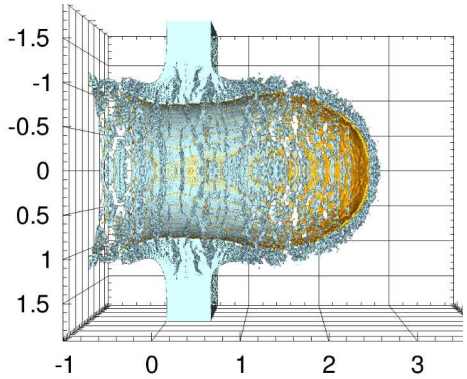
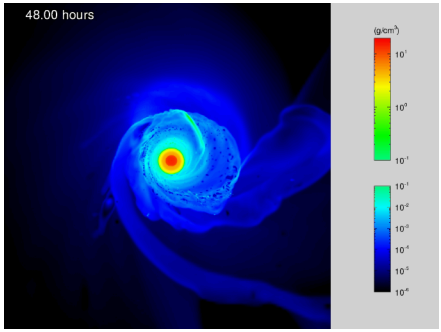
SAND2016-4871PE

Sandia National Laboratories





Engineering Sciences for National Security Applications

April 28, 2016

Justine Johannes
Engineering Sciences Center, Director
Sandia National Laboratories
jejohan@sandia.gov

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

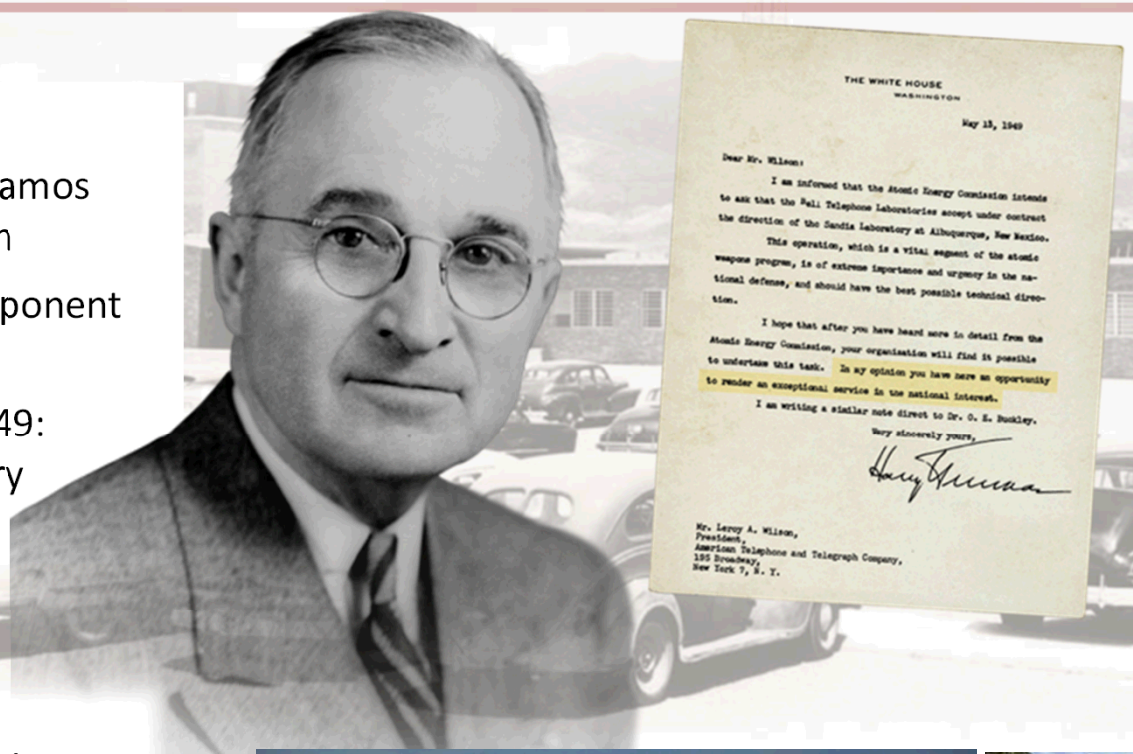
Sandia's History

Exceptional service in the national interest

Sandia National Laboratories

Then….

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory established



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,

Harry Truman

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

Now….

- Multiple sites with majority in NM, and CA
- Core mission in Nuclear Weapons
- Addressing the nation's most challenging National Security problems

Albuquerque, New Mexico

Livermore, California

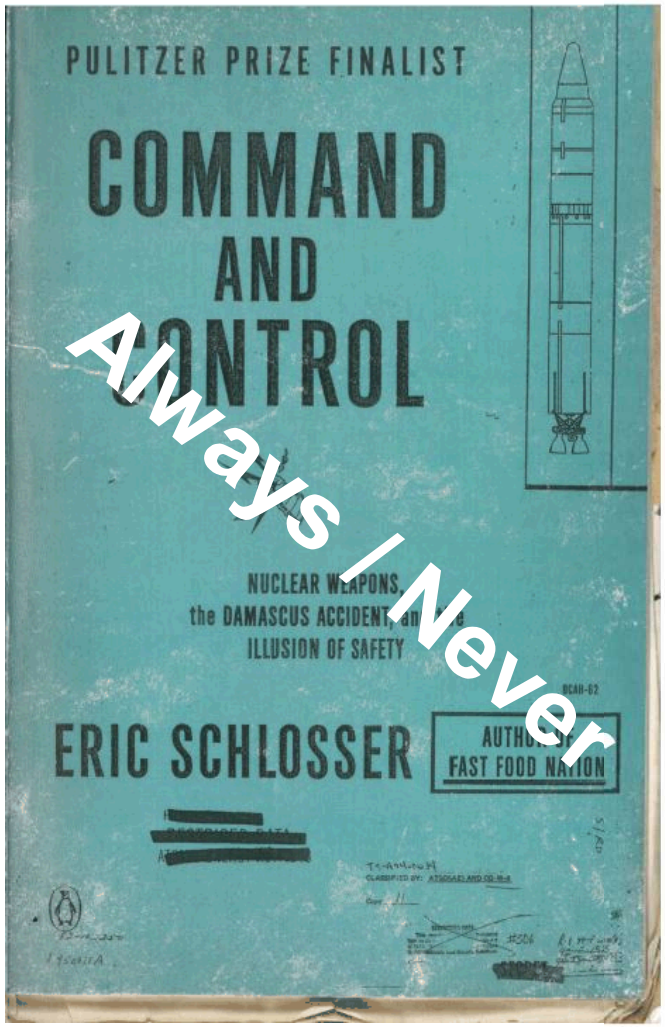
National Security Landscape

Sandia National Laboratories

Past 25 years…..

Uncertain and unknowable future, motivates a strong technical base.

Sandia's Core Nuclear Weapons Mission
Defined the Institution and it's Capabilities



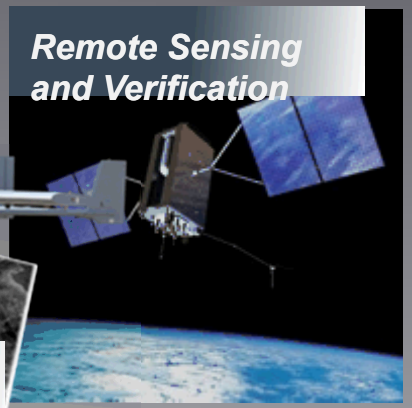
Sandia National Security Activities Beyond Nuclear Weapons

Sandia National Laboratories

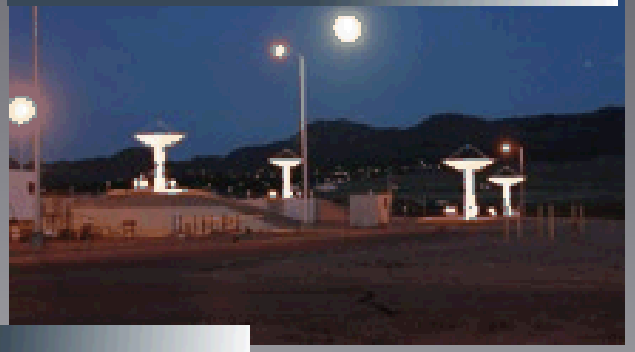
Information Operations Cyber and Infrastructure security

Surveillance & Reconnaissance

Remote Sensing and Verification

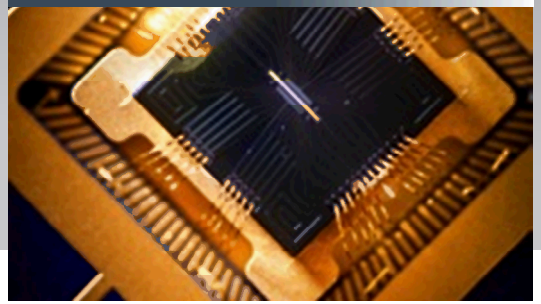


Space Mission



Integrated Military Systems

Science & Technology Products



Proliferation Assessment

Homeland Security Programs

We Define National Security Broadly
Energy & Climate Work at Sandia

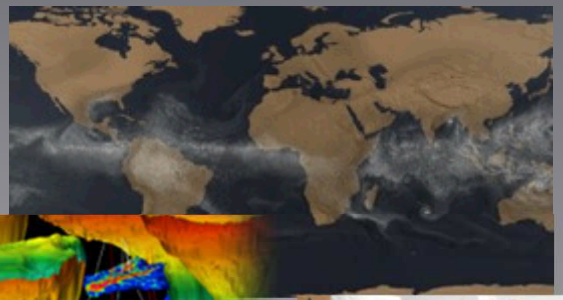
Sandia National Laboratories

Energy Research

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

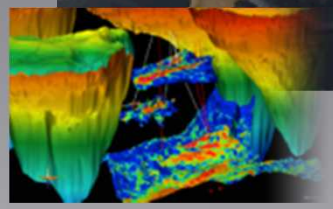
Climate & Environment

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

Renewable Energy, Energy Efficiency, Grid and Storage Systems

Transportation Energy & Systems

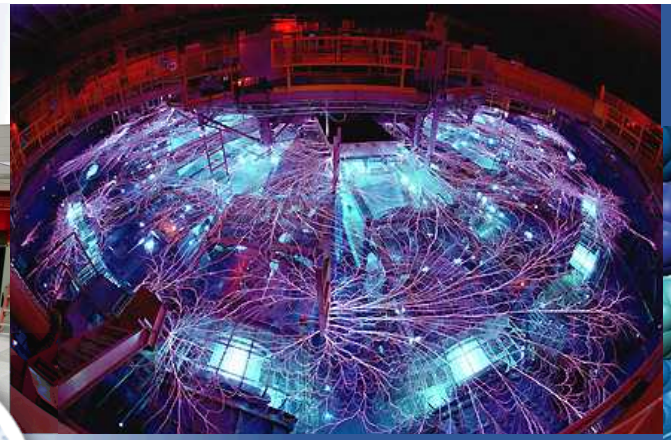
Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology

Our Research Framework

Strong research foundations play a differentiating role in our mission delivery

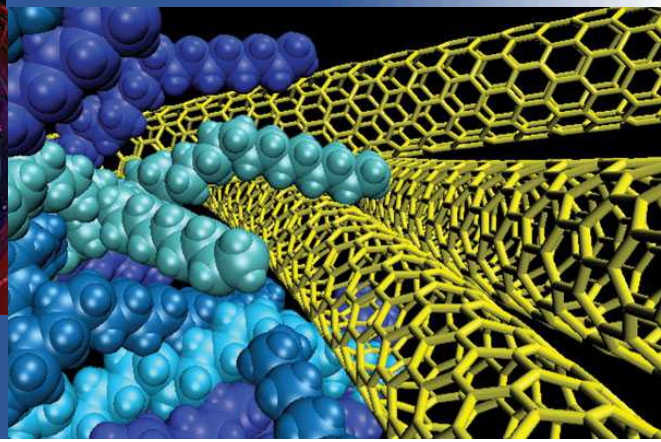
Sandia National Laboratories

Computing & Information Sciences

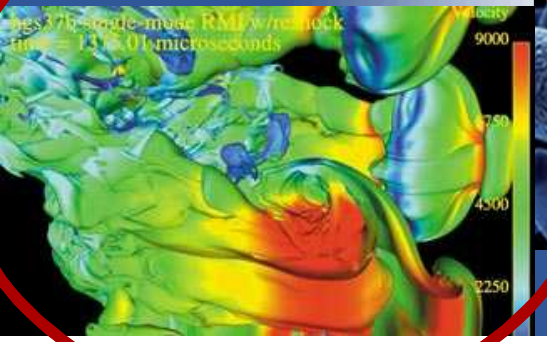


Radiation Effects & High Energy Density Science

Materials Sciences

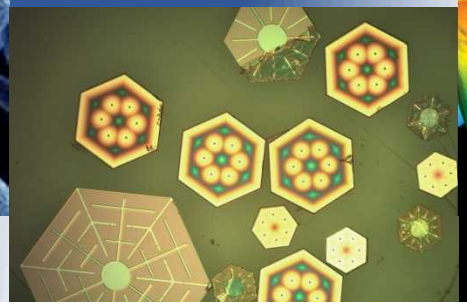


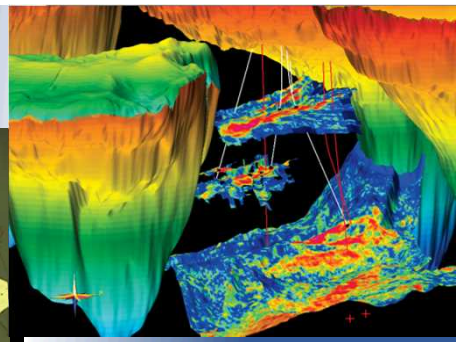
Engineering Sciences



Bioscience

Nanodevices & Microsystems





Geoscience

Partnerships are Critical
UTEP is part of Sandia Partnership Strategy

Sandia National Laboratories

Campus executive program was establish to create enduring partnerships with a focused set of universities to nurture talent, conduct collaborative research, and to foster mutual national advocacy.

Recruit, retain and develop the best and brightest

Build two-way relationships of mutual benefit and advocacy

Conduct collaborative world-class R&D to support mission needs

Academic Alliance Is a Subset of the Campus Executive Program

Sandia National Laboratories

- Establish a strategic FFRDC-university partnership model to maximize collective S&T value to the nation
  - Envision and define future of science and engineering for the nation
  - Provide thought leadership on critical S&T issues
- Provide opportunities for university partners to expand their engagement in national security R&D
  - Alliance partners share a common interest and commitment to service
- Enrich our mutual capabilities and expand our impact
  - Solve significant problems we could not address alone
  - Sustain and enrich our talent pipeline
  - Accelerate the commercialization and adoption of new technologies

THE UNIVERSITY of NEW MEXICO

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PURDUE UNIVERSITY

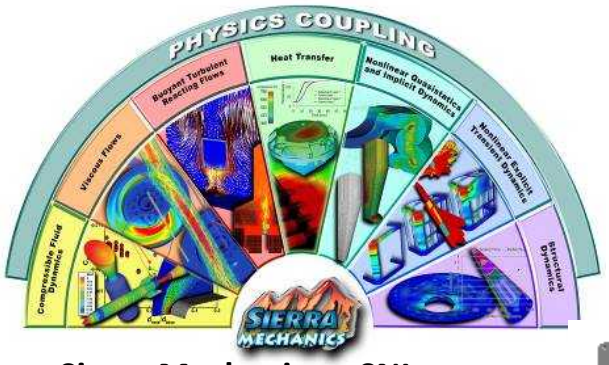
Georgia Tech

Engineering Sciences Stewards Capabilities that:

- **Advance the scientific understanding of physical phenomena underlying problems of interest to Sandia,**
- **Drive innovation and broad usage of state-of-the-art, validated computational modeling and simulation tools, and**
- **Accelerate the development of high-fidelity, spatially and temporarily resolved experimental diagnostics for discovery, model validation, and enhancement of our test and evaluation capabilities.**

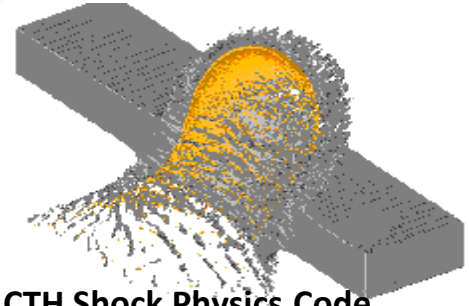
Engineering Disciplines Supported Are Broad:
Solid Mechanics, Structural Dynamics, Thermal, Fluids, Kinetics, Aerodynamics, and Electromagnetics

Integrated theory, computational simulation and experimental discovery/validation for technical basis of complex systems.

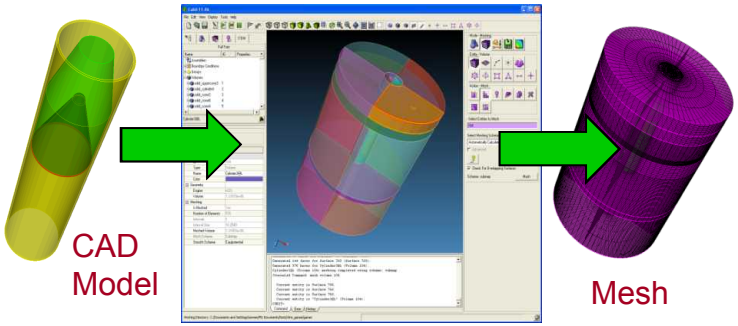


Sierra Mechanics – SNL core engineering mechanics code family

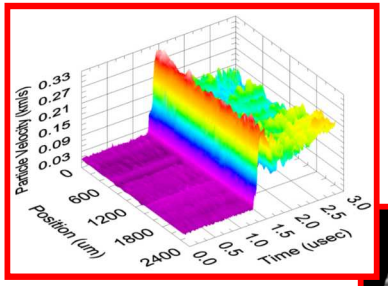
Computational Simulation Capabilities



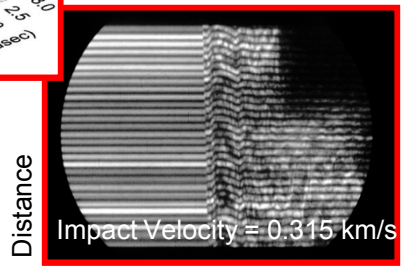
CTH Shock Physics Code

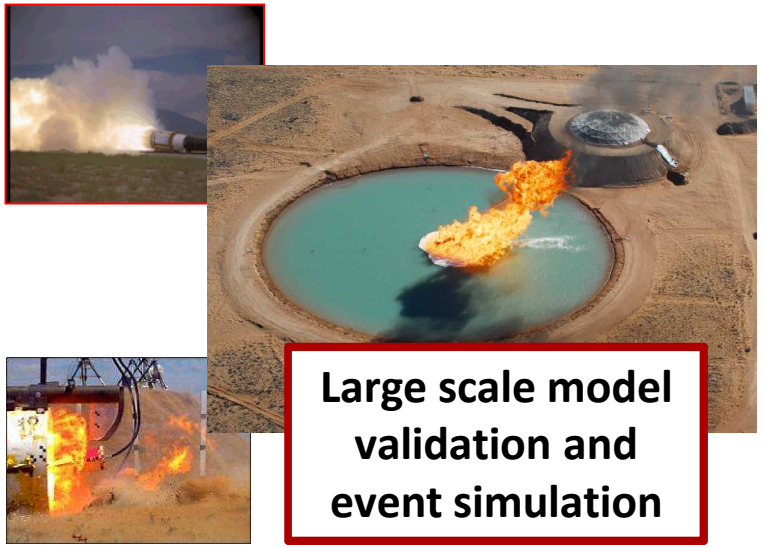


Workflow supporting analysis



Diagnostic and physics model development



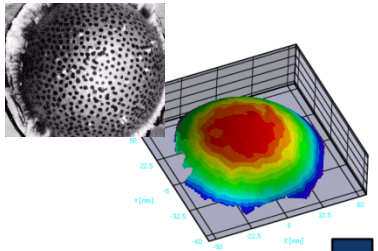


Large scale model validation and event simulation

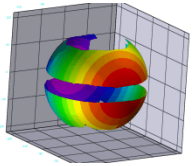
Enabling Fundamental Investigations
Diagnostic Development and Implementation

Sandia National Laboratories

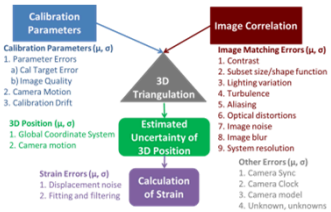
Displacement, velocity and strain



360º coverage

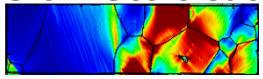


Stereo-DIC Uncertainty Quantification
From colors to metrology.



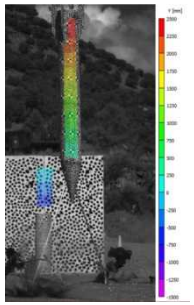
DIC for Material Properties
- Quantified Uncertainty
- More parameters per test
- Parameter interaction
- High-throughput
- Model validation

Grain Scale strain

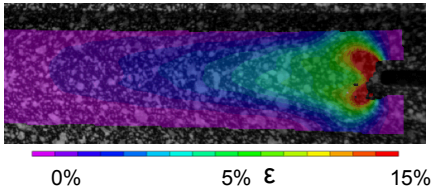


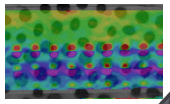
2005 | 2007 | 2009 | 2011 | 2013 | 2015

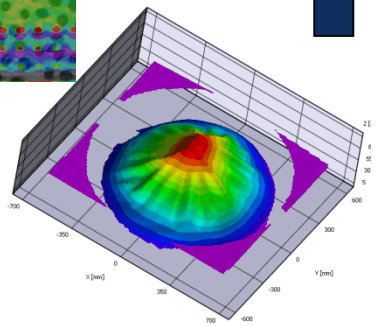
Introduction of DIC to Sandia



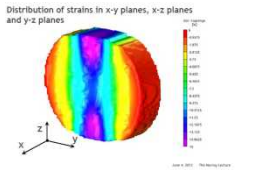
Crack-tip and Fracture Strain







Explosive Panel Deformation



Volumetric DIC

Digital Image Correlation is now used routinely for tests

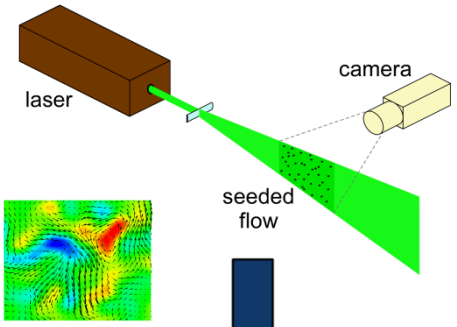
Aerosciences – Pushing the limits of spatial and temporal resolution up to hypersonic speeds

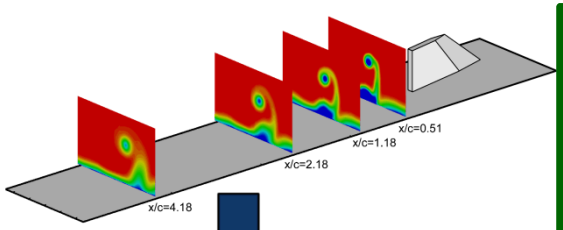
Sandia National Laboratories

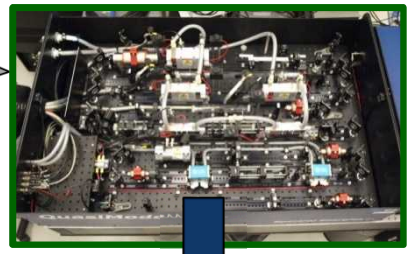
2-Component PIV

3-Component PIV (Stereosopic)

Time-Resolved PIV with Pulse-Burst Laser







Velocity measurements

2000

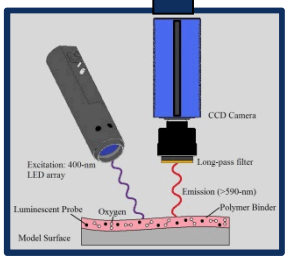
2005

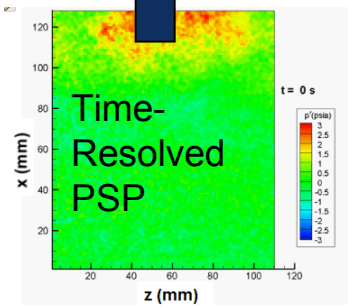
2015

Surface pressure measurements

Point Sensors

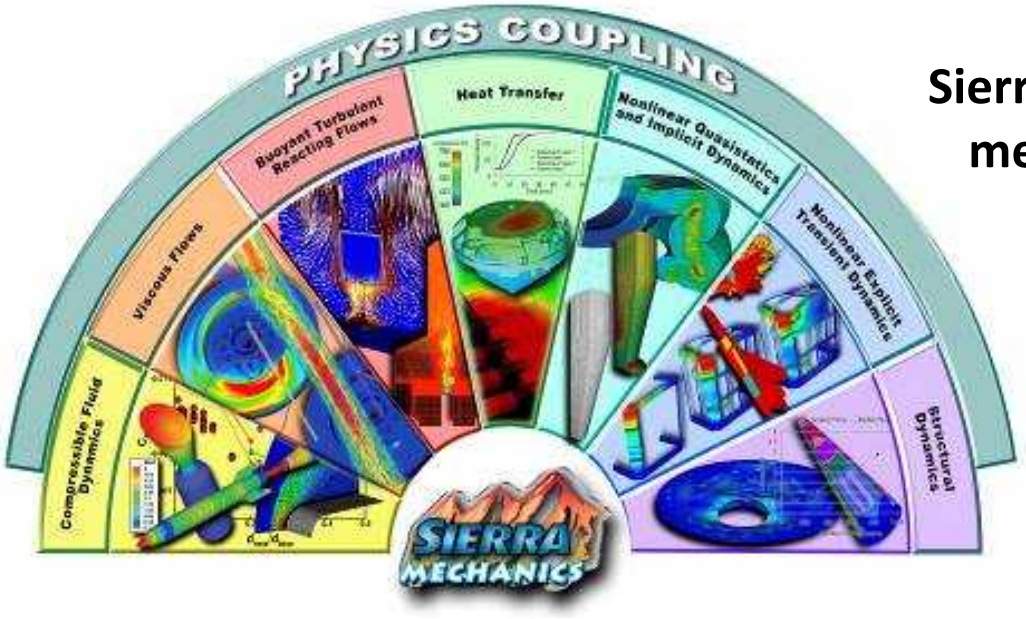
Pressure Sensitive Paint (PSP)





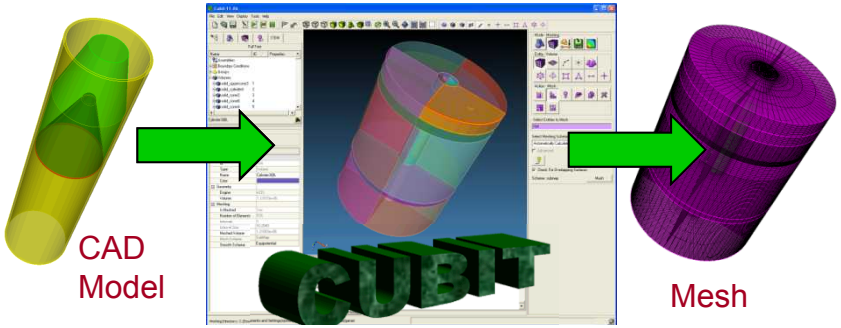
Improving measurements for acoustical loading and qualification environments for providing customer solutions

Developing Computational Tools Is Required to Support our Unique Mission Drivers

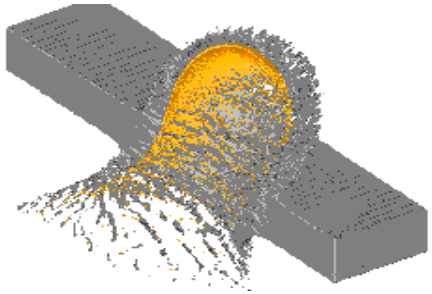


Sierra Mechanics is our core engineering mechanics code family (NW & other)

- Coupled physics
- Highly parallel > 10M dof
- Verification and validation focus



Preprocessing - meshing



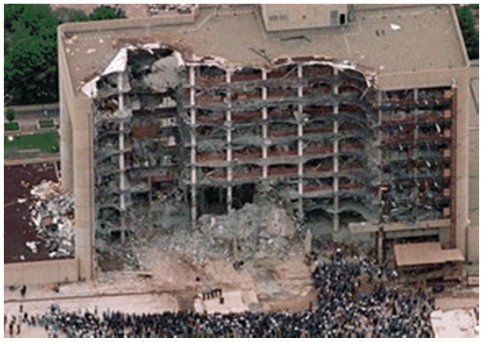
CTH large deformation, shock-physics code

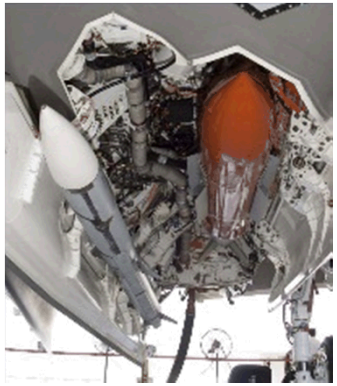
Computational Tools for Coupled, Multi-physics

Sandia National Laboratories

- Air and Fluid Shock
- Reacting Flow-Thermal-Structure
- Pervasive material and structural failure
- High Mach Fluid-structure-interaction

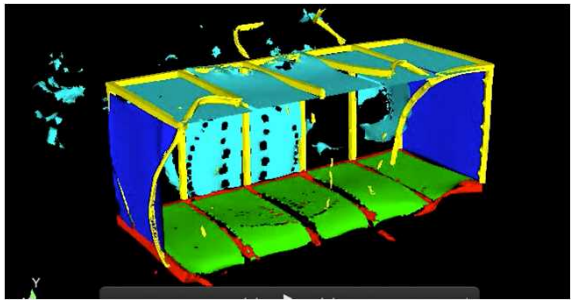
Underwater blast on Structure



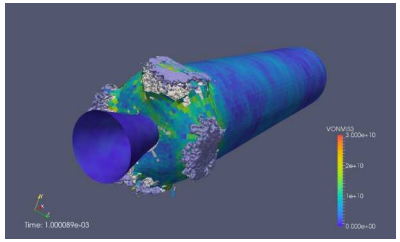


Captive Carry Fluid Structure Interaction

Fire-Structural Collapse



Blast-on-Structures



Rocket Motor propellant-structure Interaction

Reacting flows-structural response

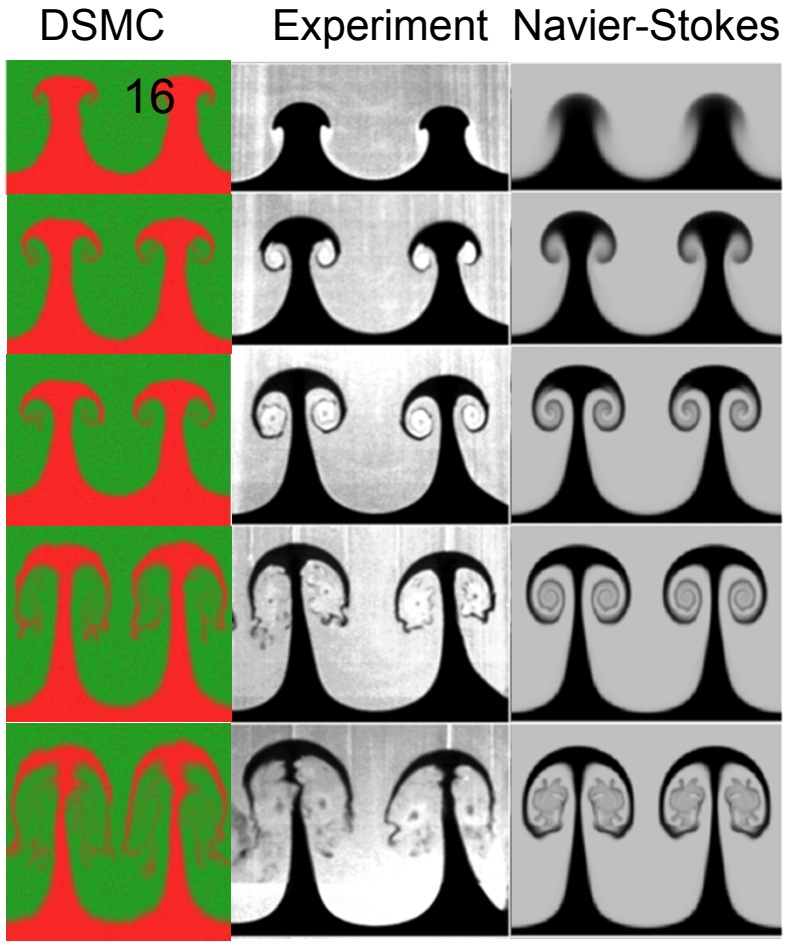
Computational Simulation capability for Physical Phenomena Investigations

Sandia National Laboratories

Richtmyer–Meshkov instability (RMI) investigations using Direct Simulation Monte Carol methods.

Air-SF6 Mixture: Mach = 1.4 Shock
Numerical parameters
Mesh: 10,000×40,000 = 0.4 billion cells
Molecules: 6 billion molecules
Time steps: 200,000×0.1 ns

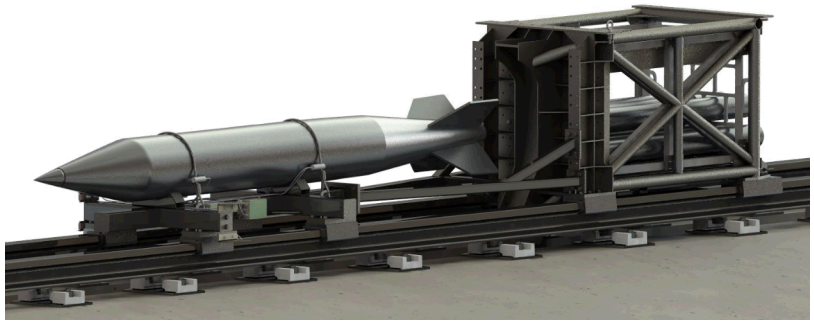
Computational aspects
Platform: Sequoia, 30 hours
Processors: ~1/2 million cores (16k nodes)



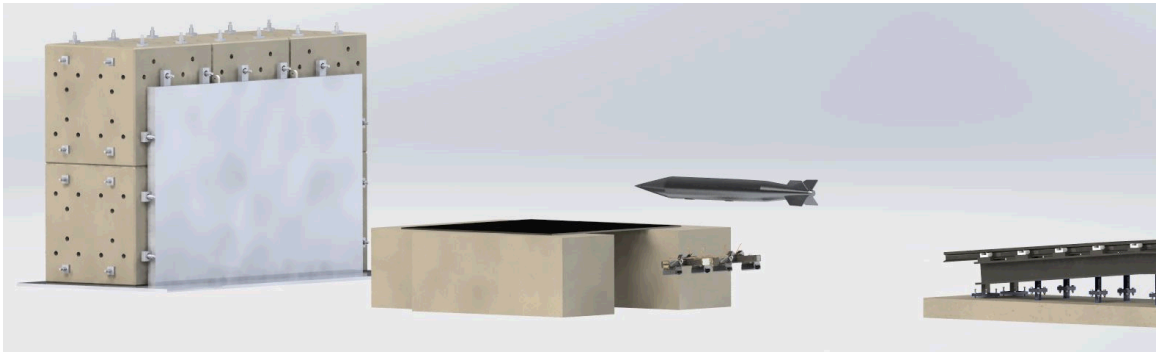
Morgan *et al.* JFM 2012

Gallis et al., *PoF*, **27**, 084105 (2015).

Complex, large scale engineering tests
Test hardware and validates models



Link to video:
SAND2016-2681 V
Has been approved for public release



Sandia has been called upon to support investigations of national importance

Sandia National Laboratories

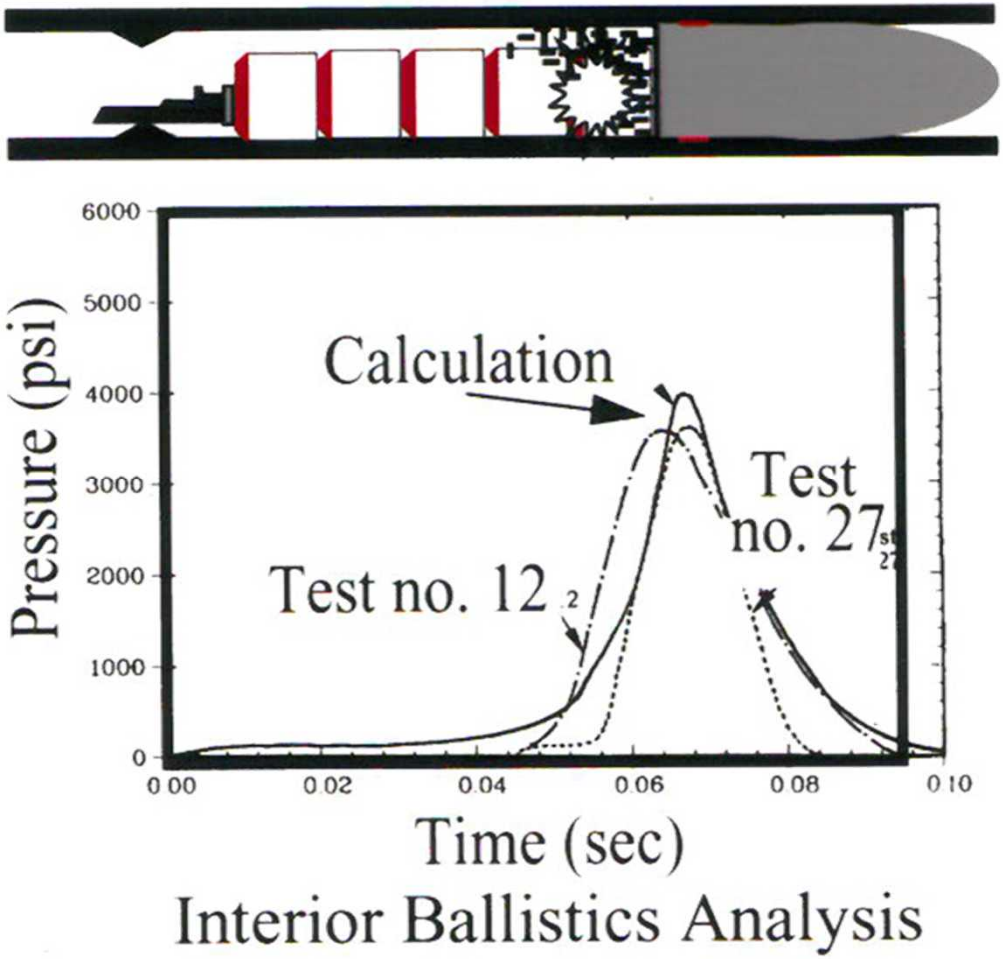
- *USS Iowa Investigation (April 19, 1989)*
- TWA Flight 800 Accident Investigation (July 1997)
- Post 9/11 Vulnerability Studies (Nov 11, 2001)
- *Columbia Space Shuttle Accident (February 4, 2003)*
- *I-35W bridge collapse in Minneapolis (August 1, 2007)*
- BP Deepwater Horizon Oil Spill Accident (Sept 8, 2010)
- Aircraft Vulnerability (Jan 11, 2013)
- Waste Isolation Plant Leak (February 15, 2014)
- *Traumatic Brain Injury (on-going)*

USS Iowa accident investigation

- Training accident occurred in 2nd turret, 47 sailors were killed
- The Navy concluded that Clayton Hartwig intentionally placed an incendiary device between two propellant bags to kill himself
- Sandia was chosen by Congress to conduct independent investigation

Sandia pulled from a broad set of capabilities (thermal, fluid, chemical, and structural) for investigation

- Forensic evidence combined with the Sandia analyses led to the conclusion that the explosion was an accident
- Sandia presented their results to the Navy Sea System command:
  - The next day the Chief of Naval Operations retired
  - The Navy formally apologized to the family of Clayton Hartwig and the families of the deceased sailors

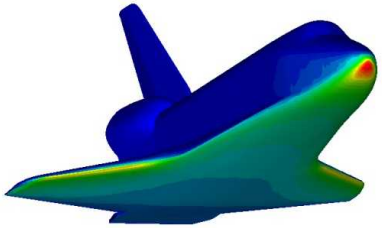


Computational and experimental results caused initial naval results to be reconsidered

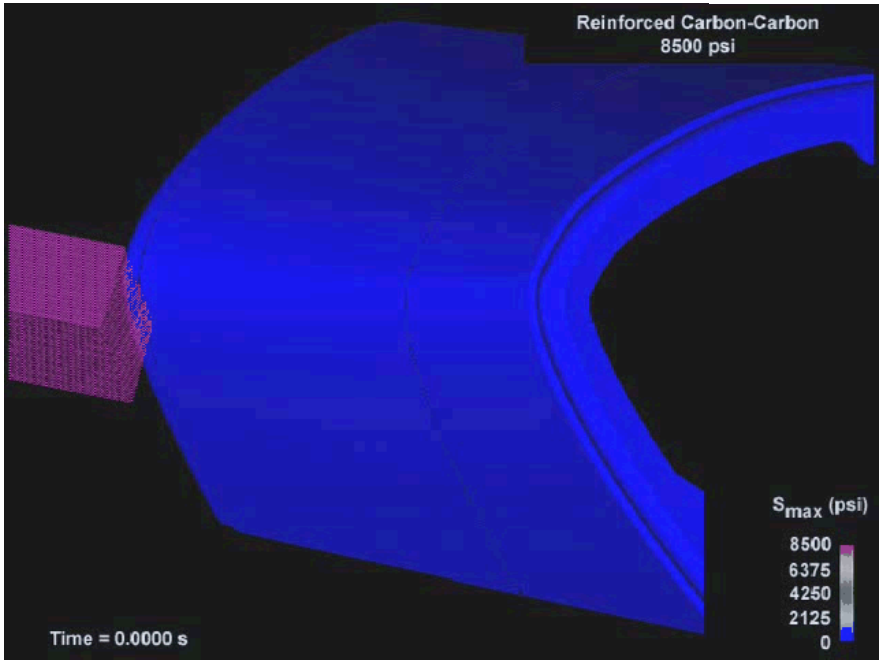
Columbia accident investigation

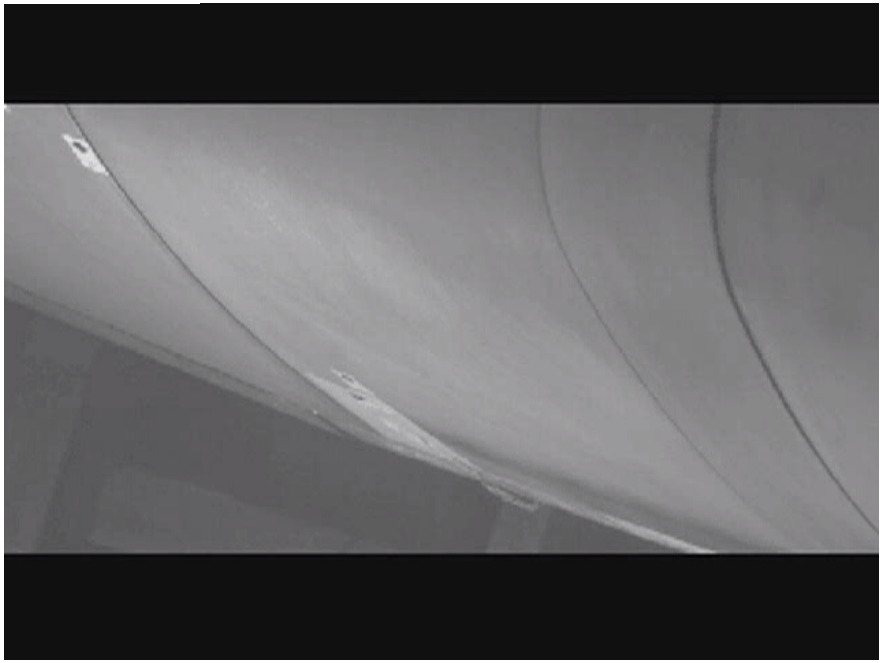
Sandia National Laboratories

Use smooth particle hydrodynamic model of foam, hex model in Pronto 3D of RCC wing leading edge panels



SwRI test demonstrated foam impact was probable cause of Columbia accident





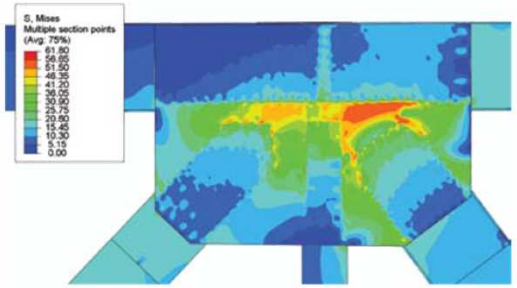
Sandia Simulation

Experimental Validation, SwRI

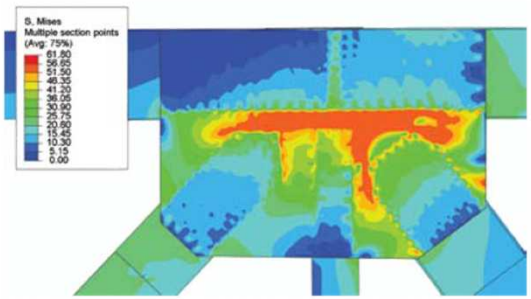
SNL created database of expected sensor output as a function of impact severity , used by NASA on subsequent flights

I-35 Minneapolis bridge collapse

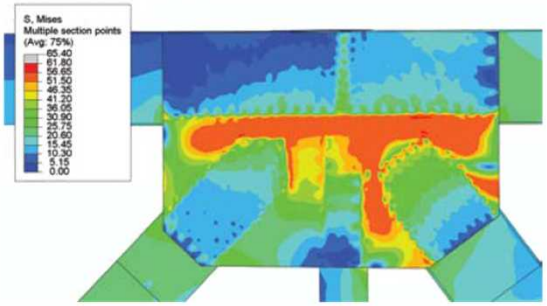
As the capacity was exceeded, a plastic hinge formed in the gusset plate and subsequent tearing from rivet line resulted in bridge failure



Stress at bridge opening, 1967



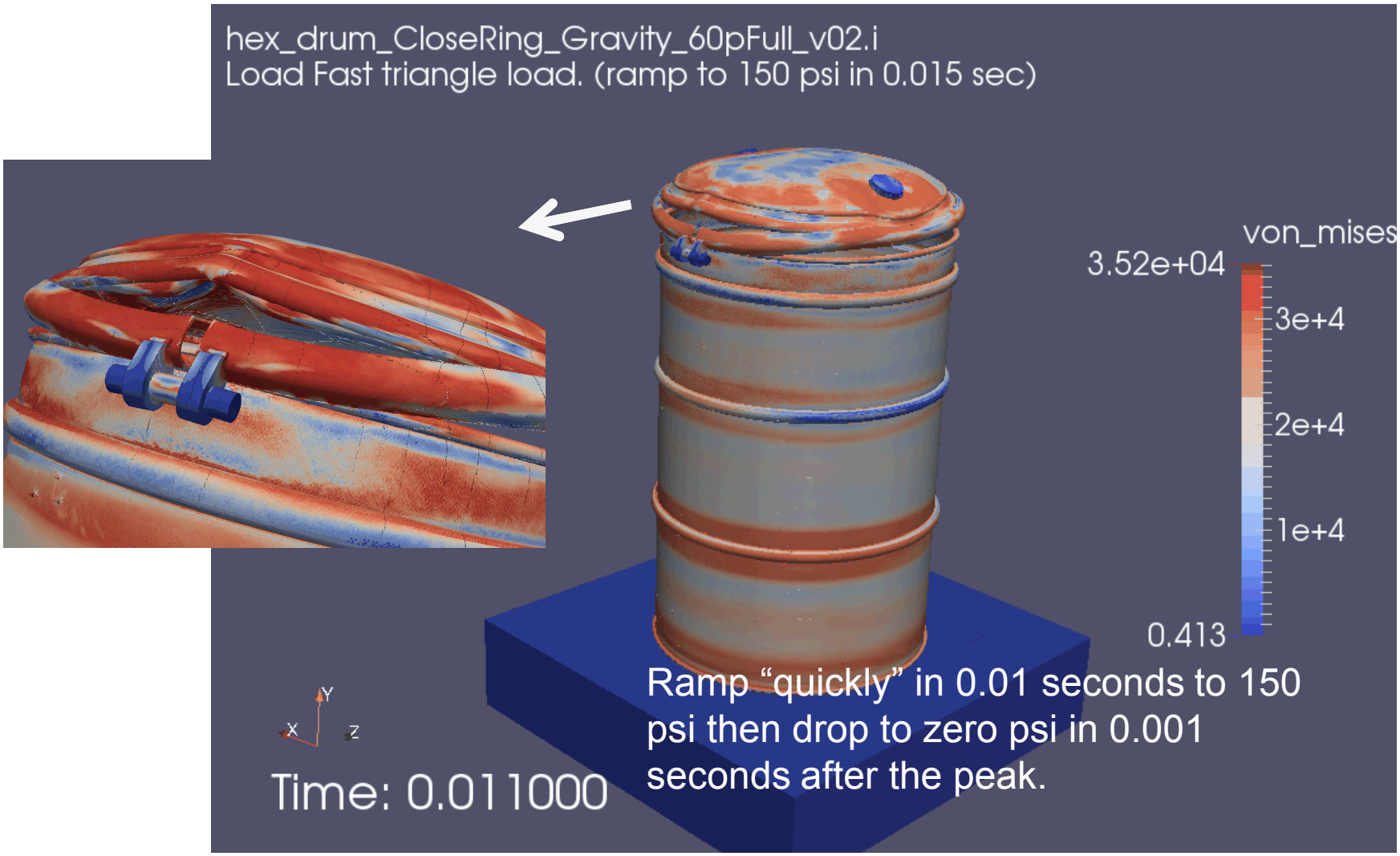
Stress in joint after 1977 and 1998 renovations



Stress in joint Aug, 2007 at time of collapse

Stress in critical bridge gusset plate

Understanding WIPP Event
Drum reaction chemistry and drum failure



Leaning into future needs and how our capabilities might look in the future

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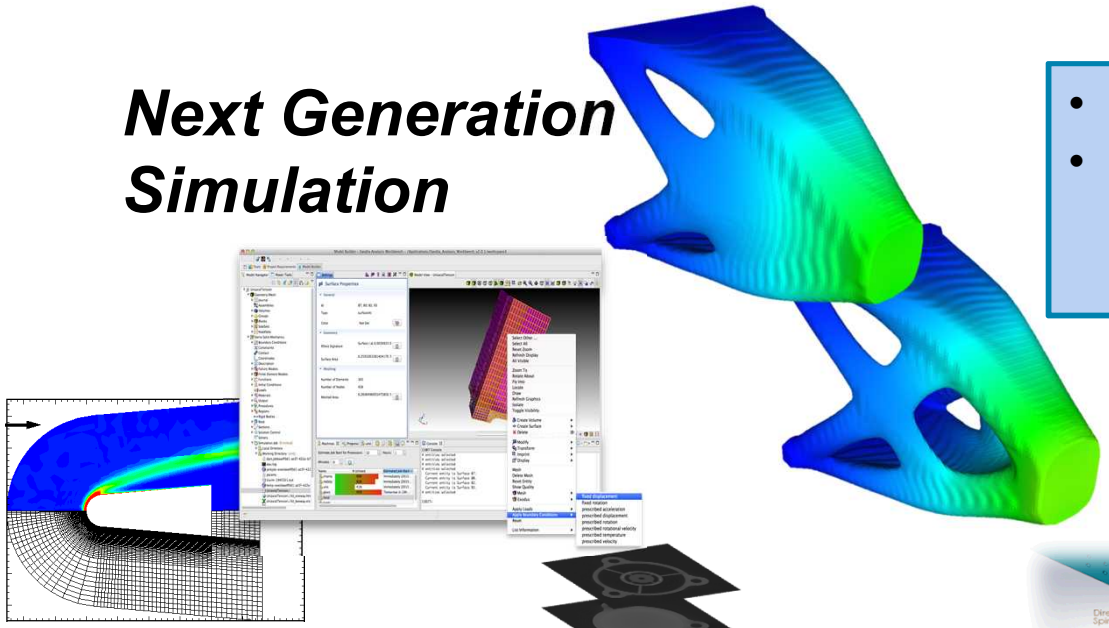
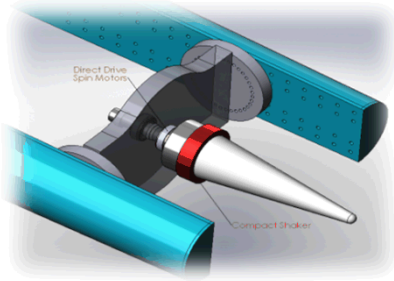
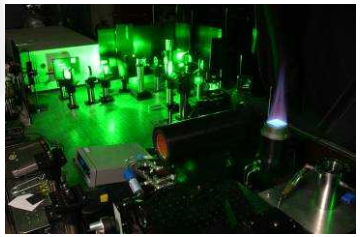
Next Generation Simulation



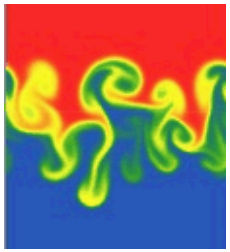
- Thinking is just getting started
- Aligns with our desire for bold outcomes and continued mission engagement

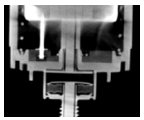
Modern Discovery, Design and Qualification Approaches



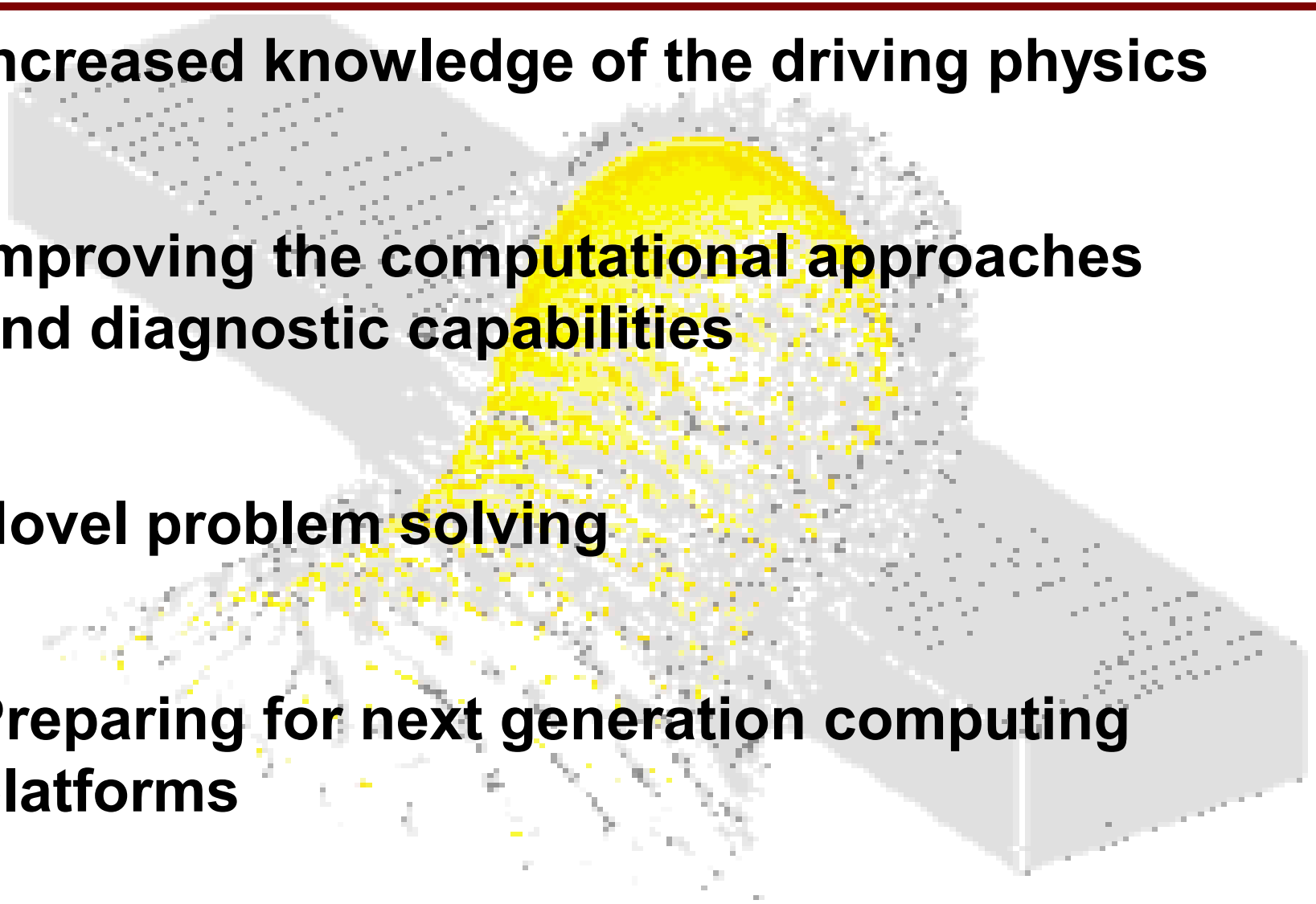


Data Sciences





The challenges and opportunities are abundant Partnerships are critical for success



- Increased knowledge of the driving physics
- Improving the computational approaches and diagnostic capabilities
- Novel problem solving
- Preparing for next generation computing platforms