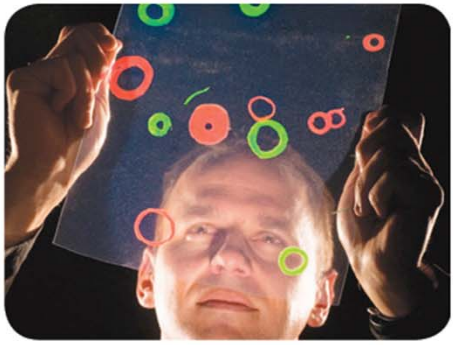
SAND2012-2963C

Exceptional service in the national interest

Sandia National Laboratories


Sandia National Laboratories

An Overview for UNL's Tau Beta Pi Group

Presented by Douglas A. Dederman, Manager Terminal Ballistics Technology

April 12, 2012; dadeder@sandia.gov

U.S. DEPARTMENT OF ENERGY | NNSA 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. SAND2011-0439P

Sandia's History

Sandia National Laboratories

AMERICAN TELEPHONE & TELEGRAPH CO. AND ASSOCIATED COMPANIES — BELL SYSTEM

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 [illegible] of Albuquerque, New Mexico. This operation, which is [illegible] atomic [illegible] national defense, and should have the [illegible] executive direction [illegible].

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 Mr. C. E. Buckley.

Very sincerely yours,

Harry Truman

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

exceptional service in the national interest.

A little about myself

- **Douglas A. Dederman (a.k.a. – Doug)**
  - Lincoln East High School
  - Spouse – Grand Island High School
  - Daughter Recent UNL Graduate 12/2011
  - Son a Sophomore at UNL
- **Employed at Sandia for 28+ years**
- **Went to University of Nebraska – Lincoln from 1977-1983**
  - BS Civil Engineering ‘81
  - MS Engineering Mechanics ‘83
- **Past Positions**
  - Shock & Vibration Test Engineer
  - Engineer & Project Lead for STARS SRM Boosters
  - Lead Engineer for Red Crow Mission
  - Missile Defense Countermeasures
- **Current Position (Nov.’03 to Present)**
  - Manager, Terminal Ballistics Technology
  - Mission: Technology Development for Characterization, Defeat & Protection of Targets

Sandia National Laboratories

Sandia's Governance Structure

Sandia Corporation

- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–present
- Existing contract expires Sept. 9, 2012

Government owned, contractor operated

Federally funded research and development center

Sandia's Sites

Sandia National Laboratories

Albuquerque, New Mexico

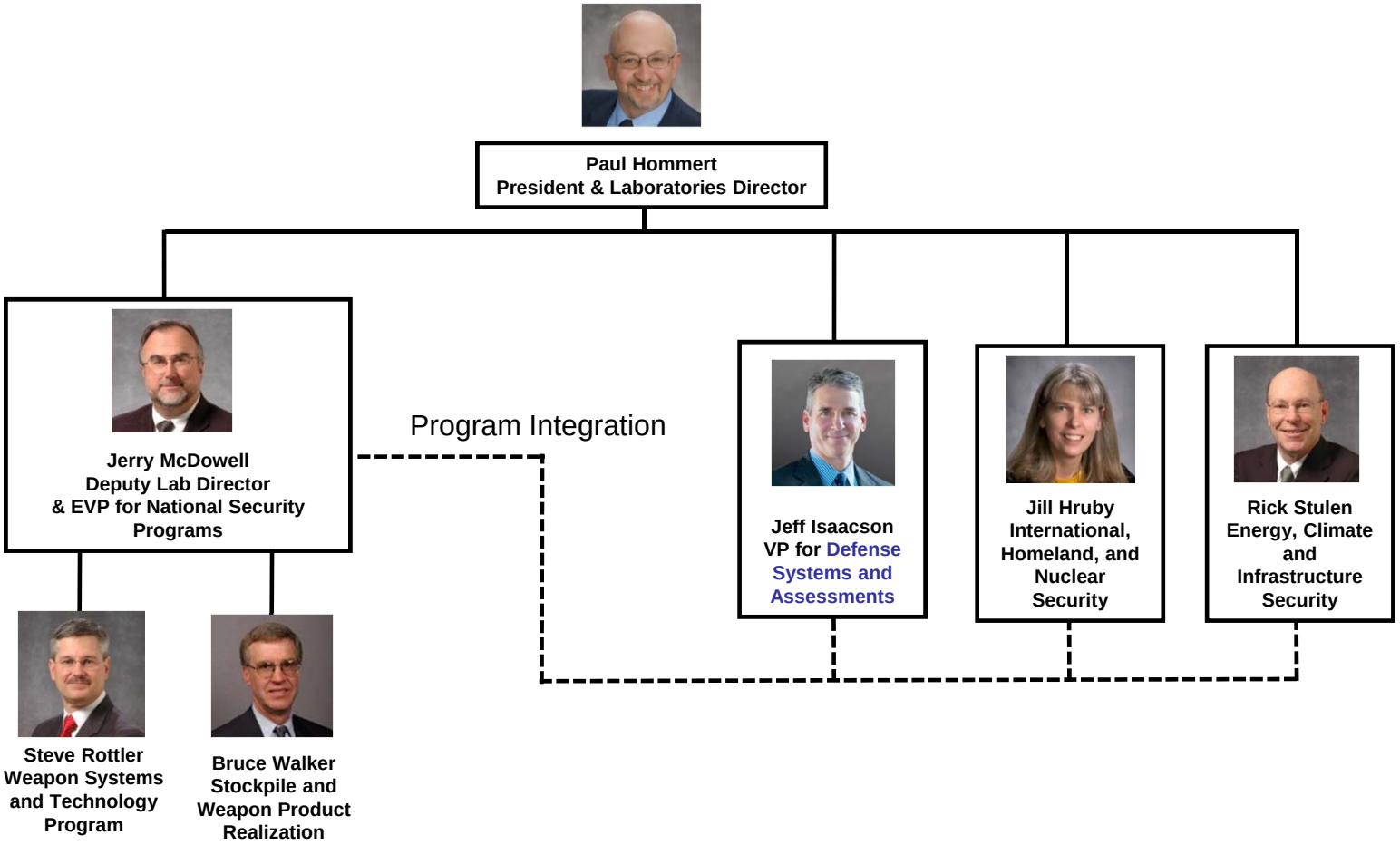
Livermore, California

Tonopah, Nevada

Waste Isolation Pilot Plant, Carlsbad, New Mexico

Pantex, Texas

Executive Management Programmatic Reporting Structure

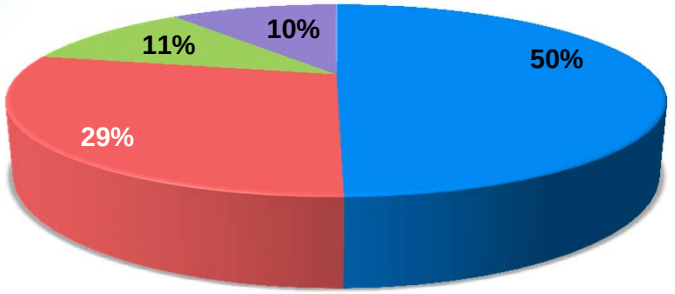


People and Budget

(As of October 11, 2011)

- On-site workforce: 11,876
- Regular employees: 9,122
- Gross payroll: ~$943 million

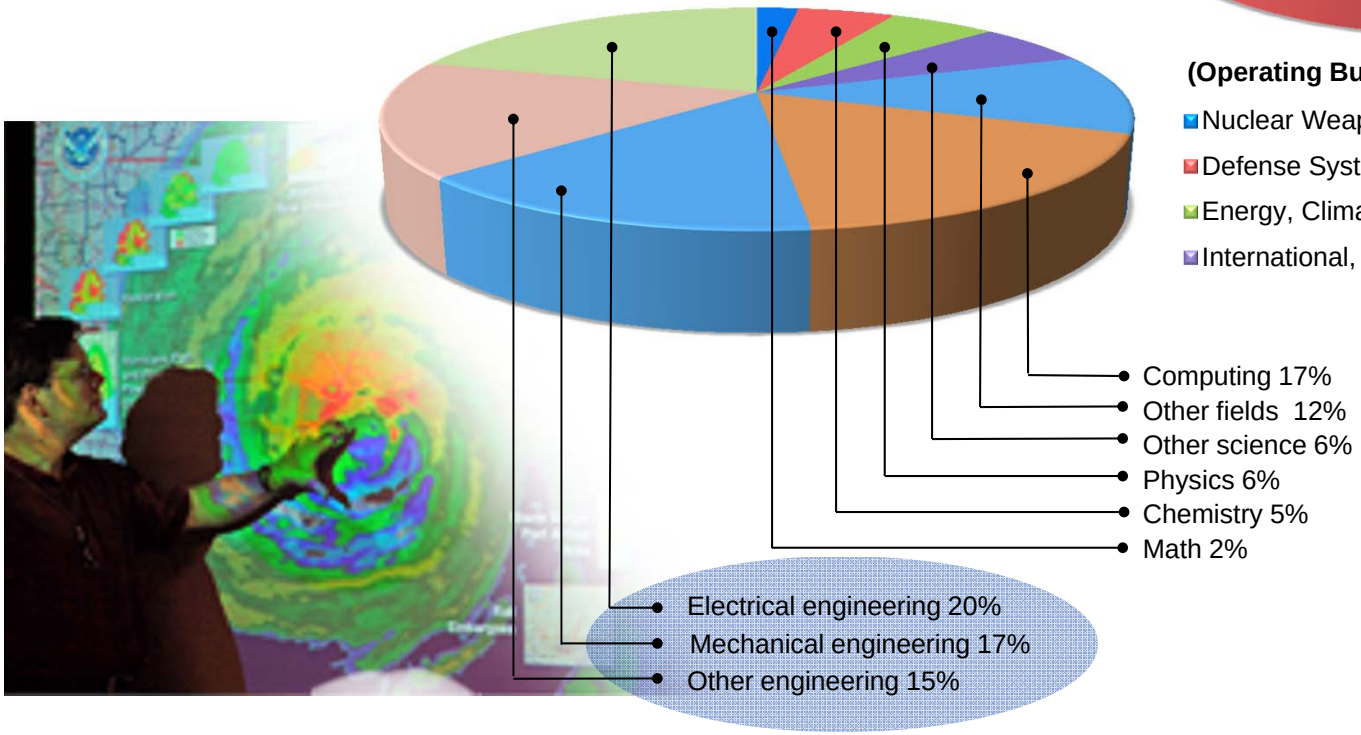
FY11 Operating Revenue
$2.4 billion



(Operating Budget)

- Nuclear Weapons
- Defense Systems & Assessments
- Energy, Climate & Infrastructure Security
- International, Homeland, and Nuclear Security

Technical staff (4,557) by discipline



Addressing Our Evolving National Security Environment is of the Greatest Importance

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Traditional strategic nuclear threats

Threats from other nation states

Threats from non nation states

Threats of tech surprise

Other threats: natural disasters, climate change, energy supply

Nuclear Weapons

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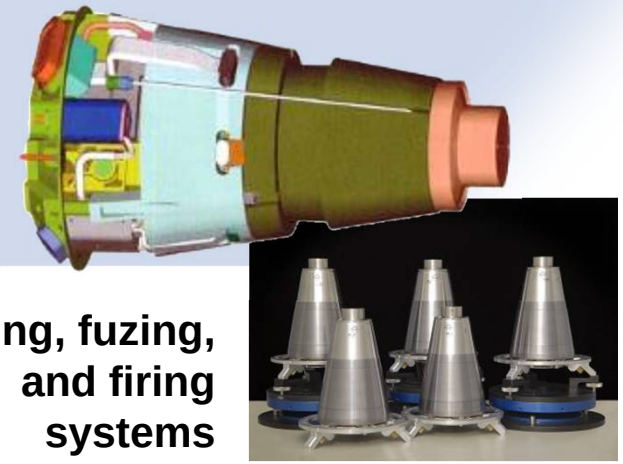
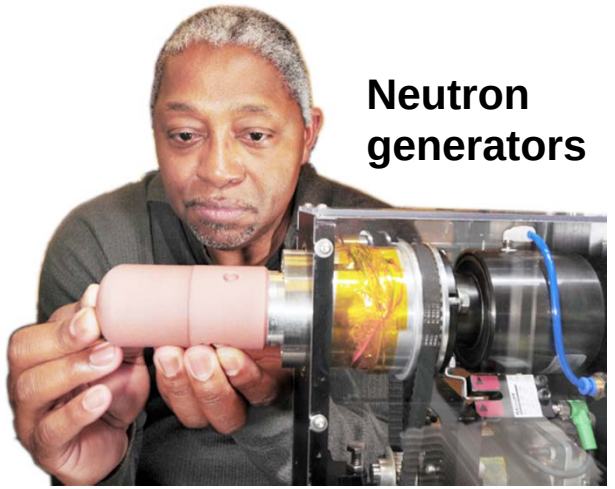
Integrated, engineered warhead systems



Arming, fuzing, and firing systems

Safety systems

Gas transfer systems



Neutron generators

Nuclear Weapons

High reliability, high consequence of failure, challenging environments, and technology solutions

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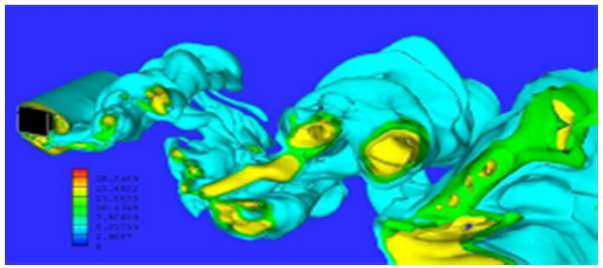
Facilities and Capabilities

Microelectronics and microsystems

Design, fabricate, package, and test trusted semiconductor components



Computational simulation

High-performance hardware and software tools to enable solutions requiring massively parallel computers

Environmental testing

Simulate environmental conditions and collect relevant data for systems, subassemblies, and components

Defense Systems and Assessments

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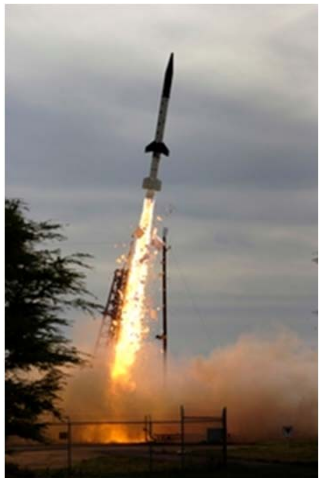
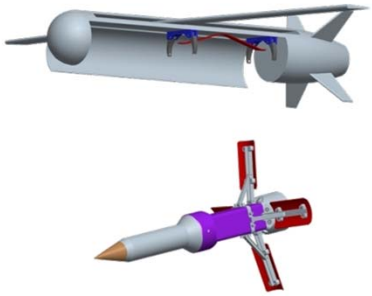
Program Areas

- Information Operations
- Integrated Military Systems
- Proliferation Assessment
- Remote Sensing & Verification
- Space Mission
- Surveillance & Reconnaissance

Areas of Expertise

- Nuclear Detonation Detection System
- Nonproliferation
- Cyber Security
- Synthetic Aperture Radar
- Space Situational Awareness
- Data Processing and Exploitation

Energy, Climate, and Infrastructure Security

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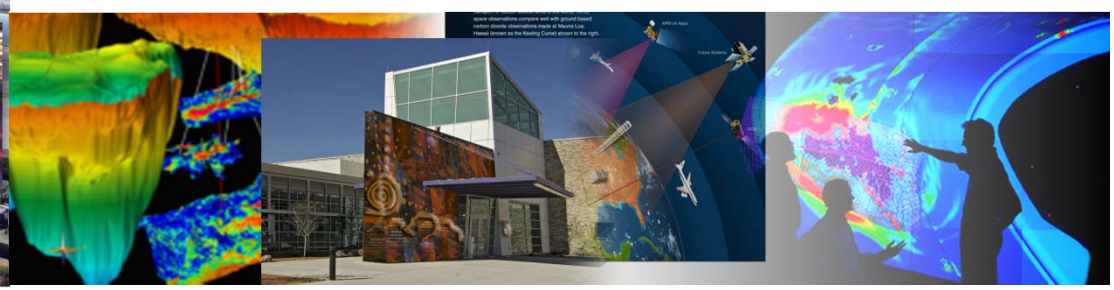
Program Areas

- Infrastructure Security
- Energy Security
- Climate Security
- Enabling Capabilities

Areas of Expertise

- Modeling & Analysis, Cyber, Electricity Distribution, and Energy Assurance
- Renewables, Energy Efficiency, Energy for Transportation, and Nuclear Energy Systems
- Sensing & Monitoring, Carbon Capture, Sequestration, Modeling and Analysis, and Water
- Discovery Science & Engineering, Systems Analysis, and Regulatory & Policy



International, Homeland, and Nuclear Security

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Program Areas

- Critical Asset Protection
- Global Security
- Homeland Defense and Force Protection
- Homeland Security

Areas of Expertise

- Countering Bioterrorism
- Nuclear, Radiological, and Chemical Risk Reduction
- Nonproliferation and Arms Control
- Physical Security
- Emergency Response
- Systems Analysis and Engineering
- Border Security
- Aviation and Airworthiness Security

Research Disciplines Drive Capabilities

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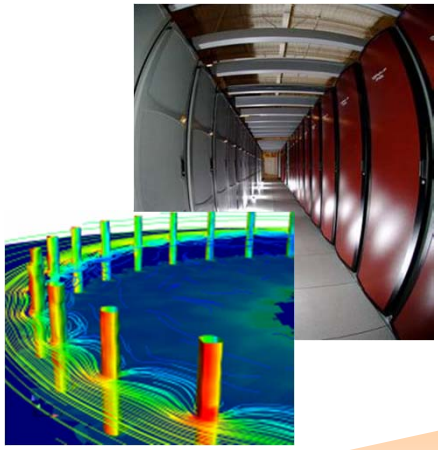
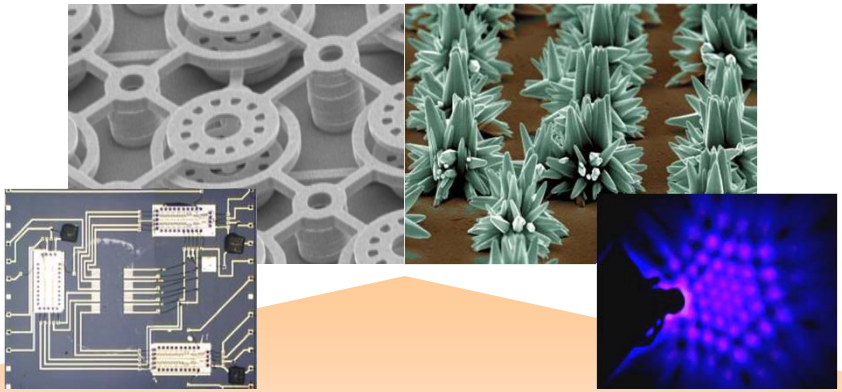
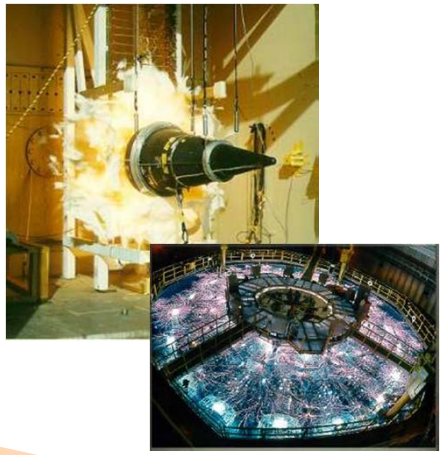




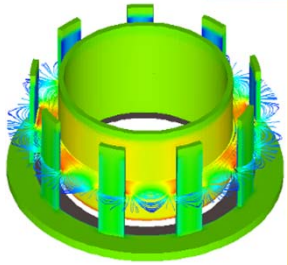


High Performance Computing

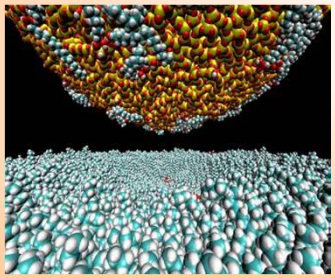
Nanotechnologies & Microsystems

Extreme Environments

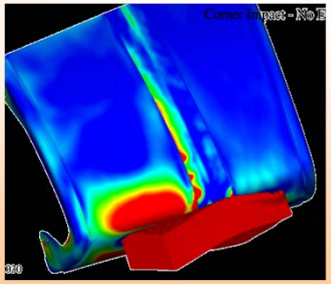
Computer Science



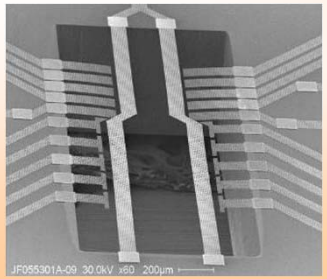
Materials



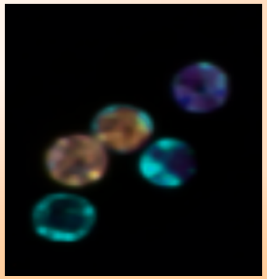
Engineering Sciences



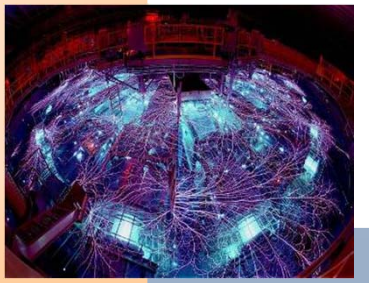
Micro Electronics



Bioscience



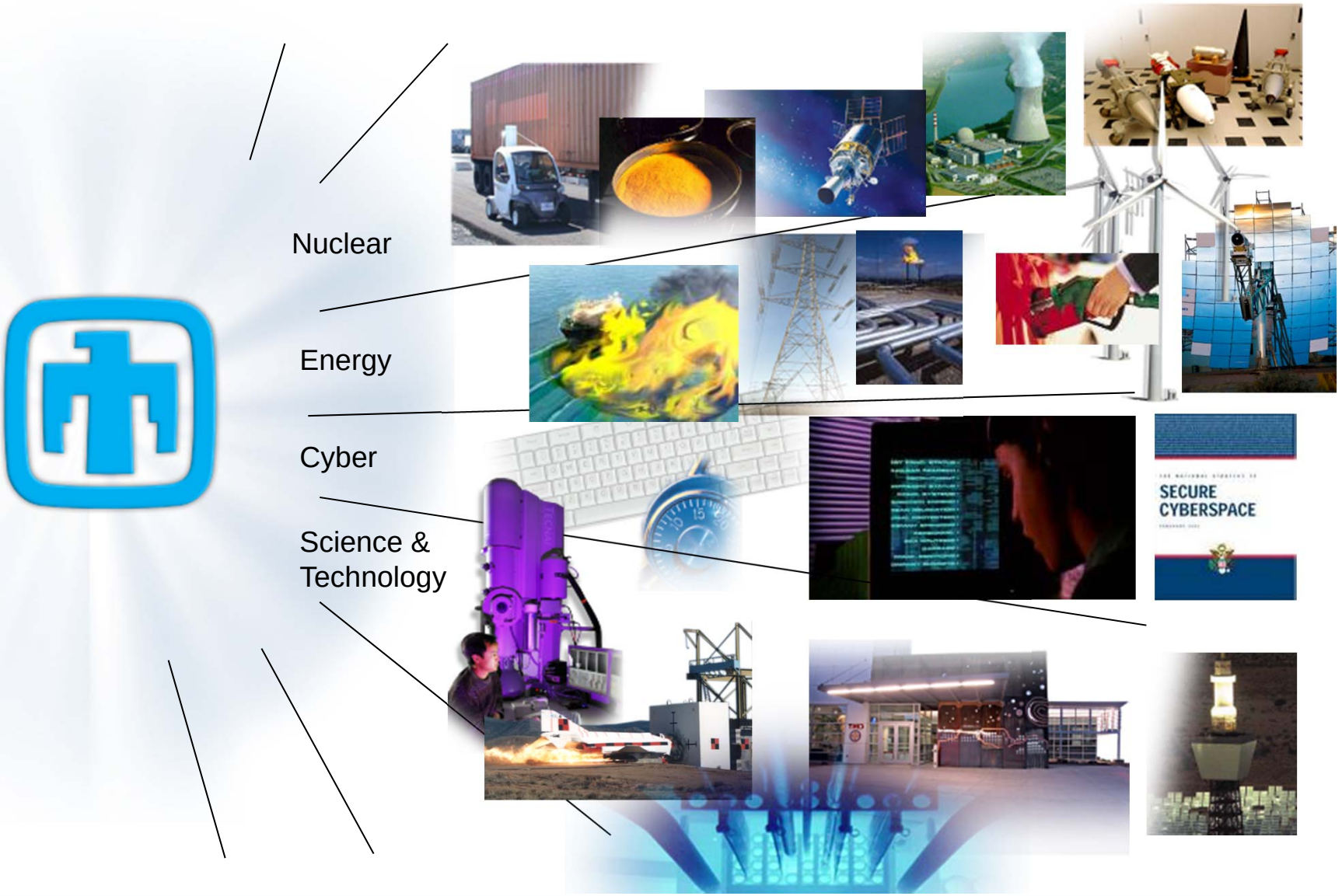
Pulsed Power



Research Disciplines

Emerging National Security Thrusts

Sandia National Laboratories



Why am I here?

- **Husker Engineers make a difference at Sandia**
  - Late ‘70s thru early ‘80s SNL actively recruited graduate students
  - Making an Impact with my fellow UNL graduates/colleagues
    - Dave Foral, Lincoln, BSME ‘81 (MSME – Wisconsin)
    - Jim Nelsen, Nebraska City, BSME ’79 & MSME ‘81
    - Kevin Eklund, Omaha, BSME ‘81 & MSME ’83
    - Doug Dederman, Lincoln, BSCE ‘81 & MSEM ‘83

- **Reestablish/Expand the Big Red Pipeline with Sandia**
  - Building Faculty Relationships & Recruiting
  - Student Interns, Masters Fellowship Program, Employment

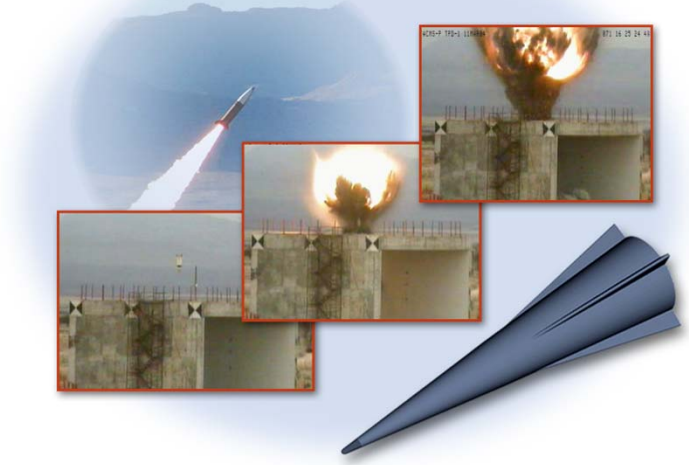
- **Exceptional Service in the National Interest**

Sandia National Laboratories

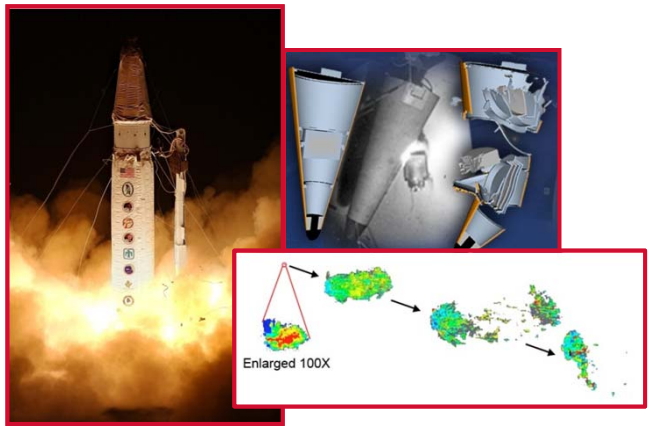
Integrated Military Systems Program

Sandia National Laboratories

Strike Systems & Aerospace Technologies



Missile & Air Defense



Military Systems & Technologies

Warhead and Energetics

- FY11 FTEs: 221

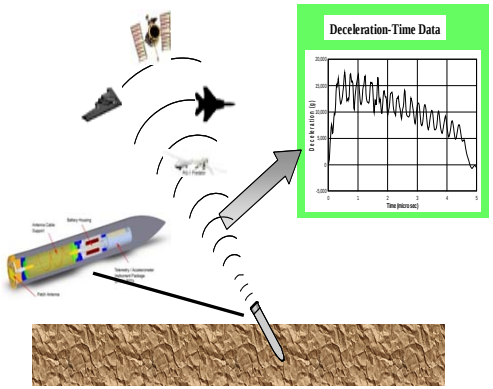
TBT Mission

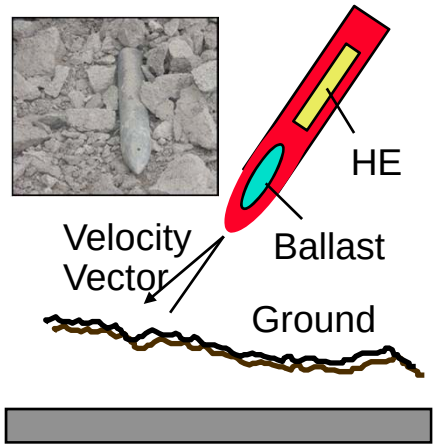
D. A. Dederman
Manager, Terminal Ballistics Technology (TBT)
Integrated Military Systems Development

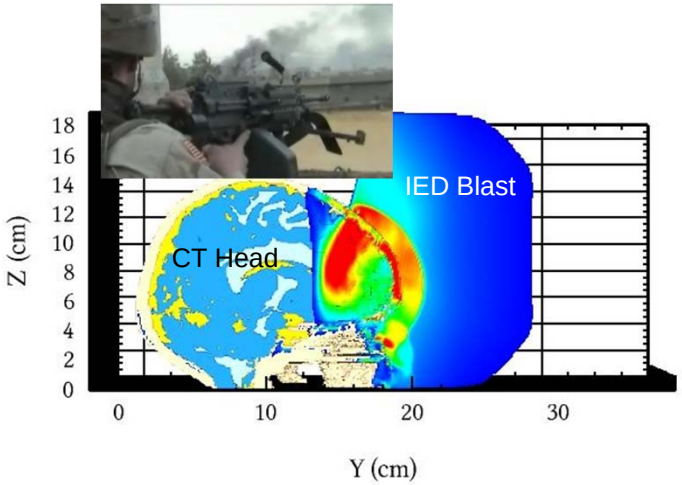
Terminal Ballistics Technology
TBT
Target Protect
Target Defeat

Sandia National Laboratories

Design, develop, & demonstrate terminal ballistics enabling technologies that enhance survivability and functionality of lethal & nonlethal projectiles/probes for characterization, defeat or protection of military & nonmilitary targets







- Penetration & Perforation M&S Analyses
- Terminal Ballistics Testing & Evaluation
- Verification & Validation for Improved Predictive Tools

Leveraged with Internal & External Partnerships

Terminal Ballistics Mechanics

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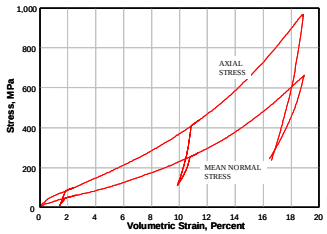
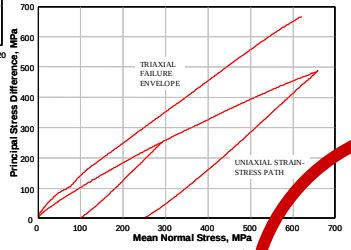
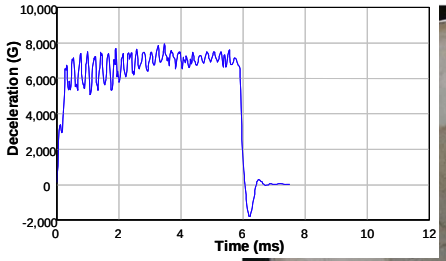
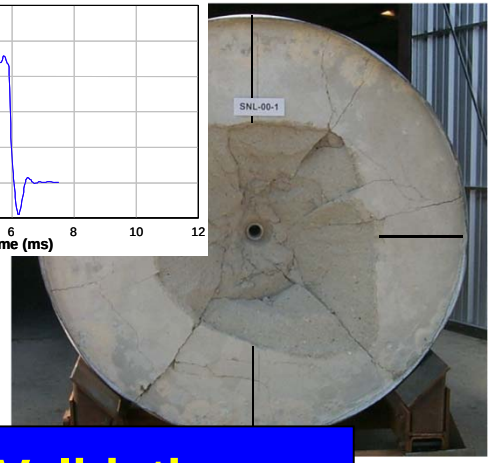
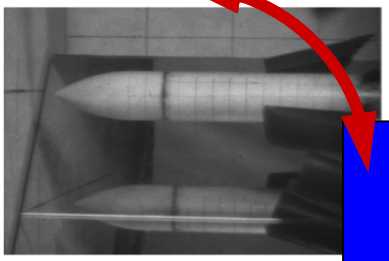








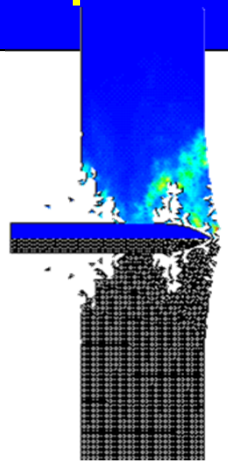
Material Properties



Validation Experiments

Constitutive Models

Numerical Simulations



Peridynamic model:
A new theory of continuum mechanics

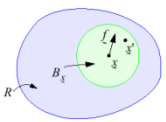
Computational Physics & Mechanics Department

- Classical theory uses PDE's.
  - PDE's don't hold on cracks or localization surfaces.
- Peridynamic theory instead uses an integral formulation.

$$\rho\ddot{\underline{y}}(\underline{x},t) = \int_{B_{\underline{x}}} \underline{f}(\underline{y}(\underline{x}',t) - \underline{y}(x,t), \underline{x}' - \underline{x})dV_{\underline{x}'} + \underline{b}$$

where $\underline{f}$ represents interparticle force.

- Advantages:
  - Same equations apply everywhere, even on a crack face.
  - Method lends itself to mesh-free code implementation.



Test & Evaluation Capabilities

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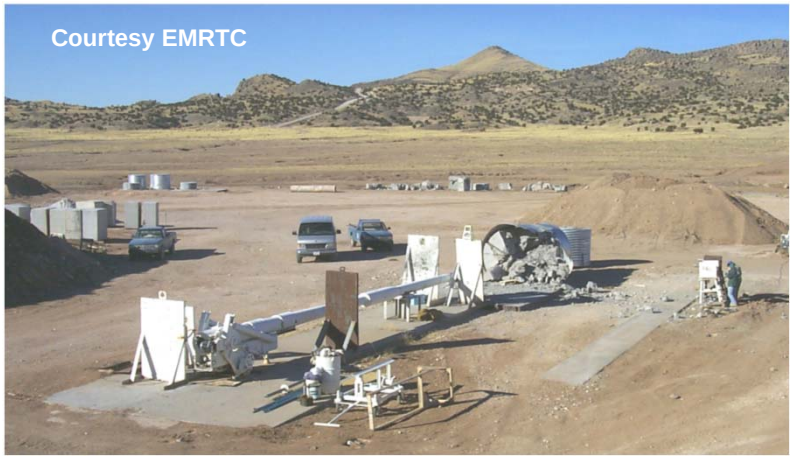
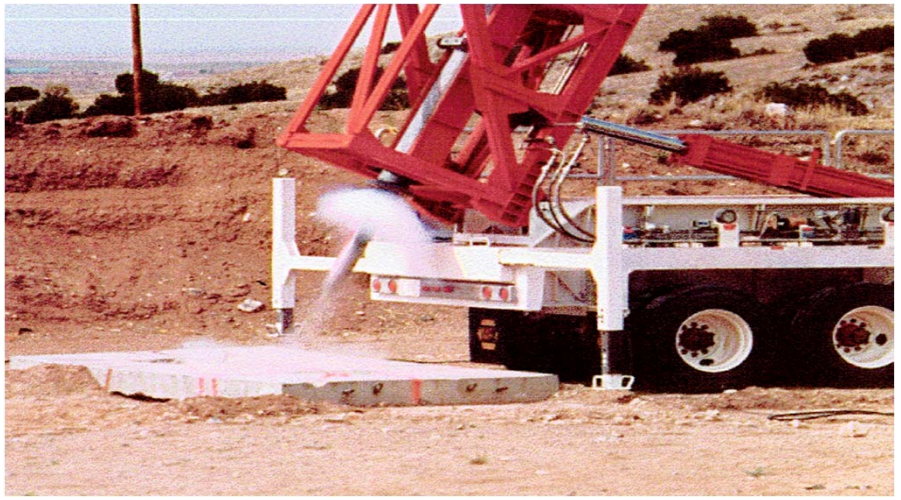


16” Davis Gun test firing at WSMR

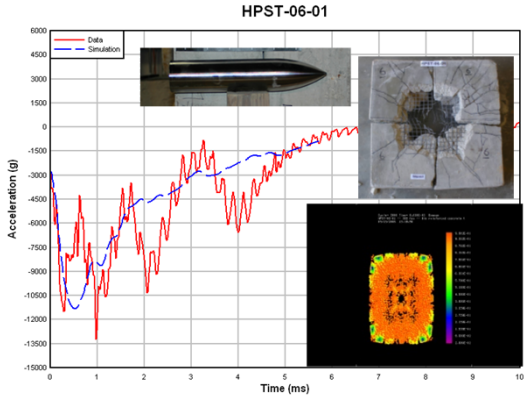


SNL 6” Mobile Gas gun firing of instrumented penetrator into a engineered target

Modeling and Simulation Challenges for Projectile/Target Physics

- Projectile best modeled in Lagrangian formulation, Target best modeled as Eulerain
  - Need improvements in efficient coupling, contact algorithms
- Challenges in modeling pressure dependent, strain rate dependent geomaterials
- Probabilistic modeling
  - Target Uncertainties
- Still have work to do and need talented engineers on team
- Marriage of M&S with Verification Experiments

Normal & Oblique Impact Testing with Instrumented Penetrators



Terminal Ballistics Technology

TBT

Target Protect
Target Defeat

Traumatic Brain Injury (TBI)

Sandia Focus: Military Relevance

- US Soldiers are surviving blast and impacts due to effective body armor, rapid evacuation, & availability of critical trauma care
- Closed-Head Blast Injuries are leading cause of traumatic brain injury (TBI) in military personnel returning from combat [1,2]
  - As of 2010, 160,000 US warfighters sustained TBI
  - 69% as a result of IED blast exposure in Iraq & Afghanistan

- Blast Injury categories:
  - Primary: direct exposure to explosion-produced air blast
  - Secondary: impact by flying objects thrown by air blast
  - Tertiary: impact into stationary object (soldier thrown by air blast)
- Our focus is on Primary Blast Injury and investigating mechanisms associated with brain injury
  - Once know, want to mitigate blast mechanisms through helmet design

[1] Defense & Veterans Brain Injury Center TBI numbers: DoD numbers for traumatic brain injury. 2010
[2] Fischer, H., 2007, United States Military Casualty Statistics: Operation Iraqi Freedom and Operation Enduring Freedom, Congressional Research Service Report RS22452.

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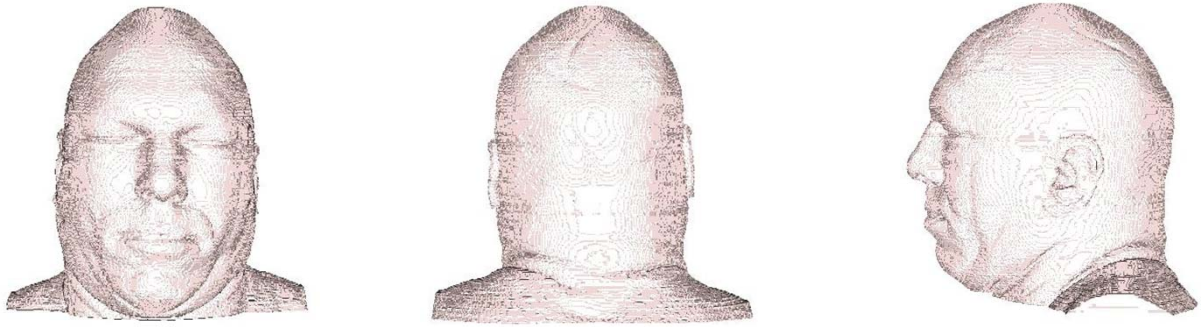
Modeling & Simulation

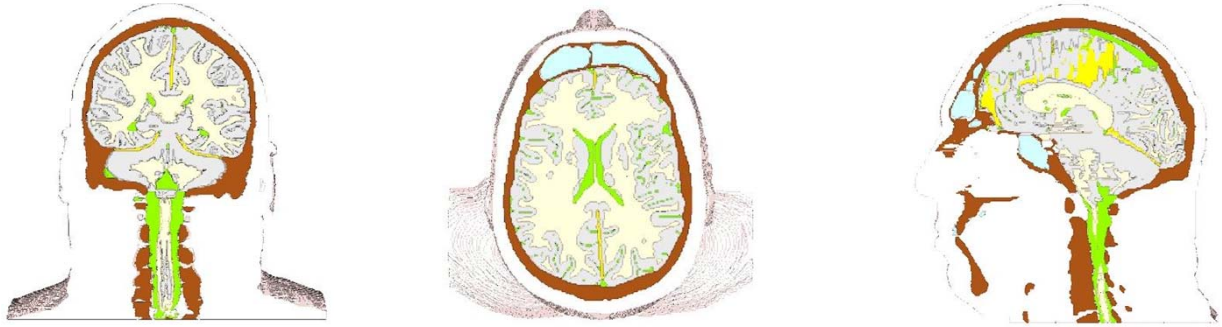
Development of Head-Neck Model

- Constructed finite volume model from Visible Human Project [3] data
  - Constructed from 256 1mm-thick, axial slices of anatomical sections of human male from the VHP
  - Anatomically correct distributions of white & gray brain matter, cerebral spinal fluid, bone, falx & tentorium membranes, muscle/scalp

Full Model Images:



Coronal, Axial, & Sagittal Cuts:



Model Size: 5.9M Cells

[3] National Institutes of Health, 2007, "The Visible Human Project," National Library of Medicine http://www.nlm.nih.gov/research/visible/visible_human.html

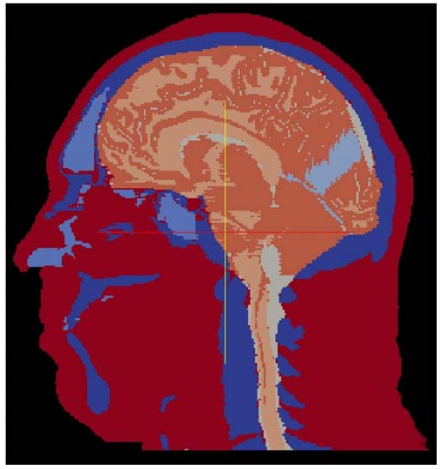
Terminal Ballistics Technology

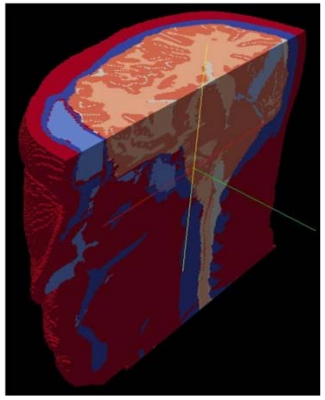
TBT Target Protect Target Defeat

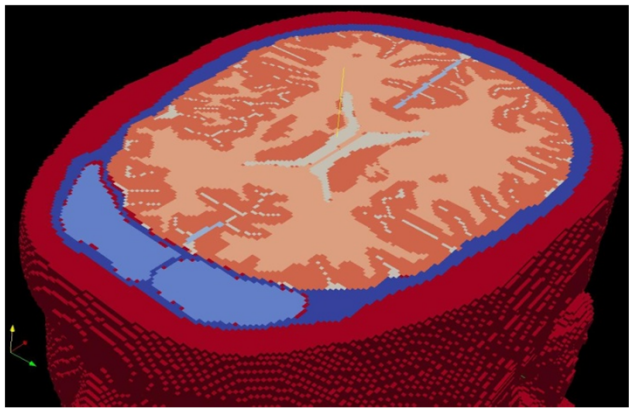
Modeling & Simulation

Development of Head-Neck Model

- Constructed Finite element version of head-neck model
  - Possesses anatomically correct distributions of white & gray brain matter, cerebral spinal fluid/blood, bone, falx & tentorium membranes, muscle/scalp
  - 5.9 million hex elements
    - Brain: 1.4M elements (1.4 L)
      - GM: 794K
      - WM: 509K
      - Falx/Tentorium: 21K
      - CSF/Blood: 89K
    - Sinus: 98K elements (0.098 L)
    - Bone: 749K elements (0.75 L)
    - Scalp/Muscle: 3.6M elements (3.6 L)
  - For use in Lagrangian finite element simulations and coupled Eulerian-Lagrangian simulations







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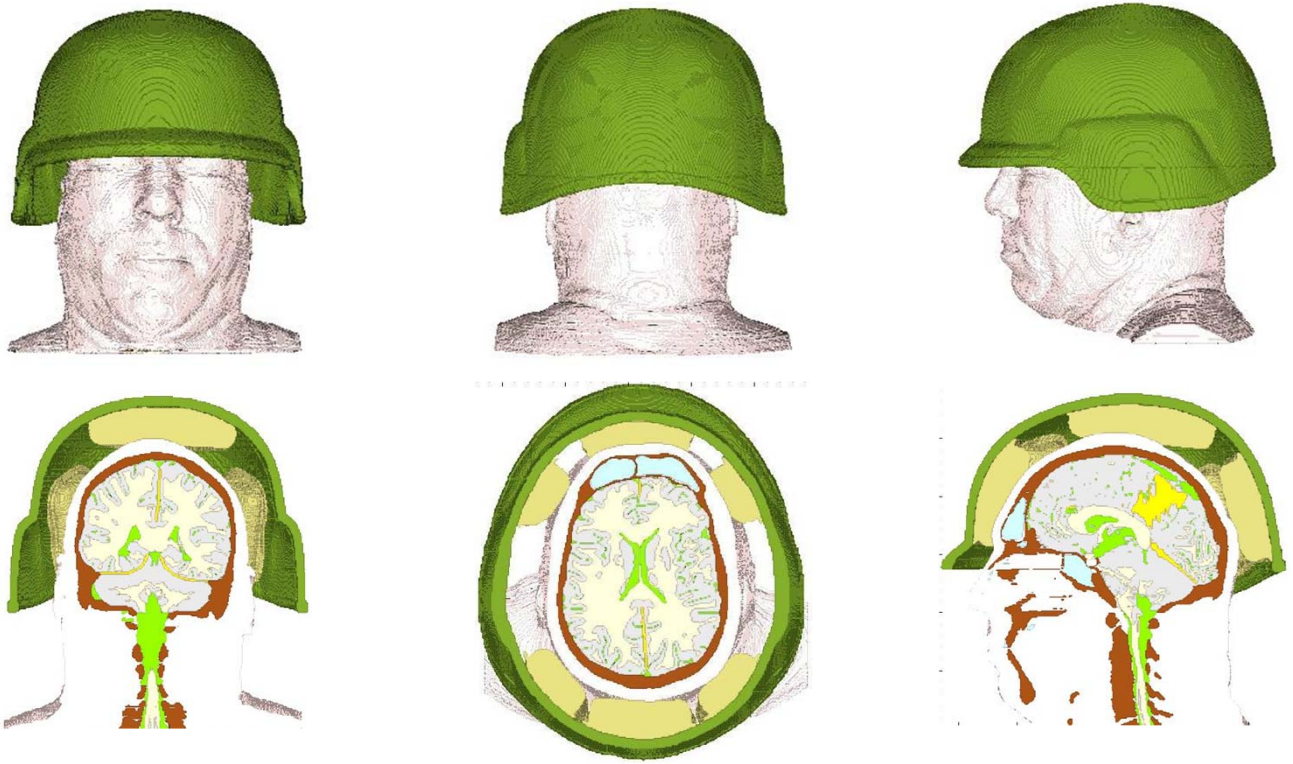
Terminal Ballistics Technology

TBT Target Protect Target Defeat

Modeling & Simulation

Development of Helmet Model

- Constructed representation of military helmet
  - Helmet shell: Kevlar Composite
  - Pads: Polyurethane Foam Pads
  - Strapping removed; Not necessary in timeframe of interest (3-4 ms)
    - Helmet moves only 3-4 mm during course of our simulations



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Terminal Ballistics Technology

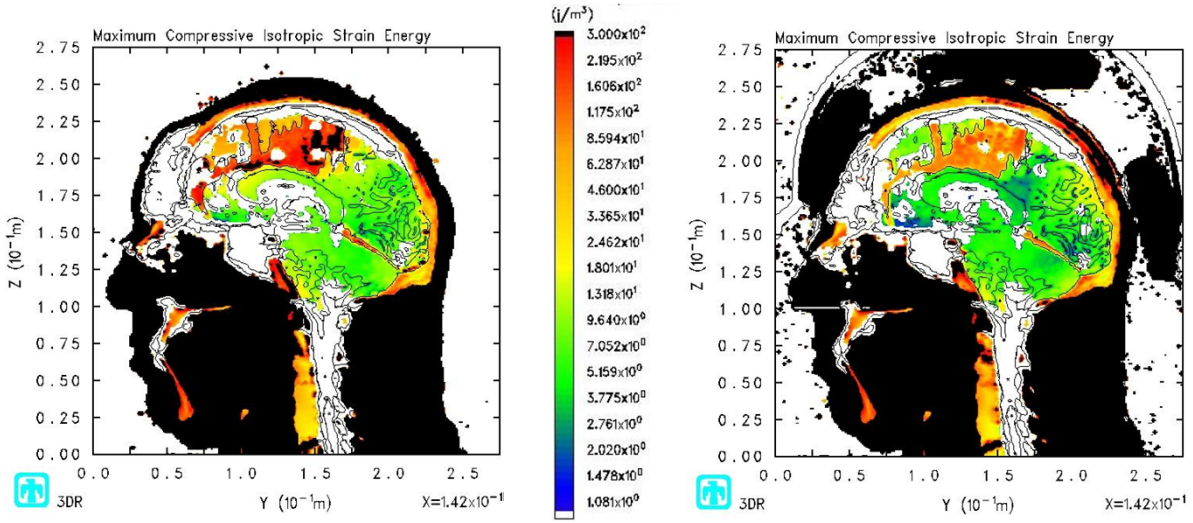
TBT Target Protect Target Defeat

Blast Mitigation Effects of Helmet Protection

3.6 bar Frontal Blast Exposure: Isotropic Strain Energy Maxima

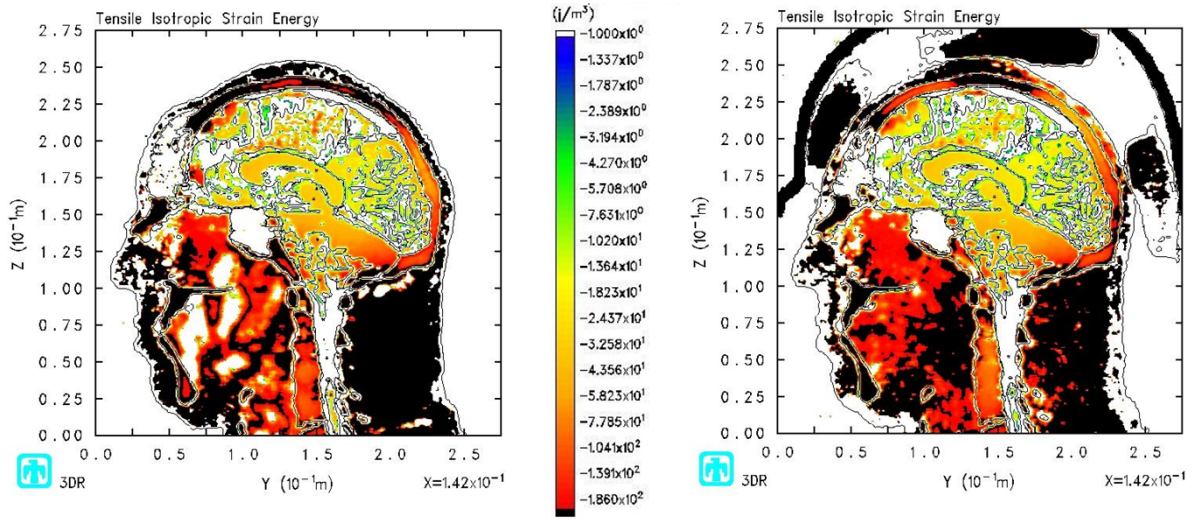
Compressive Isotropic Strain Energy

"Crush"



Tensile Isotropic Strain Energy

"Dilatation" (leads to Cavitation)



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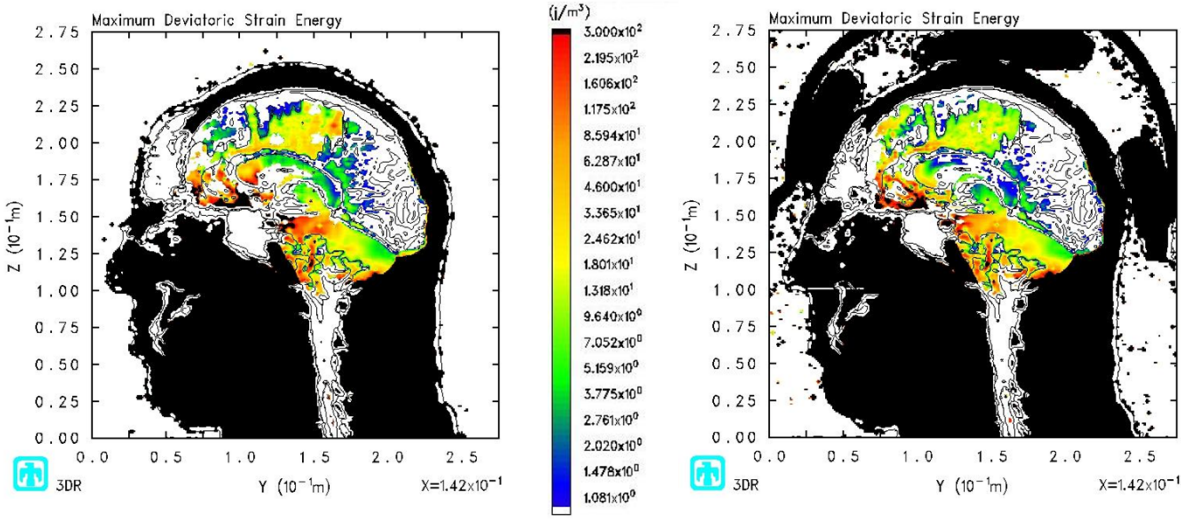
Terminal Ballistics Technology

TBT Target Protect Target Defeat

Blast Mitigation Effects of Helmet Protection

3.6 bar Frontal Blast Exposure: Deviatoric Strain Energy Maxima

Deviatoric Strain Energy



"Tearing"

- For frontal blast, we predict Helmet:
  - Reduces compressive isotropic energy deposition (~50%)
  - Does not reduce tensile isotropic energy deposition
    - Slightly reduces compression-to-dilatation swing in frontal brain region
  - Does not significantly reduce deviatoric strain energy
    - Significant! Deviatoric stress & energy are associated with mild TBI outcomes [8]

[8] Zhang, L., Yang, K.H., & King, A.I., 2004, "A Proposed Injury Threshold for Mild Traumatic Brain Injury," ASME J. Biomech. Eng., 126(2), pp.226-236.

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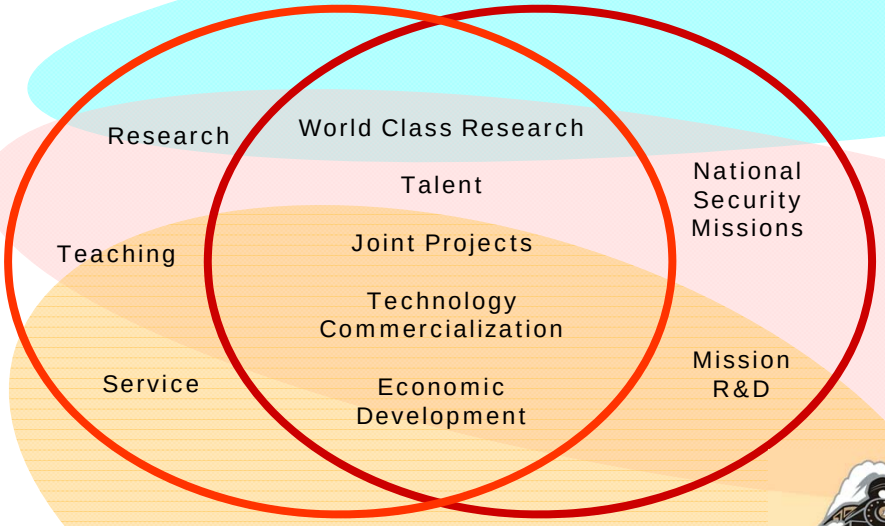
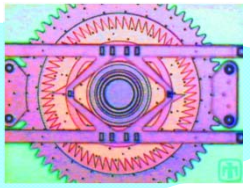
University Partnerships deliver world class science + top talent…



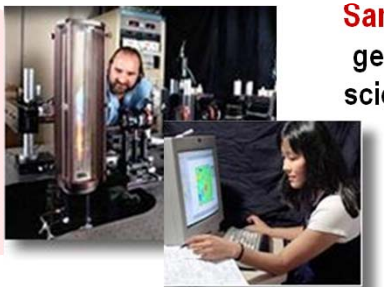
Universities… are the nation's primary source of new knowledge.



Sandia's world class research

- **$25M in university research annually**
- **Faculty research sabbaticals**
- **PECASE awards**

Universities… create the nation's talent pool.



Sandia's next generation of scientists and engineers

150 new technical employees annually
400 technical interns annually
90 Sandia graduate fellows
140 Post-docs

Universities… enhance research impact and funding through collaboration.

Strategic university alliances:
- **ASCI, RAMP, CINT, MESA, etc.**
- **Campus Executive Program**

Sandia's commitment to education

Sandia National Laboratories

Student Internships

Institutes

- National Institute for Nanoscale Engineering (NINE)
- Physical Sciences Institute
- Computer Science Research Institute
- Center for Cyber Defenders
- Enabling Predictive Simulation Research Institute
- Sandia Institute for Modeling and Simulation
- National Security Engineering Institute

Internships and Co-ops

- Year-round and summer
- Must be a U.S. citizen with full-time enrollment status
- Minimum cumulative GPA of 3.2/4.0 for undergraduates or 3.5/4.0 for graduate students
- STEM and business disciplines
- Apply online at Sandia's website: www.sandia.gov
- Pay based on job classification and the number of academic credit hours completed prior to internship

Predictive Simulation of 4340 Steel Projectiles Perforating 6061-T6 Aluminum Targets with Peridynamics

SIP Symposium Event

August 9th, 2011

Embassy Suites, Albuquerque, NM

Ryan Terpsma

University of Nebraska – Lincoln

Mechanical Engineering Intern

SNL Terminal Ballistics Technology Department, 5431

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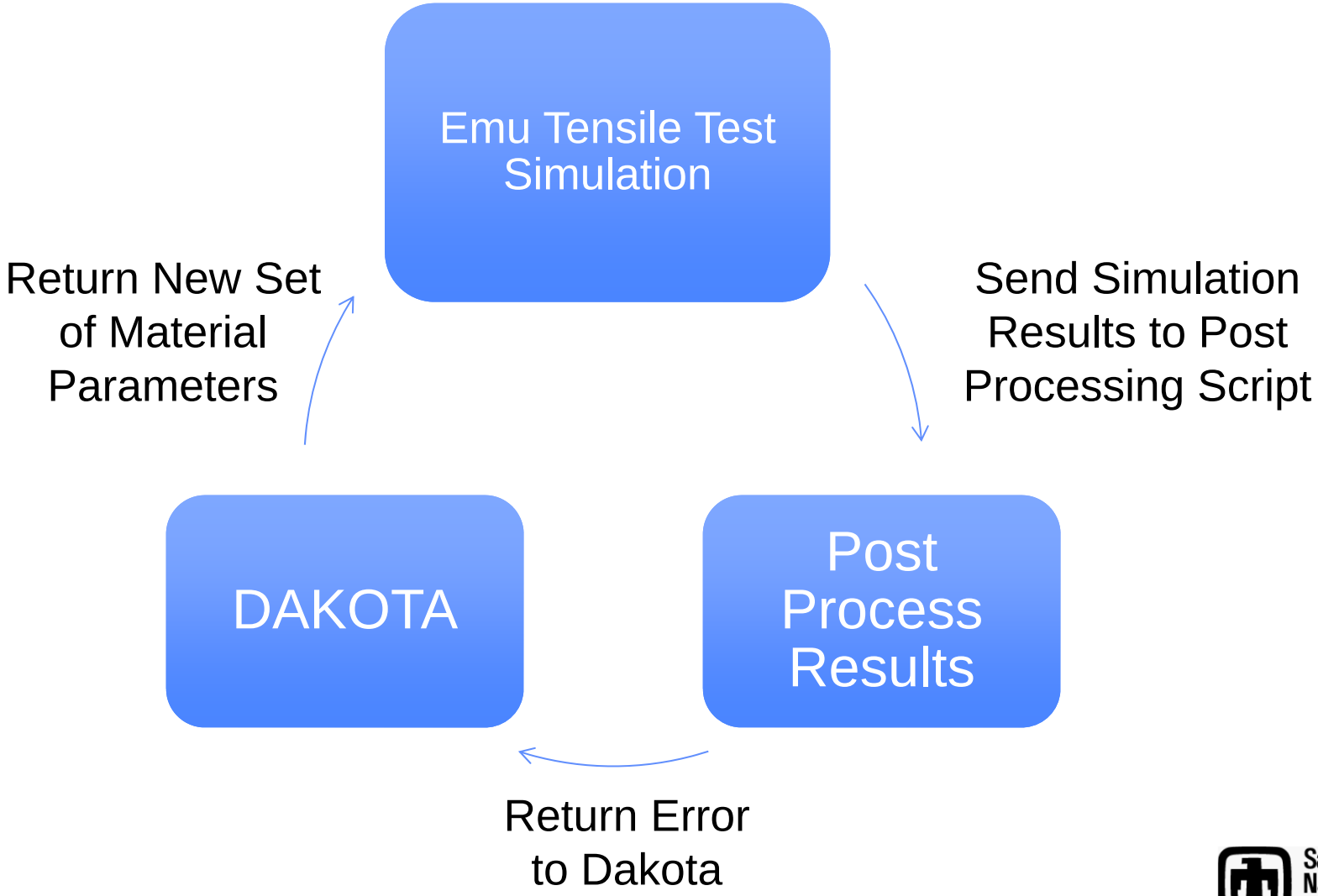
DAKOTA – Emu Flowchart



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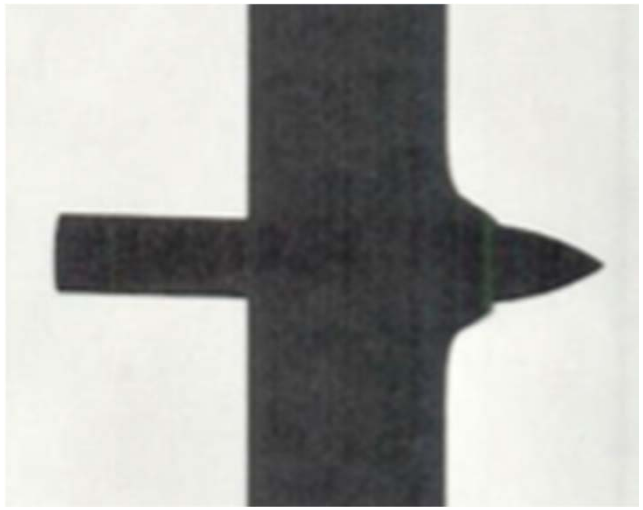
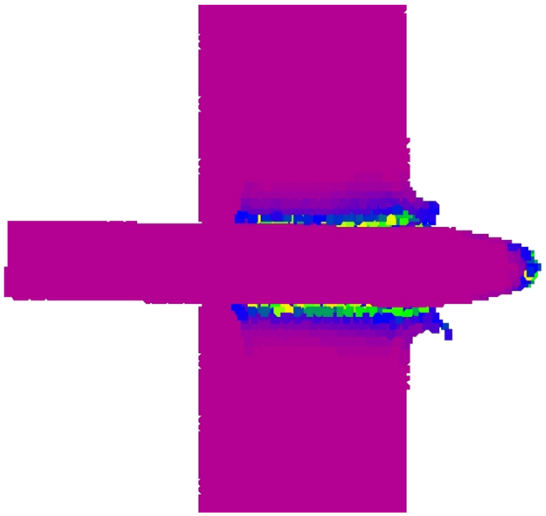
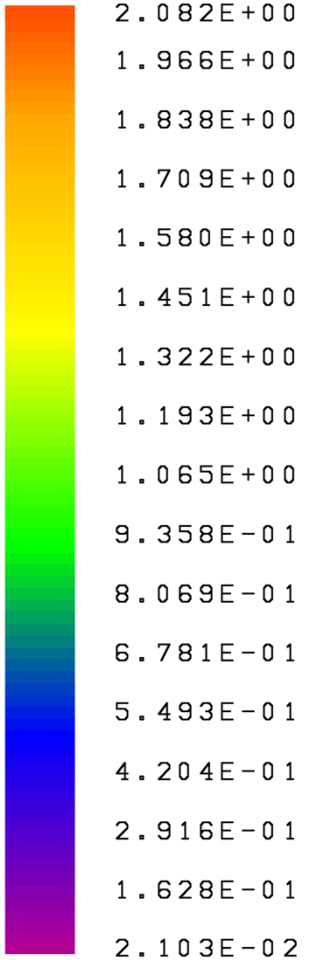
Simulation – Experiment Comparison (Test No. 6-2635)





T = 75 x 10^{-6} sec

Equivalent Plastic Strain:



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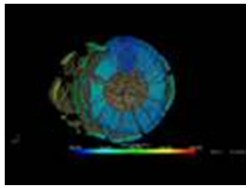

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140,800+ views

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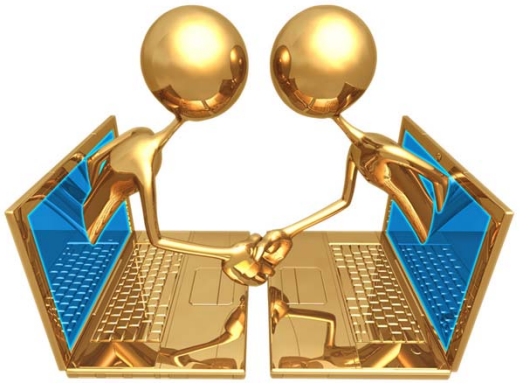
64,200+ views

Rocket Powered Train Impact Test
59,000+ views



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