FY 2017 Budget Request to Congress for DOE’s Office of Science

ASCAC Meeting, April 4, 2016

Cherry A. Murray
Director, Office of Science
www.science.energy.gov
Department of Energy Mission Areas

Energy

Science

Nuclear Safety and Security

Environmental Cleanup
DOE Organization Chart 2016

DEPARTMENT OF ENERGY

Office of the Secretary
Dr. Ernest J. Moniz
Secretary
Dr. Elizabeth Sherwood-Randall
Deputy Secretary
Chief of Staff

Federal Energy Regulatory Commission
Inspector General

Office of the Under Secretary for Nuclear Security and National Nuclear Security Administration
Dr. Franklin Orr
Under Secretary for Nuclear Security

Office of the Under Secretary for Science & Energy

Office of the Under Secretary for Management & Performance

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1 The director of the Office of Technology Transitions also serves as DOE’s Technology Transfer Coordinator who reports to the Secretary of Energy.
Office of Science FY16 - $5.35B

Largest Supporter of Physical Sciences in the U.S.

Research: 42%, $2.2B

~40% of Research to Universities

> 20,000 Scientists Supported

Funding at >300 Institutions including all 17 DOE Labs

Construction: 13.5%, $723M

Facility Operations: 38%, $2.02B

>30,000 Scientific Facility Users
Largest Supporter of Physical Sciences in the U.S.

Research: 42%, $2.4B

~40% of Research to Universities

> 20,000 Scientists Supported

Funding at >300 Institutions including all 17 DOE Labs

Facility Operations: 36%, $2.06B

>30,000 Scientific Facility Users

$1.8B Mission Innovation

Office of Science FY17 Request: $5.67B, +6.1%
President’s DOE FY 2017 Proposed Budget

- **Energy** (7.2B, 22%)
- **Science** (5.7B, 17%)
- **Environmental Management** (6.1B, 19%)
- **Science - Mandatory, $0.10B**
- **Energy - Mandatory, $1.49B**
- **Other** (0.7B, 2%)
- **Nuclear Security** (13.1B, 40%)

Bar chart showing:
- **Nuclear Security**
  - FY15: $11.6B
  - FY16: $12.8B
  - FY17: $13.1B
- **Science**
  - FY15: $5.1B
  - FY16: $5.3B
  - FY17: $5.7B
- **Energy**
  - FY15: $9.3B
  - FY16: $10.1B
  - FY17: $12.9B
- **Environmental Management**
  - FY15: $6.5B
  - FY16: $6.9B
  - FY17: $6.8B

Pie chart showing:
- **Energy** (40%)
- **Science** (22%)
- **Environmental Management** (19%)
- **Other** (2%)
- **Nuclear Security** (17%)
### Office of Science Programs

<table>
<thead>
<tr>
<th>Program</th>
<th>FY2016</th>
<th>FY2017 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Scientific Computing Research</td>
<td>$621M</td>
<td>+6.8%</td>
</tr>
<tr>
<td>Basic Energy Sciences</td>
<td>$1849M</td>
<td>+4.7%</td>
</tr>
<tr>
<td>Biological and Environmental Research</td>
<td>$609M</td>
<td>+8.7%</td>
</tr>
<tr>
<td>High Energy Physics</td>
<td>$795M</td>
<td>+2.9%</td>
</tr>
<tr>
<td>Fusion Energy Sciences</td>
<td>$438M</td>
<td>-9.1%</td>
</tr>
<tr>
<td>Nuclear Physics</td>
<td>$617M</td>
<td>+3.0%</td>
</tr>
</tbody>
</table>
Office of Science FY 2017 Budget Request to Congress  
(Dollars in thousands)

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Scientific Computing Research</td>
<td>541,000</td>
<td>523,411</td>
<td>621,000</td>
<td>663,180</td>
<td>+42,180 +6.8%</td>
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<tr>
<td>Basic Energy Sciences</td>
<td>1,733,200</td>
<td>1,682,924</td>
<td>1,849,000</td>
<td>1,936,730</td>
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<td>Biological and Environmental Research</td>
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<td>572,618</td>
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<td>661,920</td>
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<tr>
<td>Fusion Energy Sciences</td>
<td>467,500</td>
<td>457,366</td>
<td>438,000</td>
<td>398,178</td>
<td>-39,822 -9.1%</td>
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<tr>
<td>High Energy Physics</td>
<td>766,000</td>
<td>745,232</td>
<td>795,000</td>
<td>817,997</td>
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<tr>
<td>Nuclear Physics</td>
<td>595,500</td>
<td>580,744</td>
<td>617,100</td>
<td>635,658</td>
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<td>Workforce Development for Teachers and Scientists</td>
<td>19,500</td>
<td>19,500</td>
<td>19,500</td>
<td>20,925</td>
<td>+1,425 +7.3%</td>
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<tr>
<td>Science Laboratories Infrastructure</td>
<td>79,600</td>
<td>79,600</td>
<td>113,600</td>
<td>130,000</td>
<td>+16,400 +14.4%</td>
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<tr>
<td>Safeguards and Security</td>
<td>93,000</td>
<td>93,000</td>
<td>103,000</td>
<td>103,000</td>
<td>.....       +100.0%</td>
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<td>Program Direction</td>
<td>183,700</td>
<td>183,700</td>
<td>185,000</td>
<td>204,481</td>
<td>+19,481 +10.5%</td>
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<tr>
<td>University Grants (Mandatory)</td>
<td>.....</td>
<td>.....</td>
<td>.....</td>
<td>100,000</td>
<td>+100,000 +100.0%</td>
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<tr>
<td>Small Business Innovation/Technology Transfer Research (SC)</td>
<td>.....</td>
<td>132,905</td>
<td>.....</td>
<td>.....</td>
<td>.....</td>
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<tr>
<td>Subtotal, Science</td>
<td>5,071,000</td>
<td>5,071,000</td>
<td>5,350,200</td>
<td>5,672,069</td>
<td>+321,869 +6.0%</td>
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<tr>
<td>Small Business Innovation/Technology Transfer Research (DOE)</td>
<td>.....</td>
<td>65,075</td>
<td>.....</td>
<td>.....</td>
<td>.....</td>
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<tr>
<td>Rescission of Prior Year Balance</td>
<td>-3,262</td>
<td>-3,262</td>
<td>-3,200</td>
<td>.....</td>
<td>+3,200 -100.0%</td>
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<tr>
<td><strong>Total, Science</strong></td>
<td><strong>5,067,738</strong></td>
<td><strong>5,132,813</strong></td>
<td><strong>5,347,000</strong></td>
<td><strong>5,672,069</strong></td>
<td><strong>+325,069 +6.1%</strong></td>
</tr>
</tbody>
</table>
SC Investments for Mission Innovation
$100M in new funding in FY 2017

ASCR (+$10M)
- Computational Partnerships with EFRCs on solar, CO$_2$ reduction, catalysis, storage, subsurface, and biofuels; possibly new partnerships in wind and nuclear ($10M)

BES (+$51M)
- Energy Efficiency: Catalysts, modeled after nature’s enzymes, that can operate at low-temperature and under ambient conditions; lightweight metallic materials; thermocaloric materials ($34.4M)
- Materials for Clean Energy: Self-healing materials for corrosive and high radiation environments (next-gen corrosive-resistant materials based on experiments and multi-scale modeling; chemistry under harsh or extreme environments) ($16.6M)

BER (+$35M)
- Biosystems design (computationally design and then bio-engineer biosystems) to introduce beneficial traits into plants and microbes for clean energy applications ($20M)
- Bioenergy Research Centers: New investments to translate 10 years of BRC research to industry ($15M, $5M per BRC)

FES (+4M)
- Whole-device fusion modeling and simulation using SciDAC partnerships ($4M)
SC Increases Academic Research by $100M (Mandatory) in FY 2017

Investments are made in all of the SC programs, emphasizing emerging research areas, especially those recently identified by Federal Advisory Committees or other community activities. A few examples are:

- **ASCR**: Applications software, applied mathematics, and computer science for capable exascale computing; mathematics for large-scale scientific data; neuromorphic computing architectures and information processing for extreme and self-reconfigurable computing architectures.

- **BES**: Topics described in the 2015 BESAC Report *Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science*, including hierarchical architectures, non-equilibrium matter, non-ideal systems, coherence in light and matter, modeling & computation, and imaging across multiple scales.

- **BER**: New platform microbes for biofuels and bioproducts engineering; biofuel crop modeling for incorporation into a predictive framework.

- **FES**: Plasma/fusion research centers emphasizing the results of the 2015 community workshops, including for example low-temperature plasmas, plasma measurements, and verification & validation for magnetic fusion.

- **HEP**: Topics described in the 2014 HEPAP Long Range Plan and also topics that span multiple SC programs, including quantum information sciences/the entanglement frontier and quantum field theory across disciplines.

- **NP**: Topics described in the 2015 NSAC Long Range Plan, including research to accelerate discovery at FRIB, fundamental nuclear structure and nuclear astrophysics, fundamental symmetries, and super-heavy elements.
Advanced Scientific Computing Research
Computational and networking capabilities to extend the frontiers of science and technology

- **Exascale Computing Initiative (ECI) and Exascale Computing Project (ECP).** The ECP is initiated as a joint ASCR/NNSA partnership using DOE’s formal project management processes. A new budget line is created for the ECP.

- **Facilities** operate optimally and with >90% availability; deployment of 10-40 petaflop upgrade at NERSC and site preparations for NERSC-9; upgrade of high traffic links on Esnet; and continued preparations for 180-200 petaflop upgrades at ALCF and OLCF.

- **SciDAC partnerships** will be recompeted in FY 2017 with new activities to include accelerating the development of clean energy technologies.

- **Applied Mathematics research** addresses challenges of increasing complexity and **Computer Science research** addresses exploration of “beyond Moore’s law” architectures and supports data management, analysis, and visualization techniques.

- The **Computational Sciences Graduate Fellowship** is funded at $10,000K.
Components of the Exascale Program

- **Exascale Computing Initiative (ECI)**
  - The ECI was initiated in FY 2016 to support research, development, and computer-system procurements to deliver an exascale \(10^{18}\) ops/sec computing capability by the mid-2020s.
  - It is a partnership between SC and NNSA, addressing science and national security missions.
  - The Exascale Crosscut includes primary investments by SC/ASCR and NNSA/ASC and software application developments in both SC (BES and BER) and NNSA.

- **Exascale Computing Project (ECP)**
  - Beginning in FY 2017, the ASCR ECI funding is transitioned to the DOE project (the ECP), which is managed according to the principles of DOE Order 413.3b.
  - The new ECP subprogram in ASCR (SC-ECP) includes only activities required for the delivery of the exascale computers. An ECP Project Office has been established ORNL.
  - NNSA/ASC Advanced Technology Development and Mitigation (ATDM) supports activities for the delivery of exascale computers and the development of applications.

- **Relationship of the ECI and ECP to the National Strategic Computing Initiative**
  - On July 29, 2015, an executive order established the National Strategic Computing Initiative (NSCI) to ensure a coordinated Federal strategy in HPC research, development, and deployment.
  - DOE, along with the DoD and NSF, co-lead the NSCI. Within DOE, SC and NNSA execute the ECI and the ECP, which are the DOE contributions to the NSCI.
## ASCR Computing Upgrades At a Glance

<table>
<thead>
<tr>
<th>System attributes</th>
<th>NERSC Now</th>
<th>OLCF Now</th>
<th>ALCF Now</th>
<th>NERSC Upgrade</th>
<th>OLCF Upgrade</th>
<th>ALCF Upgrades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name Planned Installation</td>
<td>Edison</td>
<td>TITAN</td>
<td>MIRA</td>
<td>Cori 2016</td>
<td>Summit 2017-2018</td>
<td>Theta 2016</td>
</tr>
<tr>
<td>System peak (PF)</td>
<td>2.6</td>
<td>27</td>
<td>10</td>
<td>&gt; 30</td>
<td>200</td>
<td>&gt;8.5</td>
</tr>
<tr>
<td>Peak Power (MW)</td>
<td>2</td>
<td>9</td>
<td>4.8</td>
<td>&lt; 3.7</td>
<td>13.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Total system memory</td>
<td>357 TB</td>
<td>710TB</td>
<td>768TB</td>
<td>~1 PB DDR4 + High Bandwidth Memory (HBM)+1.5PB persistent memory</td>
<td>&gt; 2.4 PB DDR4 + HBM + 3.7 PB persistent memory</td>
<td>676 TB DDR4 + High Bandwidth Memory (HBM)</td>
</tr>
<tr>
<td>Node performance (TF)</td>
<td>0.460</td>
<td>1.452</td>
<td>0.204</td>
<td>&gt; 3</td>
<td>&gt; 40</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Node processors</td>
<td>Intel Ivy Bridge</td>
<td>AMD Opteron</td>
<td>Nvidia Kepler</td>
<td>64-bit PowerPC A2</td>
<td>Intel Knights Landing many core CPUs Intel Haswell CPU in data partition</td>
<td>Multiple IBM Power9 CPUs &amp; multiple Nvidia Voltas GPUS</td>
</tr>
<tr>
<td>System size (nodes)</td>
<td>5,600 nodes</td>
<td>18,688 nodes</td>
<td>49,152</td>
<td>9,300 nodes 1,900 nodes in data partition</td>
<td>~4,600 nodes</td>
<td>&gt;3,200 nodes</td>
</tr>
<tr>
<td>System Interconnect</td>
<td>Aries</td>
<td>Gemini</td>
<td>5D Torus</td>
<td>Aries</td>
<td>Dual Rail EDR-IB</td>
<td>Aries</td>
</tr>
<tr>
<td>File System</td>
<td>7.6 PB 168 GB/s, Lustre®</td>
<td>32 PB 1 TB/s, Lustre®</td>
<td>26 PB 300 GB/s GPFS™</td>
<td>28 PB 744 GB/s Lustre®</td>
<td>120 PB 1 TB/s GPFS™</td>
<td>10PB, 210 GB/s Lustre initial</td>
</tr>
</tbody>
</table>
In FY 2017, the Energy Science Network (ESnet) will increase bandwidth to address the growing data requirements of SC facilities, such as the light sources, neutron sources, and particle accelerators at CERN. This includes upgrading high-traffic links to 400 gigabits per second (gbps). ESnet will also continue to extend science engagement efforts to solve the end-to-end network issues between DOE facilities and universities.
Materials for Nuclear Energy
Simulations at NERSC reveal structural defects from irradiation in nuclear power plants that can’t be seen in experiments. (R. Devanathan, PNNL)

Photosynthesis
A team from the University of Illinois at Urbana-Champaign (UI-UC) used the OLCF to achieve a milestone in the field of biomolecular simulation, modeling a complete photosynthetic organelle of the bacteria Rhodobacter sphaeroides in atomic detail. The project is the first of its kind. (C. Shulten, UI-UC)

Reducing Friction
A team of researchers used the ALCF to observe a mechanism for eliminating friction at the macroscale with potential to achieve superlubricity for a wide range of mechanical applications. (S. Sankaranarayanan, ANL)

Materials for Fusion Energy
Researchers used the OLCF to obtain fundamental understanding of the plasma heat-load impinging on the Tokomak divertor and its dependence on the plasma current in present-day tokamak devices and in ITER. (C.S. Chang, PPPL)

Clean Coal Combustion
Researchers at the University of Utah and its Carbon Capture Multi-Disciplinary Simulation Center (CCMSC) are using the OLCF to enable petascale simulations to guide the design of next-generation oxy-coal boilers for clean electric energy. (M. Berzins, Utah)

Superconductivity
ALCF research is providing advanced calculations to identify the electronic mechanisms for high-temperature superconductivity in cuprates. (L. Wagner, UI-UC)

Cellulosic Ethanol
To understand barriers to biofuel production, researchers used the OLCF to develop detailed knowledge of lignin behavior that can guide genetic engineering of enzymes that produce bioethanol more efficiently. (J. Smith, ORNL)

Better Engines
The ALCF is partnering with industry to develop simulation capabilities that can improve the fuel economy of vehicles. (S. Som, ANL)
HPC Accelerating Energy Technology Development

**General Motors**

Increasing Fuel Efficiency of Cars

GM used the OLCF to accelerate, by at least a year, research to develop new thermoelectric materials that increase the fuel efficiency of cars. Typical car engines lose about 60 percent of fuel energy to waste heat. Access to DOE computers allowed GM to develop unique materials that convert some waste heat into electricity that can power various subsystems, removing a major burden from the car’s main generator and lowering fuel consumption. GM also used the OLCF to optimize injector hole pattern design for desired in-cylinder fuel-air mixture distributions with a 4 - 40x improvement in workflow throughput via 100s of ensembles.

**Pratt & Whitney**

Accelerating Energy Efficient Jet Engine Design

Airlines are constantly seeking better fuel efficiency and lower emissions, but redesigning jet engines has traditionally involved many time-consuming, repetitive experiments. Pratt & Whitney has dramatically decreased problem-to-solution turnaround times by adding computer based virtual testing to the design process. Using the ALCF, Pratt & Whitney improved the fuel efficiency in its Pure Power engines by 12–15% with potential savings to airlines of nearly $1M per aircraft per year. The new design is also 75 percent quieter.

**SmartTruck Systems**

Reducing Truck Fuel Consumption

SmartTruck Systems of South Carolina used the OLCF to reduce by 50% the time to develop add-on parts that substantially improve the fuel efficiency - up to 12% - exceeding the EPA SmartWay requirements for long-haul Trucks. Add-on parts from SmartTruck can save each outfitted truck up to 3,700 gallons of fuel each year.

**Ramgen Power Systems**

Compressor Design Innovation

Ramgen Power Systems, a small firm in Bellevue, WA used the OLCF to accelerate the design of shock wave turbo compressors for carbon capture and sequestration and for energy production. Very high resolution computer models enabled the company to go from computer testing to cutting a titanium prototype in two months.

**Bosch**

Li-ion Batteries

Bosch used OLCF resources to discover and optimize new classes of solid inorganic Li-ion electrolytes with high ionic and low electronic conductivity, and good electrochemical stability.

**Fiat Chrysler Automobiles**

Improving Pickup Aerodynamics

FCA has begun working with the OLCF to better understand the aerodynamics of a pickup truck. They will be doing large scale design of experiment studies to understand the influence of about 40 different geometric parameters on the aerodynamic behavior, specifically the drag coefficient, of pickup truck designs.

**The Boeing Company**

Aircraft Efficiency and Safety

Increasingly, aircraft manufacturers use predictive computational tools to take the place of expensive wind tunnel tests. Boeing used the OLCF to discover multiple solutions for steady RANS equations with separated flow to explain why numerical models sometimes fail to capture maximum lift.

**Ford Motor Company**

Underhood Cooling

Ford used OLCF resources to develop a new, efficient and automatic analytical cooling package optimization process leading to one-of-a-kind design optimization of cooling systems. Ford also used the OLCF to develop a high-performance computational strategy for modeling engine Cycle-to-Cycle Variation (CCV) - the first such simulation at scale.

**Convergent Science**

Engine Design

Convergent Science is an Independent Software Vendor specializing in Computational Fluid Dynamics tools. They used the ALCF to improve scaling of combustion simulations to allow unprecedented number of simultaneous jobs, providing a valuable design tool for engine manufacturers jobs, providing a valuable design tool for engine manufacturers.

**United Technologies Research Center**

Jet Efficiency & Catalysis

UTRC used the OLCF to conduct first-of-a-kind high-fidelity LES computations of flow in turbomachinery components for more fuel efficient, next-generation jet engines. They also used the OLCFs to Demonstrate biomass as a viable, sustainable fuelstock for fuel cell hydrogen production; showed that nickel is a feasible catalytic alternative to platinum.

**General Electric**

Advancing Wind Energy

GE used ALCF resources to enable the design of quieter, more efficient wind turbines by accurate simulations of the complex behavior of air flows around wind turbine blades. GE also used the OLCF to conduct first time simulations of ice formation within million-molecule water droplets. This is expanding understanding of freezing at the molecular level to enhance wind turbine resilience in cold climates.
Basic Energy Sciences
Understanding, predicting, and controlling matter and energy at the electronic, atomic, and molecular levels

- Increased funding for **Energy Frontier Research Centers** (EFRCs) will fully fund up to five new awards in the area of subsurface science, with an emphasis on advanced imaging of geophysical and geochemical signals.

- A new activity in **Computational Chemical Sciences** will leverage U.S. leadership in computational chemistry community codes for petascale and in anticipation of exascale computing.

- Core research increases to advance the **Mission Innovation** agenda, targeting materials and chemistry for energy efficiency and for use in extreme environments.

- Both **Energy Innovation Hubs** continue. Joint Center for Energy Storage Research (JCESR) will be in its 5th year. Joint Center for Artificial Photosynthesis (JCAP) will be in its 3rd year of renewal.

- To maintain international competitiveness in discovery science, support continues for the **Linac Coherent Light Source-II (LCLS-II)** construction project and the **Advanced Photon Source Upgrade (APS-U)** major item of equipment project.

- **BES user facilities** operate at optimal levels.
Biological and Environmental Research
Understanding complex biological, climatic, and environmental systems

- **Genomic sciences** supports the Bioenergy Research Centers, new microbiome research, and increases efforts in biosystems design for bioenergy and renewable bioproducts.

- **Mesoscale-to-molecules** research supports the development of enabling technology to visualize key metabolic processes in plant and microbial cells at the subcellular and mesoscale.

- **Climate and Earth System Modeling** supports development of physical, chemical, and biological model components to simulate climate variability and change at regional and global scales.

- **Atmospheric System Research (ASR)** addresses major uncertainties in climate change models: the role of clouds and the effects of aerosols on precipitation, and the atmospheric radiation balance.

- **Environmental System Science** supports research to provide a robust, predictive understanding of terrestrial surface and subsurface ecosystems. Includes Next Generation Ecosystem Experiments targeting climatically sensitive terrestrial ecosystems not well represented in models.

- **Climate and Environmental Data Analysis and Visualization** employs server side analysis to simplify analysis of large scale observations with model-generated data.

- **User facilities operate at optimal levels:** ARM continues measurements at fixed sites, and mobile facilities deploy to the Arctic, Antarctic, and the Atlantic Ocean. JGI provides genome sequence data, synthesis, and analysis. EMSL continues novel research using the High Resolution and Mass Accuracy Capability.
### FY 2017 SC Contributions to DOE Crosscuts

<table>
<thead>
<tr>
<th>Crosscut</th>
<th>Adv Mat</th>
<th>ECI</th>
<th>Subsurface</th>
<th>EWN</th>
<th>Cybersecurity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Scientific Computing Res.</td>
<td>0</td>
<td>154,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>154,000</td>
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<tr>
<td>Basic Energy Sciences</td>
<td>17,600</td>
<td>26,000</td>
<td>41,300</td>
<td>0</td>
<td>0</td>
<td>84,900</td>
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<tr>
<td>Biological and Environmental Research</td>
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<td>10,000</td>
<td>0</td>
<td>24,300</td>
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<td>34,300</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>27,197</td>
<td>27,197</td>
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<tr>
<td>Total, SC Contribution Crosscuts</td>
<td>17,600</td>
<td>190,000</td>
<td>41,300</td>
<td>24,300</td>
<td>27,197</td>
<td>300,397</td>
</tr>
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- **Adv Mat:** Advanced Materials Crosscut
- **ECI:** Exascale Computing Initiative Crosscut
- **Subsurface:** Subsurface Technology and Engineering RD&D Crosscut
- **EWN:** Energy-Water Nexus Crosscut
- **Cybersecurity:** Cybersecurity Crosscut
SC Contributes to Five FY 2017 DOE Crosscuts

**Advanced Materials (Adv Mat):** Identified as a priority in both the 2015 QTR and the QER, activities in the Adv Mat crosscut address faster development of new materials and reductions in the cost of materials qualification in clean energy applications, from discovery through deployment. New activities emphasize DOE-wide efforts in (1) materials design and synthesis, (2) applied design, (3) process scale-up, (4) qualification, and (5) digital data and informatics.

**Exascale Computing Initiative (ECI):** Activities in the ECI crosscut, a partnership between SC and NNSA, address accelerating R&D to overcome key challenges in parallelism, energy efficiency, and reliability, leading to deployment of exascale systems in the mid-2020s. In addition to underpinning DOE’s missions in science and national security, the computational capabilities developed in the ECI also will support R&D in DOE’s applied energy technology areas, as described in the 2015 QTR.

**Subsurface Technology and Engineering RD&D (Subsurface):** Activities in the Subsurface crosscut address coordinated research in Wellbore Integrity, Stress State and Induced Seismicity, Permeability Manipulation, New Subsurface Signals, and Risk Assessment Tools. Over 80 percent of our total energy supply comes from the subsurface; the goals of this crosscut are enhanced energy security, reduced impact on climate change via CO₂ sequestration, and significantly mitigated environmental impacts from energy-related activities and operations.

**Energy-Water Nexus (EWN):** The EWN crosscut addresses the transition to more resilient energy and coupled energy-water systems. The EWN crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making; (2) investments in targeted technology research offering the greatest potential for impact; and (3) policy analysis and stakeholder engagement designed to build from and strengthen the two preceding areas while motivating community involvement and response.

**Cybersecurity:** The Department of Energy (DOE) is engaged in two categories of cyber-related activities: protecting the DOE enterprise from a range of cyber threats that can adversely impact mission capabilities and improving cybersecurity in the electric power subsector and the oil and natural gas subsector. The cybersecurity crosscut supports central coordination of the strategic and operational aspects of cybersecurity and facilitates cooperative efforts such as the Joint Cybersecurity Coordination Center (JC3) for incident response and the implementation of Department-wide Identity Control and Access Management (ICAM).
Research is supported for the DIII-D and NSTX-U national programs.

NSTX-U operates for 16 weeks; DIII-D operates for 14 weeks; Alcator C-Mod ceases operation as scheduled and MIT scientists collaborate full-time on domestic and international facilities.

Support continues for U.S. research involvement on international machines EAST (China), KSTAR (Korea), and W7-X (Germany).

HEDLP research is focused on the MEC instrument at LCLS.

General plasma science activities continue, including the partnership with NSF for discovery-driven plasma science and engineering research.

U.S. contributions to ITER support US ITER Project Office; the US direct contribution; and progress on hardware contributions, including fabrication of the central solenoid magnet modules and structures and the toroidal field magnet conductor.
High Energy Physics
Understanding how the universe works at its most fundamental level

- The FY 2017 HEP budget reflects the way the P5 plan has evolved as the U.S. and international community have adopted and responded to it

- **Energy Frontier:** Continue active engagement in highly successful LHC program
  - Initial LHC detector upgrade project funding ends in FY 2017
  - Scope being determined for high luminosity (HL)-LHC, P5’s highest priority near-term project; CD-0 in 2016
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis of world’s highest energy particle collider data, at 13 TeV

- **Intensity Frontier:** Solidify international partnerships for U.S.-hosted LBNF/DUNE
  - Rapid progress on LBNF/DUNE has attracted attention from interested international partners, and FY 2017 investments in site preparation and cavern excavation aim to solidify formal agreements
  - Fermilab will continue improvements to accelerator complex while serving high-intensity neutrino beams to short-and long-baseline experiments enabling full utilization of the FNAL facilities

- **Cosmic Frontier:** Advance our understanding of dark matter and dark energy
  - Fabrication funding ramp up in FY 17 supports key P5 recommended Cosmic Frontier projects to study dark matter and dark energy: LSSTcam, DESI, SuperCDMS-SNOLab, and LZ
High Energy Physics
The technology and construction needed to pursue physics

- Construction & project support increases to implement the P5 strategy:
  - LBNF/DUNE aims to solidify partnerships with FY 2017 investments in site preparation and excavation of caverns for the neutrino detectors and cryogenic infrastructure
  - LHC ATLAS and CMS Detector Upgrade projects continue fabrication; HL-LHC upgrades begin
  - Muon g-2 completes project funding profile and will begin receiving beam at Fermilab
  - Dark energy: LSSTcam and DESI fabrication support increase according to planned profiles
  - Dark matter: LZ will continue fabrication as SuperCDMS-SNOLab proceeds to final design
  - Construction continues for the Muon to Electron Conversion Experiment (Mu2e)
  - FACET-II support begins, in order to create a new facility that will enable accelerator R&D aimed at dramatically improved capability and cost-effectiveness in future high-energy colliders

- Accelerator Stewardship
  - AS works to make particle accelerator technology widely available to science and industry by supporting use-inspired basic research in accelerator science and technology
  - FY17 Request supports research activities at laboratories, universities, and in industry for technology R&D areas such as laser, ion-beam therapy, and accelerator technology for energy and environmental applications
  - FY17 Request supports Brookhaven Accelerator Test Facility (ATF) operations and the continuation of the Accelerator Stewardship Test Facility Pilot Program
Nuclear Physics
Discovering, exploring, and understanding all forms of nuclear matter

- Funding for research increases to advance activities across the program, including R&D to develop new approaches for isotopes not currently available in sufficient quantities.

- A graduate traineeship is initiated in radiochemistry and nuclear chemistry with an emphasis in isotope production ($1M).

- Operations at RHIC increase to explore the properties of the quark gluon plasma first discovered there and to enable studies of spin physics.

- The 12 GeV CEBAF Upgrade is completed in FY 2017 and the scientific program is initiated promising new discoveries and an improved understanding of quark confinement.

- Construction continues on the Facility for Rare Isotope Beams. The Gamma-Ray Energy Tracking Array (GRETA) MIE is initiated to exploit the scientific potential of FRIB.

- Fabrication begins for a Stable Isotope Production Facility (SIPF) to produce enriched stable isotopes, a capability not available in the U.S. for almost 20 years.
FY2017 Issues and Priorities

- BALANCE - Discovery research vs science for clean energy and departmental crosscuts

- BALANCE - Research funding vs scientific user facilities construction vs operation

- Exascale computing project! National Strategic Computing Initiative

- International partnerships in Big Science
  - Defining moment in fusion sciences
  - LHC CMS, ATLAS upgrades at the same time as LBNF/DUNE

- Enhance communications with Congress and research universities

- Best practices in national lab management
**DOE Funding Modalities**

- **Discovery Research**
  - Goal: new knowledge / understanding
  - Focus: phenomena
  - Metric: knowledge generation

- **Use-Inspired Basic Research**
  - Goal: practical targets
  - Focus: performance
  - Metric: milestone achievement

- **Technology Maturation & Deployment**

- **Office of Science**

- **ARPA-E**
  - Goal: practical targets
  - Focus: performance
  - Metric: milestone achievement

- **Applied Programs**

- **Consortia, Crosscuts**

- **Bioenergy Research Centers, Hubs**

- **Energy Frontier Research Centers**

- **Core Research / Individual PIs**

*ARPA-E targets technology gaps, high-risk concepts, aggressive delivery times*
DOE Mission Innovation R&D, FY 16 and 17

- FY15: $10.1B
- FY16: $12.8B
- FY17: $13.1B

- FY15: $5.1B
- FY16: $5.3B
- FY17: $5.7B

- FY15: $9.3B
- FY16: $10.1B
- FY17: $12.9B

- FY17 $4.8B scored as Mission Innovation by OMB, 70% of applied energy, 32% of science
FY 2016
28 user facilities
Office of Science User Facility Statistics FY14

Universities 65%
DOE Laboratories 23%
Other 8%
Private Sector 4%

33,671 Total Users

Other includes many institutions, such as: non-DOE labs, federal agencies, research hospitals, K-12 students, and international institutions.
Data on University Grants and Users Across Country

http://science.energy.gov/universities/interactive-grants-map/

http://science.energy.gov/user-facilities/user-statistics/
SC Investments in Research, Facilities, and Construction

% of Total SC Funding

% Research
% Facility Operations
% Construction & MIEs

40% of FY16 research to universities
30% of FY16 construction to universities
From: Dr. Cherry A. Murray (Director, Office of Science)

I am writing to present a new charge to BESAC, related to the prioritization of upgrades of existing user facilities and major construction projects for new user facilities.

The following are the two criteria to be considered in your evaluation:

1. The ability of a proposed facility or upgrade to contribute to world-leading science, noting in particular the relevance to the 2015 BESAC report “Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science.” Activities will be placed in one of three categories: (a) absolutely central; (b) important; and (c) don’t know enough yet.

2. The readiness to proceed to construction, noting whether the concept has been thoroughly studied, the R&D performed to date is sufficient, the technical challenges can be met, and the extent to which the cost to build and operate the facility is understood. Concepts will be placed in one of three categories: (a) ready to initiate construction; (b) significant scientific/engineering challenges to resolve before initiating construction; and (c) mission and technical requirements not yet fully defined.
Exascale Computation Grand Challenge


http://science.energy.gov/bes/community-resources/reports/abstracts/#NCFMtSA
DOE’s Exascale Computing Initiative: Next Generation of Scientific Innovation

- **Departmental Crosscut** – In partnership with NNSA
- **“All-in” approach**: hardware, software, applications, large data, underpinning applied math and computer science
- **Supports DOE’s missions in national security and science:**
  - Stockpile stewardship – support annual assessment cycle
  - Discovery science – *next-generation materials; chemical sciences*
  - Mission-focused basic science in energy – next-generation *climate software*
  - Use current Leadership Computing approach for users
- **The next generation of advancements will require Extreme Scale Computing**
  - 100-1,000X capabilities of today’s computers with a similar physical size and power footprint
  - Significant challenges are power consumption, high parallelism, reliability
- **Extreme Scale Computing, cannot be achieved by a “business-as-usual,” evolutionary approach**
  - Initiate partnerships with U.S. computer vendors to perform the required engineering, research and development for system architectures for capable exascale computing
  - Exascale systems will be based on marketable technology – Not a “one off” system
  - Productive system – Usable by scientists and engineers
“…not later than May 2, 2016, the Secretary of Energy shall submit to the Committees on Appropriations of both Houses of Congress a report recommending either that the United States remain a partner in the ITER project after October 2017 or terminate participation, which shall include, as applicable, an estimate of either the full cost, by fiscal year, of all future Federal funding requirements for construction, operation, and maintenance of ITER or the cost of termination.”
P5 recommended LBNF as the centerpiece of a U.S.-hosted world-leading neutrino program
  – the highest-priority large project in its timeframe

The world’s most intense neutrino beam will be produced at Fermilab and directed 800 miles through the earth to Lead, South Dakota
  – Fermilab will lead this effort with a few international partners, most notably CERN

A very large (40 kiloton) liquid argon neutrino detector will be placed in the Homestake Mine in Lead, SD
  – An international collaboration has been established for the Deep Underground Neutrino Experiment (DUNE)
  – The U.S. will contribute to the detector as part of the LBNF project
END