## Council on Competitiveness Science & National Labs Caucus
## April 10, 2013

### Funding in 2009 (using page 4-35 of NSF document)

| | | | |
|---|---|---|---|
| DOE | Basic research | $4,061.9 M | 41% of funding received |
| | Applied research | $3,127.2 M | 32% of funding received |
| | Development | $2,701.8 M | 27% of funding received |
| | | **Total = $9,889.9 M** | |
| NSF | Basic research | $5,623.9 M | 92% of funding received |
| | Applied research | $471.3 M | 8% of funding received |
| | Development | 0 | 0% of funding received |
| | | **Total = $6,095.2 M** | |
| NASA | Basic research | $1,021.6 M | 17% of funding received |
| | Applied research | $681.8 M | 12% of funding received |
| | Development | $4,233.5 M | 71% of funding received |
| | | **Total = $5,937 M** | |
| DOD | Basic research | $1,735 M | 2.5% of funding received |
| | Applied research | $5,071.4 M | 7.4% of funding received |
| | Development | $61,306.5 M | 90% of funding received |
| | | **Total = $68,113.0 M** | |

DOE + NSF development piece = $2,701.8 M, which is 17% of the total R&D funding ($15,985.1 M) received by DOE and NSF combined.

DOD development piece = $61,306.5 M, which is 90% of the funding received.

## A. Introductory remarks

Good afternoon, ladies and gentlemen,

I'm pleased for the opportunity to talk with you in this forum. I will begin my remarks by noticing that it's an impressive fact that the DOE national labs and the university system together conduct approximately 50% of the nation's basic and applied research in the areas of physical sciences, engineering, math, and computer sciences. It is also a fact, however, that they are responsible for only a small portion of the nation's development work. This reality highlights the importance of ensuring a strong, synergistic connection between the labs, universities, and the private sector.

The DOE national labs play a special role in the nation's R&D efforts. For more than 60 years, they have changed and improved the lives of millions of Americans. Originally created in response to the needs of the nation's nuclear weapons program, these laboratories have since evolved into a group of distinctive organizations whose focus addresses a whole range of national priorities and needs.

## B. The national laboratories are mission-driven institutions

Those mission drivers, along with the complex operational, security, and safety needs that accompany them, separate the laboratories from academic and industrial institutions.

- The mission of the weapons (or NNSA) laboratories (Sandia, Los Alamos, and Lawrence Livermore) is to conduct research and development activities to maintain a safe, secure, and effective nuclear deterrent.
- The mission of the science laboratories (e.g., Pacific Northwest, Berkeley, and Oak Ridge) is to conduct research that advances the science needed in support of the missions of the DOE Office of Science: Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, Nuclear Physics.
- The mission of the energy laboratories (Idaho National Lab and National Renewable Energy Lab) is to conduct research to ensure the nation's energy security with safe nuclear energy and renewable energy systems (e.g., wind and solar).

**Lab mission statements**

*Sandia:* 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.

*Los Alamos:* Develop and apply science and technology to ensure the safety, security, and reliability of the U.S. nuclear deterrent; reduce global threats; and solve other emerging national security and energy challenges.

*Lawrence Livermore:* Strengthening the United States' security through development and application of world-class science and technology to enhance the nation's defense; reduce the global threat from terrorism and weapons of mass destruction; and, more broadly, respond with vision, quality, integrity and technical excellence to scientific issues of national importance.

*Pacific Northwest:* Strengthen U.S. scientific foundations for innovation; increase U.S. energy capacity and reduce dependence on imported oil; prevent and counter terrorism and the proliferation of weapons of mass destruction; and reduce the environmental effects of human activities and create sustainable systems.

*Lawrence Berkeley:* Overarching commitment to pioneering science; highest integrity/impeccable ethics; uncompromising safety; diversity in people and thought; and sense of urgency.

*Oak Ridge:* Deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation.

*Idaho Nat. Lab*: Ensure the nation's energy security with safe, competitive, and sustainable energy systems and unique national and homeland security capabilities.

*National Renewable Energy Lab:* 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.

## C. The national laboratories serve the interest of the nation

*(Segue)* The DOE labs are a national resource for the entire federal government because they **address, in a multidisciplinary way**, **complex problems of national importance,** such as the safety, security, and reliability of the nuclear deterrent, cyber security, the potential effects of climate change, domestic and international terrorism, and clean, affordable energy.

### 1. Stockpile stewardship work for homeland security

After the Cold War, the national security labs moved into the stockpile stewardship era, during which the quintessential challenge was the loss of underground testing. The sustained support received for stewardship has allowed us to make enormous progress in understanding nuclear weapons function in the absence of underground testing. The tools of stewardship will continue to be applied at this time, when our country's nuclear deterrent is being modernized.

2. **Work in predicting potential effects of climate change and in diminishing prediction uncertainties**

The national labs are at the forefront of these efforts. The modeling work conducted by the DOE—for example, the **Community Earth System Model used by DOE and developed jointly by NSF and DOE**—is a good example in this regard. The **Climate Science for a Sustainable Energy Future (CSSEF)** is a collaborative project among Oak Ridge National Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, and Sandia National Laboratories, together with the National Center for Atmospheric Research to transform the climate model development and testing process and thereby accelerate the development of the Community Earth System Model's sixth-generation version, CESM3. Needed high resolution and associated uncertainty quantification will be feasible on DOE petascale computers.

3. **Work in response to national and international emergencies**

The national labs are also called upon to respond to national and international emergencies. One well-known recent international example was the accident at **Fukushima Dai-Ichi**. The DOE national labs responded immediately to this event. Representatives from Idaho, Pacific Northwest, and Sandia national laboratories were deployed, as well as airborne monitoring system aircraft and sensors. In addition, the DOE stood up a Science Council supported by DOE and national laboratory staff. Among the participants were Argonne, Pacific Northwest, Brookhaven, Oak Ridge, Lawrence Livermore, Sandia, Savannah River, and Los Alamos national laboratories. DOE's Knolls Atomic Power Laboratory also participated.

Another such example is the **BP Deep Water Horizon oil spill** (April 2010). The DOE national labs were significantly involved in the work that would lead to stopping the Gulf of Mexico oil spill, considered the largest accidental marine oil spill in the history of the petroleum industry. Sandia participated technical work from the beginning of the effort.

4. **Work in support of NASA's deep space missions**

- Sandia's contributions to the shuttle program (orbiter boom sensor system)
- Work on the nuclear-detonation detection system done jointly by Sandia and Los Alamos. Specifically, the work was on the payloads of the global burst detection (GBD) system for the Global Positioning System (GPS) satellites.

5. **Sandia's MegaDroid project for cyber security**

- Sandia cyber researchers linked together 300,000 virtual hand-held computing devices running the Android operating system so they can study large networks of smartphones and find ways to make them more reliable and secure.
- The work is expected to result in a software tool that will allow others in the cyber research community to model similar environments and study the behaviors of smartphone networks.

Ultimately, the tool will enable the computing industry to better protect hand-held devices from malicious intent.

- Bluetooth and Wi-Fi sensors mean smartphones are location-dependent, providing an opportunity for attacks. The researchers used a spoof GPS based on a simulation of a typical urban smartphone user's data to simulate a more accurate environment.
- This latest development by Sandia cyber researchers represents a significant steppingstone for those hoping to understand and limit the damage from network disruptions due to glitches in software or protocols, natural disasters, acts of terrorism, or other causes. These disruptions can cause significant economic and other losses for individual consumers, companies and governments.

## D. The national laboratories deliver scientific discovery and innovation

The national laboratories have the ability to deliver discovery and innovation. Over the years, DOE laboratory scientists have provided our country with innovative research and complex problem solving that keep the United States in the forefront of scientific discovery. **More than 80 Nobel Laureates from DOE labs** are a proud testimony to the quality and impact of those discoveries.

In recent decades, discoveries at the national laboratories have

- bolstered the innovative tools needed to keep the nuclear stockpile safe, secure, reliable, and effective without underground testing (the last UGT was conducted September 23, 1992)
- explained photosynthesis, work that allows scientists to derive sustainable energy sources from the sun (**Note:** Discovery mentioned among the "50 Breakthroughs")
- revolutionized medical diagnostics, including today's cancer-detecting, compact nuclear-imaging devices and the magnets in MRI scanners (**Note:** Discovery mentioned among the "50 Breakthroughs")
- led to invention of the material (crystalline silico-titanates) that removed radiation from contaminated seawater after the Fukushima Daiichi nuclear accident

The scale and scope of the national labs enable them to employ **multidisciplinary teams to solve complex problems, using basic science that eventually translates into technological innovation.**

For example, **the national labs drove the creation and development of supercomputing** and its subsequent application to a whole range of problems. Spanning decades of research and development, from the Univacs of the 1950s to the petascale computers of today, the national labs have helped maintain U.S. leadership in high-performance computing.

In this context, I would also like to highlight the global effort that has been spent since the 1980s on **quantum computing**. Quantum computing plays an important part in computational problems that are beyond the capabilities of enormously powerful massively parallel computers (e.g., factoring integers into primes, searching through unstructured databases, analyzing quantum effect). At Sandia, the MESA (Microsystems and Engineering Sciences Applications) Complex is an enabler of many scientific discoveries and innovations, one exciting example being in the area of quantum computing research.

*Example: Quantum computing research*

- **Search for a quantum computer:** Promises to take computing to its ultimate quantum-coherent limit, just as lasers (light amplification by stimulated emission of radiation) did for light. Has potential to revolutionize simulation, sensing, energy capture, and nanoscale device fabrication.
- **Benefits:** Will increase U.S. national security and competitiveness by avoiding technological surprise and staying on the frontlines of innovation.
- **Sandia's research accomplishments:** (1) *First-ever* demonstration of a robust functional ion trap, *first-ever* fabrication of diffractive optical elements for cesium trapping and control, and *first-ever* trapping of three separated cesium atoms. (2) Operation of Sandia's first quantum device that processes information stored in a cesium atom that is laser cooled to 100 microkelvins.

## E. The national laboratories operate unique scientific facilities

*(Segue)* Beyond their role in advancing innovation, the national laboratories are recognized worldwide for their work in designing, building, and operating unique scientific instrumentation and facilities that are also used by tens of thousands of scientists and engineers from academia and industry, who partner with their colleagues from the national labs in coming up with solutions to pressing and extremely complex problems.

Some of these facilities include the **Z Pulsed Power Machine at Sandia, the National Synchrotron Light Source at Brookhaven National Laboratory, the Los Alamos Neutron Science Center (or LANSCE) at Los Alamos National Laboratory, the Accelerator Test Facility at Brookhaven National Laboratory, the Center for Neutron Scattering at Oak Ridge National Laboratory, and the Research Combustion Facility at Sandia, California**.

Another unique facility and important national laboratories collaboration is the **Joint Bio Energy Institute (JBEI).**

- JBEI is a multi-institutional partnership led by Lawrence Berkeley National Laboratory, and includes the Sandia National Laboratories, Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, the University of California (Berkeley and Davis campuses), and the Carnegie Institution for Science.
- A DOE Bioenergy Research Center, JBEI advances the development of next-generation biofuels – liquid fuels derived from the solar energy stored in the cellulosic biomass of non-

food plants. *Goal:* Provide the nation with clean, green and renewable transportation energy that will create jobs and boost the economy.

## F. Strengthening U.S. competitiveness and moving innovation to the marketplace

*(Segue)* **The national labs' ability to solve difficult national problems in a multidisciplinary way, to deliver innovation, and to operate truly unique facilities makes them indispensable to strengthening U.S. competitiveness and moving innovation to the marketplace.**

- The national laboratories partner with U.S. industry through a range of programs and different mechanisms.
- Creative efforts aimed at strengthening U.S. competitiveness and moving innovation to the marketplace.

*Example: Partnership between Sandia, Cummins engines, and Dodge through the Combustion Research Facility at SNL/CA*
Cummins used basic research on modeling of combustion chemistry and the application of laser diagnostics to fuel injection developed at the CRF to produce a new, more robust and fuel-efficient diesel engine. In addition, using computer modeling to design the engine reduced development time and cost by an estimated 10%-15%. The ISB 6.7 Liter Cummins diesel engine, first marketed in 2007, powers more than 200,000 Dodge Ram Heavy Duty Pickup Trucks.

*Cummins also partnered with Pacific Northwest Laboratory, Johnson Matthey, and Brookhaven National Laboratory* when their engines were unable to meet emission standards. *In situ* characterization identified unusual catalyst morphology changes during operation. Combining this new fundamental understanding garnered by PNNL scientists with additional applied research, the catalyst was improved and product engineers were able design a catalytic system that met 2010 emission standards. The same technology is now on other vehicles including new models of the diesel Volkswagen Jetta.

*Example: Livermore Valley Open Campus (LVOC)*
Spans the eastern sides of Sandia's California site and LLNL. Historically, both labs have been closed and self-contained, making some external alliances difficult because of administrative and security challenges. Established in 2011, the LVOC is a space for open, collaborative work in bioscience, cybersecurity, detection technologies and energy applications.

**New Mexico Small Business Assistance (NMSBA) Program**—a public-private partnership between the State of New Mexico, SNL, and LANL that assists for-profit small businesses in New Mexico to access cutting-edge technologies, solve technical challenges, and gain knowledge from lab experts at SNL and LANL.

**Entrepreneurial Separation to Transfer Technology (ESTT)** – allows Sandians to start up or expand companies with guaranteed reinstatement of a job at Sandia after two years.

*Example: AMO Wavefront Sciences*

- In 1995, Sandia was building a microelectromechanical systems (MEMS) portfolio, including the development of micro-optics and Shack-Hartmann wavefront sensors, which were used on high-energy laser applications. Dan Neal left Sandia a year later under the ESTT program to start a company to commercialize this sensor in the optical market.
- This initial technology has enabled Wavefront's continued evolution into a thriving company that creates optical measuring systems for everything from space telescopes to LASIK surgery.

## G. Training future scientists and engineers

Everything I touched upon so far suggests that the national labs provide a solid platform to support the development of the future science, technology, engineering, and mathematics (STEM) workforce. The labs' **unique facilities and capabilities are available to students and faculty at all levels.** These programs range from workshops to semester-long appointments to extended-term employment. Altogether, the laboratories engaged more than 450 academic institutions in the U.S. and Canada.

Productive collaborations between university and national laboratory researchers through **personnel exchanges**, **research collaborations** at the individual investigator level, **joint research programs** established to develop and take advantage of DOE user facilities, and **strategic institutes** established to focus on new areas of scientific endeavor. Universities are thus able to conduct

*Examples from CRO paper*

- science requiring large, complex facilities and teams trained in their safe and effective operation (the Advanced Photon Source at ANL);
- science requiring substantial engineering and instrument development (the Environmental Molecular Sciences Laboratory at PNNL); or
- science requiring specialized facilities that are costly to maintain (CRF at Sandia, CA)

## H. Conclusions

- Large nucleus of multidisciplinary scientists and engineers solve complex problems. They translate basic science into technological discovery and innovation and from there they ultimately deliver products.
- Address problems of national importance
- Steward unique scientific facilities
- Create innovative technologies that both strengthen U.S. competitiveness and transition to the marketplace

The results of the publicly funded research conducted at these laboratories are used for the U.S. public good.