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Sandia National Laboratories

Research and Technologies for National Security
A perspective from a national security laboratory

Sandia National Laboratories Director Paul Hommert

12 November 2013

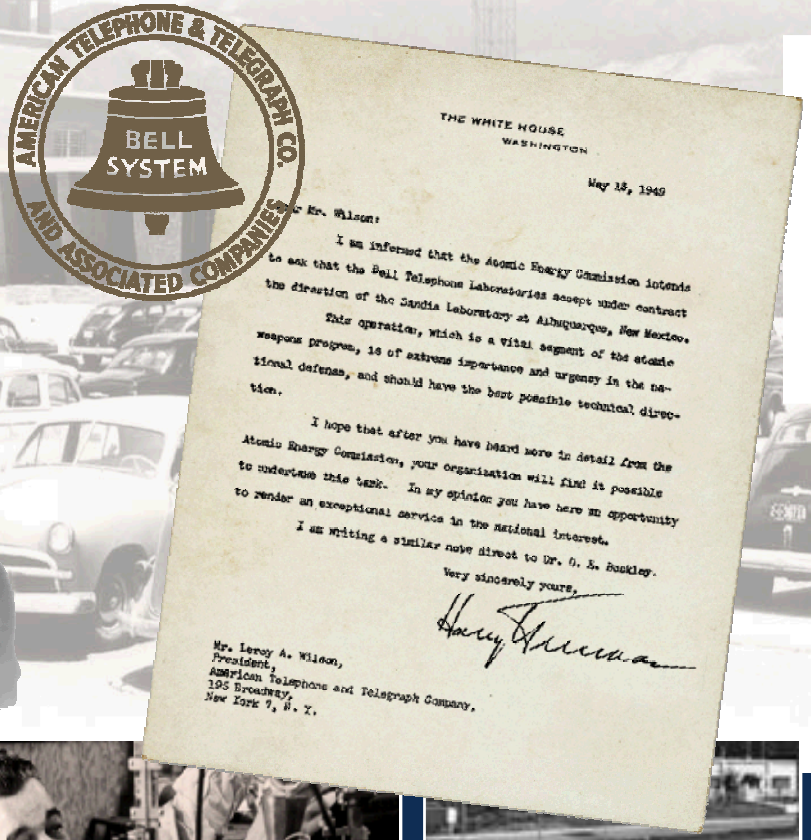
U.S. DEPARTMENT OF ENERGY

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..

Sandia's History

Exceptional service in the national interest



- **July 1945:** Los Alamos creates Z Division
- Nonnuclear component engineering
- **November 1, 1949:** Sandia Laboratory established
- **1949–1993:** AT&T
- **1995–Present:** Lockheed Martin Corporation

Vision and Mission Statements

- On behalf of our nation, we anticipate and solve the most challenging problems that threaten security in the 21st century.
- Our unique mission responsibilities in the nuclear weapons program create a foundation from which we leverage capabilities enabling us to solve complex national security problems.

Sandia's Sites

Sandia National Laboratories

Albuquerque, New Mexico

Livermore, California

Kauai, Hawaii

Waste Isolation Pilot Plant, Carlsbad, New Mexico

Pantex Plant, Amarillo, Texas

Tonopah, Nevada

Sandia's Mission Work Reflects National Security Challenges

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1950s	1960s	1970s	1980s	1990s	2000s	2010s
NW production engineering & manufacturing engineering	Development engineering	Multiprogram laboratory	Missile defense work	Post–Cold War transition	Expanded national security role post 9/11	Cyber Biosecurity Proliferation
	Vietnam conflict	Energy crisis	Cold War	Stockpile stewardship		Evolving national security challenges

Sandia's National Security Missions

- Maintain a safe, secure stockpile and an effective nuclear deterrent now and into the future
- Reduce global nuclear dangers
- Provide nuclear assessments and warning
- Enable the United States to defend and dominate in cyberspace
- Maintain U.S. defense technological superiority through synergistic products
- Maintain U.S. defense technological superiority through leveraged innovations
- Reduce global chemical and biological dangers
- Ensure a secure and sustainable energy future

Sandia's foundation

In concert, these elements form a solid base supporting our national security missions

People
- Highly educated workforce
- Strategically managed workforce of diverse skills and competencies
- Modern business practices and operations in support of our missions

Research
- Management framework ensures innovation and quality in our differentiating products
- Disciplined-based Research Foundations
- Multidisciplinary research challenges
- R&D Investments

Example Facilities and Tools
- Major Environmental Test Facilities
- Microsystems and Engineering Sciences Applications (MESA)
- High-Performance Computing
- Pulsed-Power Facility
- Center for Integrated Nanotechnologies (CINT)
- Combustion Research Facility (CRF)
- …

Capabilities for Solving 21st Century National Security Challenges

- High-reliability engineering
- Sensors and sensing systems
- Cyber technology
- Pathfinders
- Reverse engineering
- Modeling & simulation and experiment
- Natural and engineered materials
- Micro & nano electronics and systems
- Safety, risk, and vulnerability analysis

Our Research Framework

Strong research foundations play a differentiating role in our mission delivery

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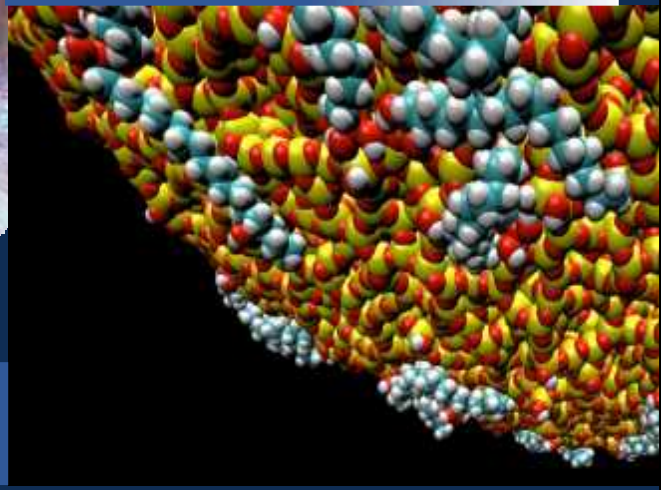
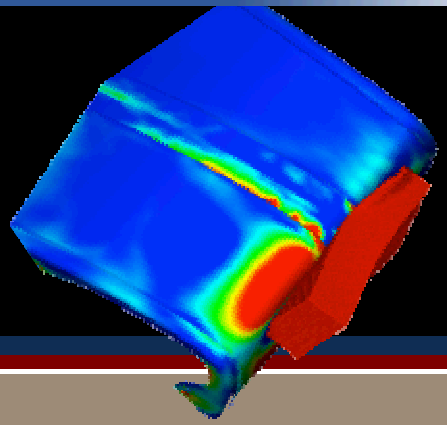
Computing & Information Sciences

Radiation Effects & High Energy Density Science

Materials Science

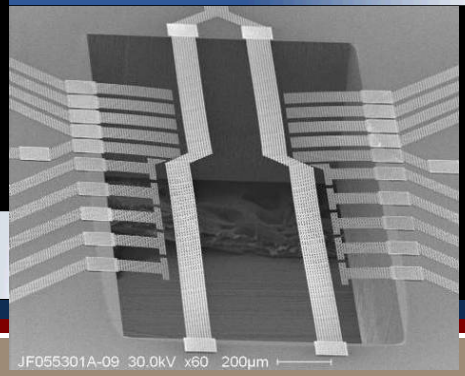


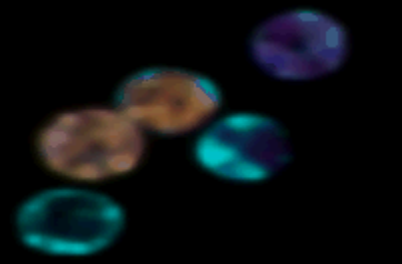
Engineering Sciences



Geoscience

Nanodevices & Microsystems





Bioscience

Our Research Framework

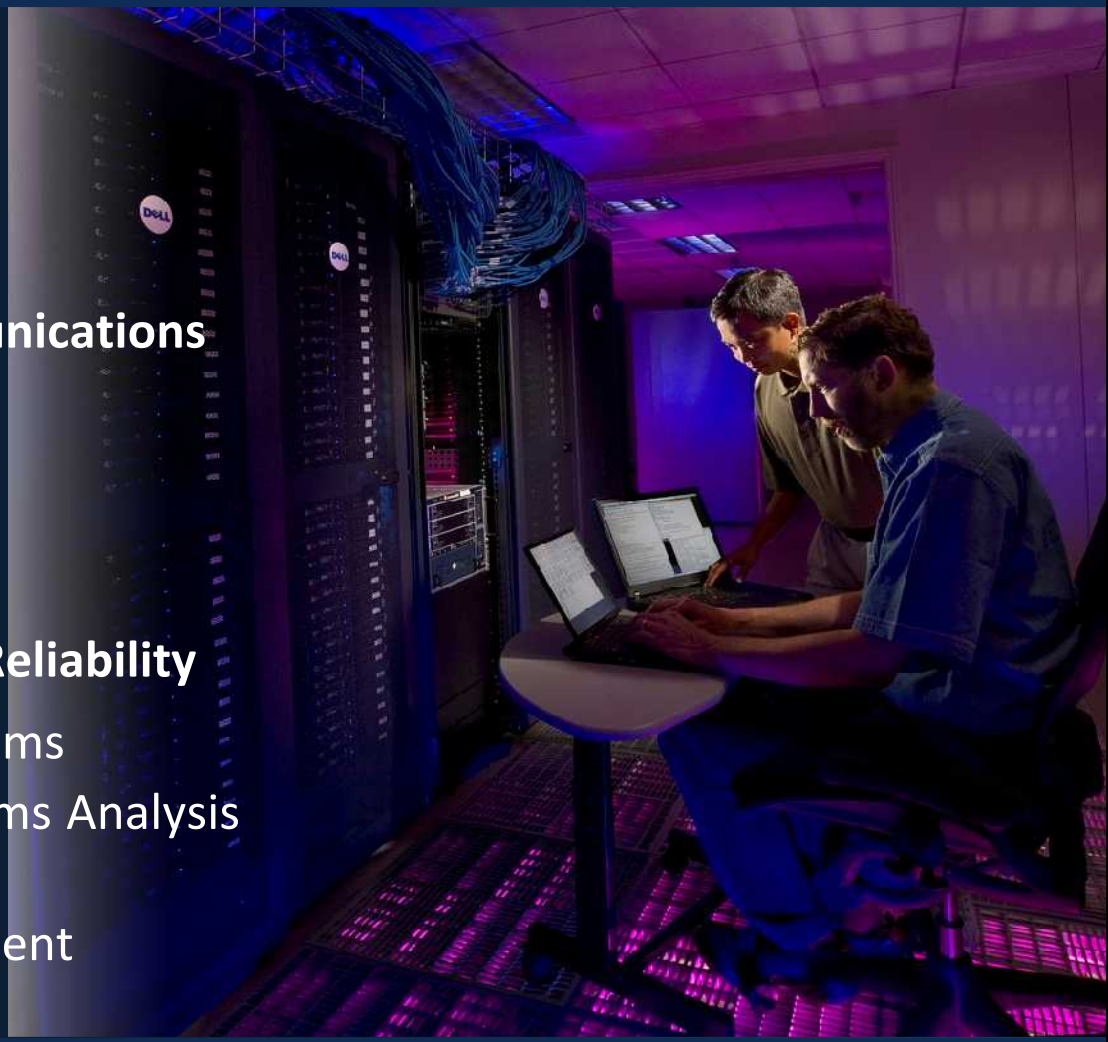
Key features of a research challenge

- Surmounts a critical path technical obstacle for a mission challenge
- Brings together a broad cross section of Laboratory capabilities and research foundations
- Requires an interdisciplinary approach and the active engagement of expertise from fundamental science to technology application
- Provides opportunities to engage with the broader research community, particularly with the academic community

Our Research Framework

Research challenges

- **Beyond Moore Computing**
- **Data Science**
- **Cyber Resiliency**
- **Trusted Systems & Communications**
- First to High Yield Fusion
- Detection at the Limit
- Power on Demand
- **Engineering of Materials' Reliability**
- Resiliency in Complex Systems
- Integrative Biological Systems Analysis and Engineering
- Embedded Annual Assessment



Beyond Moore Computing

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Background

Indications are that Moore's Law is breaking down. Silicon CMOS transistors are reaching their physical limits

Power efficiency—flattening out

Processor speed—plateauing

Circuit density—to follow suit as feature sizes are nearing atomic scales

Challenges

- Identify new technologies to succeed silicon CMOS
- Identify new component architectures to provide high performance, energy efficiency, and a path for several generations of performance increase through scaling
- Design and prototype new computing architectures

Sandia contact: John Aidun (505) 844-1209

Beyond Moore Computing (Continued)

Continued growth of high-performance computing to solve national security problems

Why did Sandia take on this challenge?

Differentiated expertise in

- Materials science with novel device expertise
- Microelectronics and nanoelectronics
- Computer architecture
- Design of operating system software and applications codes with major national security impact

Historical track record: Invented the clean room, adopted CMOS transistors and massively parallel processors, designed the Red Storm supercomputer built by Cray, Inc.

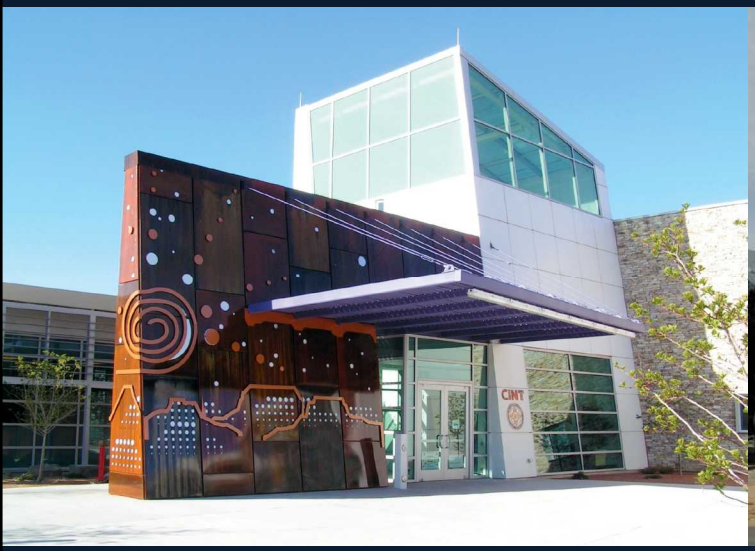
Beyond Moore Computing (Continued)

Essential infrastructure: Microsystems and Engineering Sciences Applications (MESA) facility and the Center for Integrated Nanotechnology (CINT)

MESA and CINT leadership in semiconductor technologies and nanoelectronics

→ creating an R&D hub for researchers from Sandia, universities, and industry to fabricate and test their new technology ideas

Collaborations with universities and industry are essential



Why We Should Care …

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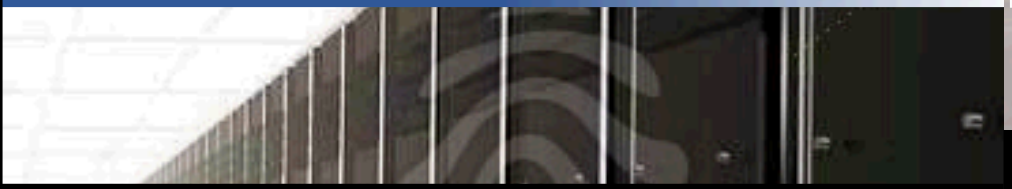
Beyond Moore Computing Devices and Architectures

Supercomputing



Million+ cores
Above exascale
Machine room environment

Missions
Stockpile stewardship
Mission computing
Scientific research

Embedded computing

Field environments

Missions
Space assets
Unmanned Aerial Vehicles
Other *in situ* computing needs

Industrial computing (spin-off benefits)

Data analytics at scale
Cloud services with dramatically improved power consumption
. . .

Data Science

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Emerging discipline focused on deriving valuable insights from large and complex data sets (known as “big data”)

Data Science is the practice of

- Obtaining predictive, actionable insight from big data
- Communicating relevant stories from the data
- Making high-confidence decisions based on the data

Why has it become important?

- Explosion of large, structured, unstructured, and semistructured data
- Powerful computing platforms are commonly available
- Big data has proved to have commercial value

Data Science (Continued)

Sandia's Goal: Develop techniques to identify, characterize, and respond to key signatures buried in big data and, through this effort, better support our national security missions.

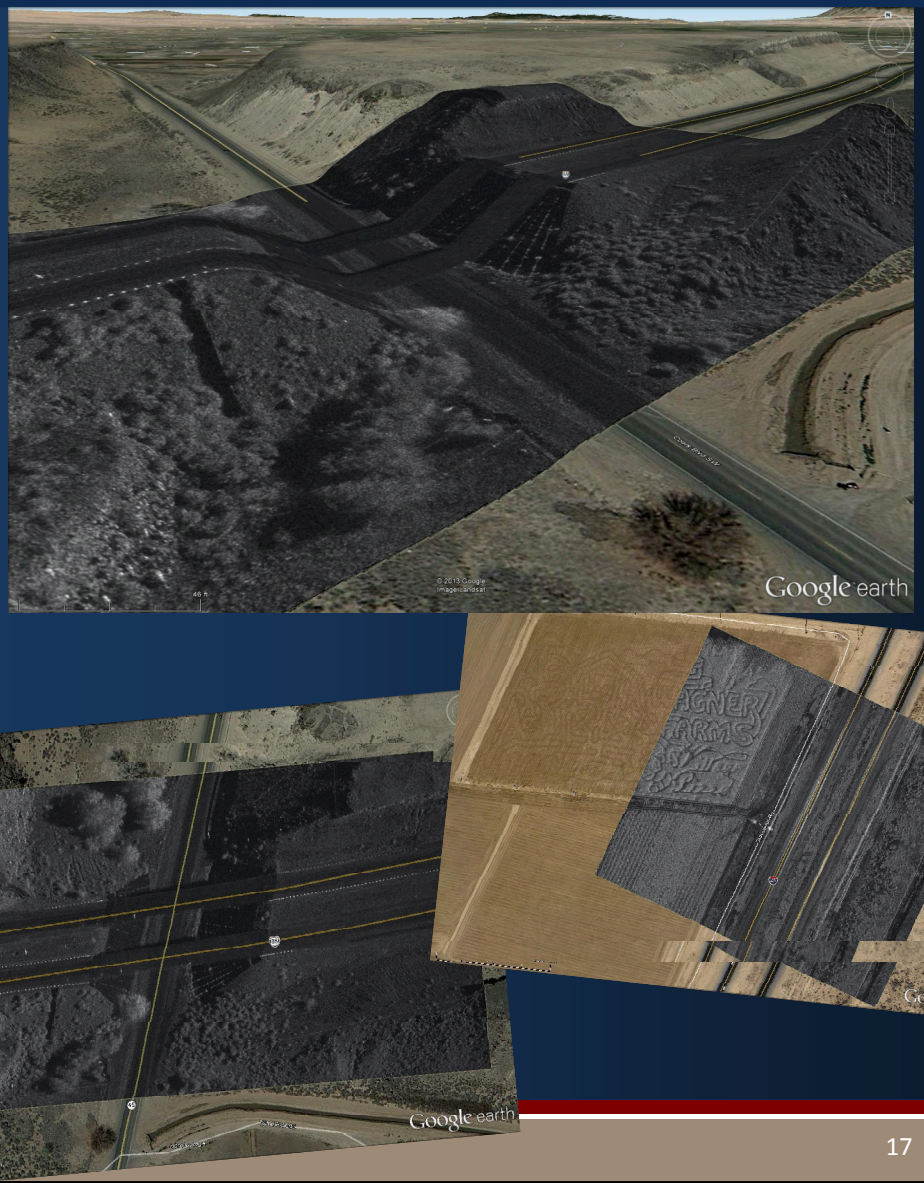
Opportunities for partnerships with universities and industry

- Intense research is going on in many different organizations.
- We are engaging with the data science research community while developing crosscutting data-science capabilities for solving national security challenges.

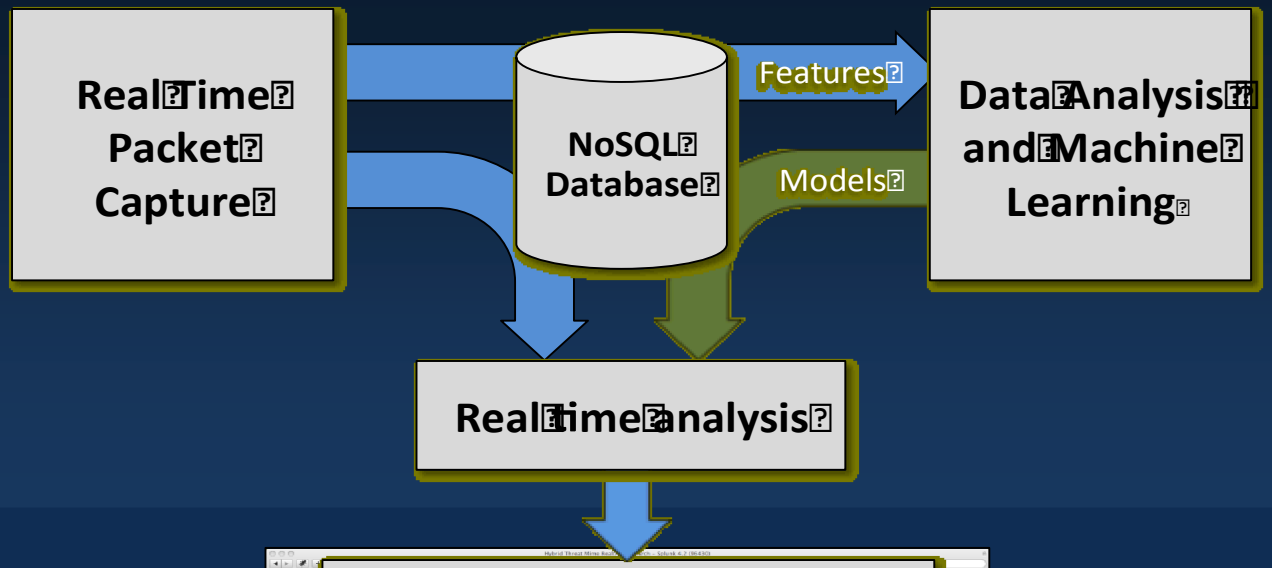
Data Science (Continued)

An example

Operational airborne radar systems developed at Sandia produce enough high-resolution imagery in a month to cover a 450-m-wide swath around Earth's circumference. This body of imagery is then analyzed, interpreted, and effectively used in the counter-insurgency fight. The imagery can reveal changes that are undetectable to the eye of a person standing on Earth's surface.



Data Science and Cyber Resiliency



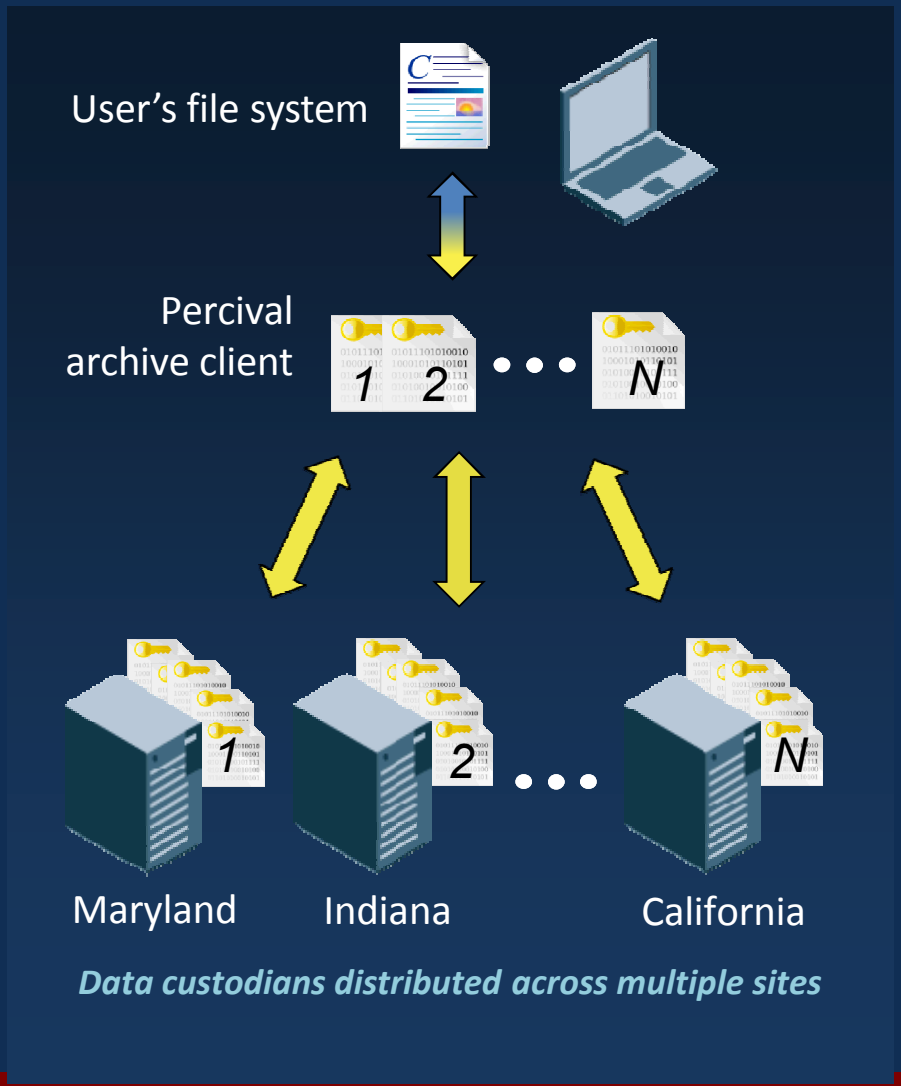
Goal: Analyze network traffic, email, and other cyber data streams to create situational awareness of emerging threats.

Research: Leverage off-line data analysis to enable real-time detection of email phishing attacks.

Sandia contact: Bill Hart (505) 844-2217

Cyber Resiliency: Percival

Using secret splitting of data for resilient, long-term archiving



- Splits a document into *N* shares to be stored in distributed repositories, creating a long-term data archive.
- Able to operate with integrity and data protection in the presence of compromise.
- Resilient to insider threat—different site administrators would have to collude to compromise the data.
- Resilient to crypto analytical attack—no single share is useful in providing information about the whole.
- **Future research** will look into secure ways to search for data from the archive.

Sandia contact: Thomas Kroeger (925) 294-6327

Trusted Systems & Communications

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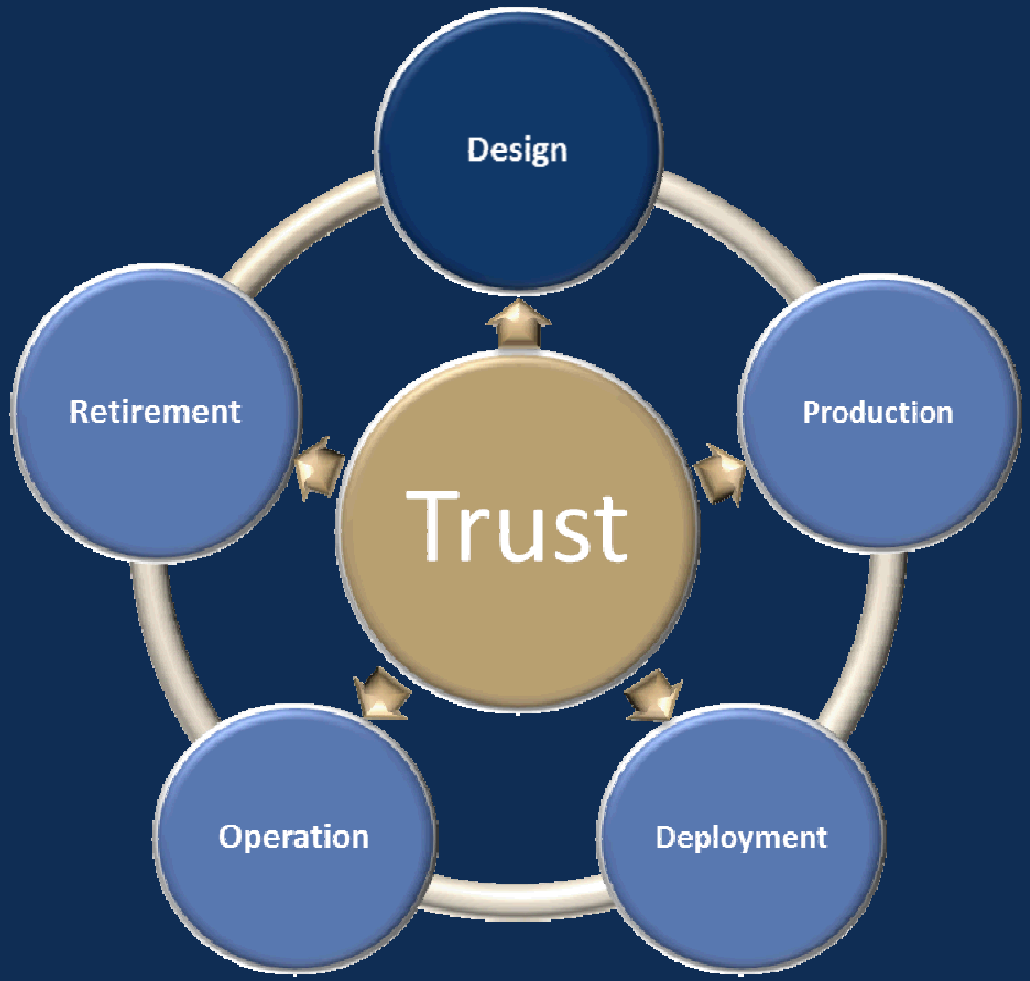
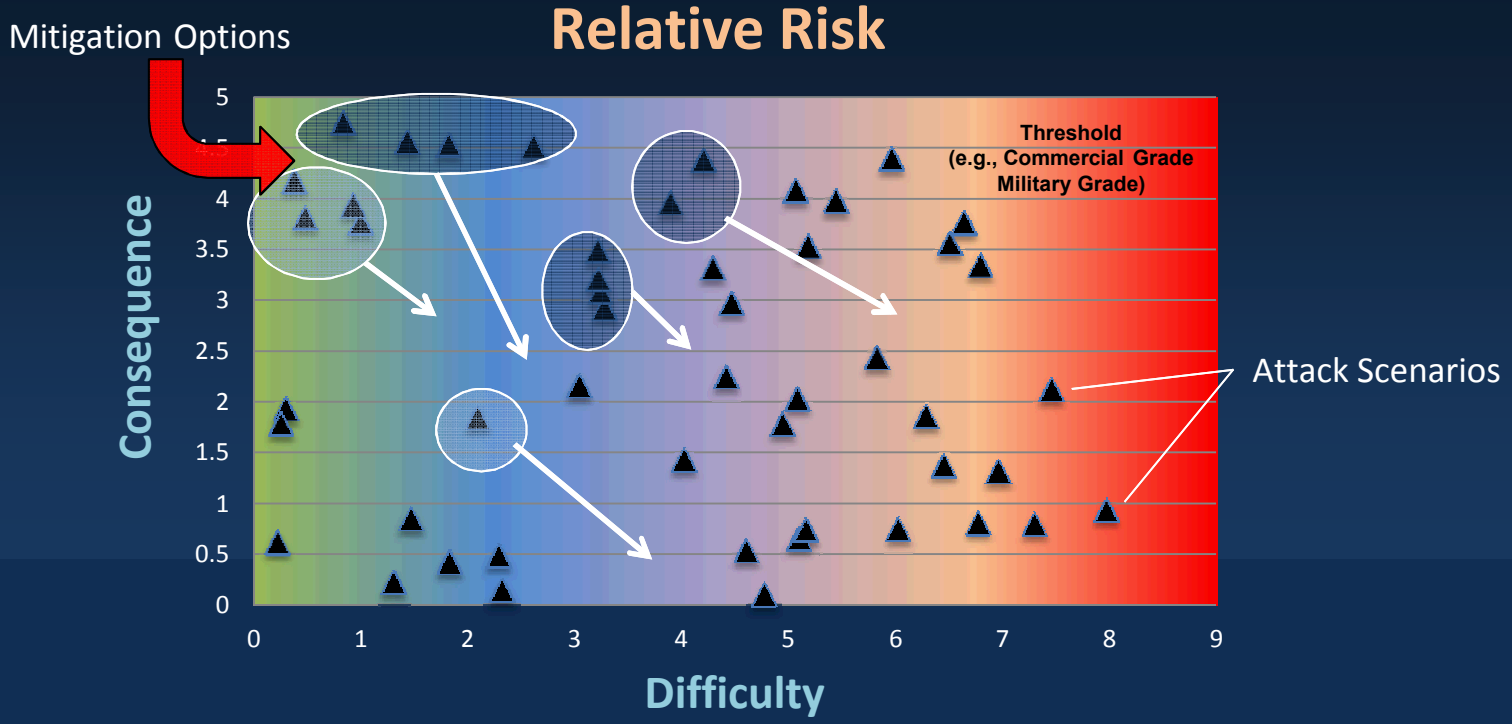
Critical Information Technology (IT) systems are increasingly vulnerable to attack by sophisticated adversaries.

> *—Defense Science Board Task Force Report, "Resilient Military Systems and the Advanced Cyber Threat," January 2013*

Mitigate this persistent threat by developing a **science-based trusted systems engineering discipline** that assures trusted performance throughout a product's lifecycle.



Data Science and Trusted Systems & Communications



Goal: Enhance trustworthiness of weapon components by assessing and mitigating supply chain risks.

Research: Optimally select mitigation options to minimize consequences and increase attack difficulty (with University of Wisconsin).

Cyber Engineering Research Institute (CERI)

Partnerships

CERI facilitates partnerships among Sandia's cyber community, industry, academia, and government.

Research

CERI provides an environment for visionary, threat-informed research on national cyber challenges.

Technology

CERI catalyzes research collaborations that align new cyber technologies with national needs.

People

CERI helps identify, recruit, and develop the next generation of cybersecurity experts.

Cyber Engineering Research Laboratory

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Human Performance Lab A cognitive neuroscience laboratory for studying human cognition (e.g., with EEG and eye tracking)

IDEA Lab This laboratory enables researchers and visitors to interactively explore large, complex data sets.

RECOIL A controlled environment for performing cyber exercises for human-centered cybersecurity research and training.

Engineering of Materials' Reliability

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Our goal at Sandia is to transition from a forensic analysis of different material failures to engineering material reliability based on a fundamental understanding of mechanisms that cause materials to degrade and fail. We must learn from the lessons of others.

Sandia contact: Justine Johannes (505) 844-1994

Engineering of Materials' Reliability

An example: Predicting performance margins

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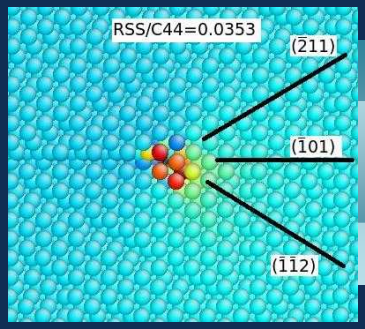
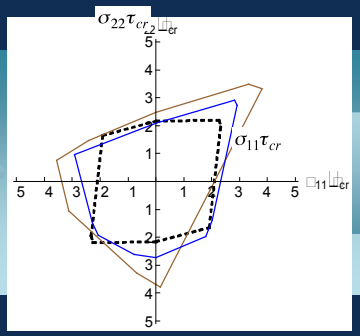
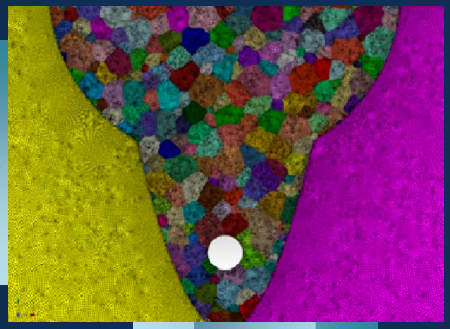
Physics



Mechanics Models

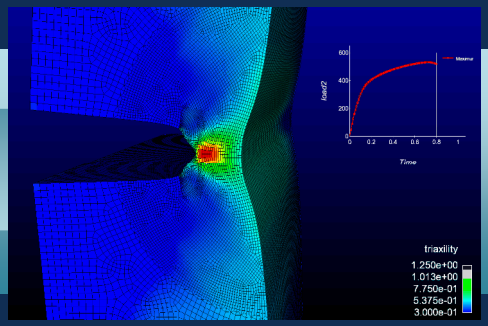


Grain-Scale Properties

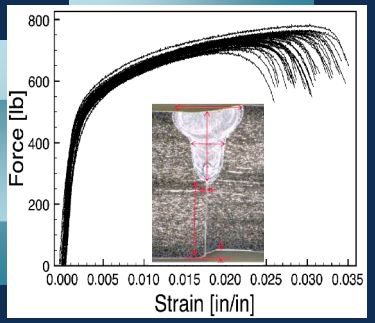


Goal: Provide a science-based foundation for design, analysis, and qualification capabilities that links mesoscopic/microscopic inhomogeneity to property variability.

System Reliability



Engineering Analysis



Material Variability

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Let’s Talk!