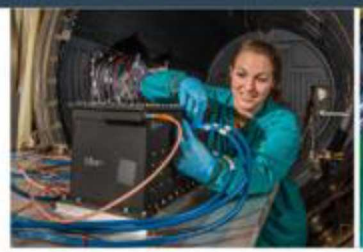
SAND2019-5978C

Sandia National Laboratories

Overview of Advanced Science & Technology (AS&T) at Sandia



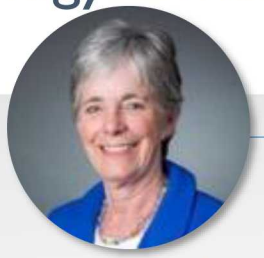

PRESENTED BY

Bryan Oliver, *Sr. Manager*
Radiation Effects Science and Applications
Sandia National Laboratories, USA

CEA/DAM - NNSA Defense Programs Fundamental Sciences Meeting | June 5-7, 2019

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and 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.

The Advanced Science &Technology Division at Sandia National Labs



Dr. Susan Seestrom

Associate Laboratories Director
Chief Research Officer
Advanced Science and Technology (Div. 1000)

Grant Heffelfinger

Deputy CRO
Director, AST Program Portfolio Management

AS&T Division Line Manager

Chief Research Officer (CRO)

Weapons Science & Technology (WS&T)

Office of Science (SC)

Advanced Science and Technology Portfolio

The AS&T Division Conducts Science Based Engineering to Ensure Mission Success

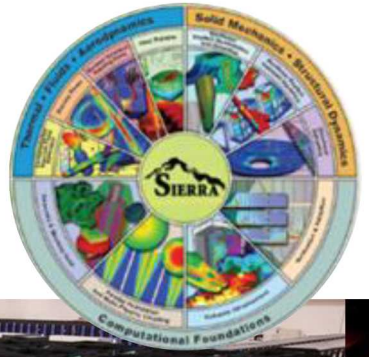
Integrating multidisciplinary efforts to advance the science of the possible for Sandia's missions

Modeling and Simulation

- High performance computing
- Software tools
- Uncertainty quantification (UQ)

DAKOTA
Explore and predict with confidence.

LAMMPS

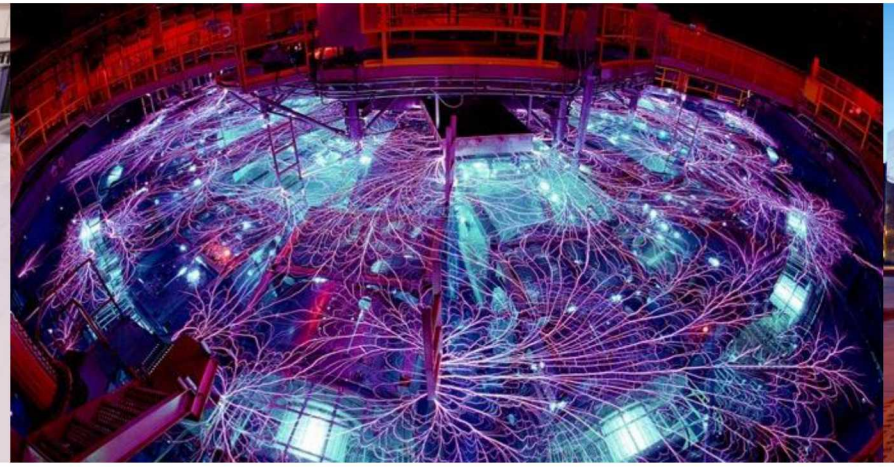


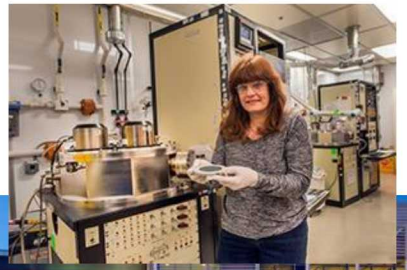
Advanced Experimental Capabilities

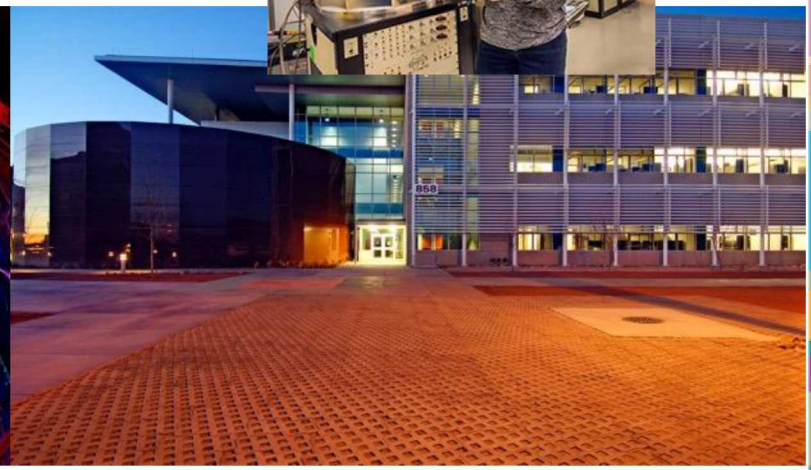
- Radiation effects
- Engineering environments
- Materials characterization and production

Microelectronics

- Microsystems & Engineering Sciences Applications (MESA) Fab
- Development of advanced semiconductor materials





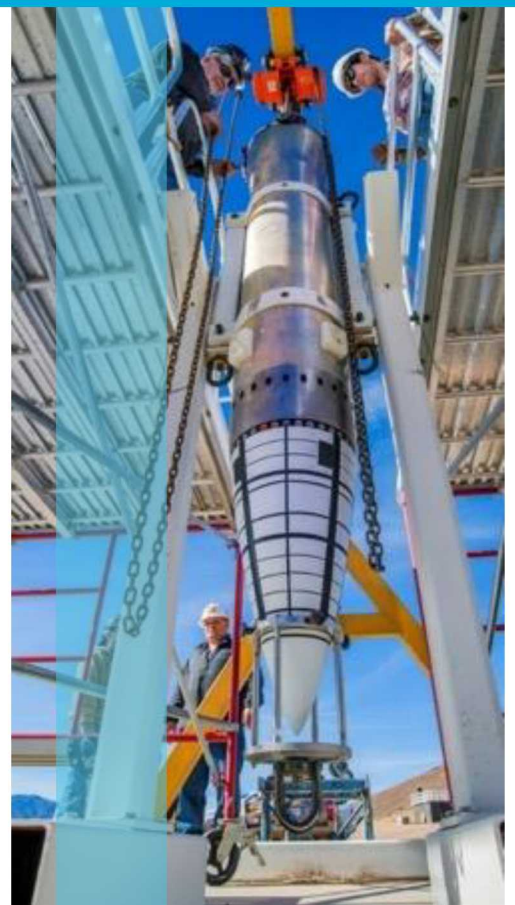


Weapons Science & Technology (WS&T): Ensuring A Safe, Secure, and Effective Stockpile

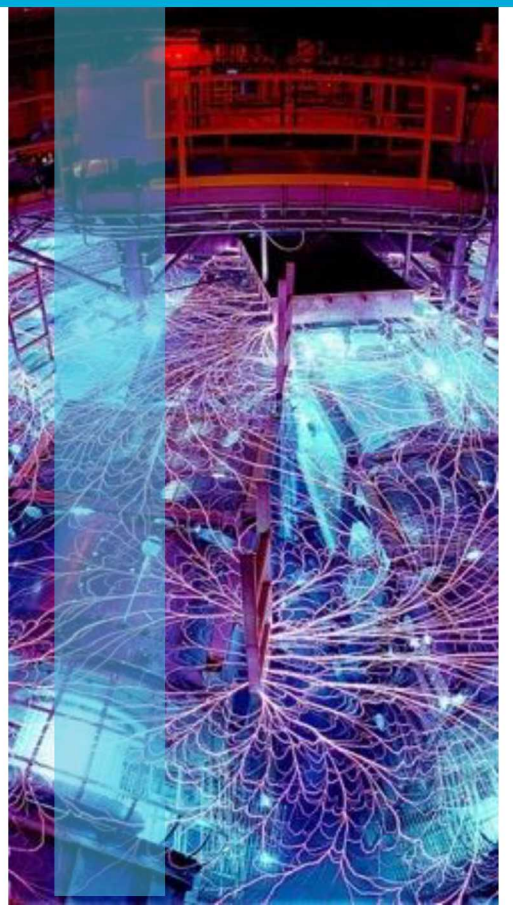
Our vision is to provide foundational science and engineering capabilities to explore the science of the possible in advancing and sustaining an effective nuclear deterrent in the evolving landscape.

Advanced Simulation & Computing

Engineering and Technology Maturation



Science Campaigns & Inertial Confinement Fusion

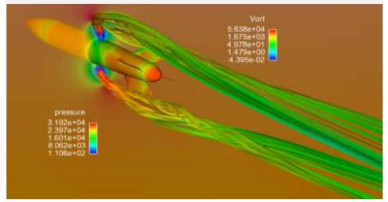


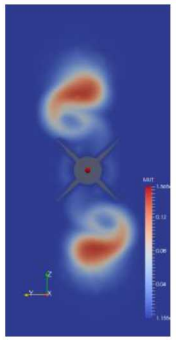
Infrastructure & Operations

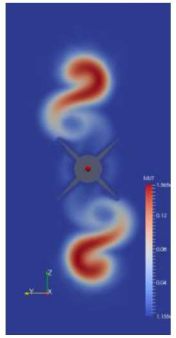
Sandia's Advanced Simulation and Computing (ASC) Program Provides Critical Computational Physics Support to our Nuclear Deterrence Program

Normal Flight Environments

Low-Mach Aero capability for spin-to-arm assessment

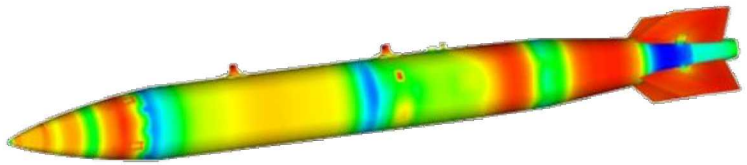






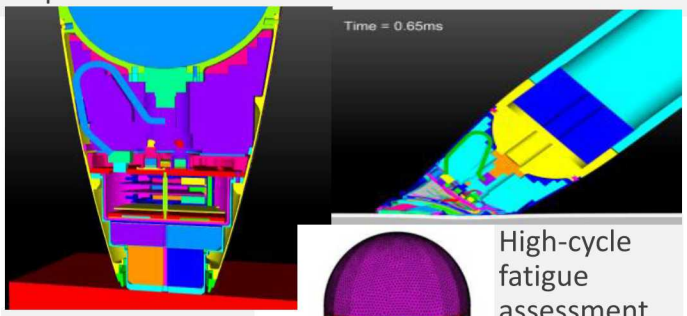
Normal Thermal Qualification

Advective bar capability for flight profile thermal modeling



Normal Mechanical Qualification

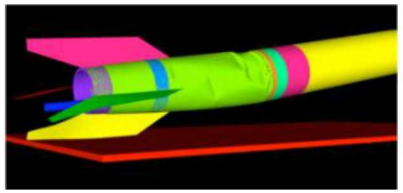
Robust failure & contact modeling for v-γ map exploration



acoustics coupling for ground-based test design

High-cycle fatigue assessment capability

Abnormal Mechanical Safety

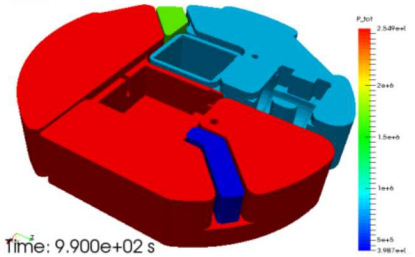


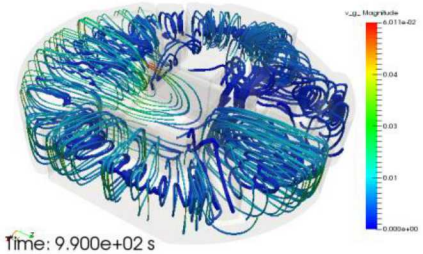
Contact performance

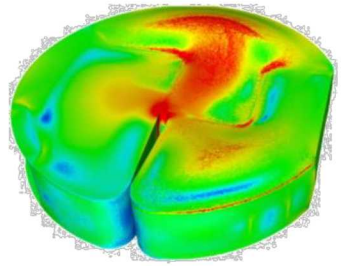
Abnormal Thermal Safety Theme

Models for pressurization & breach

B61 FCU



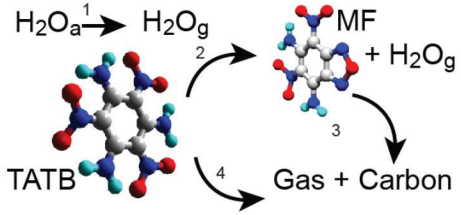




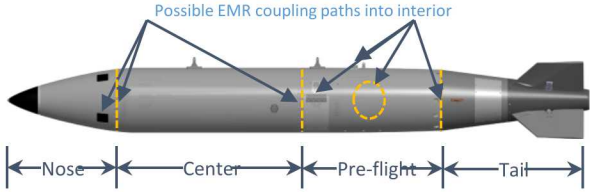
Models for energetic material response

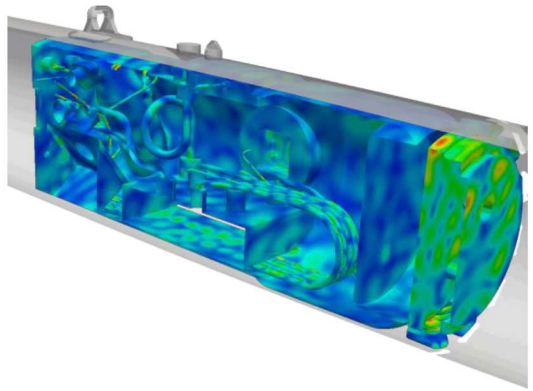
thermal model

mechanical model



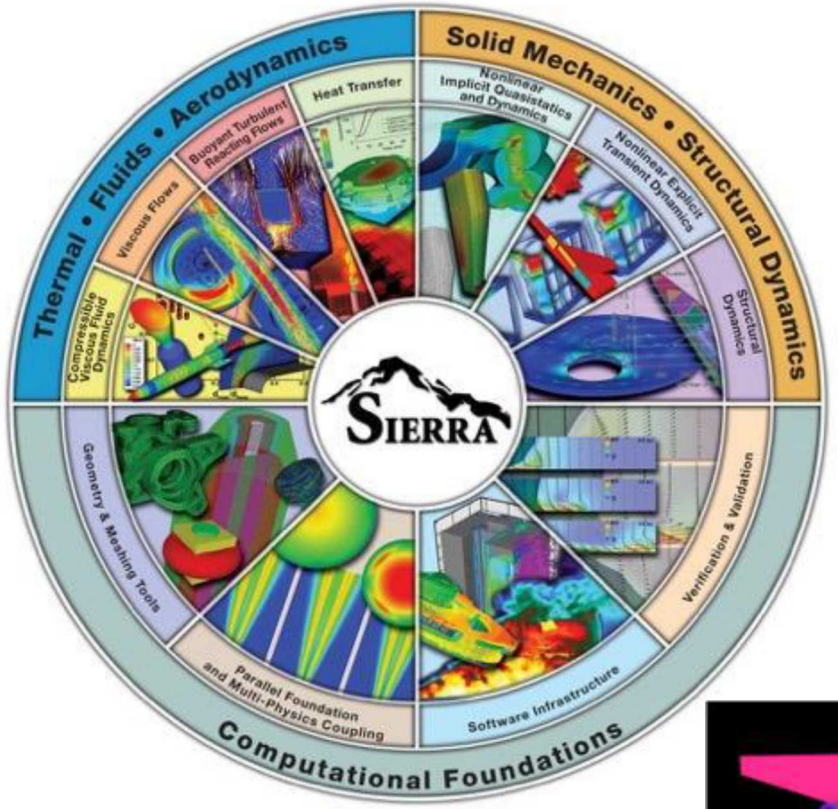
Hostile Electromagnetic Radiation Environments





Sandia's ASC Computational Simulation Code Suites Impact Weapon Lifecycle

Engineering Mechanics Code Suite

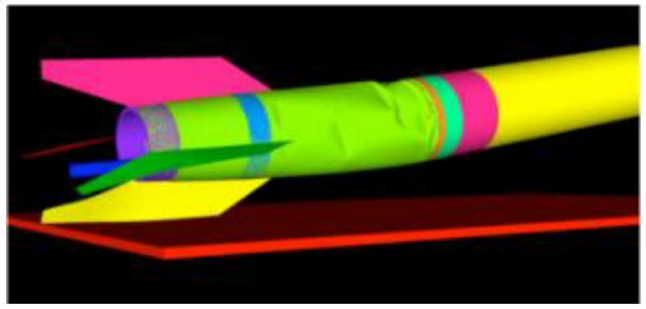


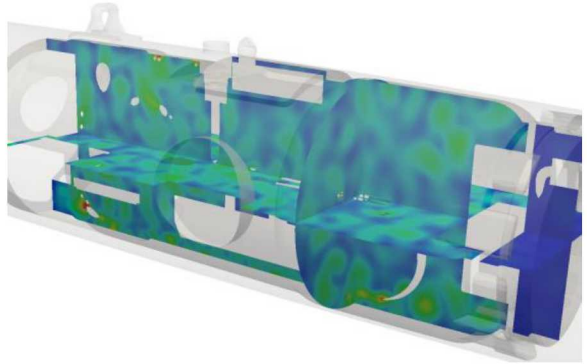
Future coupling

Electromagnetics, Radiation, and Electrical Code Suite

RAMSES

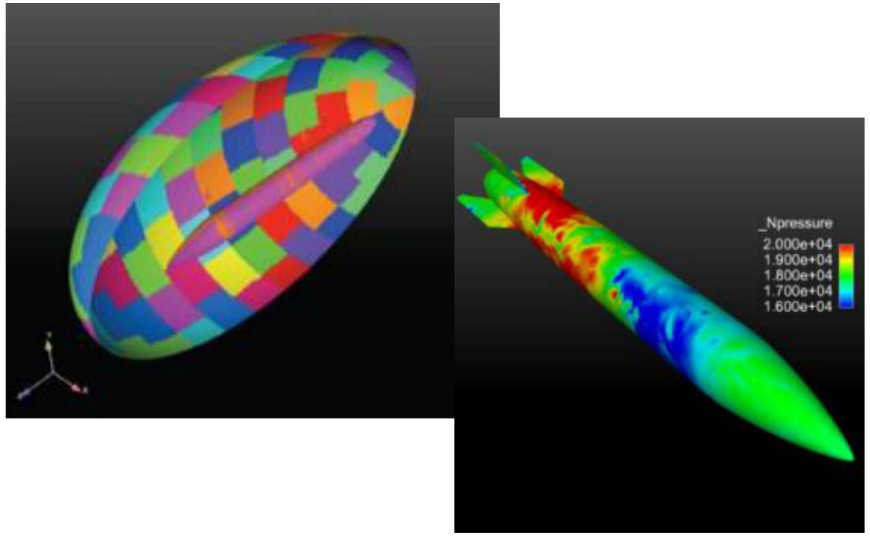
ITS SCEPTRE NuGET EIGER EMPHASIS Xyce Charon CHEETAH Gemma EMPIRE

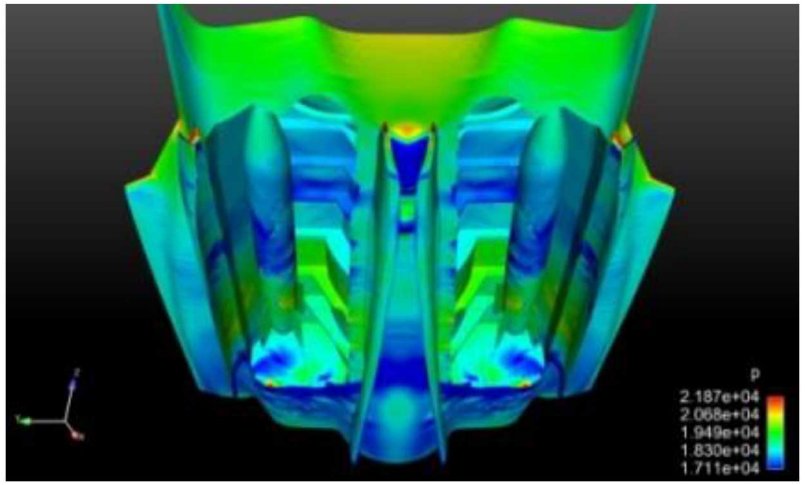




Simulations Support Shock & Vibration Environmental Specification (ES)

- Environmental Specification (ES) drives design of ***all components*** in system
- We integrate shock & vibration data from flight tests, ground tests, and computational simulation
- Computational simulation:
  - Determines environments for components not instrumented in tests
  - Supports ground testing of extreme flight profiles
  - Provides design guidance for test hardware to approximate flight conditions

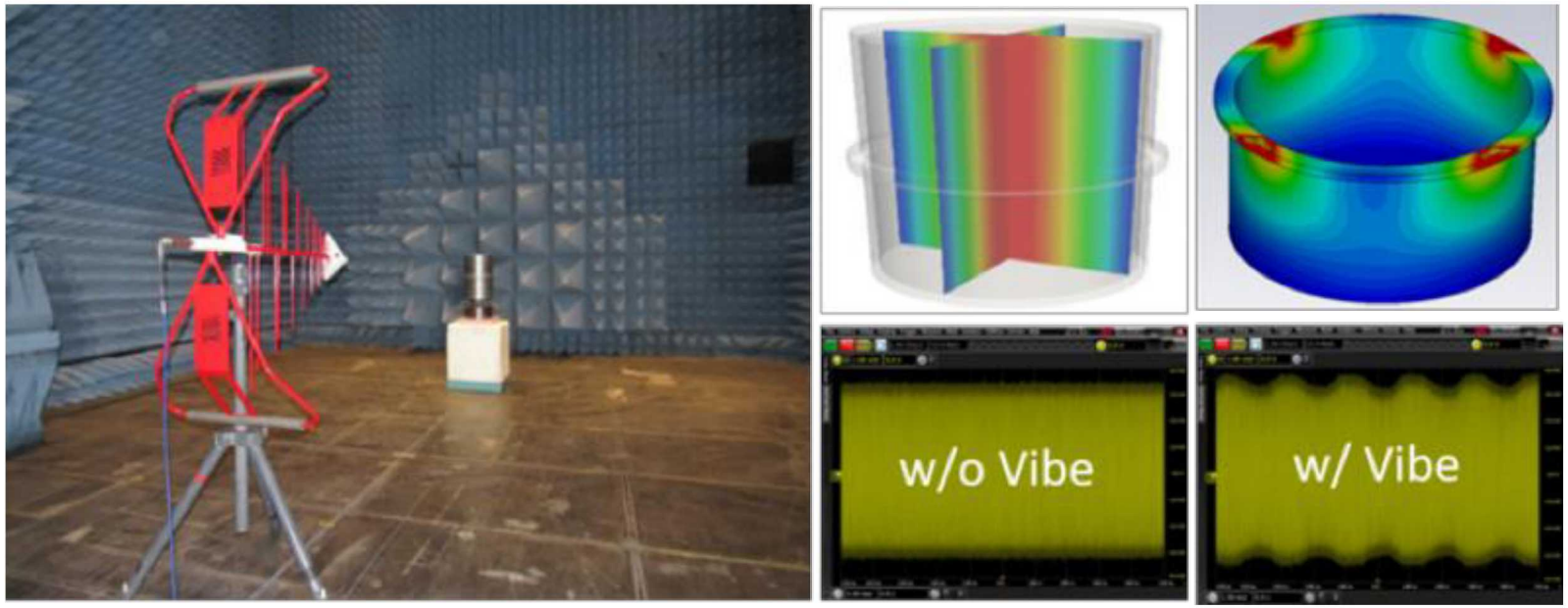




ASC simulations helped define accurate environmental specifications for military systems

Studies in Combined Mechanical + Electromagnetic Environments

- Effect of vibrations on electro-magnetic environments are not understood
- New tests and simulations show that EM-field coupling into a cavity is altered by a simultaneous vibrational environment



Experiments and simulations of a cylindrical cavity prototype are conducted to obtain a measure of the electromagnetic field coupled into the interior cavity via a representative bolted-joint

Multi-physics, coupled simulation capabilities

Development of Agile and Responsive Tools

Turn around analyses in minutes not months

Today: traditional hex meshing

CAD cleanup → CAD de-feature → CAD decomposition

months ↑

↓ *minutes*

ProE CAD → Future: background grid meshing straight from CAD

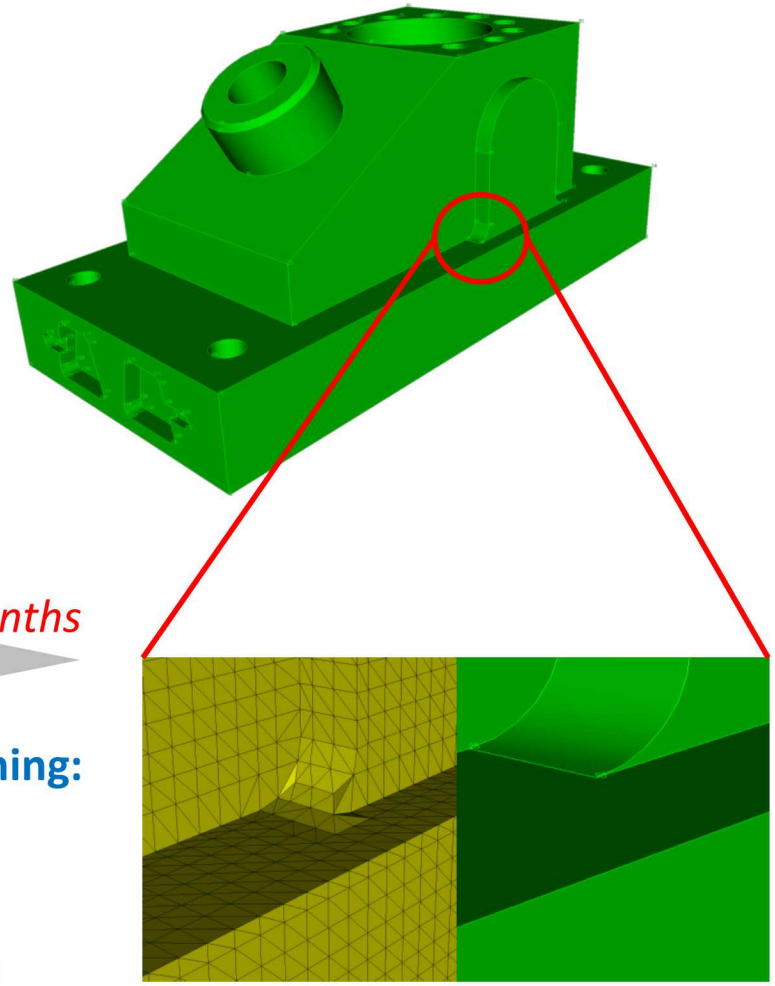
Next-generation meshing:

No geometry clean-up

Fitting to CAD geometry

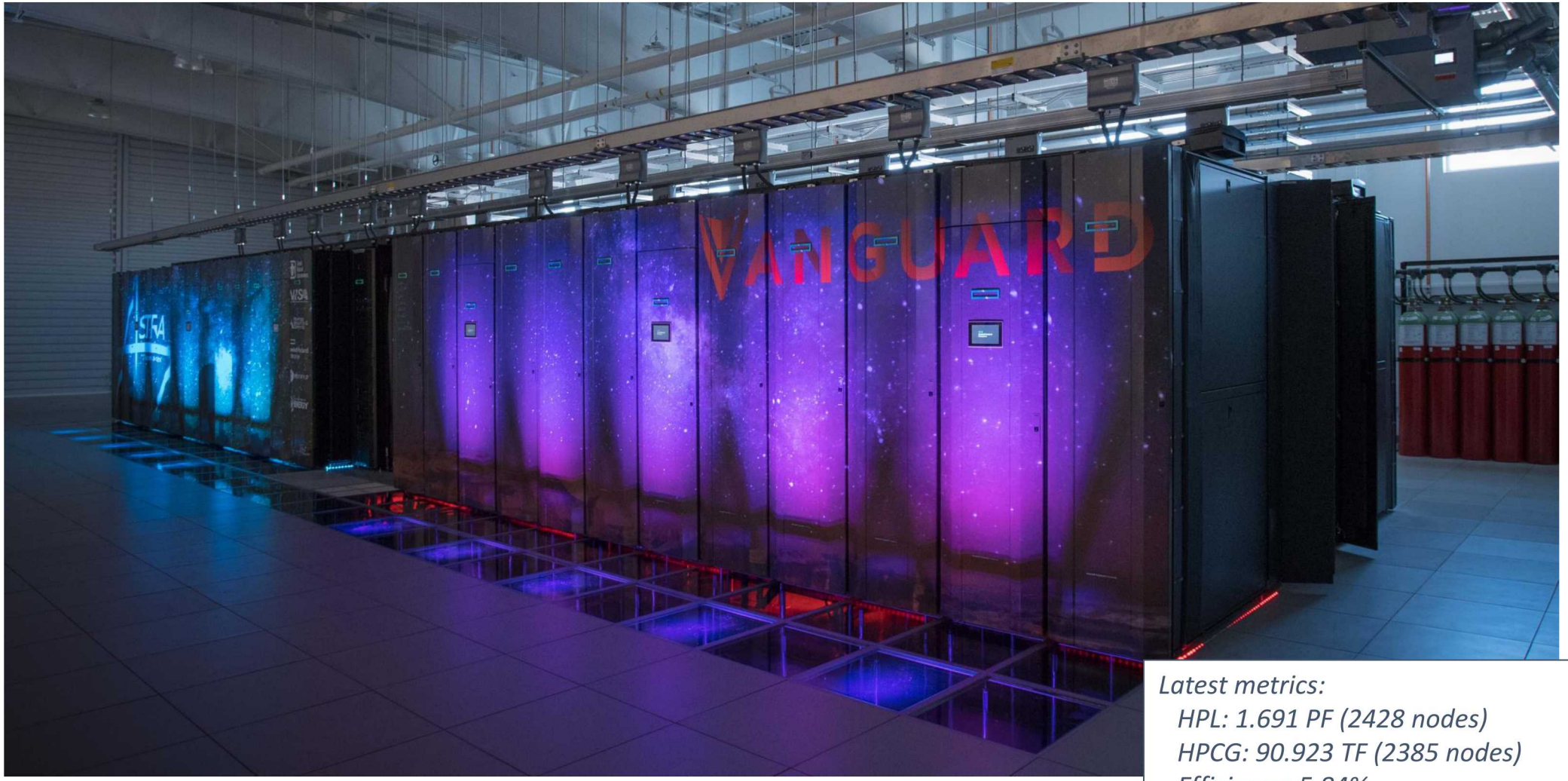
Parallel generation

Runnable (requiring new discretizations)



Agile tools will drive tailored need for compute cycles – Agile Computing

New High Performace Computing Platforms: Vanguard/Astra Arm Petascale Prototype System



Latest metrics:
- *HPL: 1.691 PF (2428 nodes)*
- *HPCG: 90.923 TF (2385 nodes)*
- *Efficiency: 5.84%*
- *RIKEN (SC18): 5.73%*

Engineering and Technology Maturation Program

Experimental testing and diagnostics capabilities to ensure a responsive stockpile that will survive complex environments.

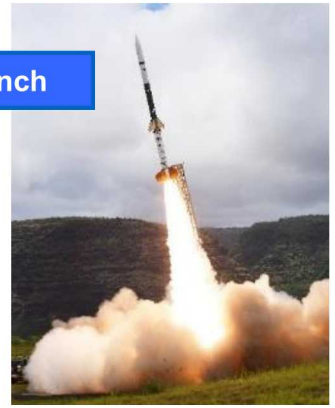
Delivery Environments – engineering science experimental capabilities to assess responses in normal flight, abnormal safety, and component production environments

Light Initiated High Explosives (LiHE) Impulse Facility

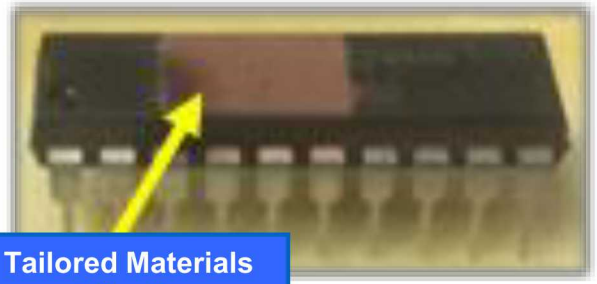
HERMES III

Nuclear Survivability - improving the technical basis qualification and assessment of the stockpile in hostile radiation and electromagnetic environments

HOT SHOT launch

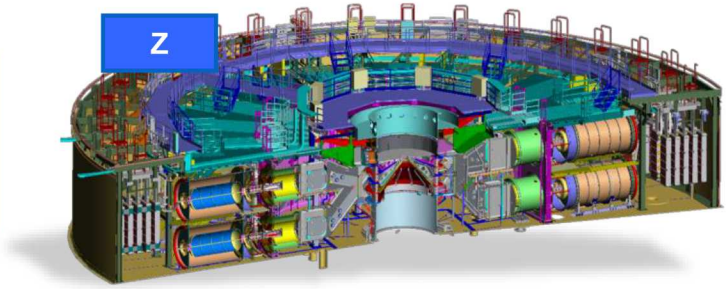


Stockpile Responsiveness – development and exploration of system concepts that increase Labs responsiveness to future deterrence



Tailored Materials and Coatings

Aging and Lifetimes – capabilities to detect, assess, predict, and mitigate material aging effects in the stockpile



Z

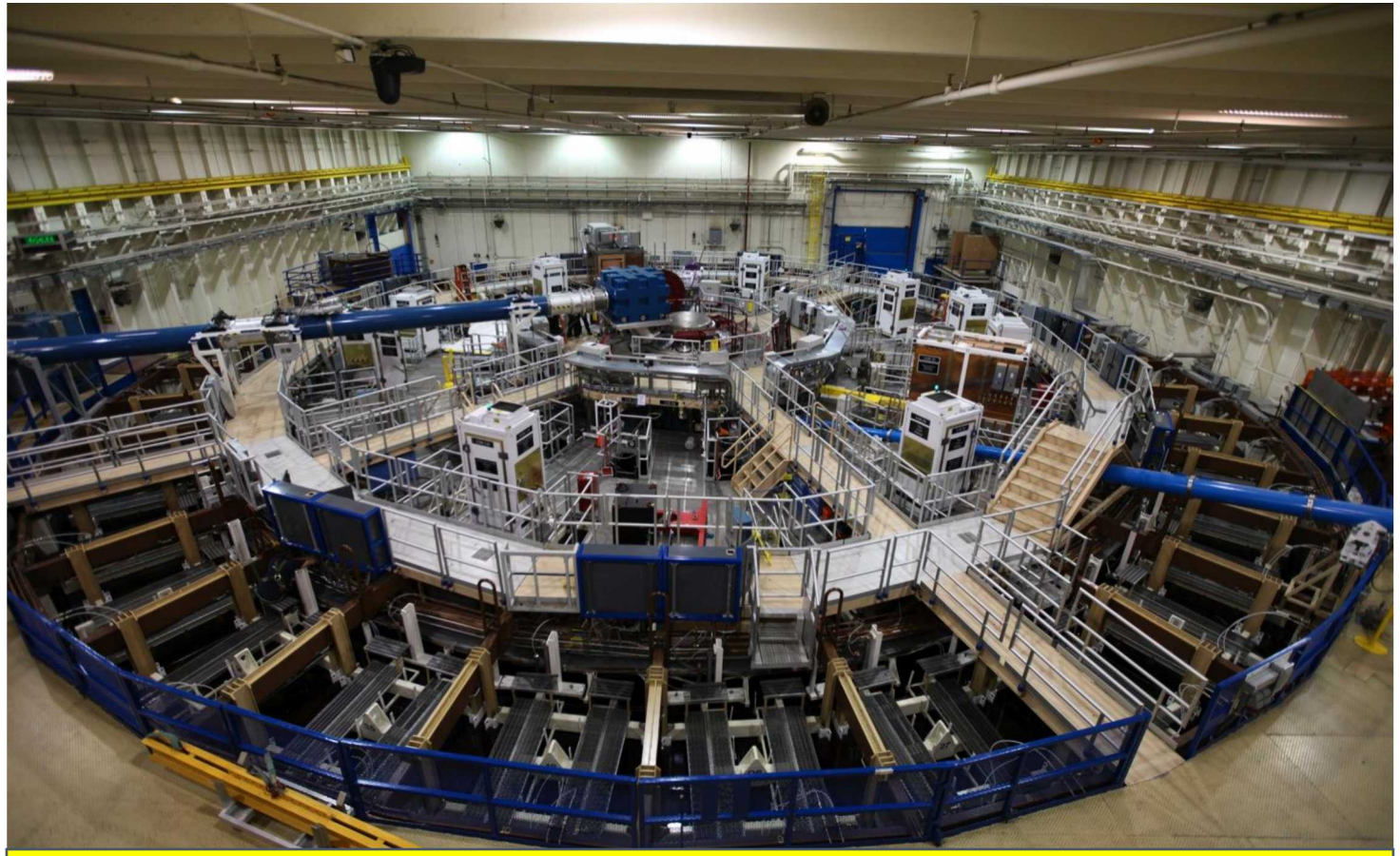
Advanced Certification and Qualification – experimental and diagnostics capabilities to certify weapons systems in the absence of underground nuclear tests

Science Campaigns and Inertial Confinement Fusion

The Z Machine creates high energy density matter and extreme x-ray environments

Major activities

- Conduct experiments to validate codes, models, and databases of physical properties.
- Provide options and assessment methodologies to support Life Extension Programs
- Develop and implement improved diagnostics
- Support fundamental science relevant to stockpile stewardship
- Mature pulsed power technologies to prepare for next-generation investments

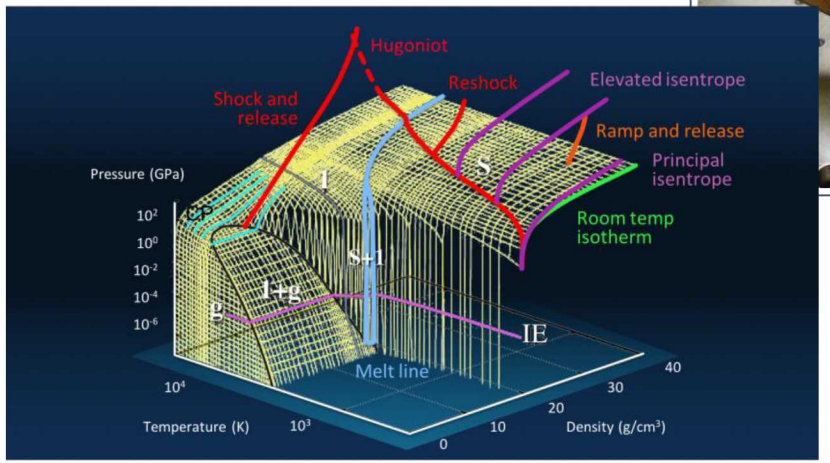


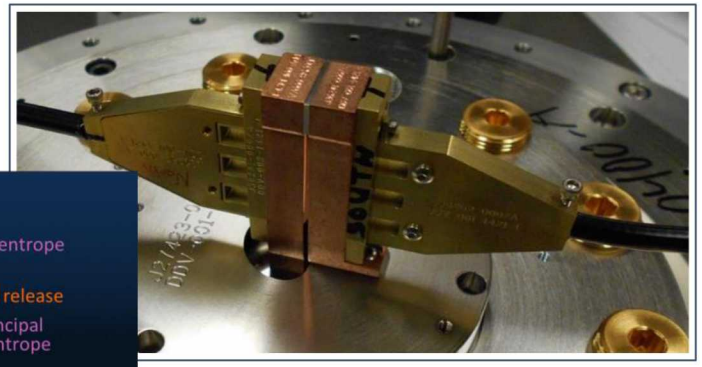
World's largest pulsed power driver 3 MJ delivered to the target
400 TW X-ray Power

Science Campaigns and ICF Support Stockpile and Fundamental Science

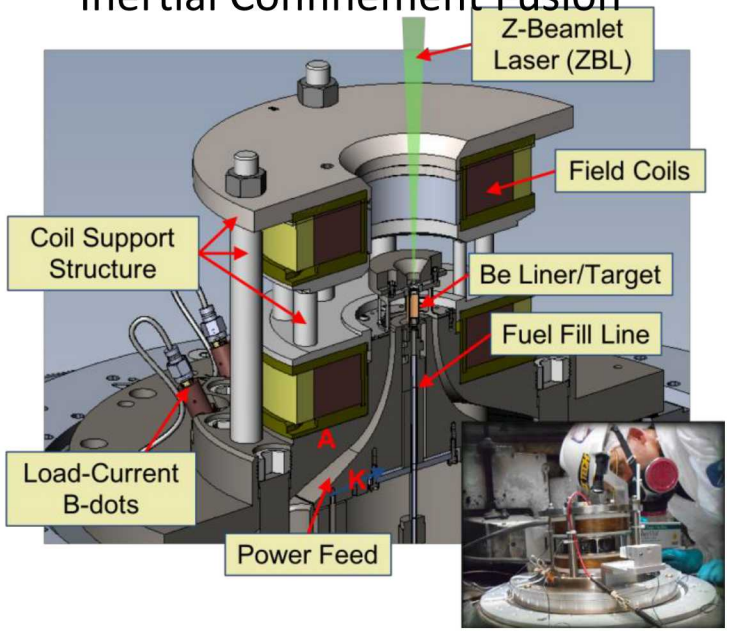
Sandia conducts a broad range of experiments: Pu properties, Radiation Effects, and Fusion

Dynamic Material Properties



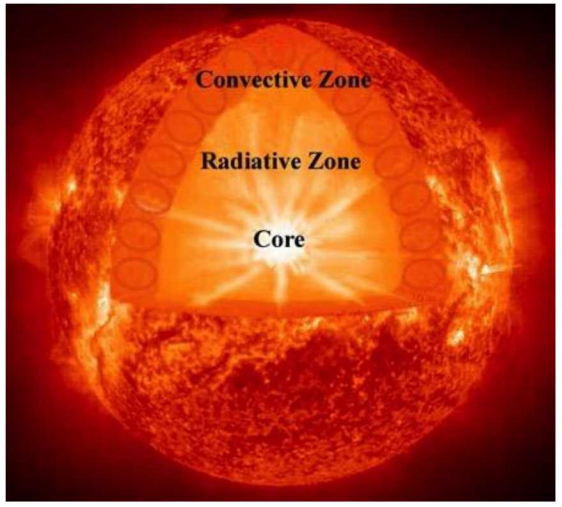


Inertial Confinement Fusion



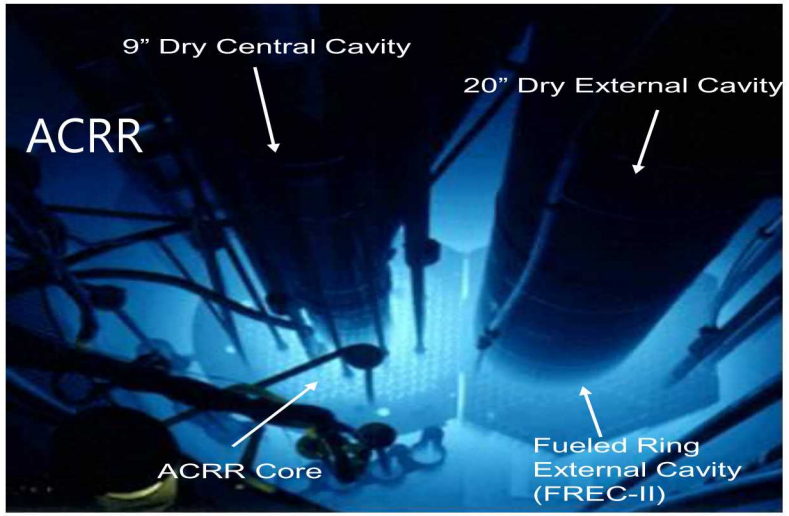
Radiation-driven Science

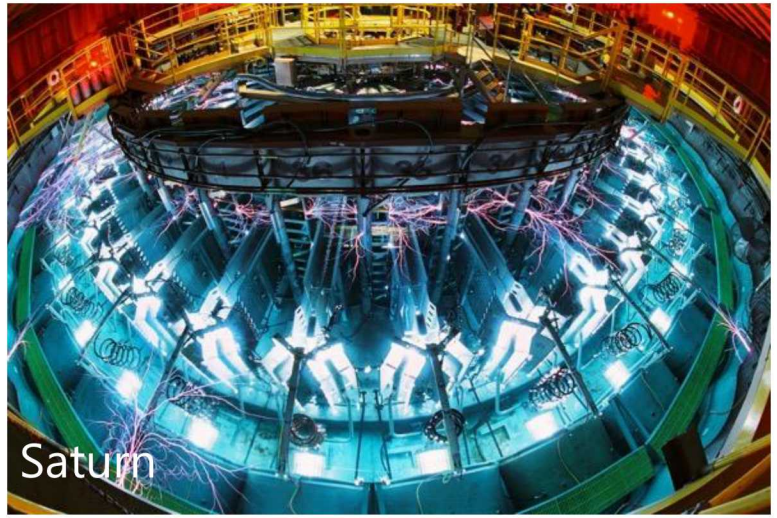
Fundamental Science Program

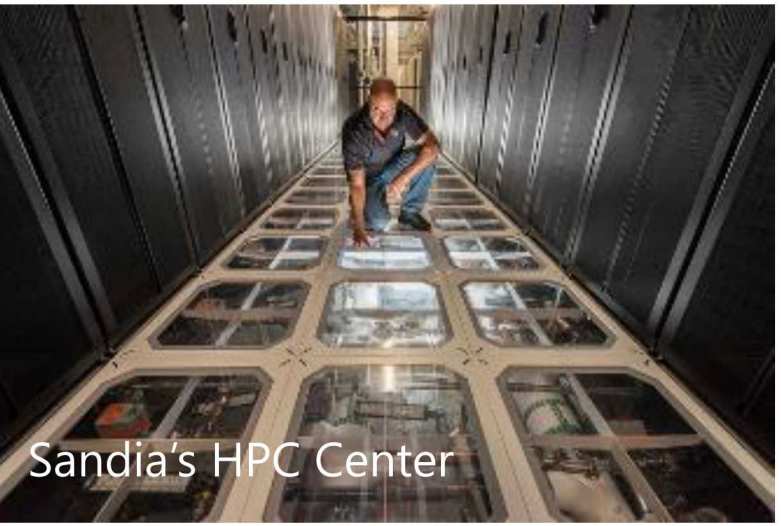


Infrastructure and Operations (I&O): Foundational FACILITIES

Sandia's Infrastructure Program develops and deploys strategies to sustain and extend critical capabilities for the Nuclear Deterrent mission.







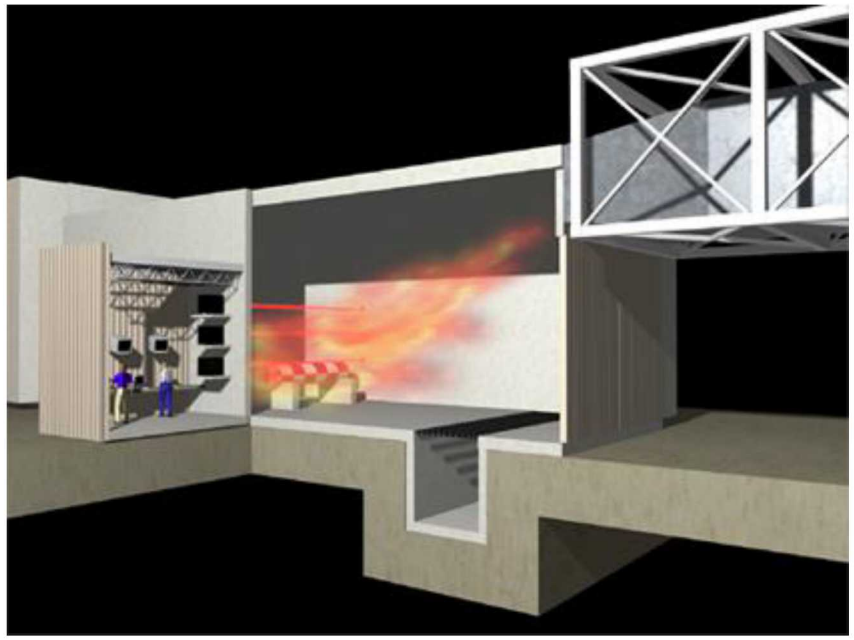
Funded by DOE Office of Science

Foundational FACILITIES

Sandia also operates a number of Large scale facilities that enable environmental testing

Thermal Test Complex (TTC)

Artist's rendering of flame facility at TTC



Drop tower facility

Destruction of hazardous materials

Explosives test

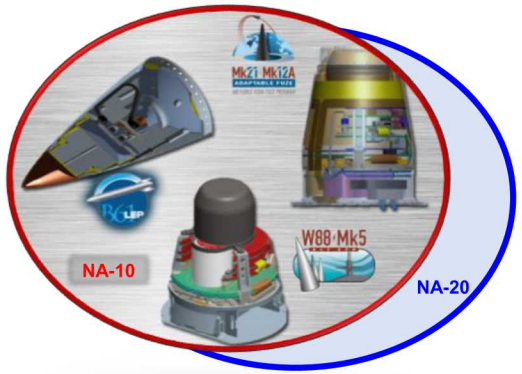
High-velocity gun

Microsystems Engineering, Science and Applications (MESA) Capabilities

Foundational capability for the Research and Development of Microelectronics.

~300,000 parts across 44 products:

- 12 Si CMOS7 ASICs
- 8 III-V HBT SSICs
- 1 MEMS Sensor
- 2 Photonic Arrays
- 2 Focal Plane Arrays
- 16 RFICs (design & qualify)
- 3 Optoelectronic device



Research & Development | Si µElectr. | III-V µElectr. | MEMS | Photonics (Si, III-V) | Focal Plane Arrays | Heterogeneous Integration

Co-located R&D and Production

MESA

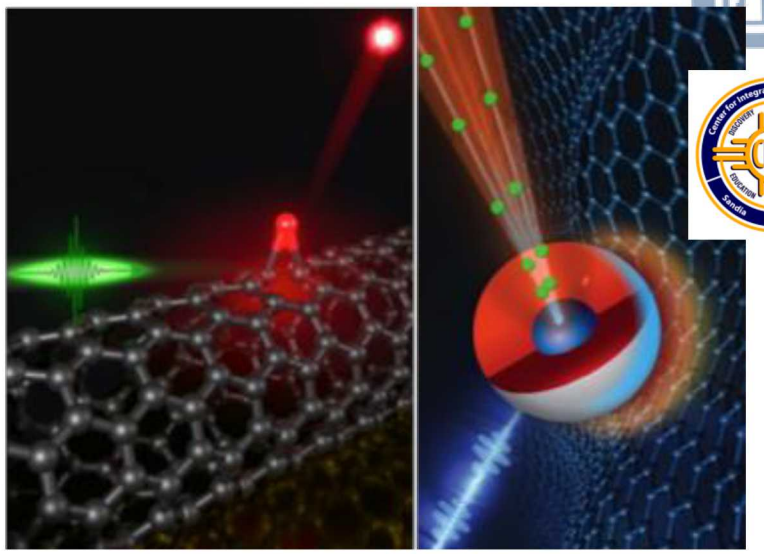
Research & Development
Design - Trusted Fabrication
Packaging - Radiation Effects Testing
Reliability/Qualification
Failure Analysis
Product Acceptance

Center for Integrated Nanotechnologies (CINT)

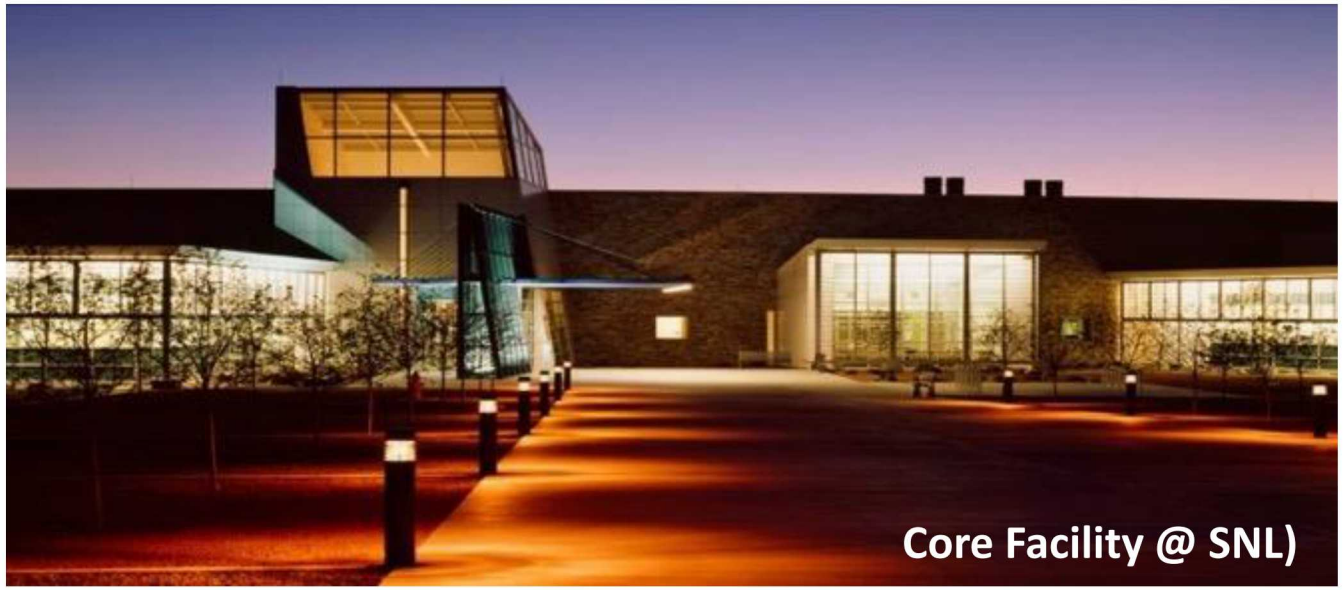
One Community Focused on Nanoscience Integration

Provide access to *scientific expertise* and *advanced capabilities* to synthesize, fabricate, characterize, understand and integrate nanostructured materials into the microscopic and macroscopic worlds.

Inspire technological innovation with enduring beneficial impact in energy, environment, human health and security.



Examples of non-classical photon emitters arising from engineered materials interactions



Office Of Science: At The Frontiers Of Science

- Hypothesis-driven inquiry in fundamental science to promote national security and international scientific leadership.
- Science-based engineering for transformational technologies.

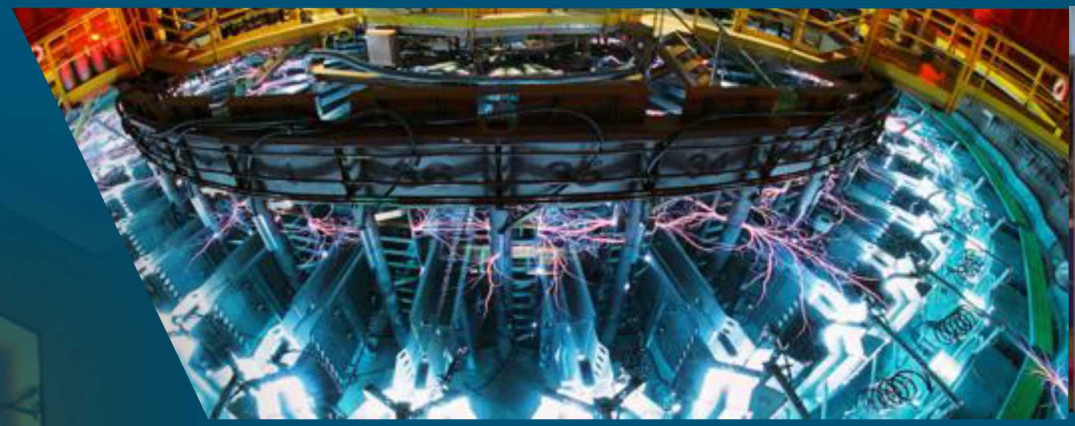
*DOE Research Facility

U.S. DEPARTMENT OF ENERGY | Office of Science

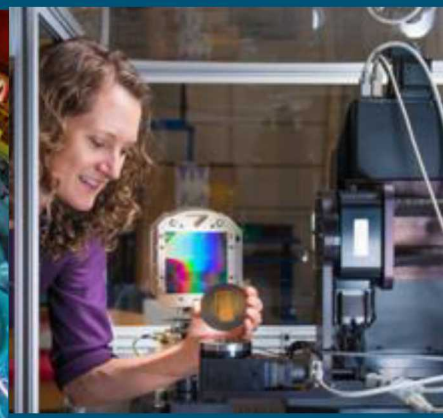
The Advanced Science &Technology Division at Sandia National Labs

Stewards our core Science and Technology Capabilities Across Sandia

Nanodevices & Microsystems

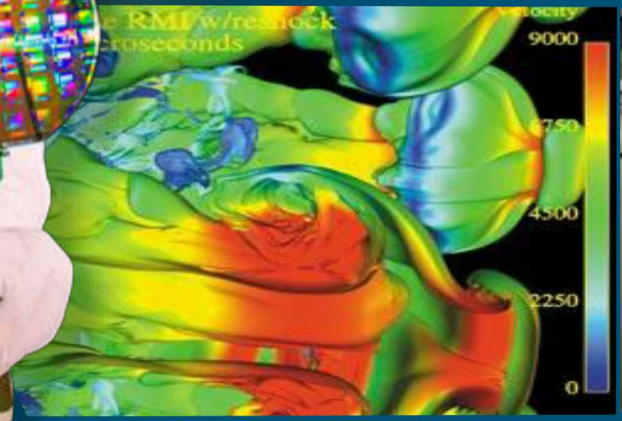


Radiation Effects & High Energy Density Science



Materials Science

Computing & Information Science



Engineering Science

Earth Science

Bioscience