SAND2019-2519PE

Computational Simulations at Sandia National Laboratories

PRESENTED BY

Scott T. Miller, Ph. D.

Computational Solid Mechanics & Structural Dynamics

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Overview

Sandia National Laboratories Overview

Engineering Sciences Center

Computational Simulation Group

Computational Solid Mechanics & Structural Dynamics

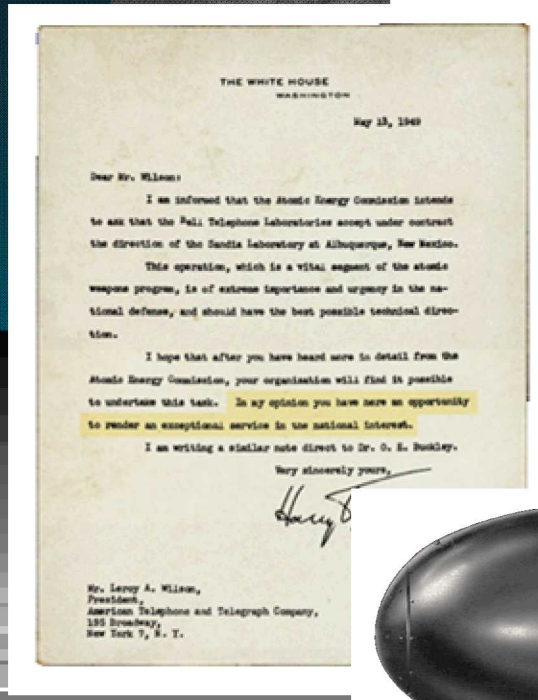
Research Topics:

- Inverse problems
- Blast-Induced Traumatic Brain Injuries
- Very large problems in structural dynamics

SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

…In my opinion you have here an opportunity to render an exceptional service in the national interest.

- July 1945
  Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949
  Sandia Laboratory established
- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–2017
- Honeywell: 2017–present



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

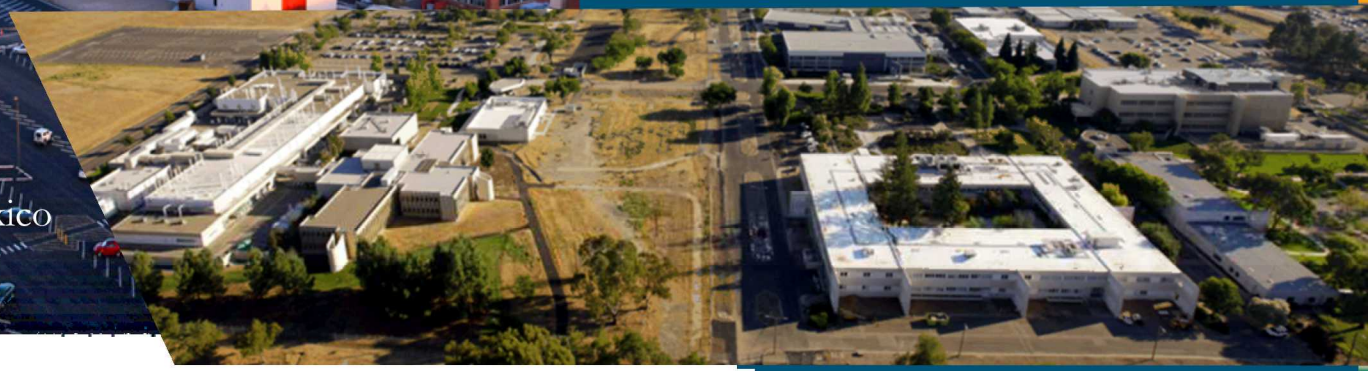
Very sincerely yours,

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

SANDIA HAS FACILITIES ACROSS THE NATION

Activity locations

- Kauai, Hawaii
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Tonopah, Nevada



Main sites

- Albuquerque, New Mexico
- Livermore, California

PURPOSE STATEMENT DEFINES WHAT WE DO

Sandia's Current Nuclear Weapons Activities

esign Agency for

Ga
Trans
Systems

Safety Systems

Arming, Fuzing, and Firing Systems

An extensive suite of multi-disciplinary capabilities are required for Design, Qualification, Production, Surveillance, Experimentation / Computation

MESA Microelectronics

Major Environmental Test Facilities and Diagnostics

Z Machine

Light Initiated High Explosive

Annular Core Research Reactor

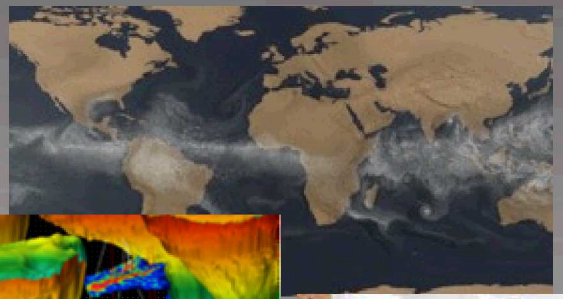
Energy

Energy Research

ARPAe, BES Chem Sciences, ASCR, CINT, Geo Bio Science, BES Material Science

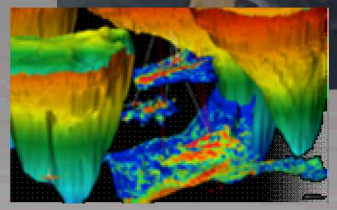
Climate & Environment

Measurement & Modeling, Carbon Management, Water & Environment, and Biofuels



Nuclear Energy & Fuel Cycle

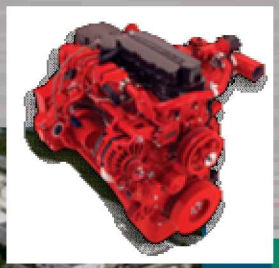
Commercial Nuclear Power & Fuel, Nuclear Energy Safety & Security, DOE Managed Nuclear Waste Disposal



Renewable Systems & Energy Infrastructure

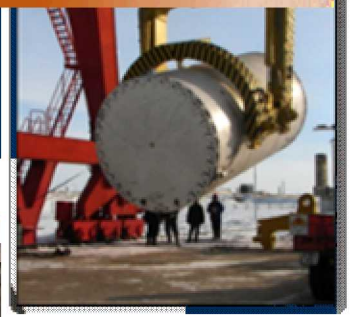
Transportation Energy & Systems

Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology



Global and Homeland Security

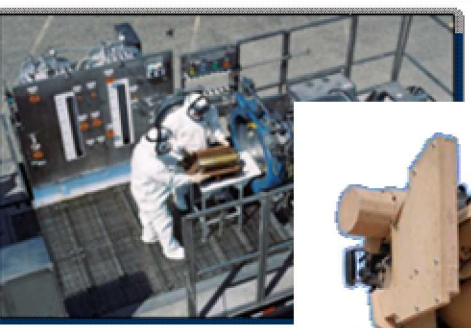
Global Security

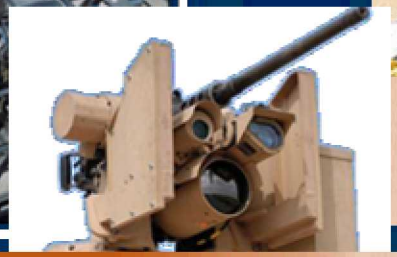


Homeland Security Programs

WMD Counterterrorism and Response

Cyber and Infrastructure Security



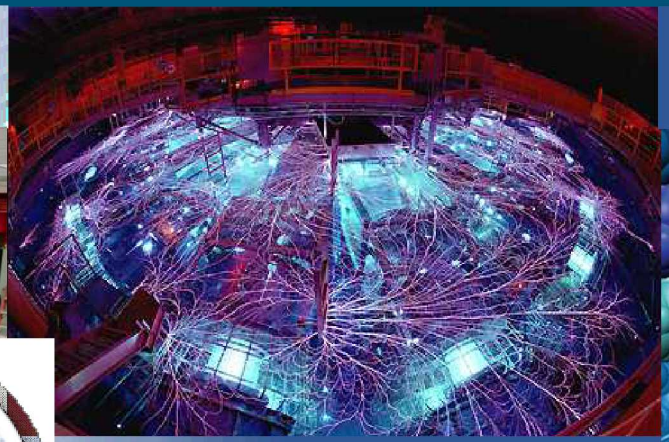


Homeland Defense and Force Protection

Our Research Framework

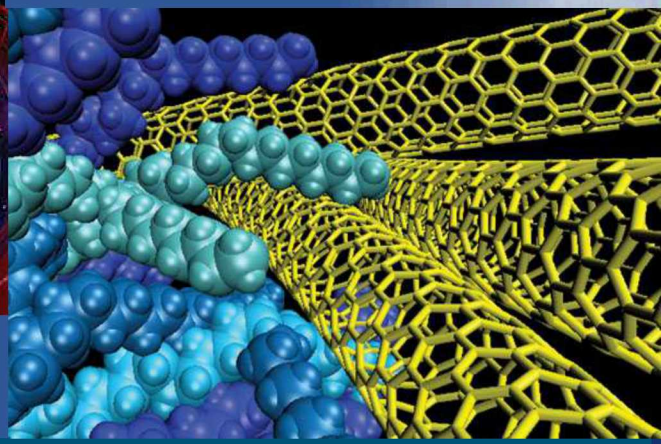
Strong research foundations play a differentiating role in our mission delivery

Computing & Information Sciences

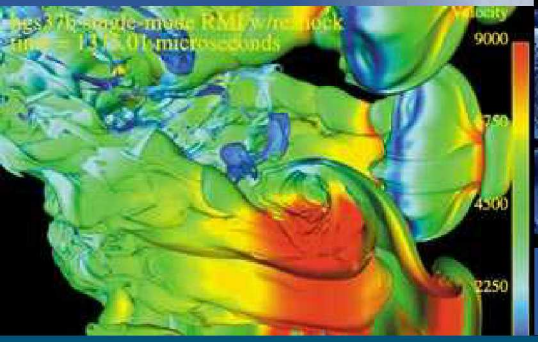


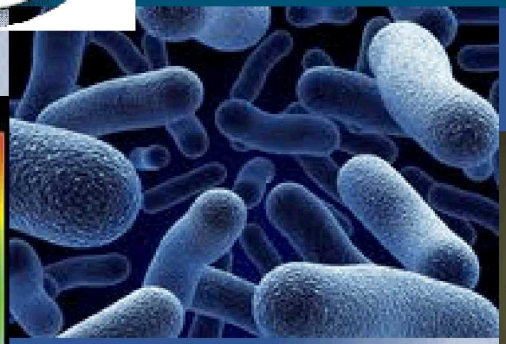
Radiation Effects & High Energy Density Science

Materials Sciences



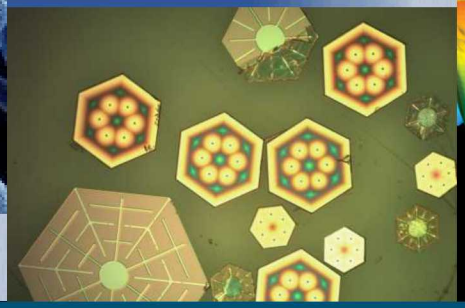
Engineering Sciences

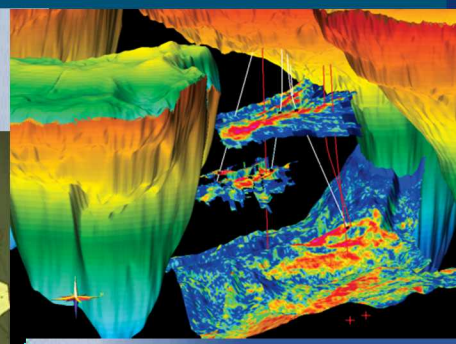




Bioscience

Nanodevices & Microsystems



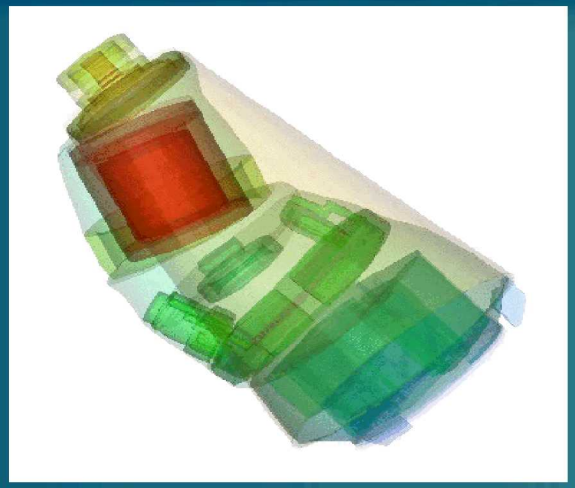


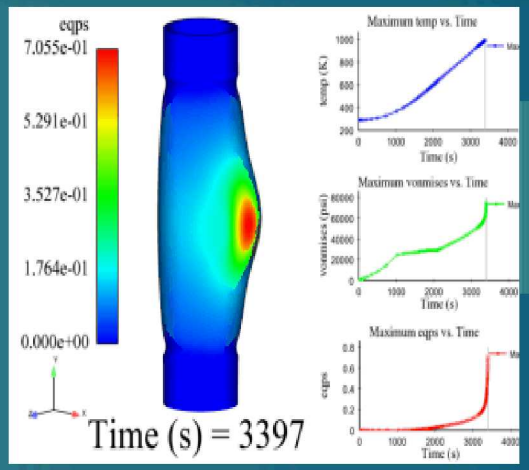
Geoscience

Engineering Sciences as The Capability Steward

Integrated theory, computational simulation, and experimental discovery/validation across length and time scales is critical to develop the technical basis for complex engineered systems.

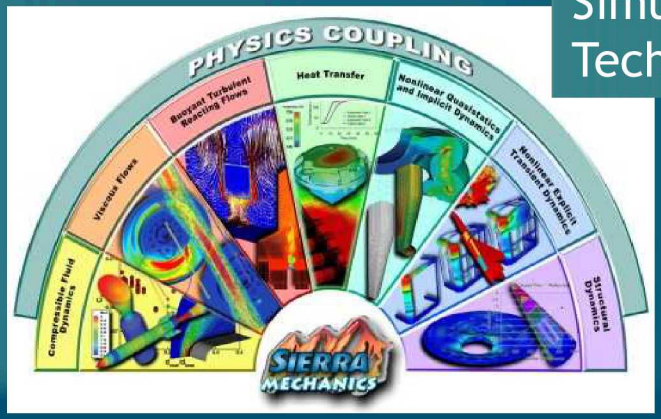
Engineering Analysis





Engineering Science Physical Phenomena

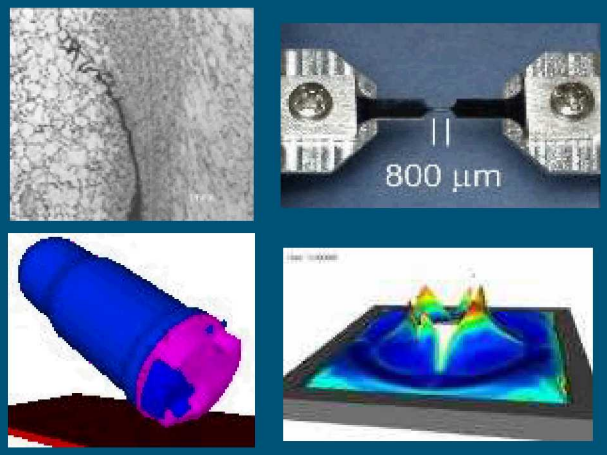
Environmental Simulation & Test



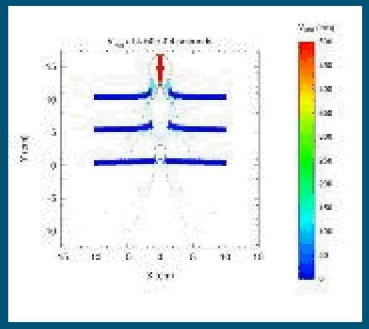
Computational Simulation Technology

Engineering Sciences Core Technical Areas

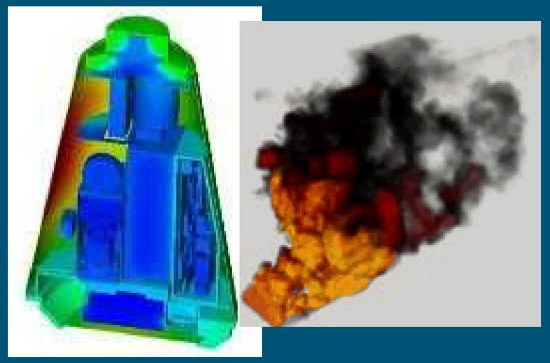
Solid Mechanics



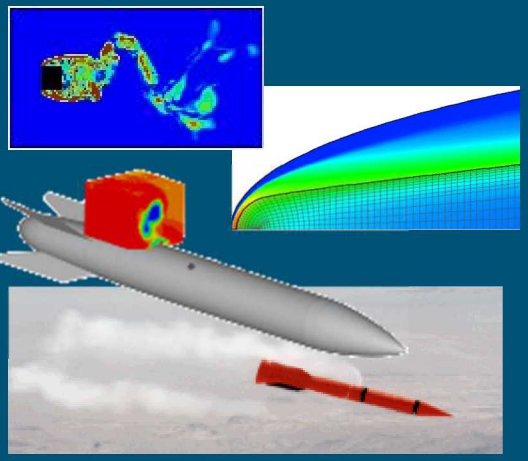
Shock Physics and Energetics



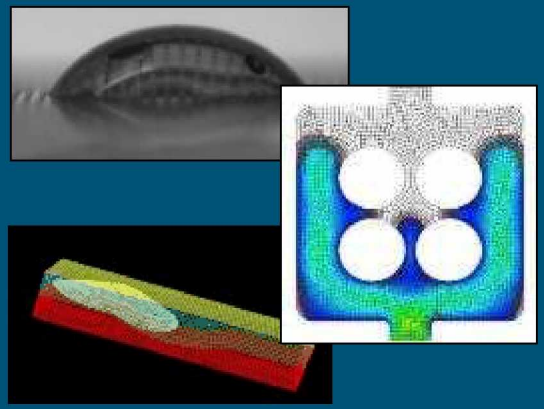
Thermal & Fire Sciences



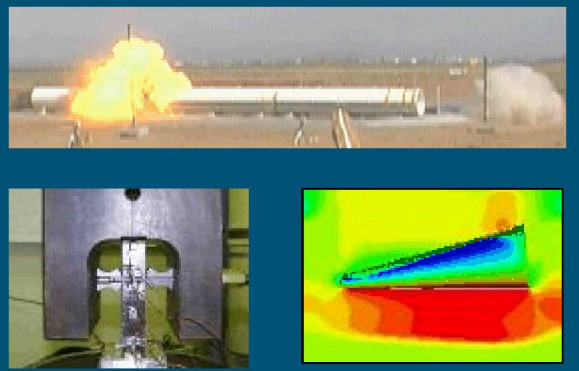
Aerosciences



Fluid Mechanics

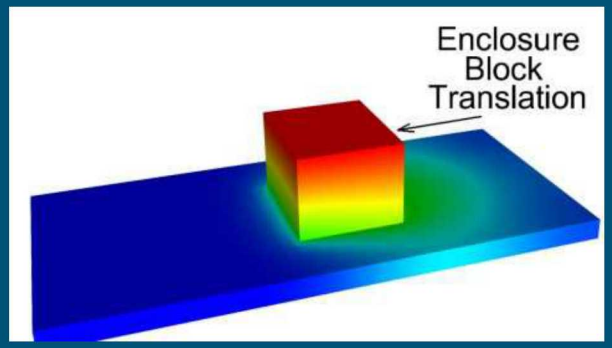


Structural Dynamics

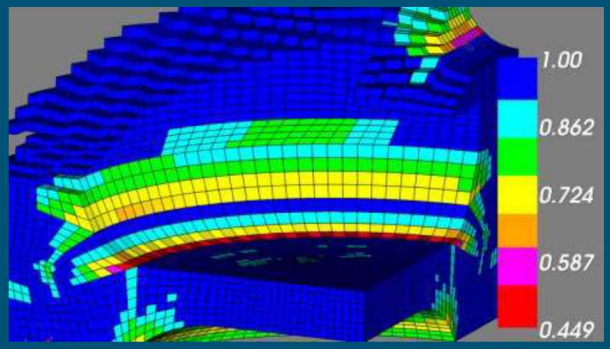


Engineering Sciences Video

Computational Simulation Group

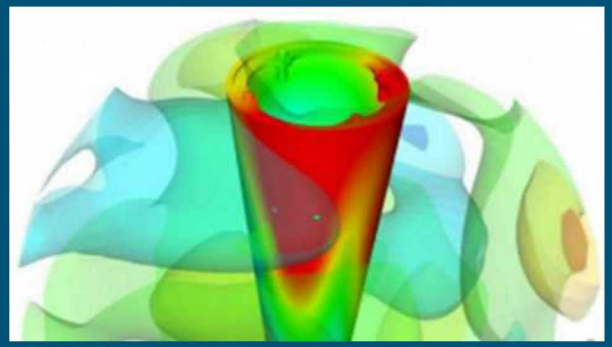


Computational Thermal And Fluid Mechanics

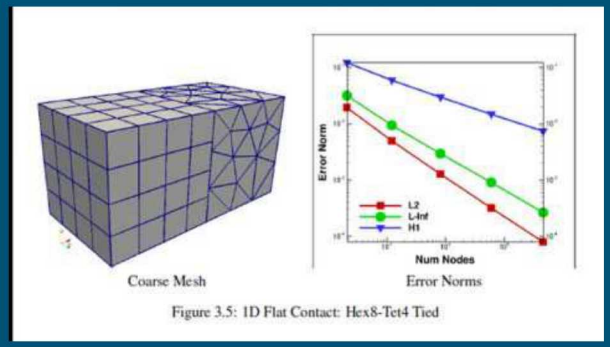


Simulation Modeling Sciences

Computational Simulation Infrastructure



Computational Solid Mechanics And Structural Dynamics



V&V, UQ, Credibility Processes

Computational Solid Mechanics

Solid Mechanics – Quasi-static, implicit & explicit transient dynamic

Shared capabilities

- large deformations, large-strain nonlinear material behavior
- implicit-explicit solution switching, multi-sequence analyses
- continuum & structural finite elements, particle methods
- parallel scalable frictional contact
- geometric and temporal multi-scale methods
- coupled thermal-mechanical modeling, with failure

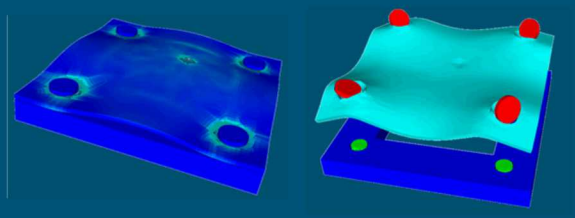
Implicit Solid Mechanics

- preloads, encapsulation & cure, incompressible material behavior

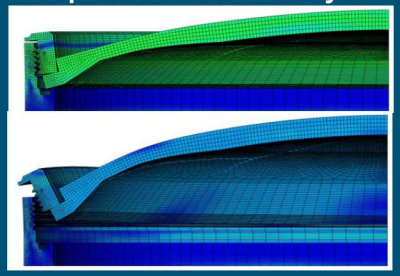
Explicit Solid Mechanics

- energy-dependent material models
- fracture & failure modeling (cohesive zones, XFEM, remeshing)
- empirical blast pressure loads (CONWEP)
- coupled to CTH shock-hydro (Zapotec), Alegra EM

Implicit→explicit switching



pressure & temperature loading
snap-thru & disassembly



2D XFEM Fracture Simulation

Computational Structural Dynamics

Structural Dynamics – Implicit Dynamics & Modal Response

Parallel Scalable Domain Decomposition Solver with many constraints

Shared mechanics capabilities

- small deformations, small-strain linear material behavior
- solid & structural elements, constraint elements
- non-linear pre-load transfer from Sierra/SM

Time domain, statics & transients

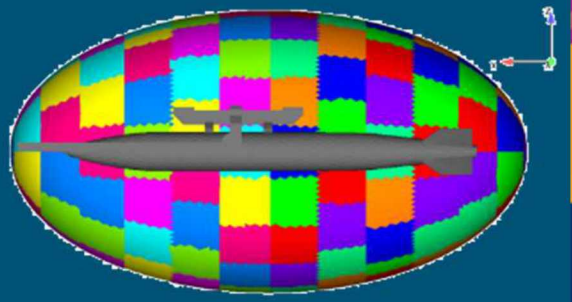
- joint models with dissipation
- material property inversion
- stochastic material (elastic) properties

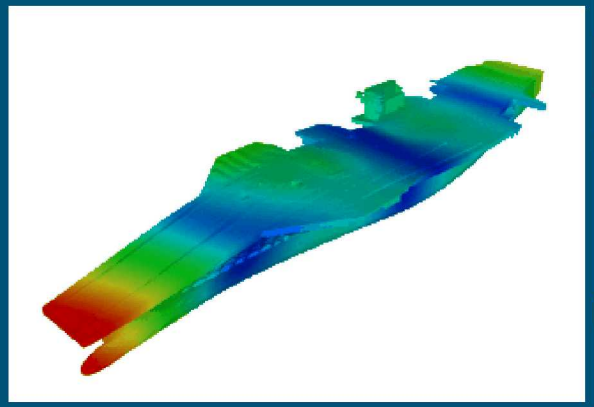
Frequency domain (Frequency Response Functions)

- Helmholtz solver for Direct FRF
- Modal FRF

Acoustics – linear

- absorbing boundaries
- acoustic pressure source inversion
- monolithic coupling with structural response





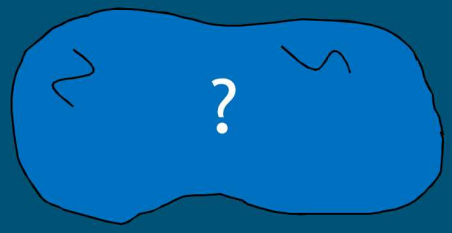
Inverse Problems: Observing the Unobservable

Inverse problems arise when we have partial information and indirect observations of a system and need to infer (hidden) quantities of interest of the system.

Can we *non-destructively* interrogate a black-box system to "see what is inside"?

Typical quantities of interest:

- Material properties
- Loads
- Boundary conditions
- Residual stresses
- Size/shape/location of inclusions (e.g. composite materials)



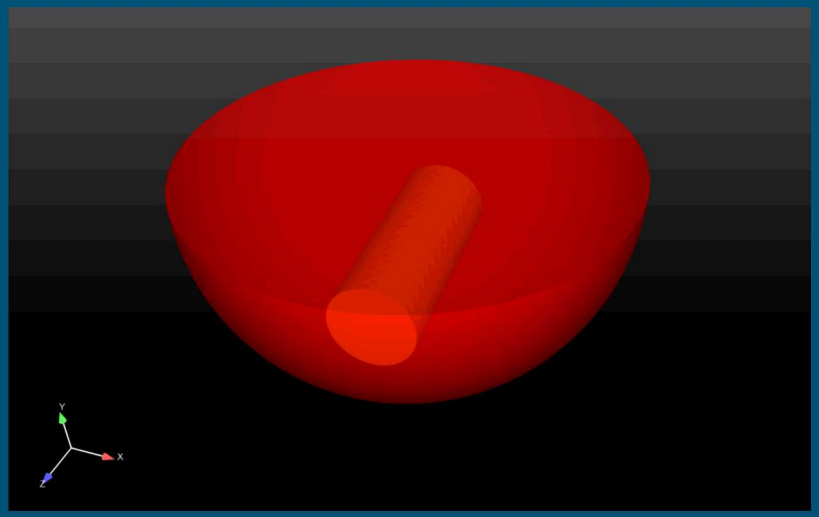
Applications include:

- Imaging: Medical ultrasound, seismic exploration (oil, gas)
- Calibration of material models and properties
- Force reconstruction
- Optimal experimental design, sensor locations
- Shape reconstruction

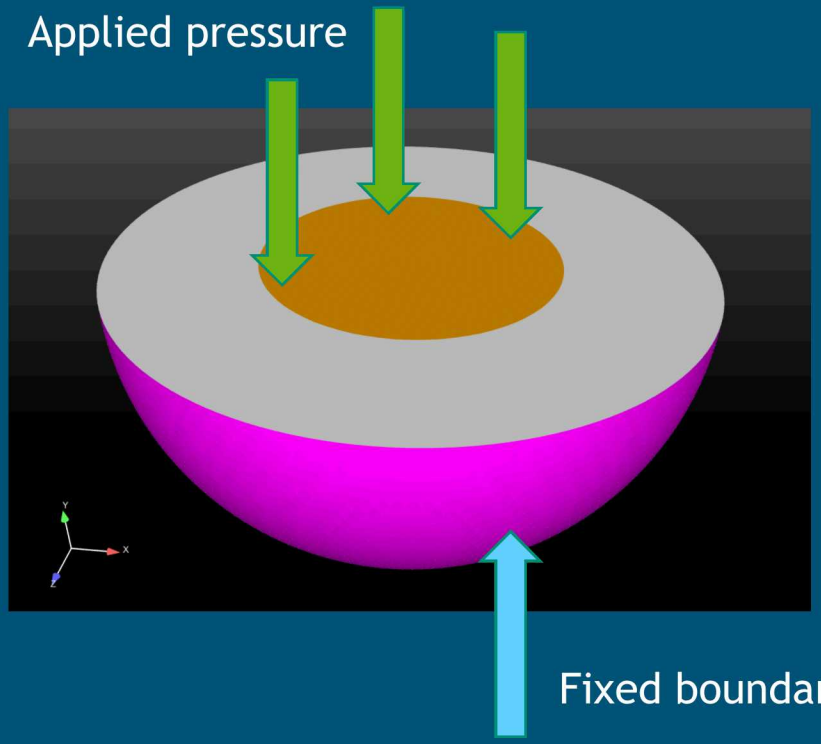
Inverse Methods: Seismic imaging

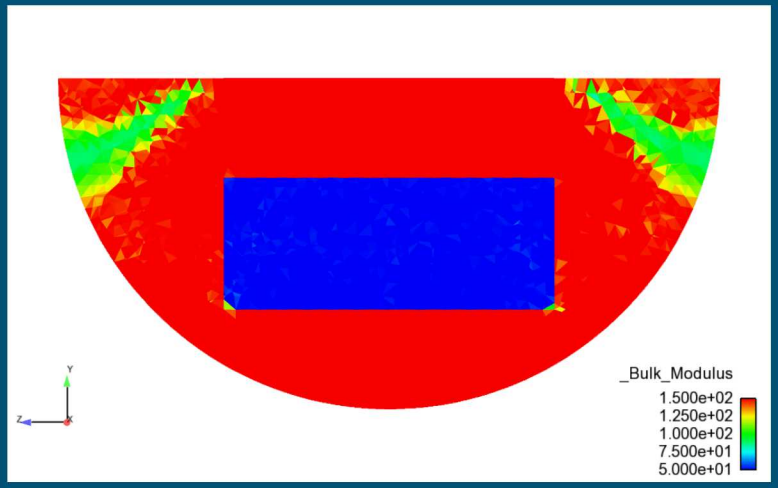
Goal: locate buried inclusion and surrounding material properties

Buried inclusion model



Applied pressure

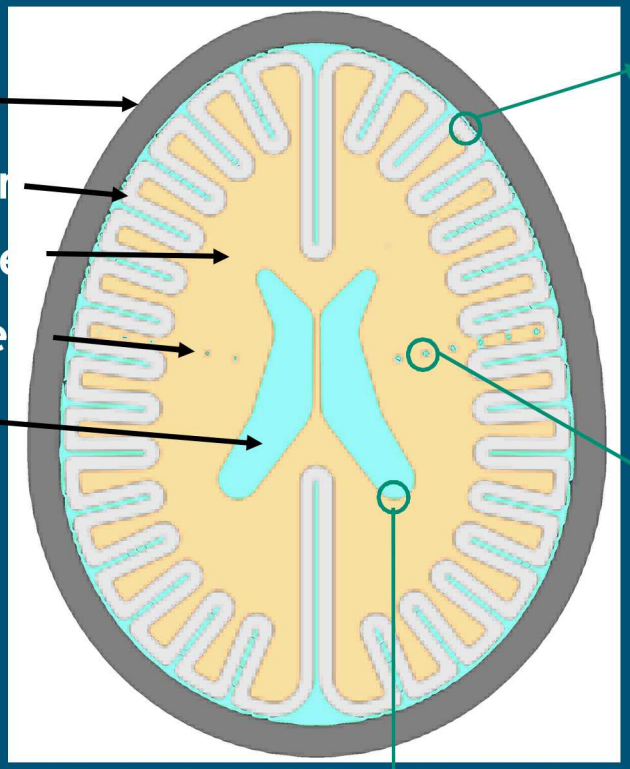


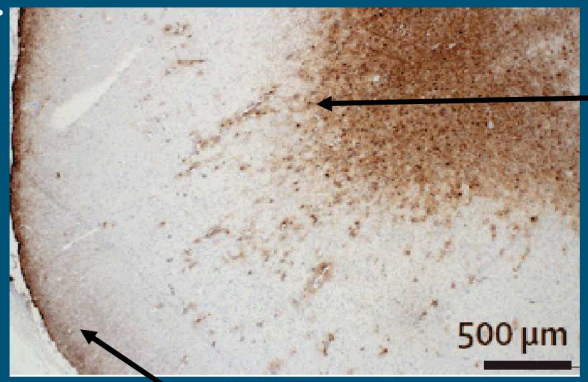


Inclusion identified in 30 iterations of inverse optimization!

Blast-Induced Traumatic Brain Injuries (bTBI)

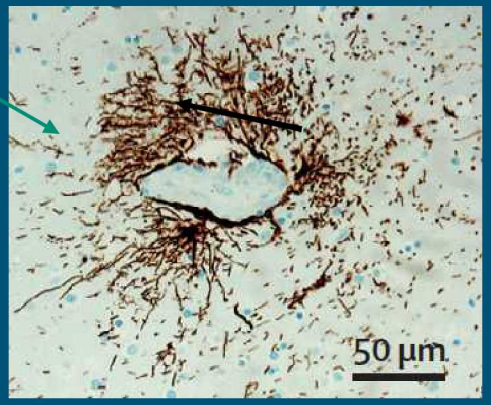
Unique neuropathological injury in bTBI :
interfacial injury



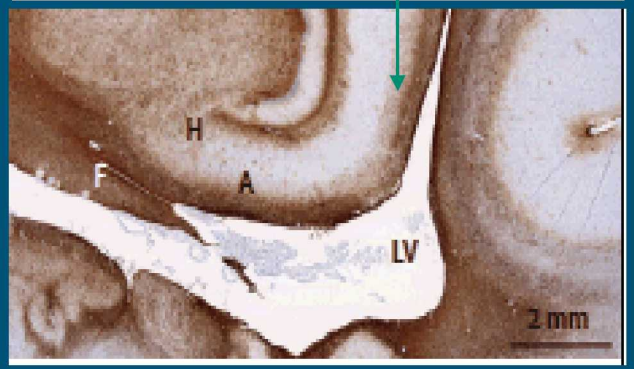


Gray-white

CSF – brain (sub-pial)

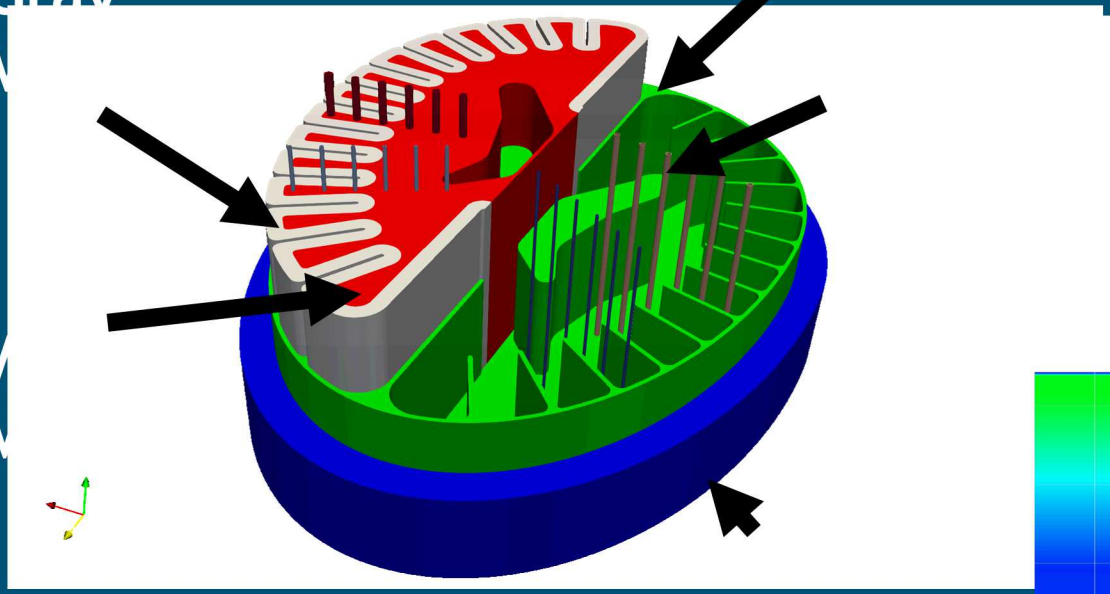


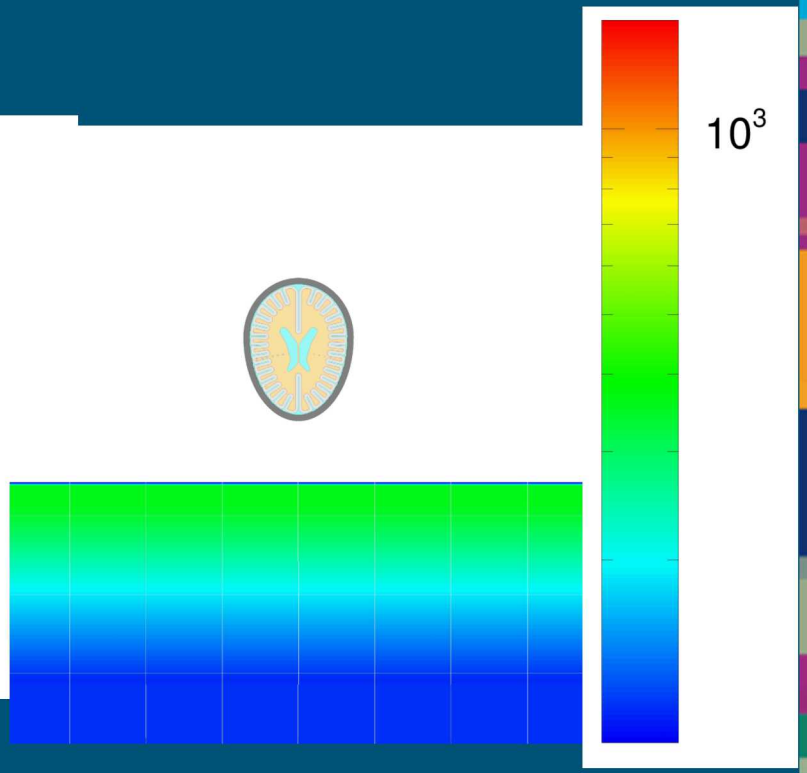
Peri-vascular



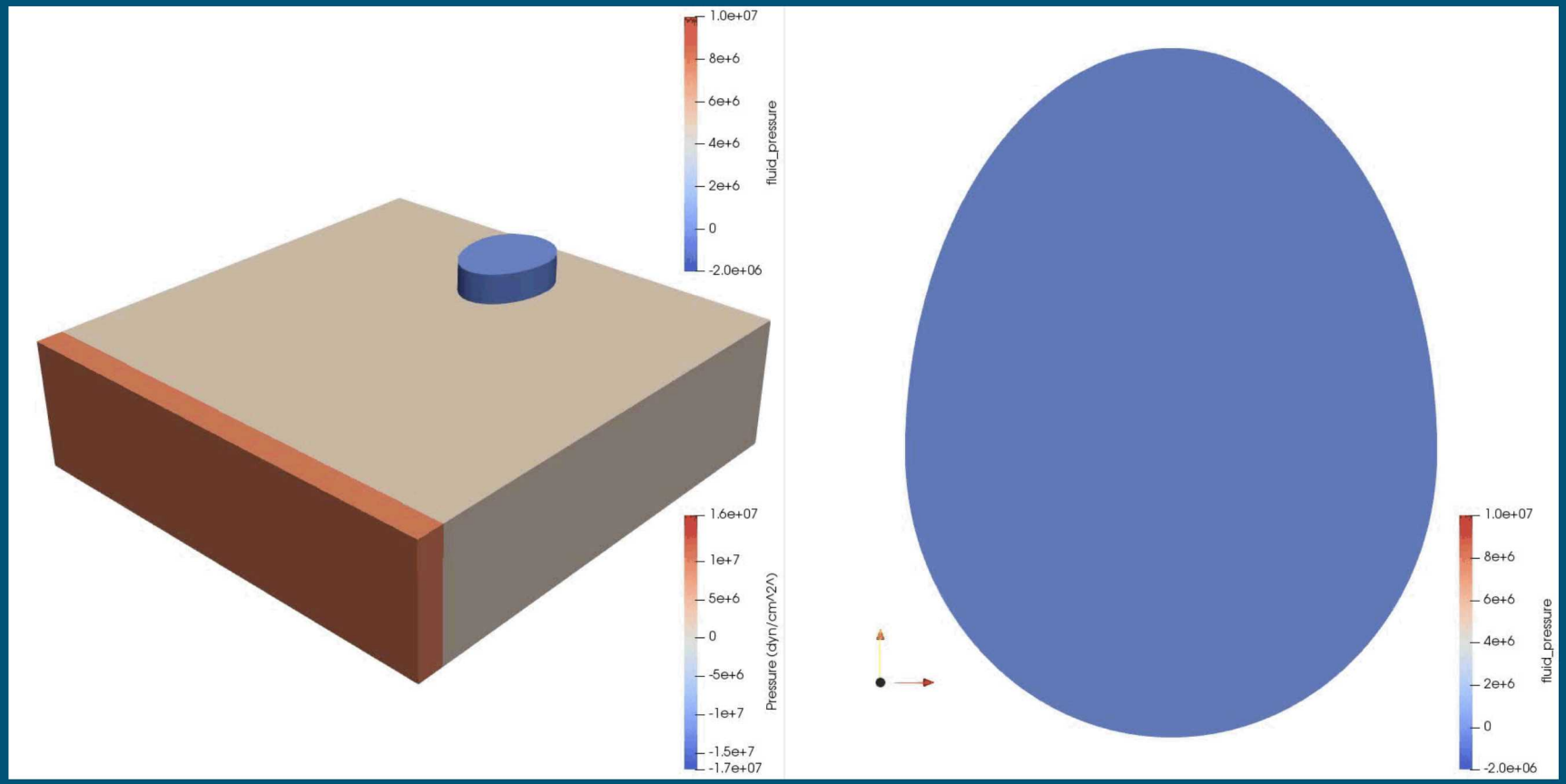
CSF-brain
(Peri-ventricular)

Computational model: hybrid finite element model and shock physics code



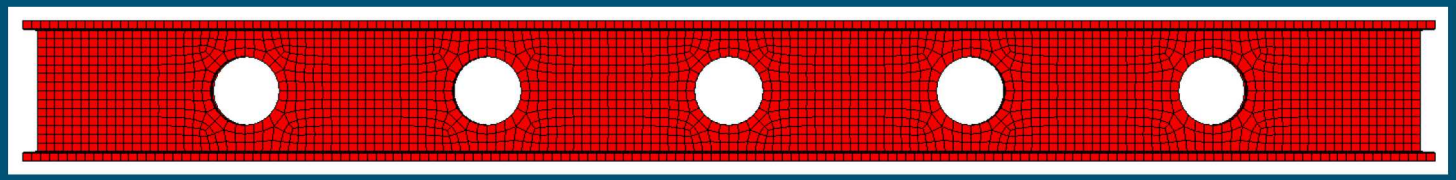


Computational model: hybrid finite element model and shock physics code

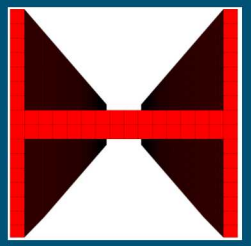


Very Large Problems in Structural Dynamics

How large of a matrix system **A.x=b** can we solve?



I-beam model



High Performance Computing/parallel processor computing

Strong scaling: how the solution time varies with the number of processors for a fixed total problem size

Weak scaling: how the solution time varies with the number of processors for a fixed problem size per processor

Some scaling results of Sierra/SD

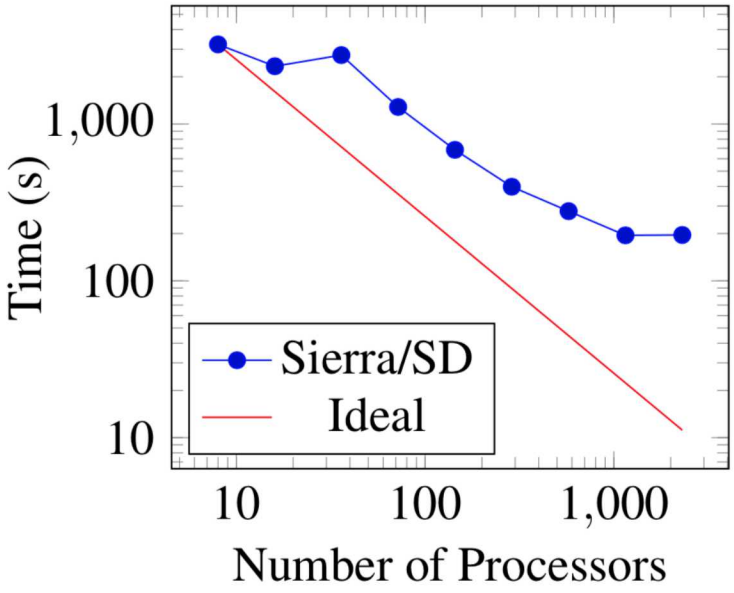
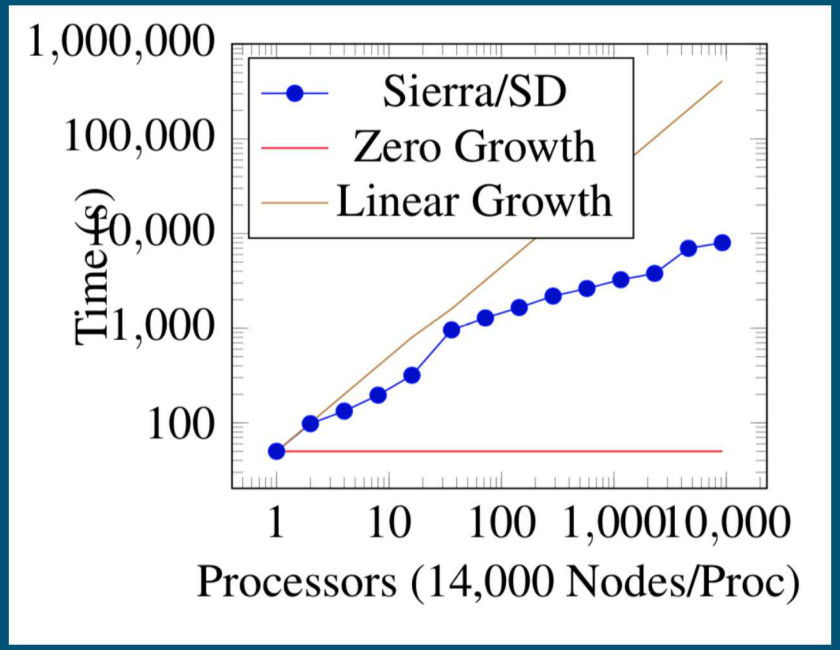


Figure 8. Scaling of Mesh 7 - 1,079,941 Nodes

Strong scaling



Weak scaling

How do you know the number of processors needed?

	Mesh Number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NumProc	Salinas Complete						Not Run						Failed (Memory)					
1																		
2																		
4																		
8																		
16																		
36																		
72																		
144																		
288																		
576																		
1152																		
2304																		
4608																		
9216																		
18432																		

Table 2. Matrix of Successful Sierra/SD Runs

Consider: speed, memory usage, and *availability!*

The End. Questions?

Interested in Sandia National Labs?

Summer internships: sandia.jobs

Career opportunities: sandia.jobs

There are many opportunities (not just at Sandia) to use your engineering and science skills to national service!