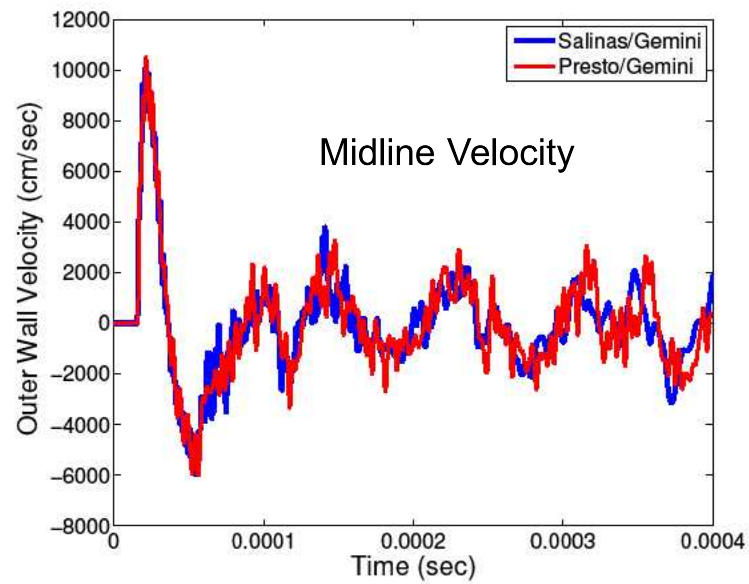
Water filled cylinder with a charge of PETN detonated.





Elastic-Plastic Aluminum Model
(Rate Independent/Power Law Hardening)





[2] G. Champers, et al. Pressure measurements on a deforming surface in response to an underwater explosion. *Shock Compression of Condensed Matter*, Ed. Schmidt, Dandekar, Forbes, American Institute of Physics, 1998.

SIERRA_SolidMechanics :
CTH hydrocode – ETD coupling

- Air-blast loading problems
- Approach: CTH (Eulerian) for blast, Presto for structural response
- 1-way coupling of Presto and CTH is complete
- 2-way coupling is being tested and verified; hydrobuldge test + plate response to explosives