U.S. DEPARTMENT OF ENERGY | Office of Science

# Program Highlights from the Office of Science

Nuclear Science Advisory Committee meeting

February 26, 2010

Dr. W. F. Brinkman
Director, Office of Science
U.S. Department of Energy
*www.science.doe.gov*

# The Administration's S&T Priorities for the FY 2011 Budget

"When we fail to invest in research, we fail to invest in the future. Yet, since the peak of the space race in the 1960s, our national commitment to research and development has steadily fallen as a share of our national income. That's why I set a goal of putting a full 3 percent of our Gross Domestic Product, our national income, into research and development, surpassing the commitment we made when President Kennedy challenged this nation to send a man to the moon."

President Barack Obama
September 21, 2009

http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-on-Innovation-and-Sustainable-Growth-at-Hudson-Valley-Community-College/

# Office of Science (SC) FY 2011 Budget Request to Congress

(B/A in thousands)

| | FY 2009 | | FY 2010 | FY 2011 | | |
|---|---|---|---|---|---|---|
| | Current Base Approp. | Current Recovery Act | Current Approp. | Request to Congress | Request to Congress vs. FY 2010 Approp. | |
| Advanced Scientific Computing Research | 358,772 | 161,795 | 394,000 | 426,000 | +32,000 | +8.1% |
| Basic Energy Sciences | 1,535,765 | 555,406 | 1,636,500 | 1,835,000 | +198,500 | +12.1% |
| Biological & Environmental Research | 585,176 | 165,653 | 604,182 | 626,900 | +22,718 | +3.8% |
| Fusion Energy Sciences | 394,518 | 91,023 | 426,000 | 380,000 | -46,000 | -10.8% |
| High Energy Physics | 775,868 | 232,390 | 810,483 | 829,000 | +18,517 | +2.3% |
| Nuclear Physics | 500,307 | 154,800 | 535,000 | 562,000 | +27,000 | +5.0% |
| Workforce Development for Teachers & Scientists | 13,583 | 12,500 | 20,678 | 35,600 | +14,922 | +72.2% |
| Science Laboratories Infrastructure | 145,380 | 198,114 | 127,600 | 126,000 | -1,600 | -1.3% |
| Safeguards & Security | 80,603 | —— | 83,000 | 86,500 | +3,500 | +4.2% |
| Science Program Direction | 186,695 | 5,600 | 189,377 | 214,437 | +25,060 | +13.2% |
| Small Business Innovation Research/Technology Transfer (SC) | 104,905 | 18,719 | —— | —— | —— | —— |
| **Subtotal, Science** | **4,681,572** | **1,596,000** | **4,826,820** | **5,121,437** | **+294,617** | **+6.1%** |
| Congressionally-directed projects | 91,064 | —— | 76,890 | —— | -76,890 | -100.0% |
| Small Business Innovation Research/ Technology Transfer (DOE) | 49,534 | 36,918 | —— | —— | —— | —— |
| Use of prior year balances | -15,000 | —— | —— | —— | —— | —— |
| **Total, Office of Science** | **4,807,170** | **1,632,918** | **4,903,710** | **5,121,437** | **+217,727** | **+4.4%** |

# SC Supports Research at More than 300 Institutions Across the U.S.


The Office of Science supports:

- 27,000 Ph.D.s, graduate students, undergraduates, engineers, and technicians
- 26,000 users of open-access facilities
- 300 leading academic institutions
- 17 DOE laboratories

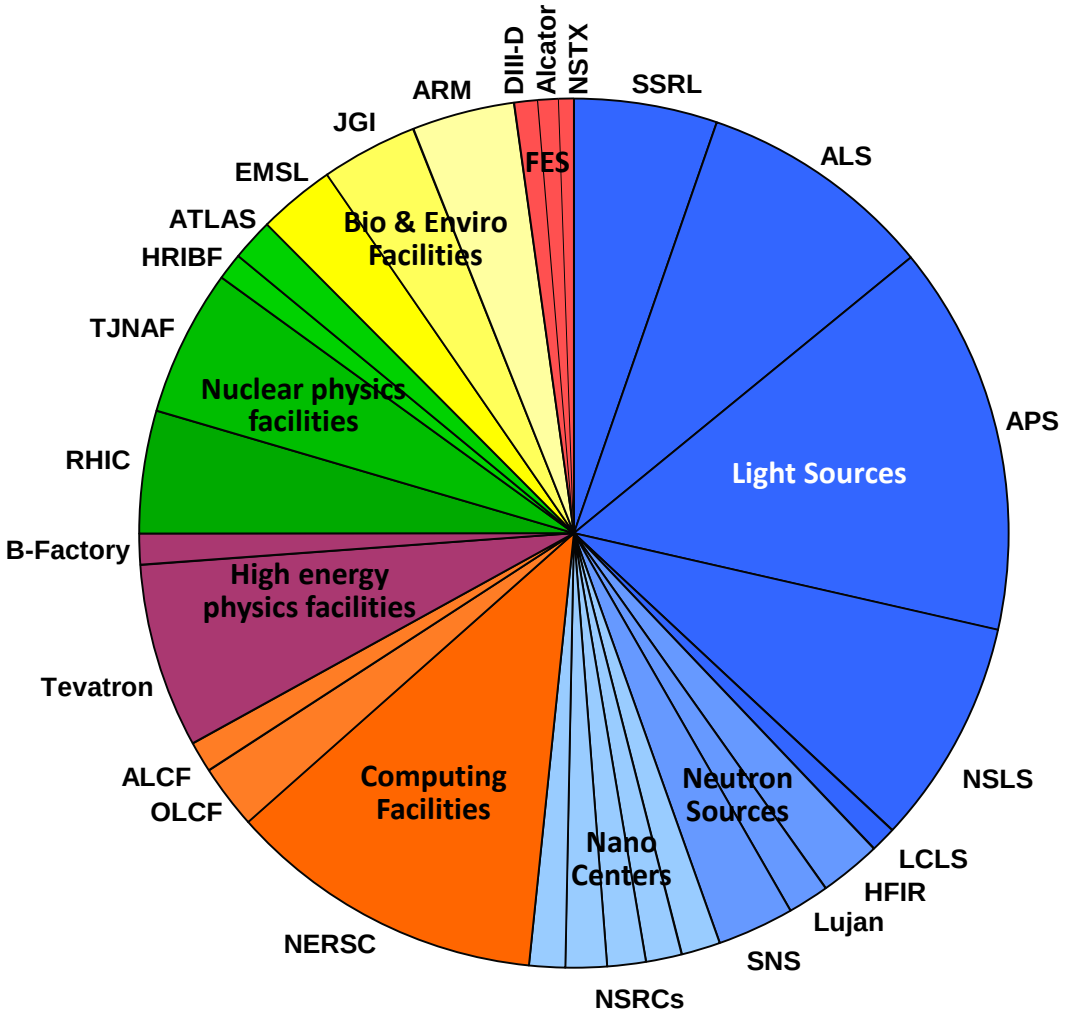
# SC Supports World-Leading, Open Access Scientific User Facilities

*User numbers continue to increase with more than 26,000 users expected in FY 2011*

Numbers of Users at SC Facilities

| | FY 2009 | FY 2010 (Est) | FY 2011 (Est) |
|---|---|---|---|
| ASCR | 3,696 | 3,850 | 4,025 |
| BES | 11,509 | 12,780 | 13,560 |
| BER | 2,716 | 2,690 | 2,690 |
| FES | 542 | 575 | 580 |
| HEP | 2,960 | 2,600 | 2,100 |
| NP | 3,170 | 3,260 | 3,300 |
| Total | 24,593 | 25,755 | 26,255 |

Breakdown of the expected users in FY 2011 by facility.



# Office of Science FY 2011 Investment Highlights

**The FY 2011 budget advances discovery science and invests in science for national needs in energy, climate, and the environment; national scientific user facilities; and education and workforce development.**

## Discovery science addressing national priorities

- Energy Innovation Hub for Batteries and Energy Storage (+$34,020K, BES)
- Enhanced activities in climate science and modeling (Regional and Global Climate Modeling, +$6,495K; Earth System Modeling, +$9,015K; Atmospheric System Research, +$1,944K; ARM Climate Research Facility, +$3,961K; BER)
- Individual investigator, small group, and Energy Frontier Research Centers (EFRCs) in areas complementing the initial suite of 46 EFRCs awarded in FY 2009 (+$66,246K, BES)
- Leadership Computing Facilities operations and preparation for next generation of computer acquisitions for S&T modeling and simulation ($34,832K, ASCR)
- Multiscale modeling of combustion and advanced engine systems (+$20,000K, BES)

## Scientific user facilities—21st century tools of science, technology, and engineering

- Facility construction is fully funded; projects are meeting baselines
- 28 scientific user facilities will serve more than 26,000 users
- Several new projects and Major Items of Equipment are initiated in (e.g., the Long Baseline Neutrino Experiment, +$12,000K, HEP)

## Education and workforce development

- Expansions of the SC Graduate Fellowship Program (+$10,000K, 170 new awards, WDTS) and the SC Early Career Research Program (+$16,000K, 60 new awards, funded in all of the SC research programs)

# The Status of the DOE Energy Innovation Hubs

*Three new Hubs are launched in FY 2010 with SC leading the Fuels from Sunlight Hub*

**Modeled after the Office of Science Bioenergy Research Centers, the Energy Innovation Hubs focus on critical energy technology challenges by building creative, highly-integrated research teams that can accomplish more, faster, than researchers working separately.**

**FY 2010 Hubs tackle three important energy challenges:**

1. **Production of fuels directly from sunlight (SC)**
2. **Energy-efficient building systems design (EERE)**
3. **Modeling and simulation of advanced nuclear reactors (NE)**

**The Fuels from Sunlight Hub** will accelerate the development of a sustainable commercial process for the conversion of sunlight directly into energy-rich chemical fuels, likely mimicking photosynthesis, the method used by plants to convert sunlight, carbon dioxide, and water into sugar. In FY 2011, BES has budgeted $24,300K for the 2nd year of the Fuels from Sunlight Hub. The FOA was released on 12/22/2009, and proposals are due on 3/29/2010.

To access the Fuels from Sunlight FOA (reference number DE-FOA-0000214) go to:
https://www.fedconnect.net/FedConnect/PublicPages/PublicSearch/Public_Opportunities.aspx
and search for "Fuels from Sunlight" in the search box (note that the search flag should be set to "Title" or "Title/Description").

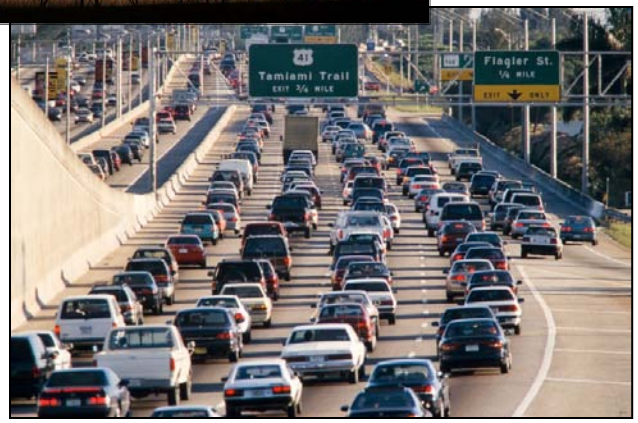
# FY 2011 Energy Innovation Hub for Batteries and Energy Storage

*Addressing science gaps for both grid and mobile energy storage applications*

The Administration's Energy Plan has two goals that require improvements in the science and technology of energy storage:

- Solar and wind providing over 25% of electricity consumed in the U.S. by 2025
- 1 million all-electric/plug-in hybrid vehicles on the road by 2015

- Grid stability and distributed power require innovative energy storage devices
  - Grid integration of intermittent energy sources such as wind and solar
  - Storage of large amounts of power
  - Delivery of significant power rapidly
- Enabling widespread utilization of hybrid vehicles requires:
  - Substantially higher energy and power densities
  - Lower costs
  - Faster recharge times



# Climate Science for a Sustainable Energy Future

*Enhanced activities in climate research to improve our predictive capability*

**The demands on climate change modeling to inform policy and investment decisions are increasing. The current state of climate models is insufficient to predict with the detail and accuracy the future interactions between climate change and energy policy.**

**FY 2011 funding increases support in BER ($21,415K) for the development of a predictive capability that will rapidly incorporate new science into state-of-the-art climate models and that will improve uncertainty quantification.**

**New and enhanced activities will emphasize:**

- Research and atmospheric data collection for improving representation of the feedbacks produced by the indirect effect of aerosols
- Enhanced uncertainty quantification for climate model simulations and predictions
- Conversion of observational data sets into specialized, multi-variable data sets for Earth System Model testing and improvement.
- Model development testbeds in which model components can be rapidly prototyped and evaluated using integrated observational datasets; development of numerical methods to enable climate models to use future computer architectures
- Atmospheric System Research and operation of new ARM Climate Research Facility instruments to provide data for improving representation of clouds and aerosols in climate models

# New BES Research Investments Address Critical Needs

*An FY 2011 BES call will cover a broad range of research awards including new EFRCs*

**About $66 million will be competed in the BES Program to support single investigators, small groups, and additional Energy Frontier Research Centers in the following areas:**

1. **Discovery and development of new materials**
   The FY 2011 solicitation will emphasize new synthesis capabilities, including bio-inspired approaches, for science-driven materials discovery and synthesis. Research will include crystalline materials, which have broad technology applications and enable the exploration of novel states of matter.

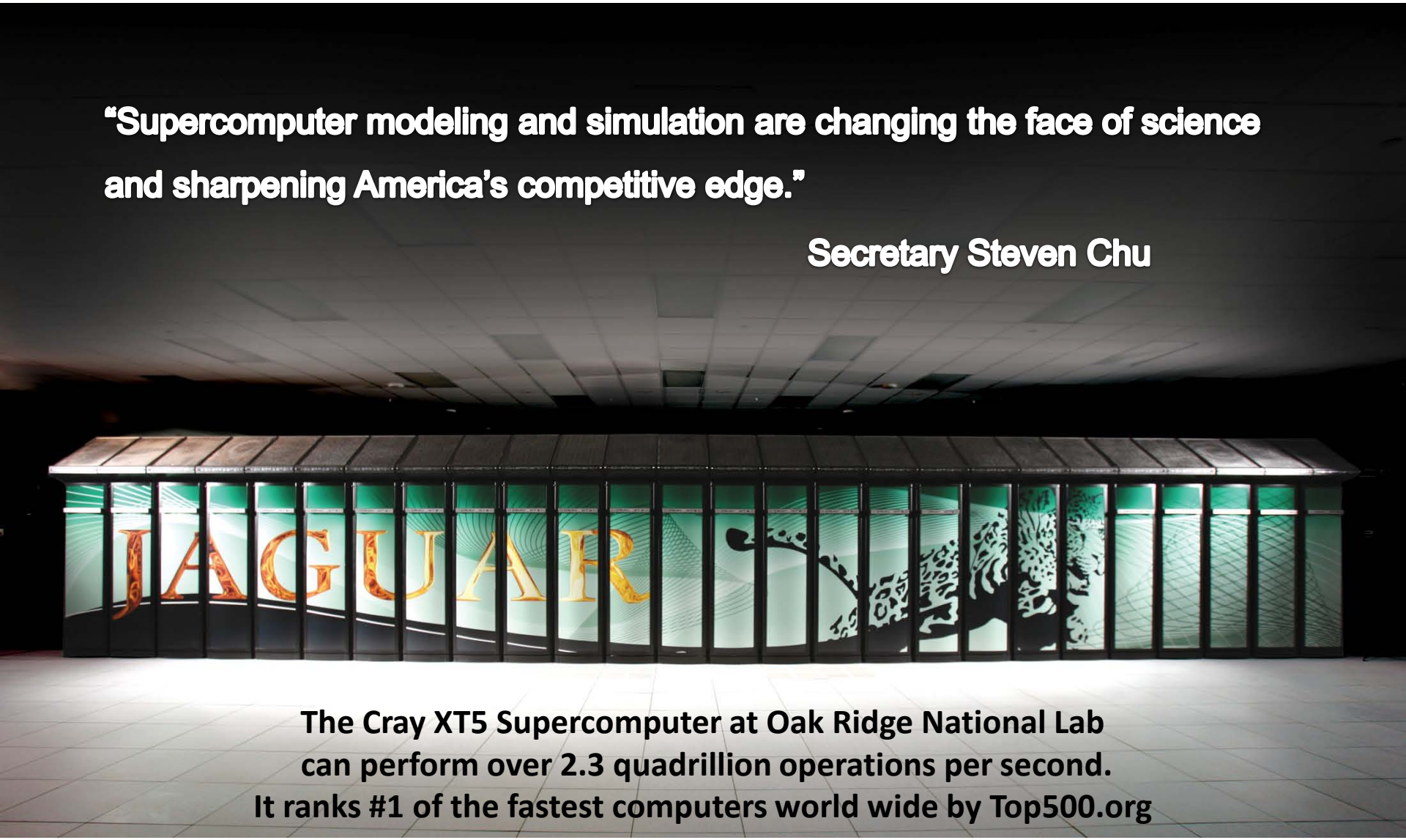
2. **Research for energy applications**
   The FY 2011 solicitation will emphasize fundamental science related to:

   - **Carbon capture**, including the rational design of novel materials and separation processes for post-combustion $CO_2$ capture in existing power plants and catalysis and separation research for novel carbon capture schemes to aid the design of future power plants.
   - **Advanced nuclear energy systems** including radiation resistant materials in fission and fusion applications and separation science and heavy element chemistry for fuel cycles.

**Awards will be competitively solicited via Funding Opportunity Announcements following the FY 2011 appropriation.**

# Leadership Computing Facilities

*The Office of Science leads the World in supercomputing capabilities*

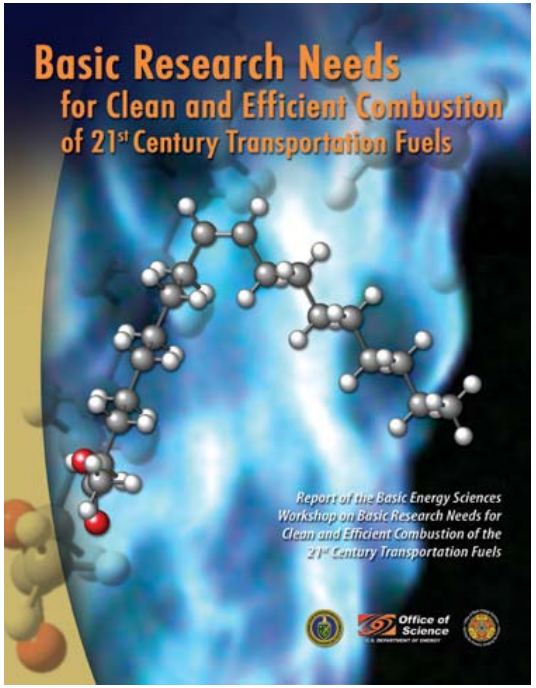



**The Cray XT5 Supercomputer at Oak Ridge National Lab can perform over 2.3 quadrillion operations per second. It ranks #1 of the fastest computers world wide by Top500.org**

# Multi-scale Simulation of Internal Combustion Engines

*A new initiative to develop the science base for computational design of advanced engines*

**Predictive simulation of combustion in an evolving fuel environment is essential for developing more efficient and cleaner engines.**




**The scientific community has provided a roadmap via:**

- BES workshop: *Basic Research Needs for Clean and Efficient Combustion*, October 2006
- ASCR/BES workshop: *Discovery in Basic Energy Sciences: The Role of Computing at the Extreme Scale*, August 2009
- SC ongoing collaboration with EERE's Vehicle Technology Program

**The new BES activity (+$20,000K) will provide:**

- **Models that span vast scale ranges:** coupling of combustion chemistry with turbulent flow requiring simulation over 9 orders of magnitude in space and time.
- **Improved understanding of fundamental physical and chemical properties:** multi-phase fluid dynamics, thermodynamic properties, heat transfer, and chemical reactivity.
- **Engine simulation:** science-based predictive simulation and modeling design

# Bioenergy Research Centers

*The BRCs have pioneered new approaches to accelerate biofuels research*

$75 million will support the fourth year of operations of the three BRCs

**Joint BioEnergy Institute (JBEI)**—research on model crops (*Arabidopsis* and rice) that can be transferred to bioenergy crops; lignin modification; synthetic biology approaches to fuels

- *Advanced biomass pretreatment using room temperature ionic liquids to remove lignin from plant cell walls improved biomass breakdown 5x.*
- *New cellulase enzyme more stable and active in ionic liquids at elevated temperatures and low pH.*

**Great Lakes Bioenergy Research Center (GLBRC)**—research on model plants and potential bioenergy plants; microbial biorefineries; sustainability of biofuel production

- *Improved screening of hydrolytic enzymes using gene expression approach coupled with enzyme screening and computational approaches – 100x more efficient than conventional methods*

**BioEnergy Science Center (BESC)**—research to overcome "recalcitrance" (resistance of plant fiber, or lignocellulose, to break down into sugars); gene discovery for recalcitrance; consolidated bioprocessing

- *New high throughput screening of chemical, structural, and genetic features of biomass – >100x faster than conventional methods.*
- *New imaging technologies to view cell wall at multiple scales to analyze recalcitrance*

# The Genomic Revolution

*Advances in DNA sequencing and analysis have revolutionized the study of biology*

**Sequencing the 3 billion base-pair human genome took 13 years and multiple national and international partners. Today the DOE Joint Genome Institute sequences over a trillion base pairs annually.**

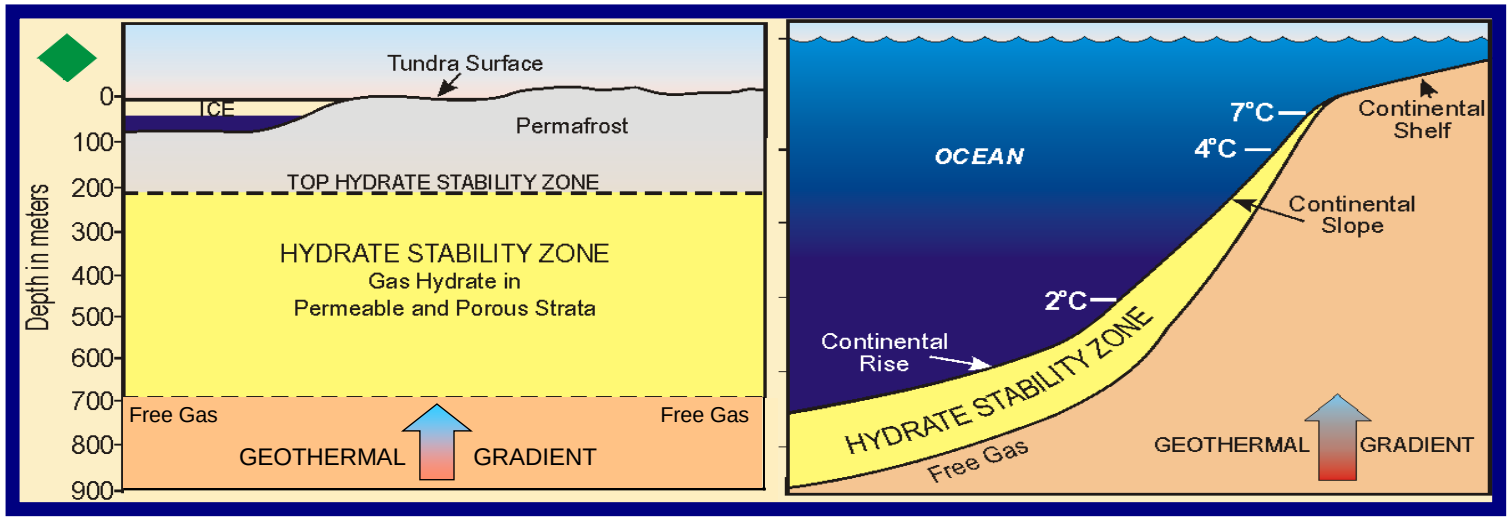
- DNA sequencing and analysis capabilities and the availability of genome data in the 1990s led to functional genomics, proteomics, metabolomics, systems biology, and synthetic biology.
- Genomic sequence information has dramatically increased our understanding of the biological processes of microbes and plants—knowledge that is being used to develop solutions for clean energy production, sequestration of atmospheric $CO_2$, and remediation of contaminated environments.
- Recent accomplishments:
  - **Sequencing the 1.1 billion base-pair soybean genome**—The largest plant project sequenced at JGI and the largest plant sequenced by the whole genome shotgun strategy, the soybean sequence will accelerate crop improvements for energy production and environmentally sustainable food and feed production for agriculture.
  - **DOE JGI publishes the Genomic Encyclopedia of Bacteria and Archaea**—The initial 56 microbial genomes sequenced resulted in the discovery of tens of thousands of genes that provide insights into natural environmental processes and advance biotechnology.
  - **Viable microbes in toxic subsurface environments—**Genetic techniques demonstrate that micoorganisms of the *Anaeromyxobacter* family, known to enzymatically reduce uranium to a less mobile form, can be detected in the most heavily contaminated environments and likely play a role in reducing the mobility of uranium in groundwater.

# Geosciences Research for Gas Hydrates

*Developing the science base for understanding the potential of gas hydrates as a resource*

BES research will investigate fundamental scientific questions about methane hydrates: their formation and occurrence; their stability in natural or engineered systems; their role in geological/ ecological systems; and their role in the carbon cycle (+$17,517K).

The program will also study hydrates via controlled *in situ* depressurization and physical, thermal, and chemical stimulation in the Arctic and the Gulf of Mexico. This research will be supported by theory and multi-scale modeling and simulation in areas such as the intermolecular forces that govern the structure and properties of gas hydrates.




Methane hydrates are naturally occurring combinations of methane and water that form at low temperatures and high pressure.

# High Energy Density Laboratory Plasmas

*Expanded research efforts in HEDLP will reveal new understanding of matter in extreme conditions*

**The emerging science of high energy density laboratory plasma (HEDLP) — the study of ionized matter at extremely high density and temperature — is enabling deeper understanding of extreme phenomena in a range of disciplines including fusion energy science, condensed matter physics, materials science, fluid dynamics, nuclear science, and astrophysics.**

The increase in the FES High Energy Density Laboratory Plasma program (+$6,489K) will enable new research awards under the HEDLP joint program between FES and NNSA, which began in FY 2009.

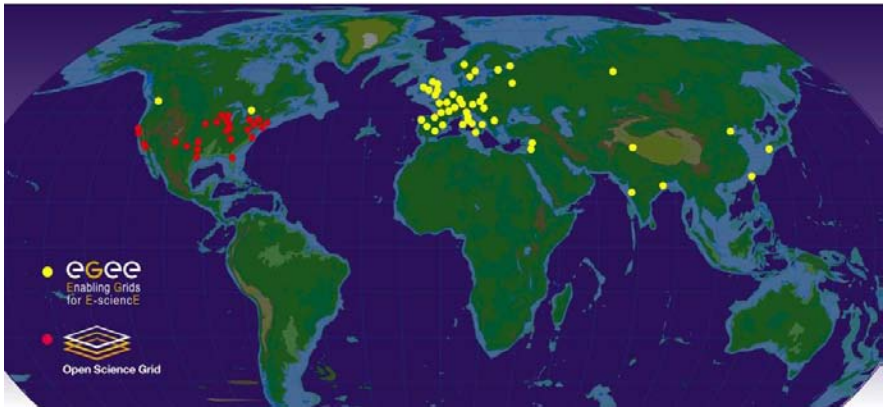
This research will leverage world-class FES and NNSA facilities to provide:

- information in assessing the viability of inertial fusion energy as a future energy source;
- first-of-kind laboratory studies of astrophysical phenomena that include testing of models used to infer the age of the universe; and
- opportunities for junior researchers to ensure continued excellence in scientific disciplines closely aligned with fusion energy science and stockpile stewardship.

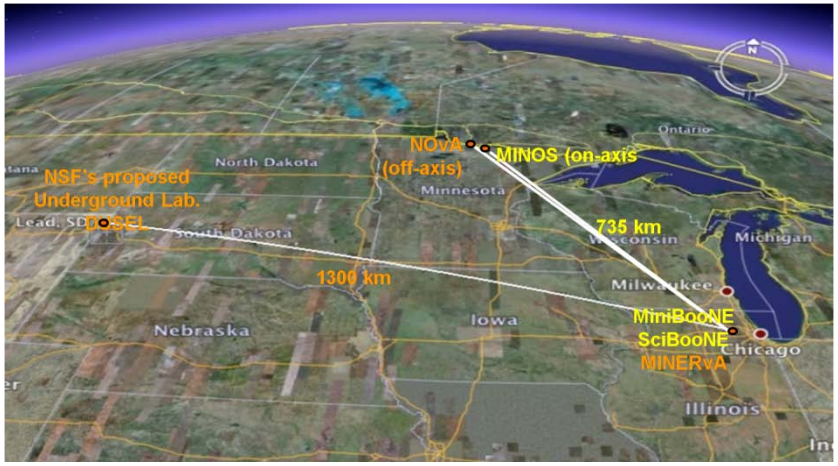
# The U.S. High Energy Physics Program

*The U.S. is uniquely positioned for a world-leading program in neutrino physics*

The U.S. is a critical and strategic partner in global scientific collaborations that push the boundaries of High Energy Physics. The U.S. has developed components for the Large Hadron Collider at CERN and hosts centers for data analysis.




Network sites of the Open Science Grid and Enabling Grids for E-sciencE used for transmitting experimental data from the LHC to scientists worldwide.




The NuMI beamline provides the world's most intense neutrino beam for the MINOS experiment and proposed NOvA and LBNE experiments

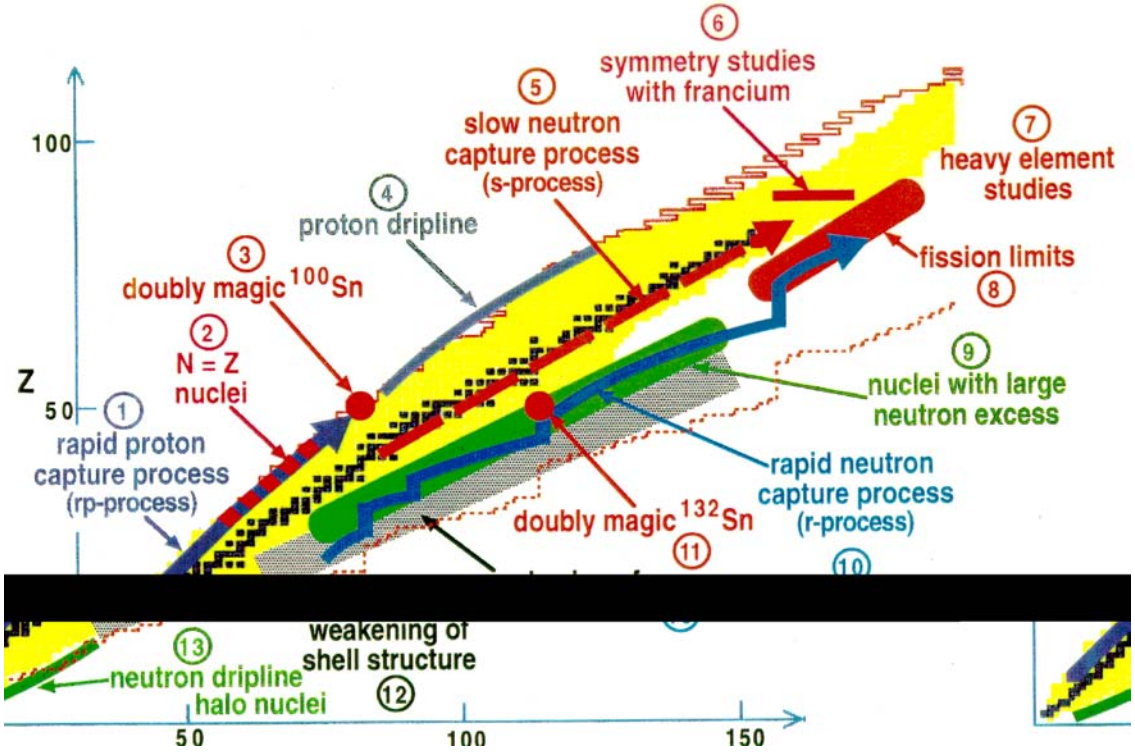
At home, HEP builds on its investments in tools and facilities to capture the unique opportunities of neutrino science. These opportunities are fundamental to the science of particle physics.

**At the heart of the DOE HEP program is the *NuMI beamline* at Fermilab, the world's most intense neutrino source, which serves MINERvA and MINOS and will support NOvA and the proposed LBNE (+$12,000K, HEP, initiated in FY 2011).**

# The DOE Nuclear Physics Program

*Charting new directions at the frontiers of nuclear science*

**The U.S. is a leader in studying the compelling questions of nuclear science, advancing our knowledge of the world, and leading to applications in energy research, medicine, national security, and isotopes for a wide variety of purposes.**




- **The Relativistic Heavy Ion Collider (RHIC)** is the only dedicated machine in the world colliding heavy ions at near light speed.
- **The Continuous Electron Beam Accelerator Facility (CEBAF)** is the world's most powerful probe for studying the nucleus of the atom.
- Investments in **Radioactive Ion Beam** experiments and capabilities (such as the **Facility for Rare Isotope Beams—FRIB**), probe the properties of rare nuclear isotopes to better understand the origin of the elements and fundamental symmetries of nature

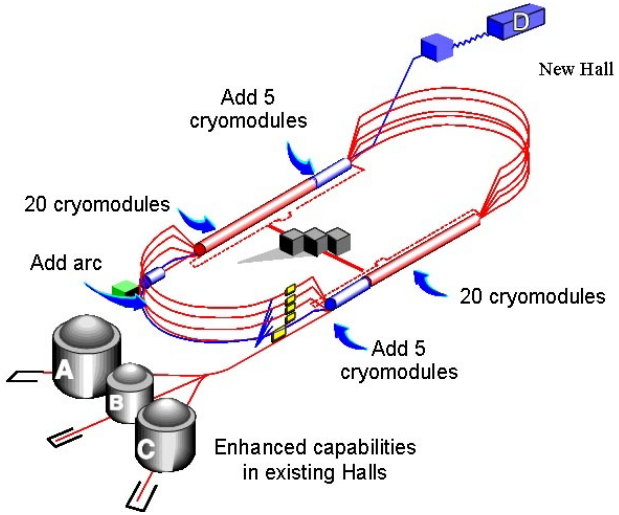
# The DOE Nuclear Physics Program

*New science follows the completion of the 12 GeV Upgrade at TJNAF*

With the completion of the 12 GeV Upgrade, researchers will address:

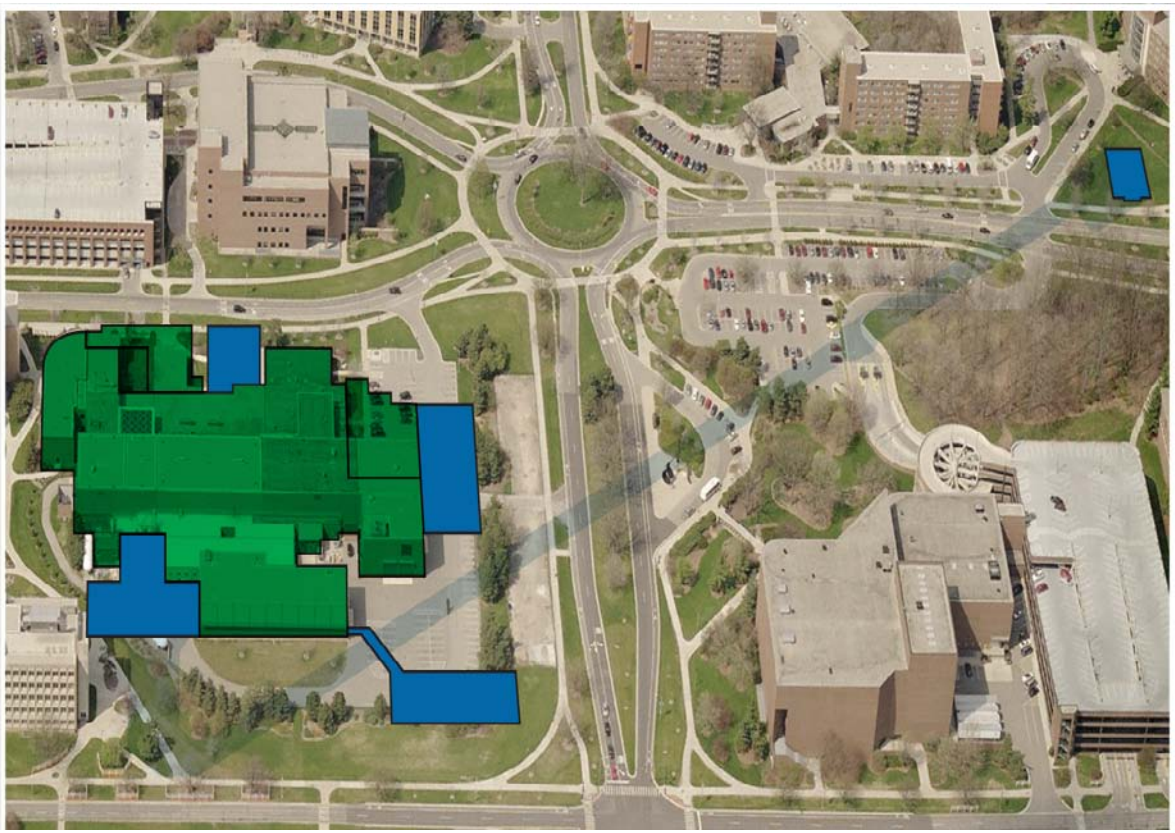
- The search for exotic mesons—a quark and an anti-quark held together by gluons, but unlike conventional mesons, the gluons are excited
- Physics beyond the Standard Model via high precision studies of parity violation
- The spin and flavor dependence of valence parton distributions—the heart of the proton, where its quantum numbers are determined
- The structure of atomic nuclei, exploring how the valence quark structure is modified in a dense nuclear medium
- Nuclear tomography to discover and explore the three-dimensional structure of the nucleon

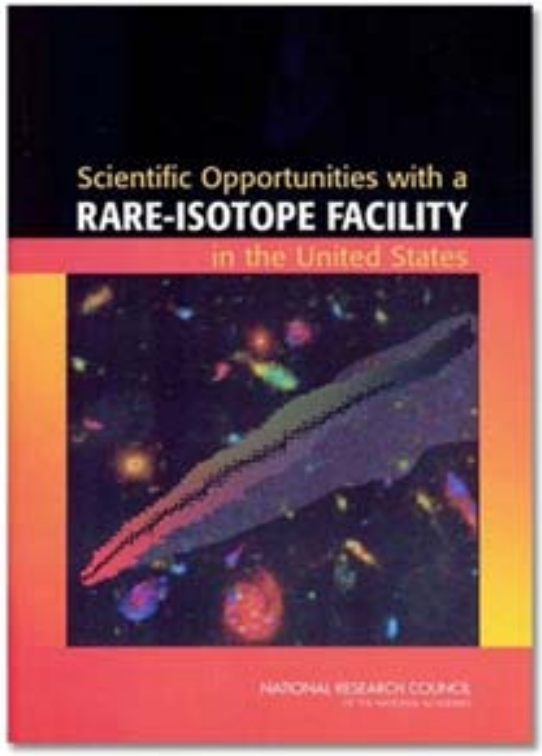
**Pouring the foundation for the Hall D complex.**



# The DOE Nuclear Physics Program

*New capability at FRIB will sustain core competency in nuclear structure & astrophysics*






- Cooperative Agreement between DOE and Michigan State University signed in June, 2009
- DOE investment of up to $550M and $94.5M cost share from MSU

# Office of Science Early Career Research Program

*Investment in FY 2011 will bring 60 new scientists into the program*

**$16 million will be available in FY 2011 to fund about 60 additional Early Career Research Program awards at universities and DOE national laboratories.**

**Purpose:** To support individual research programs of outstanding scientists early in their careers and to stimulate research careers in the disciplines supported by the Office of Science

**Eligibility:** Within 10 years of receiving a Ph.D., either untenured academic assistant professors on the tenure track or full-time DOE national lab employees

**Award Size:**

- University grants $150,000 per year for 5 years to cover summer salary and expenses
- National lab awards $500,000 per year for five years to cover full salary and expenses

**FY 2010 Results:**

- 69 awards funded via the American Recovery and Reinvestment Act
- 1,750 proposals peer reviewed to select the awardees
- 47 university grants and 22 DOE national laboratory awards
- Awardees are from 44 separate institutions in 20 states

**FY 2011 Application Process:**

- Funding Opportunity Announcement issued in Spring 2010
- Awards made in the Second Quarter of 2011

**http://www.science.doe.gov/SC-2/early_career.htm**

# DOE Office of Science Graduate Fellowships

*The FY 2011 request doubles the number of graduate fellowships in basic science*

## $10 million will be available in FY 2011 to fund about 170 additional fellowships

**Purpose:** To educate and train a skilled scientific and technical workforce in order to stay at the forefront of science and innovation and to meet our energy and environmental challenges

**Eligibility:**

- Candidates must be U.S. citizens and a senior undergraduate or first or second year graduate student to apply
- Candidates must be pursuing advanced degrees in areas of physics, chemistry, mathematics, biology, computational sciences, areas of climate and environmental sciences important to the Office of Science and DOE mission

**Award Size:**

- The three-year fellowship award, totaling $50,500 annually, provides support towards tuition, a stipend for living expenses, and support for expenses such as travel to conferences and to DOE user facilities.

**FY 2010 Results:**

- 160 awards will be made this Spring with FY 2010 and American Recovery and Reinvestment Act funds.

**FY 2011 Application Process:**

- Funding Opportunity Announcement issued in Fall 2010
- Awards made in March 2011

# Future Outlook

**The 2011 Congressional Request allows for:**

- Continued support of discovery science and advances in technology
- New opportunities for ground breaking research
- Increased support for training and advancement of the next generation of scientists
- Construction of next generation research tools and facilities

The FY 2011 Request is a challenge for NP – there is substantial growth – somewhat in competition with other Presidential initiatives

**Strong support by the research community is essential**

**Office of Science may be faced with constrained budgets in the outyears**

- President Obama has frozen discretionary spending but remains committed to doubling the budget for science
- Large U.S. international commitments will put pressure on Office of Science budgets
- Tight budgets for all programs are a real possibility; operating a large number of user facilities will be challenging
- As in the past, the Office of Science will work closely with the nuclear science community to insure high priority, compelling research continues to be accomplished

# Additional Detail

# Nuclear Physics

NP Mission: To discover, explore and understand all forms of nuclear matter and to understand how the fundamental particles—quarks and gluons—fit together and interact to create different types of matter in the universe, including those no longer found naturally.

Recent highlights:

- Measurements at CEBAF show evidence for a possible new excited state of the proton, which may help resolve the debate of whether or not the three quarks that make up the proton bind together symmetrically.
- Advances in Lattice Quantum Chromodynamics calculations using viscous fluid dynamics have provided a more realistic description of the quark-gluon plasma (QGP), corroborating that the QGP is not a nearly free gas of quarks and gluons but instead behaves as a near perfect liquid.
- Efforts to improve production of isotopes (Cu-67, Re-188, Y-86) increased availability for medical research applications.

FY 2011 Budget Highlights:

- Additional funding in Medium Energy Nuclear Physics (+$2,020K) supports university research, development of a scientific group for the new experimental Hall D at CEBAF, and operating CEBAF at the maximum allowable schedule in consideration of the 12 GeV Upgrade Project, which continues construction in FY 2011 (+$16,000K).
- RHIC operations increases to near optimal levels to support high priority science (+$6,132K).
- Funding for the FRIB supports engineering and design efforts consistent with the DOE-MSU planned project profile (-$2,000K).
- Support for university and national laboratory nuclear theory research increases to support enhanced efforts in the LQCD joint initiative with HEP, SciDAC, and activities of the National Nuclear Data Center (+$3,135K).
- Isotope Development and Production supports operation of facilities for production of critical isotopes, research on novel or optimized techniques for production and separation of isotopes in short supply, and the National Isotope Data Center (+$580K).
- Fabrication of the electromagnetic calorimeter (EMCal) for the ALICE experiment at LHC is completed in FY 2011 (-$3,795K)

# Batteries and Energy Storage: Critical Research Issues

- Batteries used in mobile (vehicles) and stationary (grid) applications differ in requirements for device size and weight.
- But critical issues that need to be addressed are the same—electrodes, electrolytes and interfaces.
- Achieving breakthroughs requires understanding atomic and molecular processes that occur across these three components.
- This will allow materials to be designed at the nanoscale, with architectures and functionalities to optimize charge storage and transfer.

# DOE Bioenergy Research Centers

*3 BRCs were launched in FY 2007 to pursue transformational science for new, sustainable biofuels*