September 2012

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Exceptional service in the national interest

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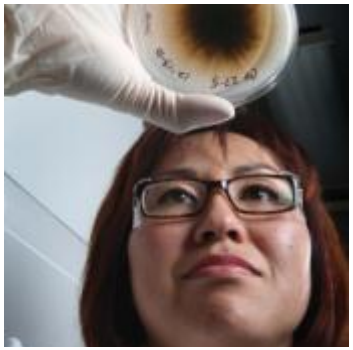


Addressing National Security Challenges of the Twenty-First Century:

The Role of the U.S. National Laboratories

David Williams

Principal Staff Director

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. SAND No. 2011-8971P

Excel in the Practice of Engineering

Sandia National Laboratories

"We have extraordinary achievement, but we can do even more on behalf of the country and on behalf of the practice of engineering. No other lab does the amount of engineering this Lab does every day. The nation should expect us to excel and lead in the practice of engineering."

--

Dr. Paul J. Hommert

Laboratories Director & President

Sandia National Laboratories

The challenge of prosperity and security in the 21st century

- Today our national security challenges are becoming more diverse and complex, and they are multidimensional.
- Our economic prosperity is a key element of national security.

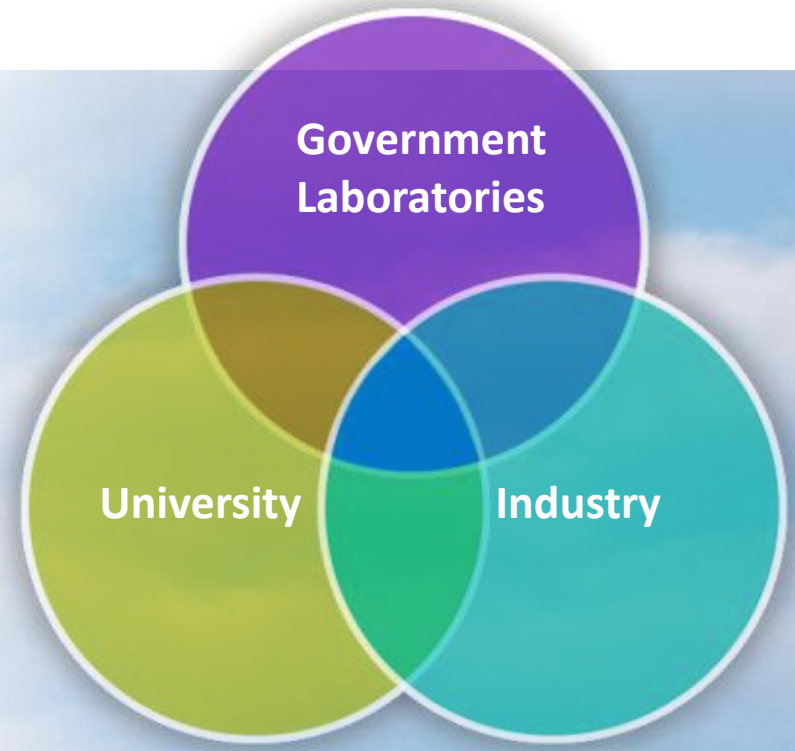
Multidisciplinary and cross-institutional scientific and engineering excellence and depth are key to our future.

National security challenges in the 21st century

- Maintaining economic strength and energy security
- Asymmetric threats (low-tech terrorism, bio, cyber)
- Science and technology surprise
- Nuclear proliferation and terrorism

These challenges demand the best of our science and engineering institutions

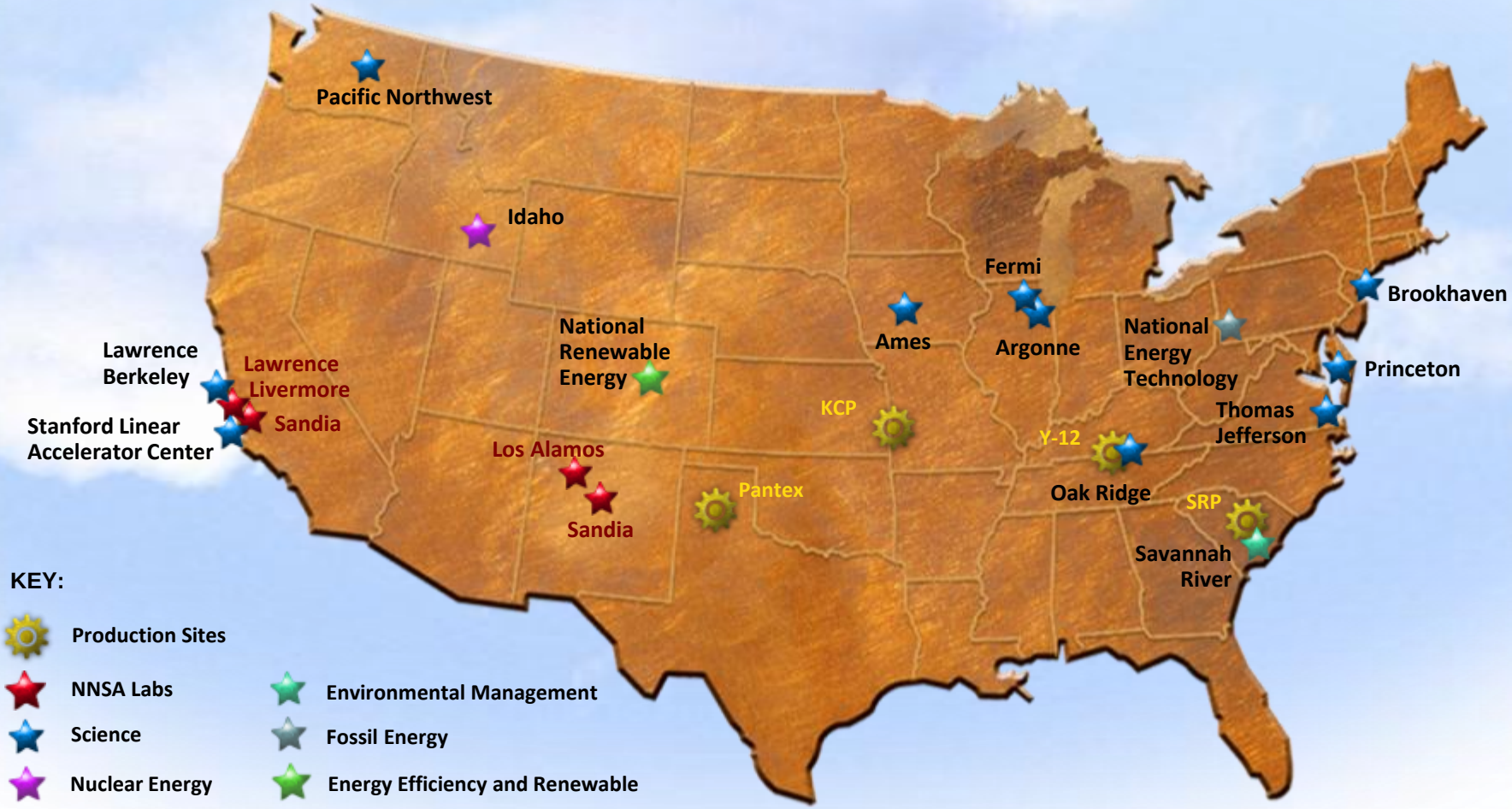
- Universities—Education, fundamental and applied research
- Industry—Market focus, product delivery
- National laboratories—Core missions, unique facilities



We are at our strongest and most effective when we partner.

Department of Energy national labs and other facilities

Sandia National Laboratories



What drives the national laboratories?

Sandia National Laboratories

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

National Renewable Energy Laboratory—"NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals."

Pacific Northwest
NATIONAL LABORATORY

Pacific Northwest National Laboratory—"We transform the world through courageous discovery and innovation."

Argonne
NATIONAL
LABORATORY

Argonne National Laboratory—"Our Mission: To apply a unique blend of world-class user facilities, science, and engineering that deliver innovative research and technology. Our scientists and engineers create new knowledge and technologies that address the most important scientific and societal needs of our nation."

INL Idaho National Laboratory

Idaho National Laboratory—"Ensure the nation's energy security with safe, competitive, and sustainable energy systems and unique national and homeland security capabilities."

Sandia's mission statement

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.

Guiding national policy for the nuclear deterrent

" . . . we will reduce the role of nuclear weapons in our national security strategy, and urge others to do the same. Make no mistake: As long as these weapons exist, the United States will maintain a safe, secure and effective arsenal to deter any adversary . . ."

— President Barack Obama
Prague Speech on Nuclear Weapons April 2009

National security challenges in the 21st century

Nuclear proliferation and terrorism

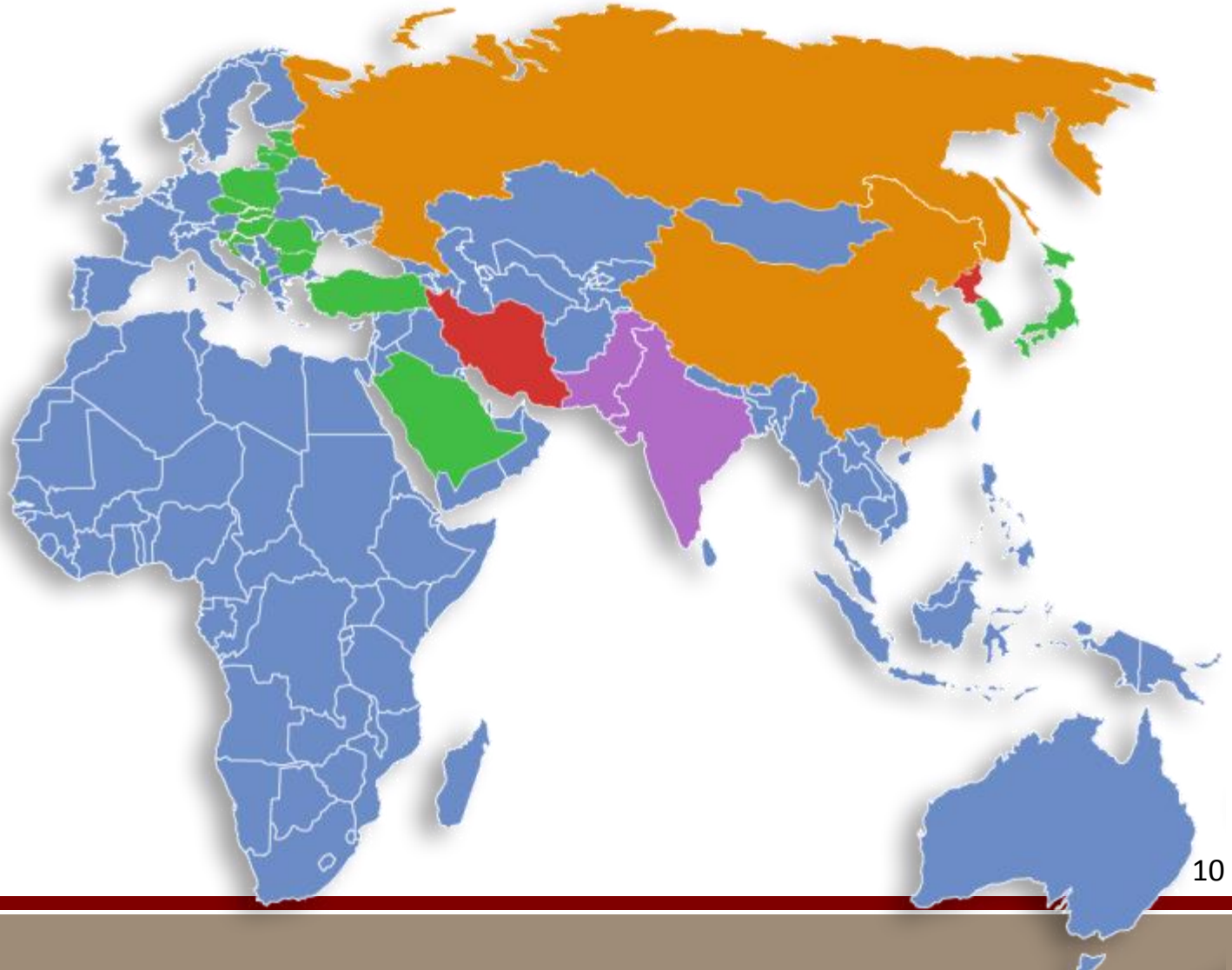
Sandia National Laboratories

Russia
China

North Korea
Iran

Pakistan
India

Japan
South Korea
Saudi Arabia
Turkey
NATO members from the former Warsaw Pact



National security challenges in the 21st century

Maintaining economic strength and energy security

- In 2010, energy represented 43% of our trade deficit.

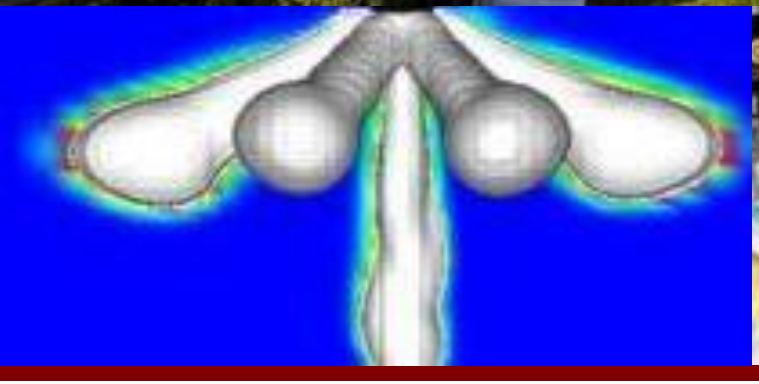
- In 2010, the Middle East and North Africa share of the world's oil supply was 35%.

Reducing our dependence on foreign oil

"… reliance on oil is the greatest immediate threat to U.S. economic and national security. Vehicle efficiency has the greatest short- and mid-term impact on oil consumption."

—DOE Quadrennial Technology Review 2011

Combustion Research Facility

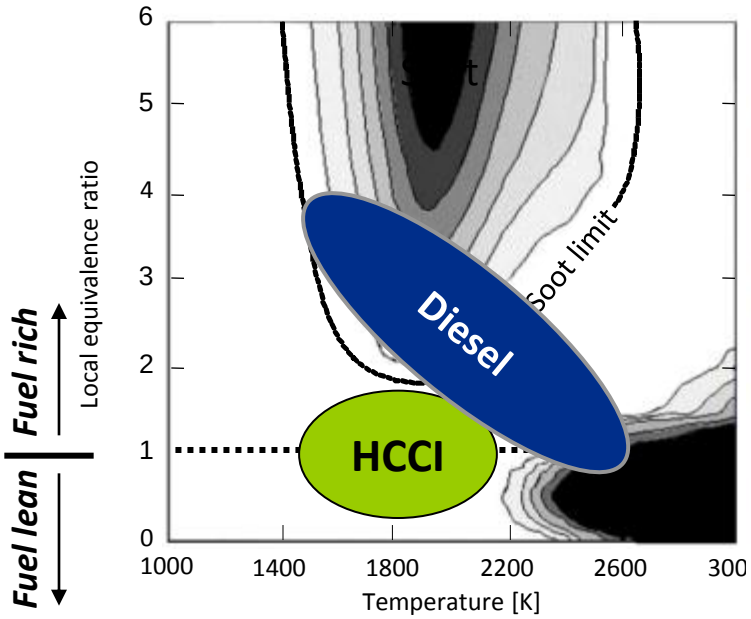


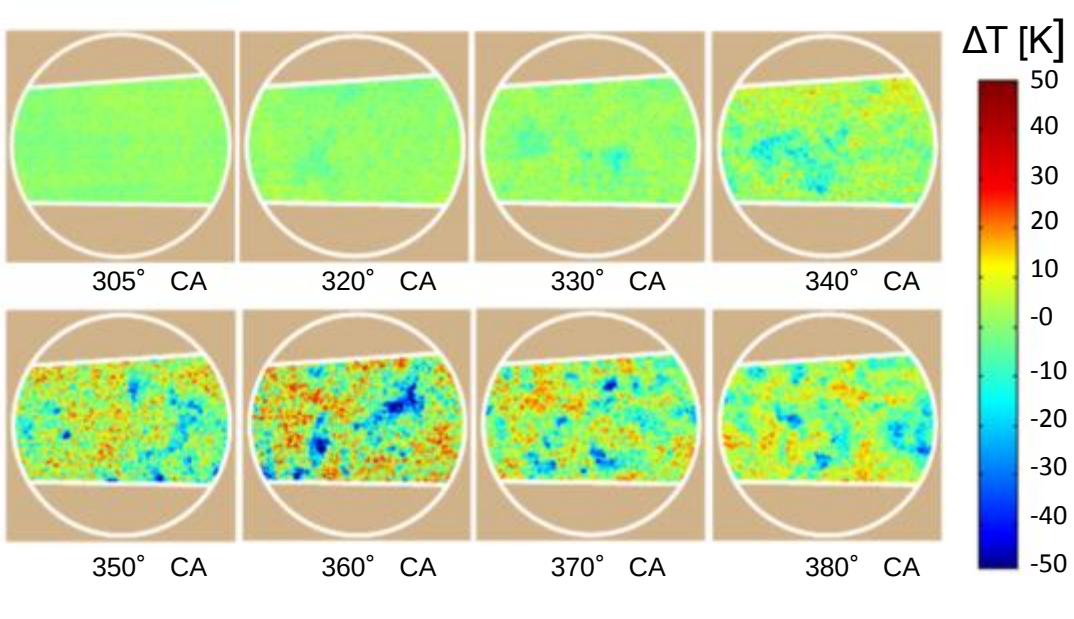
- Combustion science for greater fuel efficiency
- Combustion Research Facility
- Long-standing and deep partnership with industry and universities

Fuel injector simulations lead to greater combustion efficiency.

Challenges and potential of homogeneous charge, compression ignition (HCCI)

- HCCI holds the promise of diesel-like efficiencies and low emissions.
- Technical challenges: combustion phasing, load range, heat release rate, transient control, hydrocarbon and carbon monoxide emissions, and fuel characteristics.

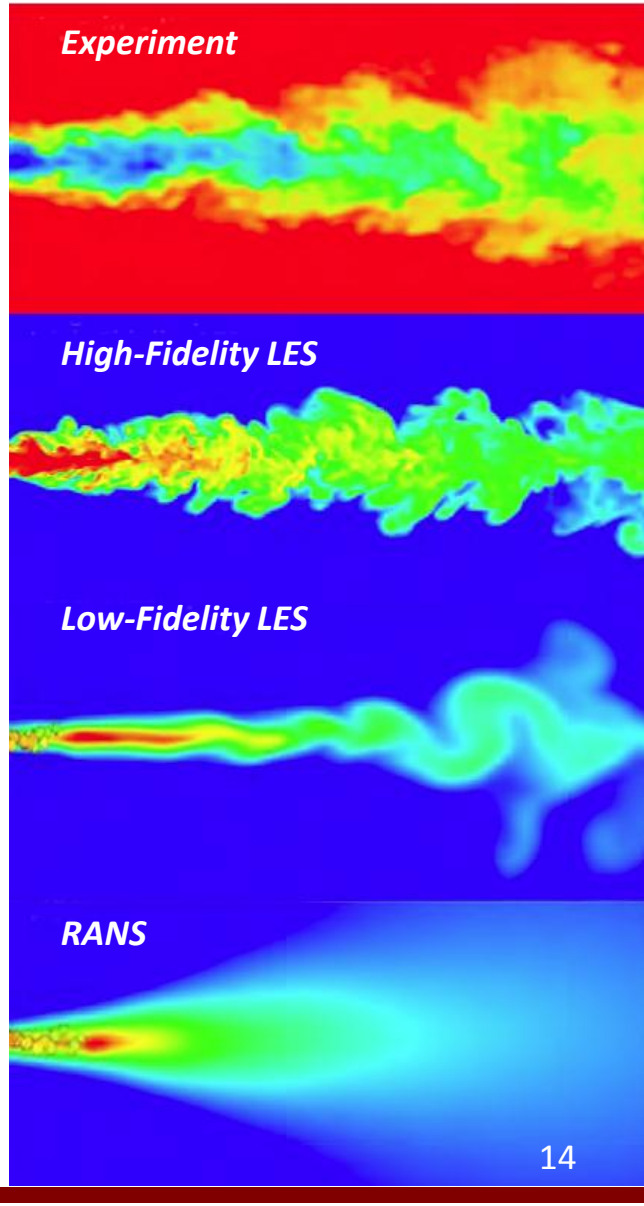




Significant efficiency gains are still achievable

Formidable scientific challenges

- Stochastic processes limit fuel-lean operation.
- Predictive spray models are required for direct injection.

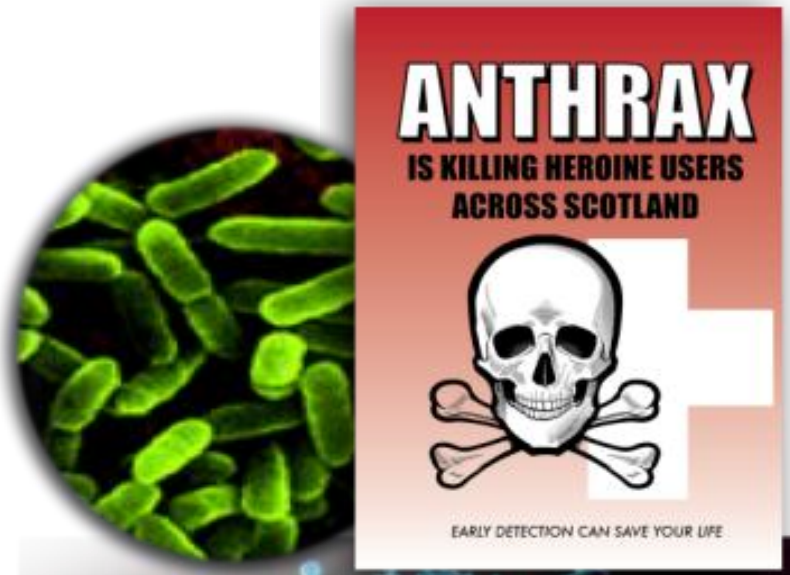


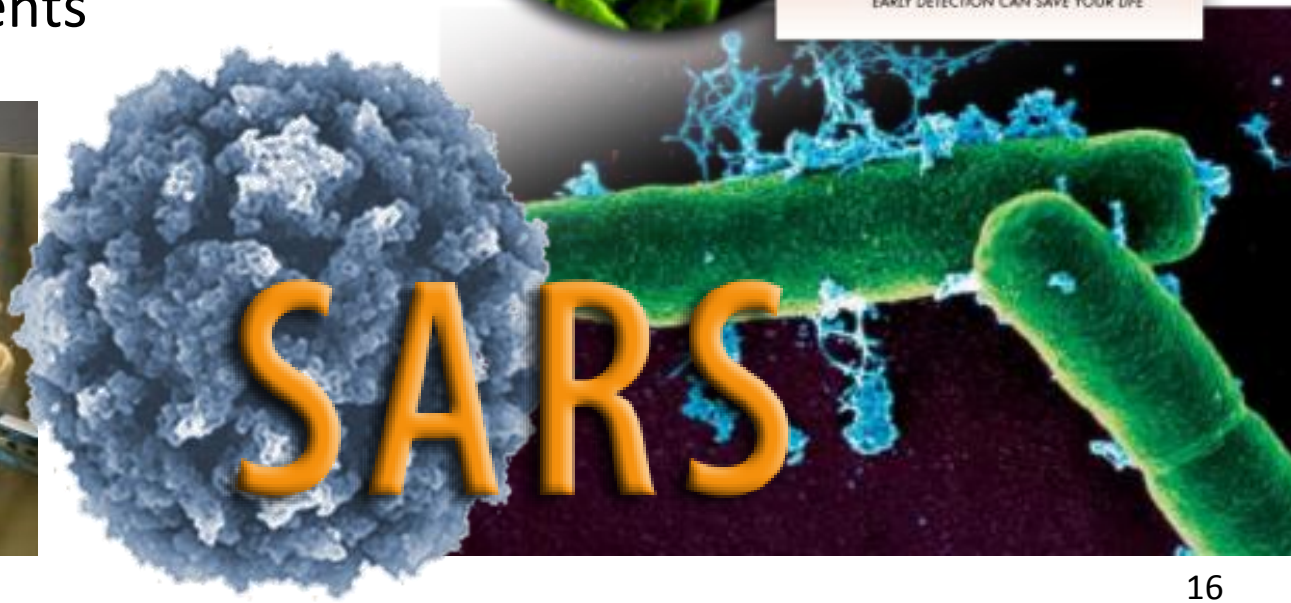
National labs and industry partner to advance combustion efficiencies

National security challenges in the 21st century

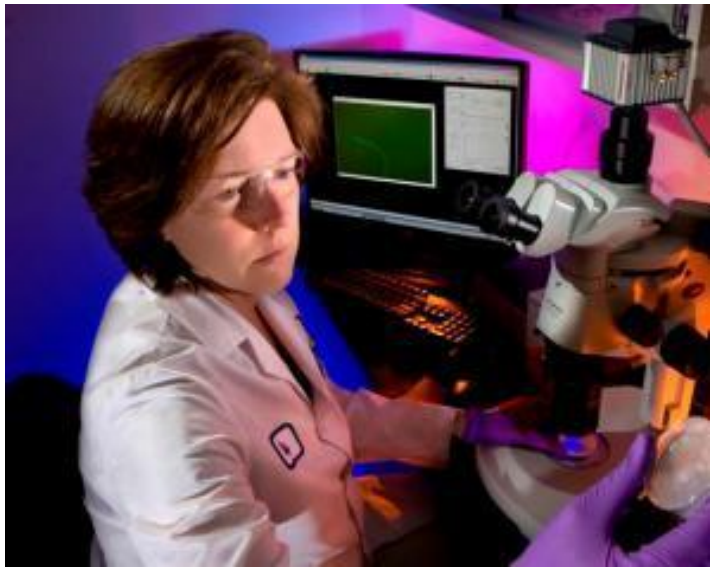
Asymmetric threats

- Traditional bioagents–
  Deliberate or accidental release
- Emerging bioagents
- Engineered bioagents





A deliberate move into biology

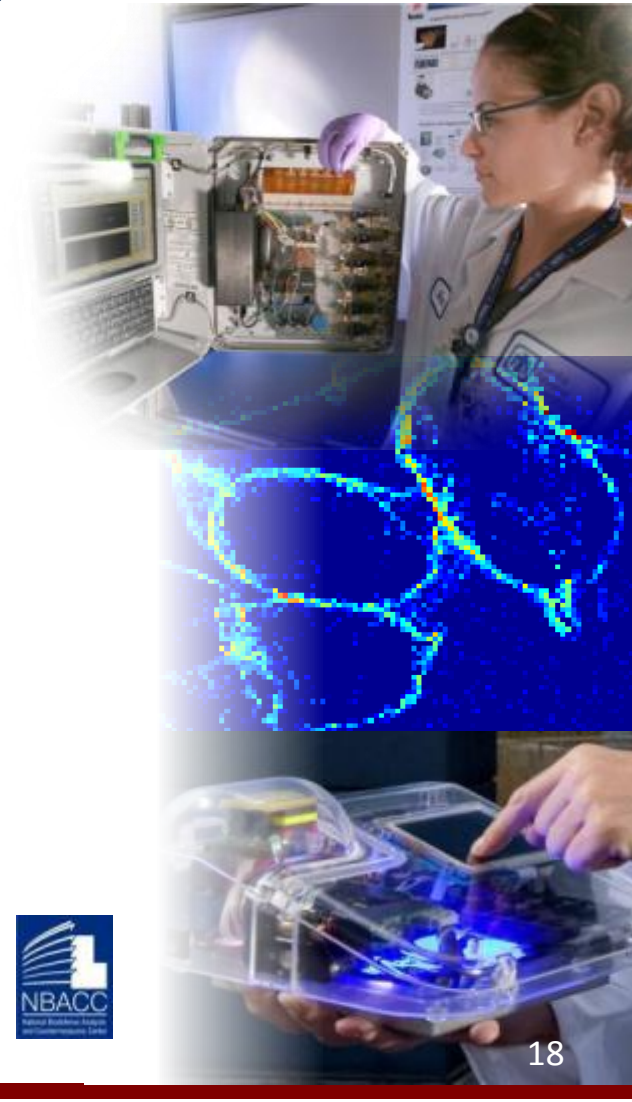


- Biological tools will soon be as powerful and ubiquitous as digital electronics are now . . . for both good and ill
- The nation needs Sandia to be involved
- Strategy set over a decade ago
  - Biofuels – Algal and lignocellulosic
  - Biodefense – Anticipate, mitigate, and counter biothreats
- Major staff growth

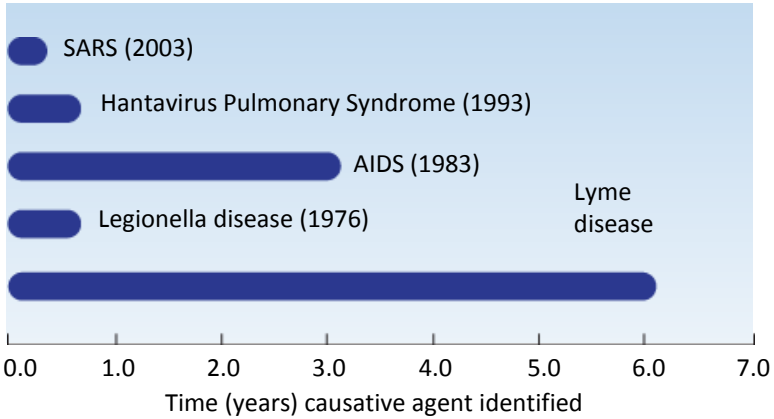
Sandia and its strategic partners work together to tackle the key challenges

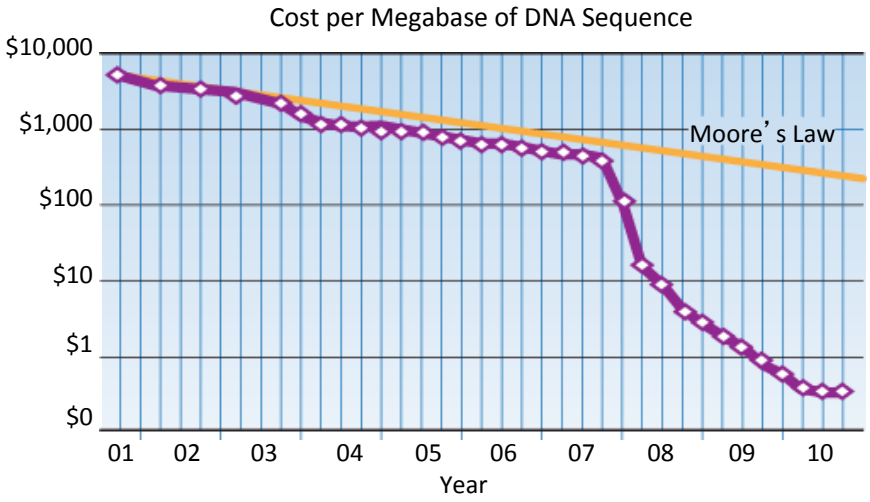
Providing rapid, sensitive bioanalytics for detection and diagnosis of biological outbreaks and effective countermeasures to contain them

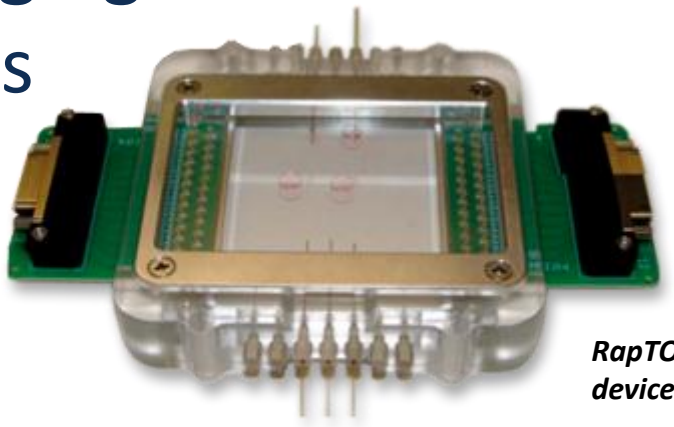
- Diagnostics for infection by known pathogens based on "biomarkers" produced early in our immune response: Early diagnosis = lives saved.
- Detecting "unknown" pathogens, characterizing their virulence, and developing effective countermeasures.
- Establishing nature of previously unknown pathogens—naturally emerging or intentionally engineered.
- Developing an effective, timely national response based on understanding the outbreak.



RapTOR characterizes emerging and engineered biological agents







RapTOR device

- Rapidly analyzes samples of unknown biological agents.
- Next-generation sequencing, combined with our engineering expertise, enables characterizing unknown biological agents in clinical samples.
- Increases the biological agent to host signal-to-noise ratio.

Cyber attacks have increased by a factor of 4 in the past decade

We play a part in national cyber security

Supervisory control and data acquisition systems

- R&D support to the national security community
- State-of-the-art defense against 30,000 attacks per hour

Collaborative research in cyber defense

Engaging and educating the next generation of cyber experts

Roles in partnerships

- Universities: Deep and more theoretical understanding in computer science and relevant fields of study
- National labs: Grounded, threat-informed mission understanding and application venue

Examples from Sandia

- Center for Cyber Defenders
- Annual University Partners Open House & Cyber Workshop
- Cyber Engineering Research Institute

Early-career research and development cyber-related projects

- Peering through the haze: Privacy and monitoring in the Cloud computing paradigm
- Authorship attribution of natural language text and software
- Identifying dynamic patterns in network traffic to predict and mitigate cyber attacks
- On-chip coherent qubit operations with microfabricated surface ion traps
- Forensic and nondestructive attribution
- Formal methods for FPGA designs
- Simplifying virtual machine security through foundational introspection capabilities
- Secure and efficient privacy preserving program obfuscation
- Nation-scale network monitoring through resilient, entropy-aware, peer-to-peer communications
- Leveraging safety applications for global revocation and congestion control in vehicular ad hoc networks
- Robust classifiers for dataset shift induced by unmodeled effects
- Uncertainty quantification and substantiation for machine learning in the context of cyber security
- Simulation-based strategic analysis of complex security scenarios

Sandia directly supports the warfighter

Working with government partners, Sandia is providing technologies that locate and help defeat improvised explosive devices (IEDs)

- Expertise in radar development for nuclear weapons → Advanced synthetic aperture radar (SAR) development.
- SARs fielded on small unmanned aerial vehicles (UAVs) locate and help defeat IEDs.
- The Department of Defense unanimously recommended this system as a "proven counter-IED system."

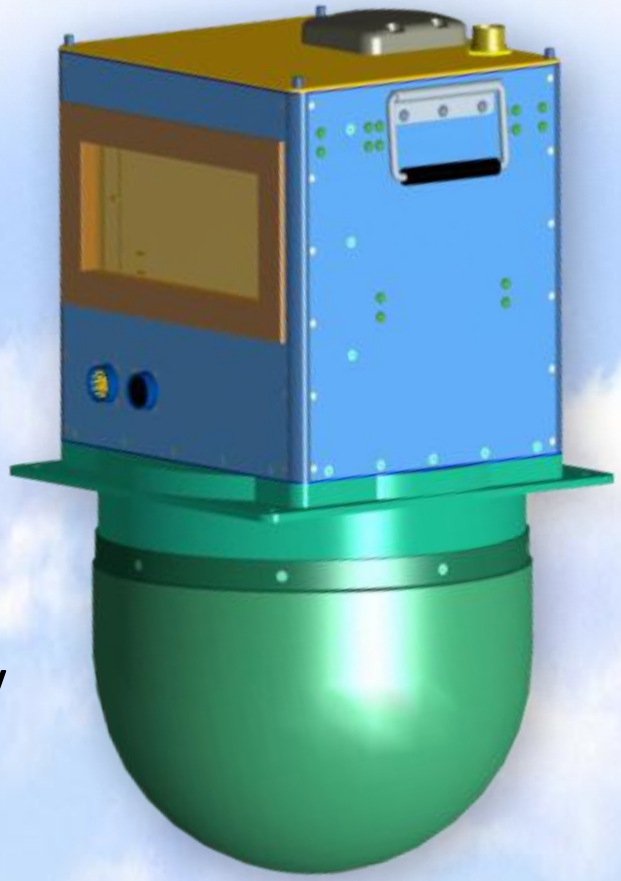
A Class III UAV outfitted with a Sandia-developed SAR.

". . . I wish we had it from the beginning. A lot of people would still be around right now . . . you all saved the day."

—Comments from the warfighter

Technical challenges

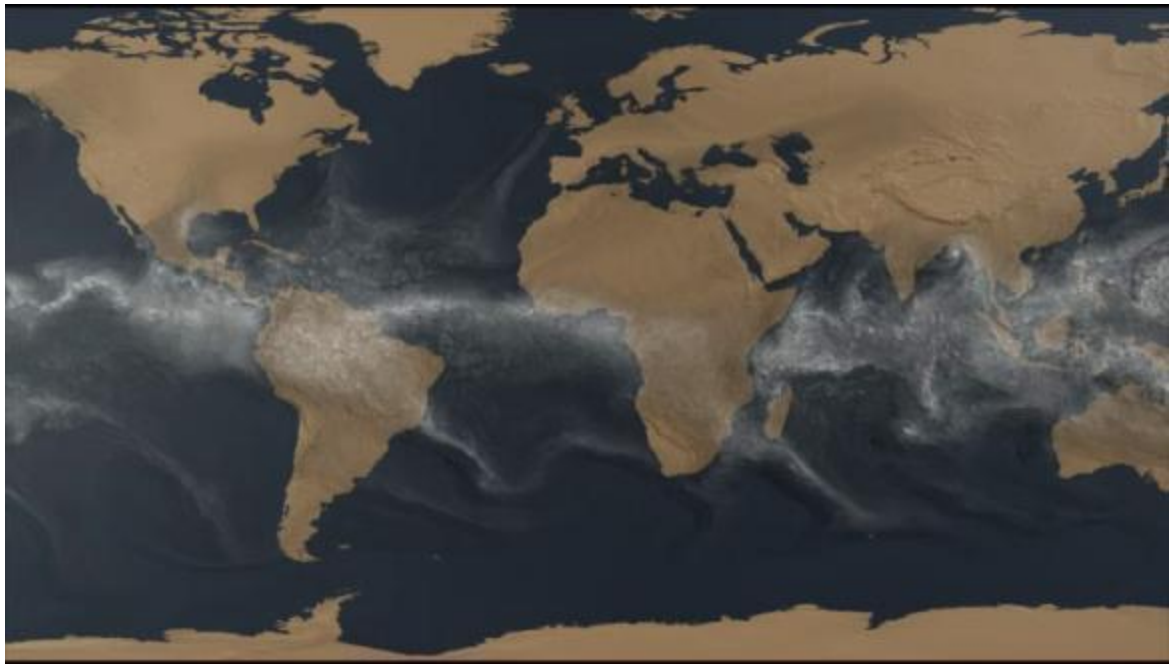
- Real-time image processing on the unmanned aerial vehicle (UAV)
- Miniaturization of a high-resolution synthetic aperture radar (SAR)
- Real-time image exploitation
- Integration of the SAR on a small UAV
- UAV endurance and flight control



The Sandia-developed SAR weighs 62 pounds, consumes 400 watts (on average), occupies 2 cubic feet of fuselage, and is mounted to the UAV with four bolts and two connectors.

Sandia exerted substantial leadership in transforming the way atmospheric models are computed

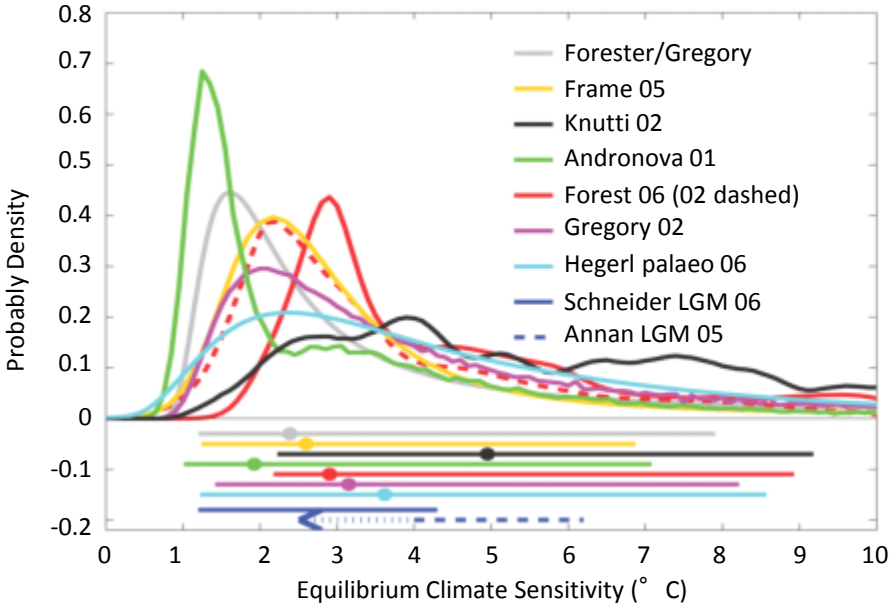
- Leader of multilab effort to develop the Community Earth System Model's petascale-ready dynamical core.
- Our atmospheric modeling capability is now very highly sought.



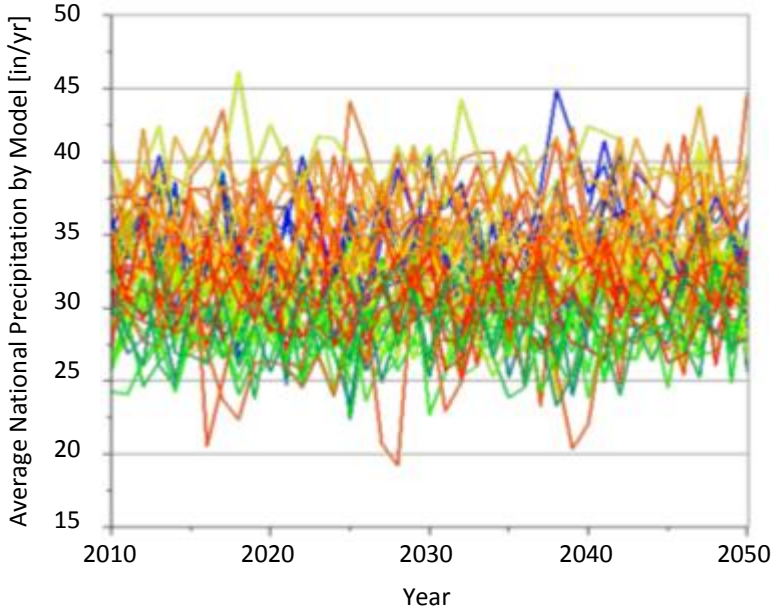
Uncertainty is a major challenge associated with climate change

- Uncertainty in model results need not prevent decision making
- A quantitative risk analysis can generate compact metrics useful for decision making

Uncertainty in PDFs for climate sensitivity

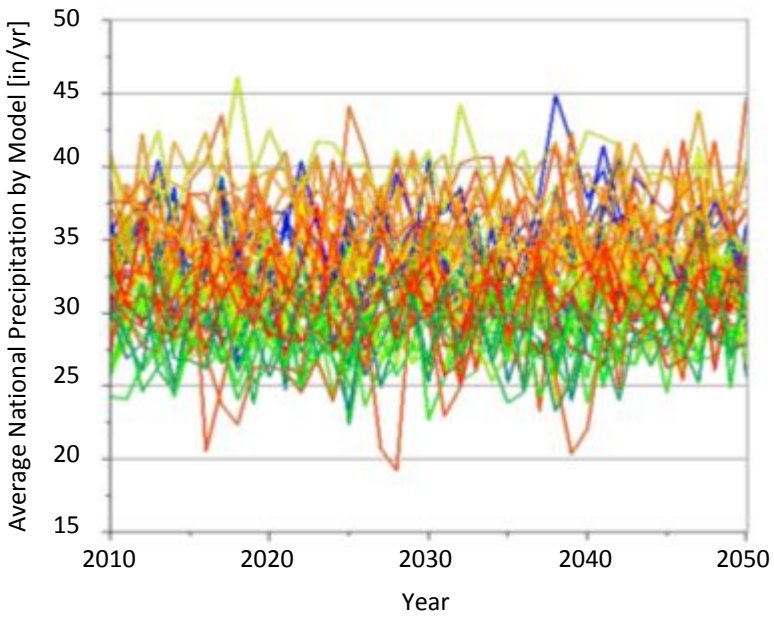


Uncertainty in model-predicted precipitation variability

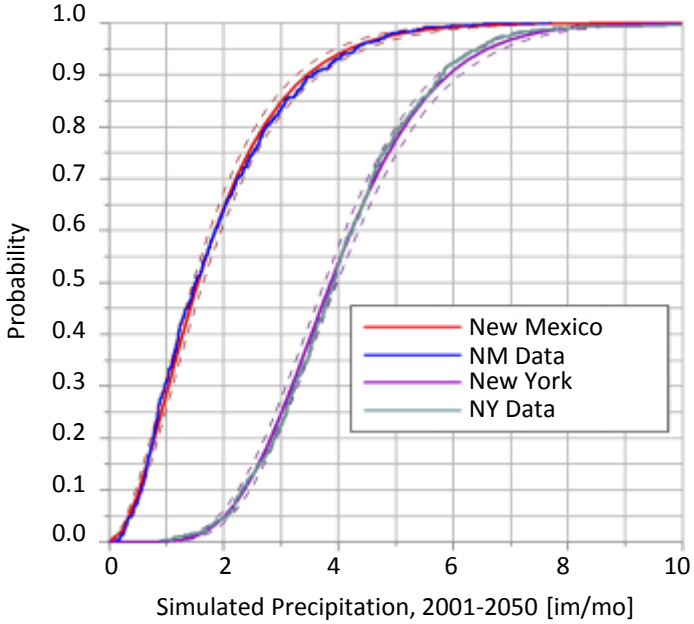


Supporting analyses in the presence of uncertainty

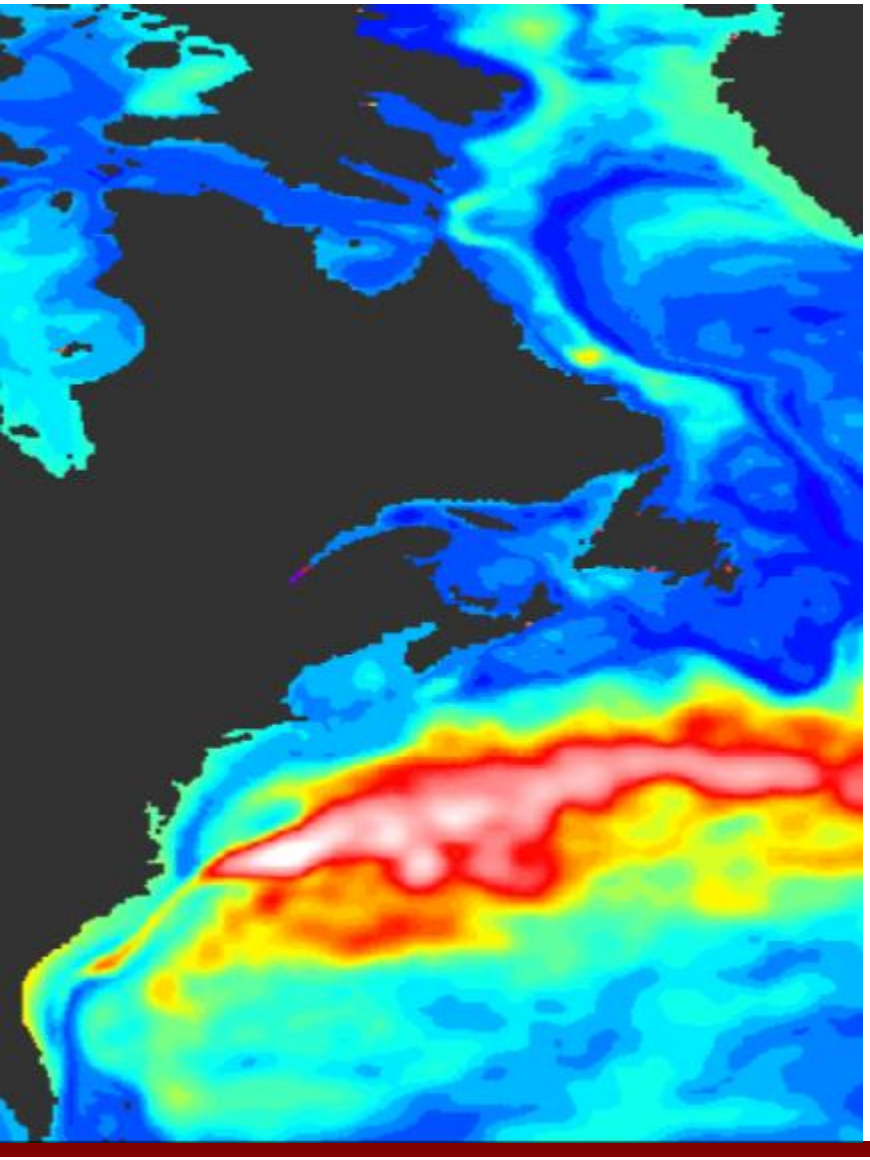
- Derived from nuclear weapon work in uncertainty quantification and integrated system risk analysis
- We are demonstrating a methodology that is agnostic to the input models



From predicting uncertainty…to risk analysis



Sandia climate collaborations



Sandia has strong laboratory and university collaborations in

- Uncertainty quantification for climate models
- Scalable atmospheric modeling methods
- Finite-element methods and solvers for land-ice modeling
- Carbon sequestration research
- Atmospheric monitoring techniques

Major laboratory collaborations: National Center for Atmospheric Research; Los Alamos, Oak Ridge, Argonne, Lawrence Berkeley, Pacific Northwest, and Lawrence Livermore national laboratories

Key university collaborations: University of Michigan, Columbia University, Florida State University, University of Texas at Austin, University of California Irvine, and New Mexico Tech

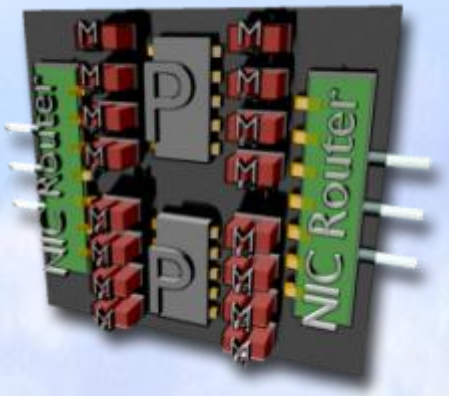
National security challenges in the 21st century

Science and technology surprise

Top 10 supercomputers in the world

- USA—Sequoia – BlueGene/Q, Lawrence Livermore National Laboratory
- Japan—K Computer, RIKEN Advanced Institute for Computational Science
- USA—Mira – BlueGene/Q, Argonne National Labs
- Germany—SuperMUC, Leibniz Rechenzentrum
- China—Tianhe-1A, National Supercomputing Center
- USA— Jaguar, Oak Ridge National Lab
- Italy— Fermi – BlueGene/Q, CINECA
- Germany— JuQUEEN, Forschungszentrum Juelich
- France—Curie Thin Nodes, CEA/TGCC-GENCI
- China—Nebulae, National Supercomputing Centre

Sandia is a national leader in computer architecture



Conceptualized Sandia board for 2018

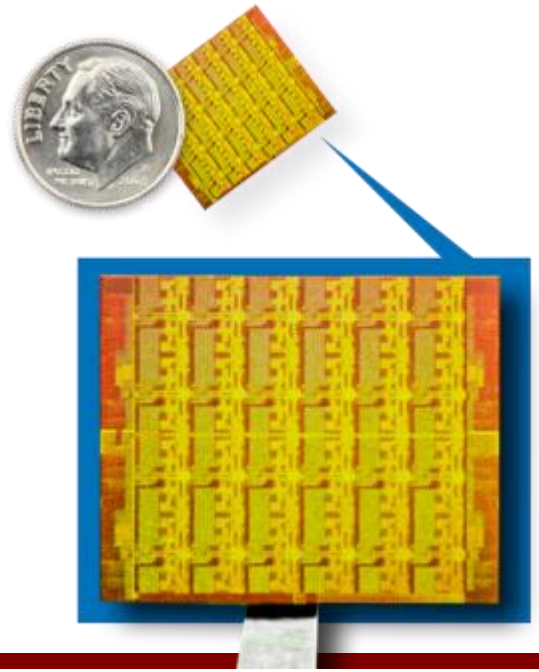
- Sandia, in partnership with Cray and Los Alamos, has successfully developed and deployed the Cielo petascale capability supercomputer for the Advanced Simulation and Computing Program.
- Sandia led adoption of co-design of architectures and applications as a key strategy of the National Exascale Computing Initiative.

- Our Exascale Grand Challenge LDRD is aimed at dramatically lowering energy consumption through 3-D integration of processing, network, and memory components.

Exascale = 1 billion $\times$ 1 billion flops

Overcoming key exascale challenges will impact all scales of computing

- Achieving exascale at 20 MW—ASCI Red, the world's first teraflop computer, will fit on a future chip and use the power of a light bulb.
- Future chips, the size of a dime, will be as challenging to program as the first massively parallel supercomputers were.
- One rack at exascale will be as fast as several hundred racks at petascale.
- Overcoming the mismatch between data movement and computation at exascale and at the desktop requires technical breakthroughs.
- National labs and universities collaborate in this field.



At exascale, hardware and software must deal with, literally, a billion things happening simultaneously.

Red Storm-XT3 impact on the supercomputing industry

- NNSA funded, Sandia architected, engineering lead by Cray, Inc.
- Sandia also developed
  - Compute node OS
  - High-performance interconnect communication protocol
- With the commercialization of Red Storm as the XT3, Cray's market share rose from 6% in 2002 to 21% in 2006.*
- In June 2011, 17 of the top 50 supercomputers were Cray systems derived from Red Storm technology.

Red Storm cabinets with unique red-black switching that allows intermittent classified and unclassified processing on the same hardware.

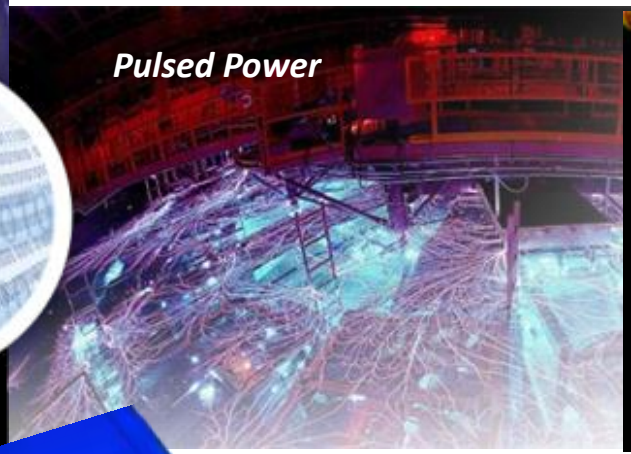
"Our partnership with NNSA and Sandia on Red Storm has resulted in the Cray XT, an extremely successful supercomputing product line for Cray with over 1,000 cabinets shipped around the world."

—Peter Ungaro,
President and CEO of Cray Inc.

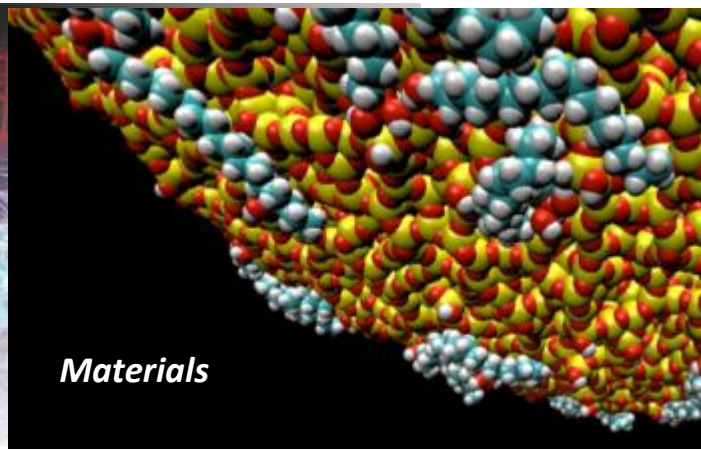
*Source: IDC #209251 *Technical Computing Systems: Competitive Analysis*, November 2007

Science and technology innovation advances our missions

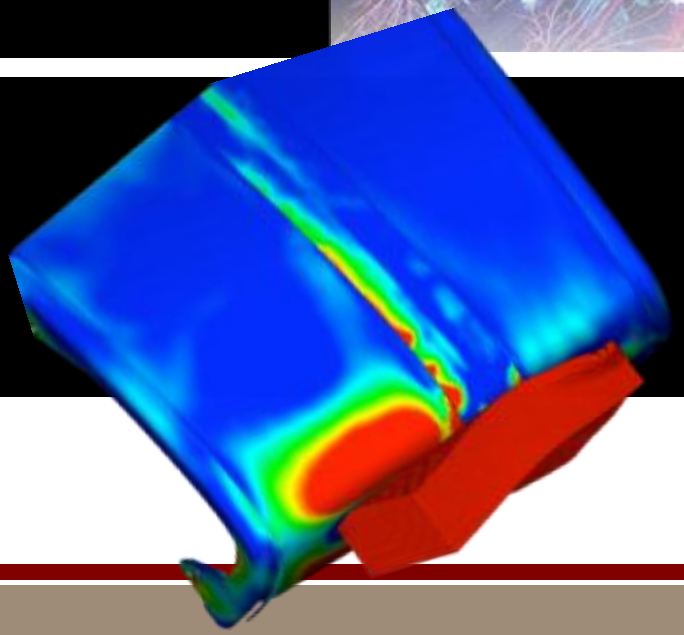
Computer Science



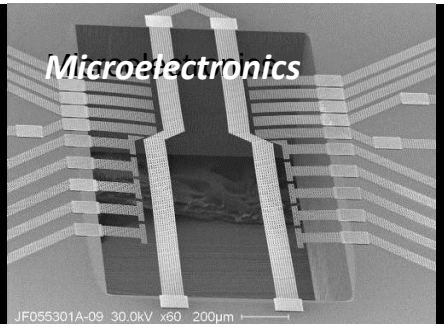
Pulsed Power



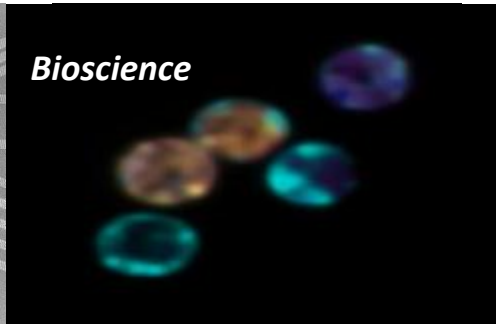
Materials



Engineering Sciences



Microelectronics



Bioscience

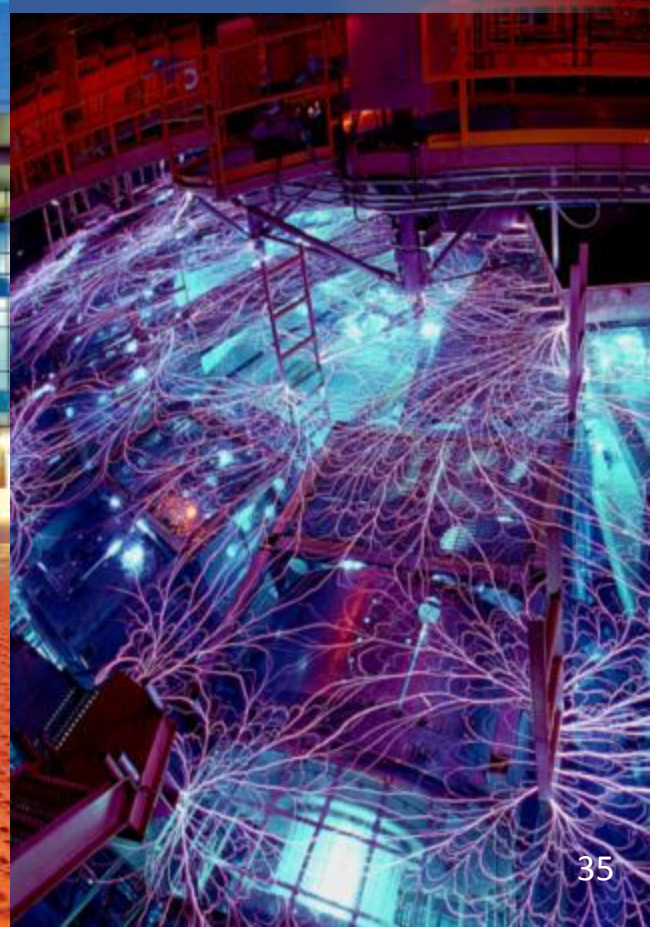
Key elements of science and technology innovation: Large-scale facilities

Sandia National Laboratories

Thermal Test Complex

Microsystems and Engineering Sciences Applications

Z Accelerator



Key elements of science and technology innovation: Large-scale facilities

Sandia National Laboratories

Ion Beam Laboratory

Pete V. Domenici National Security Center

Center for Integrated Nanotechnologies

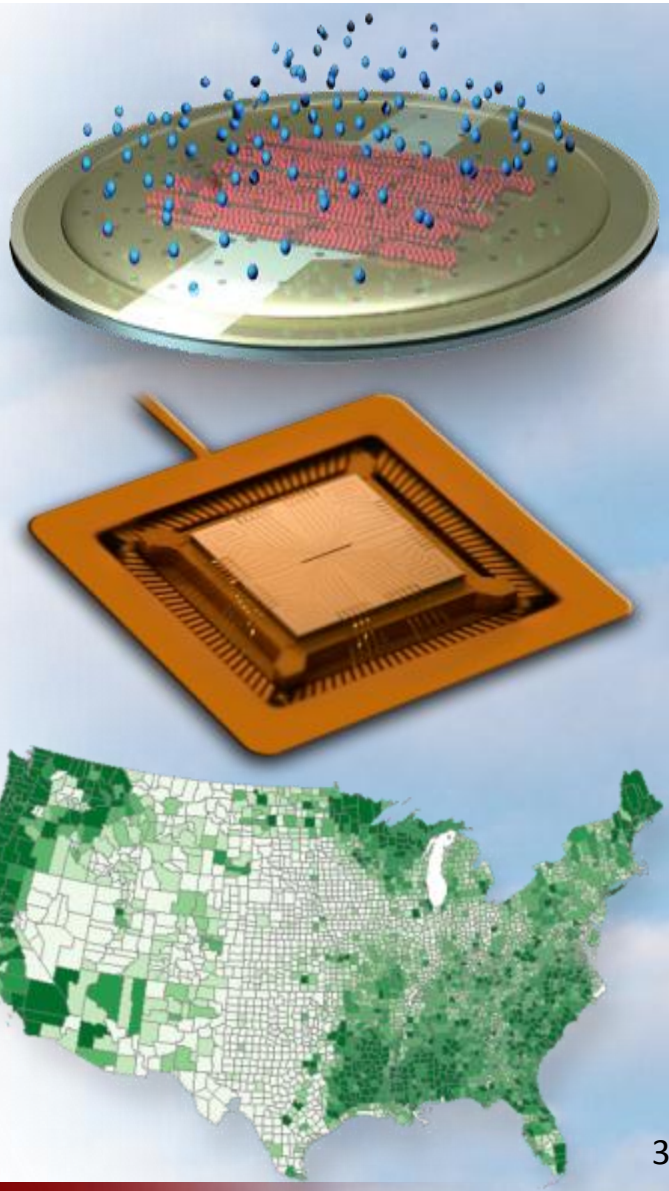
Laboratory Directed Research and Development (LDRD)

- Leading-edge technological solutions for mission challenges too risky for direct program funding

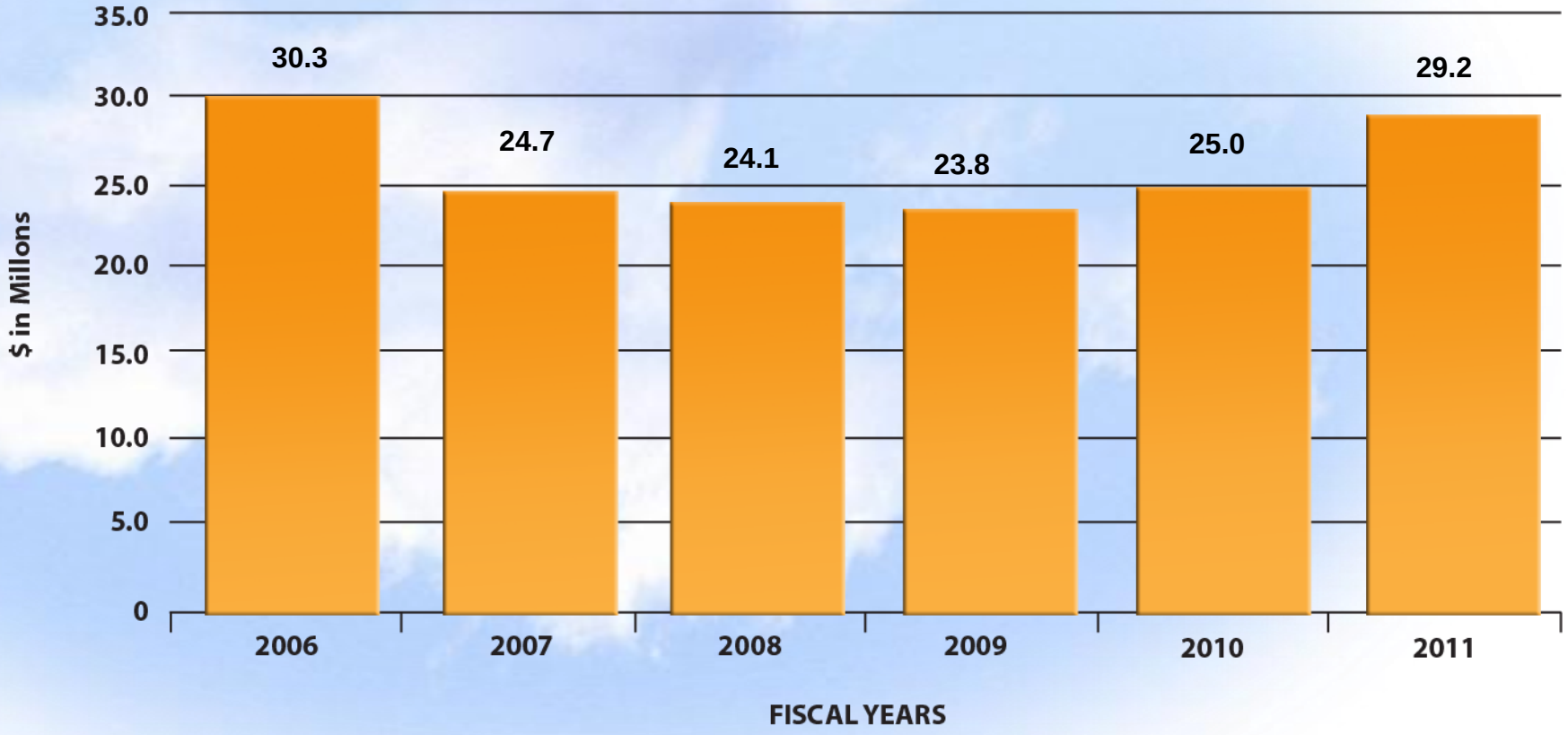
- Some LDRD Projects
  - Advanced secure scalable microgrids
  - Advanced architectures for high-performance computing
  - Novel electronics for space-based sensors
  - Innovative technologies for conversion of carbon dioxide to synthetic fuel

Carving a creative research path with the Early Career Program

- Development of chemiresponsive sensors for detection of common homemade explosives
- Ion-photon quantum interface: Entanglement engineering
- Guiding options for optimal biofuels

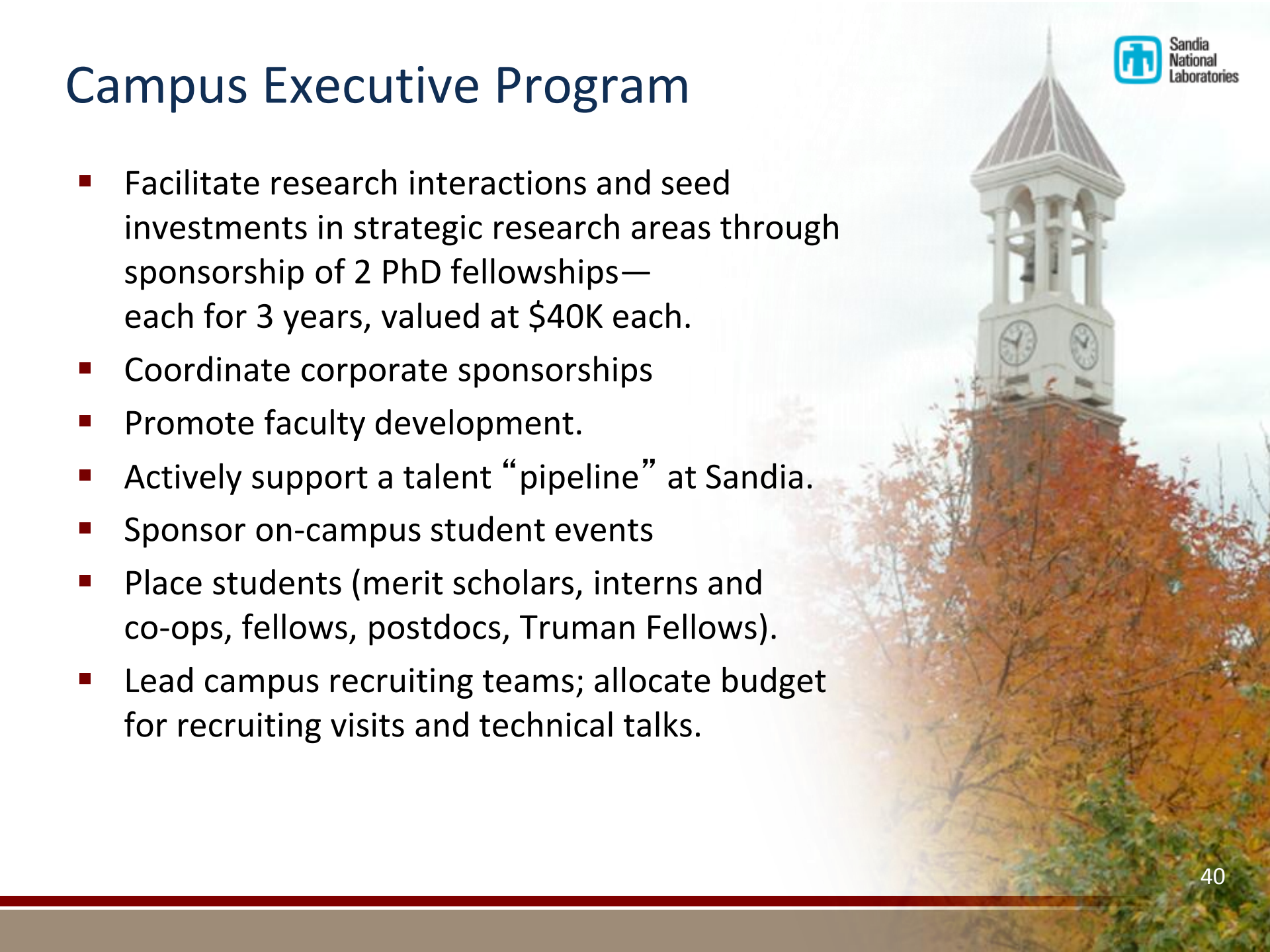


Sandia R&D spending at universities



Campus Executive Program

- Facilitate research interactions and seed investments in strategic research areas through sponsorship of 2 PhD fellowships—each for 3 years, valued at $40K each.
- Coordinate corporate sponsorships
- Promote faculty development.
- Actively support a talent “pipeline” at Sandia.
- Sponsor on-campus student events
- Place students (merit scholars, interns and co-ops, fellows, postdocs, Truman Fellows).
- Lead campus recruiting teams; allocate budget for recruiting visits and technical talks.



Education in science and engineering leads to innovation and discovery

- "40 percent of students planning engineering and science majors end up switching to other subjects or failing to get any degree." (*The New York Times*, November 4, 2011)
- "In 2006, in the United States, science and engineering degrees were about 33% of the total number of bachelor's degrees; in Japan, 63%; and in China, 53%." (*Science and Engineering Indicators* 2010—National Science Board)
- American universities are looking to reform teaching approaches in sophomore and junior years.
- The country needs scientists and engineers.

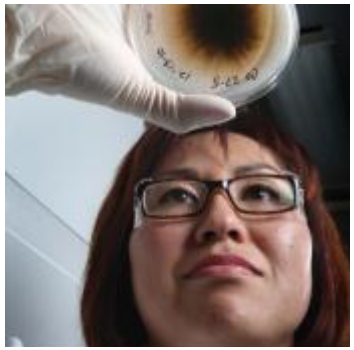
In a nutshell

- National security challenges of today are multidimensional and increasingly diverse and complex.
- We are at our strongest and most effective when we partner for solutions.
- Working together, national laboratories, universities, and industry will continue to make key contributions to our country's prosperity and security in the 21st century.

Your turn—Comments or questions?

Exceptional service in the national interest

Sandia National Laboratories


Thank you for coming!