U.S. DEPARTMENT OF ENERGY | Office of Science

FY 2016 Budget Request to Congress for DOE's Office of Science

February 2, 2015

Dr. Patricia M. Dehmer
Acting Director, Office of Science
science.energy.gov

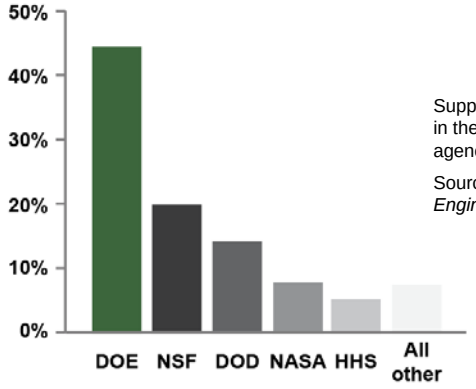
Office of Science
By the numbers

Shown is a portion of SLAC's two-mile-long linear accelerator (or linac), which provides the electron beam for the new Linac Coherent Light Source (LCLS) – the world's first hard x-ray, free-electron laser. For nearly 50 years, SLAC's linac had produced high-energy electrons for physics experiments. Now researchers use the very intense X-ray pulses (more than a billion times brighter than the most powerful existing sources) much like a high-speed camera to take stop-motion pictures of atoms and molecules in motion, examining fundamental processes on femtosecond timescales.

SC delivers scientific discoveries and tools to transform our understanding of nature and advance the energy, economic, and national security of the U.S.

Research

- Support for 47% of the U.S. Federal support of basic research in the physical sciences;
- ~22,000 Ph.D. scientists, grad students, engineers, and support staff at >300 institutions, including all 17 DOE labs;
- U.S. and world leadership in high-performance computing and computational sciences;
- Major U.S. supporter of physics, chemistry, materials sciences, and biology for discovery and for energy sciences.



Support for basic research in the physical sciences by agency.

Source: *NSF Science and Engineering Indicators 2012*

Scientific User Facilities

- The world's largest collection of scientific user facilities (aka research infrastructure) operated by a single organization in the world, used by 31,000 researchers each year.

Office of Science FY 2016 Budget Request to Congress

(Dollars in thousands)

	FY 2014 Enacted Approp. (prior to SBIR/STTR)	FY 2014 Current Approp.	FY 2015 Enacted Approp.	FY 2016 President's Request	FY 2016 President's Request vs. FY 2015 Enacted Appropriation	
Advanced Scientific Computing Research	478,093	463,472	541,000	620,994	+79,994	+14.8%
Basic Energy Sciences	1,711,929	1,662,702	1,733,200	1,849,300	+116,100	+6.7%
Biological and Environmental Research	609,696	593,610	592,000	612,400	+20,400	+3.4%
Fusion Energy Sciences	504,677	495,855	467,500	420,000	-47,500	-10.2%
High Energy Physics	796,521	774,920	766,000	788,000	+22,000	+2.9%
Nuclear Physics	569,138	554,802	595,500	624,600	+29,100	+4.9%
Workforce Development for Teachers and Scientists	26,500	26,500	19,500	20,500	+1,000	+5.1%
Science Laboratories Infrastructure	97,818	97,818	79,600	113,600	+34,000	+42.7%
Safeguards and Security	87,000	87,000	93,000	103,000	+10,000	+10.8%
Program Direction	185,000	185,000	183,700	187,400	+3,700	+2.0%
SBIR/STTR (SC)	.....	128,539	.....	.....	.....	.....
Subtotal, Office of Science	**5,066,372**	**5,070,218**	**5,071,000**	**5,339,794**	**+268,794**	**+5.3%**
SBIR/STTR (DOE)	.....	64,666	.....	.....	.....	.....
Subtotal, Office of Science	**5,066,372**	**5,134,884**	**5,071,000**	**5,339,794**	**+268,794**	**+5.3%**
Use of Prior Year Balances (SBIR)	.....	-3,846	.....	.....	.....	.....
Rescission of Prior Year Balances	.....	.....	-3,262	.....	+3,262	-100.0%
Total, Office of Science	**5,066,372**	**5,131,038**	**5,067,738**	**5,339,794**	**+272,056**	**+5.4%**

Highlights of the FY 2016 Budget Request

- Exascale computing is a top priority across SC
  (SC Exascale Crosscut: FY 2015 = $99,000K; FY 2016 = $208,624K)
  - ASCR supports HPC vendors to design and develop exascale node technologies, hardware, and software.
  - BES increases support for Computational Materials Sciences research to expand technical breadth of code development for design of functional materials.
  - BER initiates new work in Climate Model Development and Validation, which combines code development and numerical methods with ARM data to design an Earth system model with sub-10 km resolution.
- Facility operations are >98% of optimal for most facilities
- Research activities see both general and targeted increases
- Construction –
  - FY 2016
    - Facility for Rare Isotope Beams (NP) and the Linac Coherent Light Source (BES) are fully funded, and each is in its peak year of construction funding.
    - CEBAF 12 GeV Upgrade (NP) is nearing completion.
    - ITER (FES) funded at the FY 2015 level of $150,000K.
  - FY 2014 and FY 2015 saw final funding/successful completion of many projects including several large ones:
    - National Synchrotron Light Source – II (NSLS-II, BES) ($912,000K) met all CD-4 Key Performance Parameters.
    - NUMI Off-axis Neutrino Appearance (NOvA, HEP) ($274,260K)
    - Energy Sciences Building (ESB, SLI) ($95,956K)
    - SNS Instruments - Next Generation II (SING-II, BES) ($60,000K)
- Workforce Development
  - The Computational Science Graduate Fellowship (ASCR) is restored at $10,000K to fully fund a new cohort.

FY 2016 SC Budget Request by Category

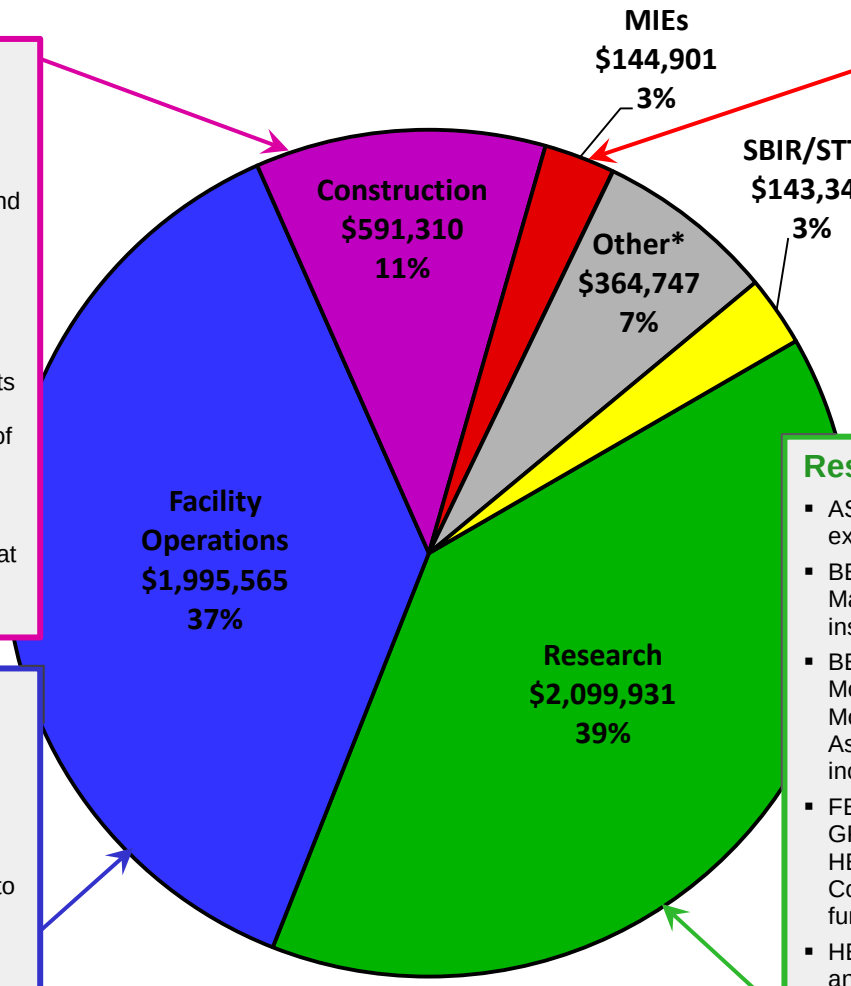
Dollars in Thousands

Construction

- BES: Linac Coherent Light Source-II continues and is in its peak funding year ($200,300K).
- FES: ITER – support for the USIPO, IO, and hardware fabrication continues ($150,000K).
- HEP: Long Baseline Neutrino Facility ($20,000K for PED); Muon to Electron Conversion ($40,100K).
- NP: FRIB continues and is at the peak of its funding profile ($100,000K); accelerator commissioning and detector construction of the CEBAF12 GeV upgrade continue ($12,000K).
- SLI: Materials Design Lab at ANL ($23,910K); Photon Science Lab Building at SLAC ($25,000K); Integrative Genomics Building at LBNL ($20,000K).

Facility Operations

- ASCR, BER, BES, HEP: Facilities operate at or near to optimal, >98%.
- FES: NSTX resumes operations for 14 weeks; DIII-D operates for 12 weeks until shutdown for installation of upgrades; Alcator C-Mod operates for 5 weeks prior to final shutdown at the end of FY 2016.
- NP: RHIC operates 22 weeks, same as in FY 2015; ATLAS operates 37 weeks; CEBAF is supported for continued machine development and commissioning of beam to Halls B and C.



*Other includes GPP/GPE amounts for BES, GPP for FES, Other (DOE/SC/Fermi/Lawrence) for NP, WDTS, SLI non-construction funding, S&S, and Program Direction.

Major Items of Equipment

- BES: Advanced Photon Source Upgrade (APS-U) ($20,000K) and NSLS-II Experimental Tools (NEXT) (15,500K).
- HEP: LHC Detector Upgrades (ATLAS and CMS) ($9,500K each); Large Synoptic Survey Telescope camera (LSSTcam) ($40,800K); Muon g-2 ($10,200K); LUX-ZEPLIN ($9,000K); SuperCDMS-SNOLab ($2,000K); Dark Energy Spectroscopic Instrument (DESI) ($5,300K).

Research

- ASCR: There is a significant increase for the exascale initiative (Δ = +$86,895K).
- BES: Increases for EFRCs, Computational Materials Sciences, and mid-scale instrumentation.
- BER: Increases for Climate and Earth System Modeling with largest percent increases for Climate Model Development & Validation and Integrated Assessment. Some decreases offset the increases.
- FES: Research continues in all areas. Increase for GPP for PPPL in support of NSTX-U operations. HEDLP is reduced, but the Matter in Extreme Conditions end station at LCLS remains fully funded.
- HEP: Research funding is nearly flat with FY 2015 and supports scientific results from operating experiments and R&D for future projects.
- NP: Research increases by more than 8% to support high-priority work.

FY 2016 SC Budget Request by Category

Dollars in Thousands

Research

- ASCR: There is a significant increase for the exascale initiative (Δ = +$86,895K).
- BES: Increases for EFRCs, Computational Materials Sciences, and mid-scale instrumentation.
- BER: Increases for Climate and Earth System Modeling with largest percent increases for Climate Model Development & Validation and Integrated Assessment. Some decreases offset the increases.
- FES: Research continues in all areas. Increase for GPP for PPPL in support of NSTX-U operations. HEDLP is reduced, but the Matter in Extreme Conditions end station at LCLS remains fully funded.
- HEP: Research funding is nearly flat with FY 2015 and supports scientific results from operating experiments and R&D for future projects.
- NP: Research increases by more than 8% to support high-priority work.

FY 2016 SC Budget Request by Category

Dollars in Thousands

Facility Operations

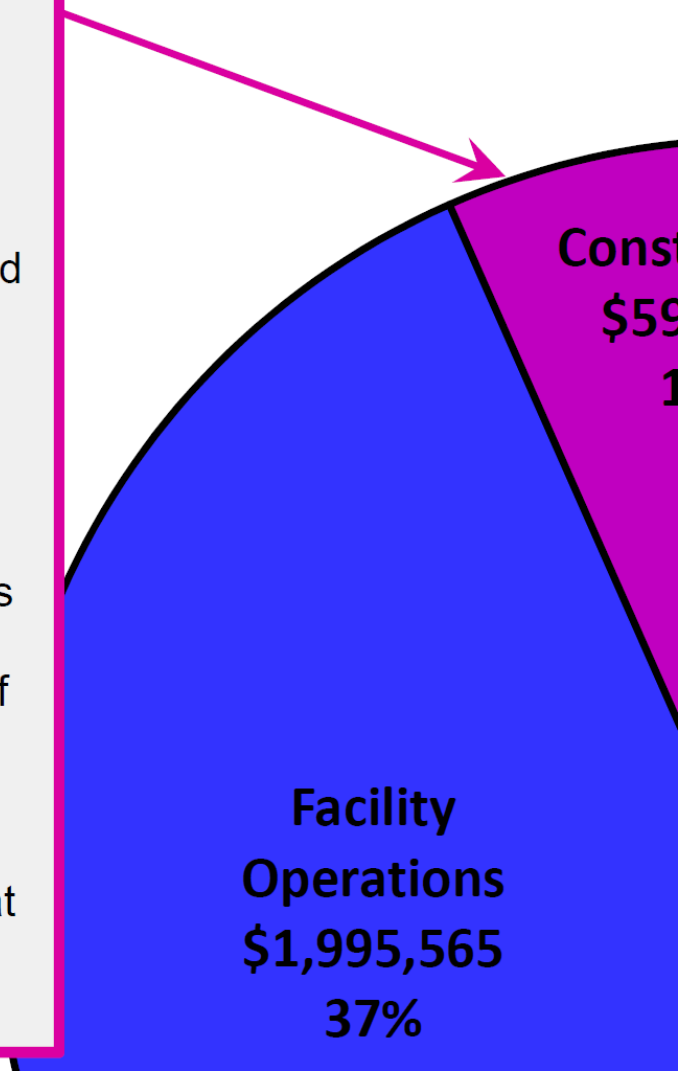
- ASCR, BER, BES, HEP: Facilities operate at or near to optimal, >98%.
- FES: NSTX resumes operations for 14 weeks; DIII-D operates for 12 weeks until shutdown for installation of upgrades; Alcator C-Mod operates for 5 weeks prior to final shutdown at the end of FY 2016.
- NP: RHIC operates 22 weeks, same as in FY 2015; ATLAS operates 37 weeks; CEBAF is supported for continued machine development and commissioning of beam to Halls B and C.

FY 2016 SC Budget Request by Category

Dollars in Thousands

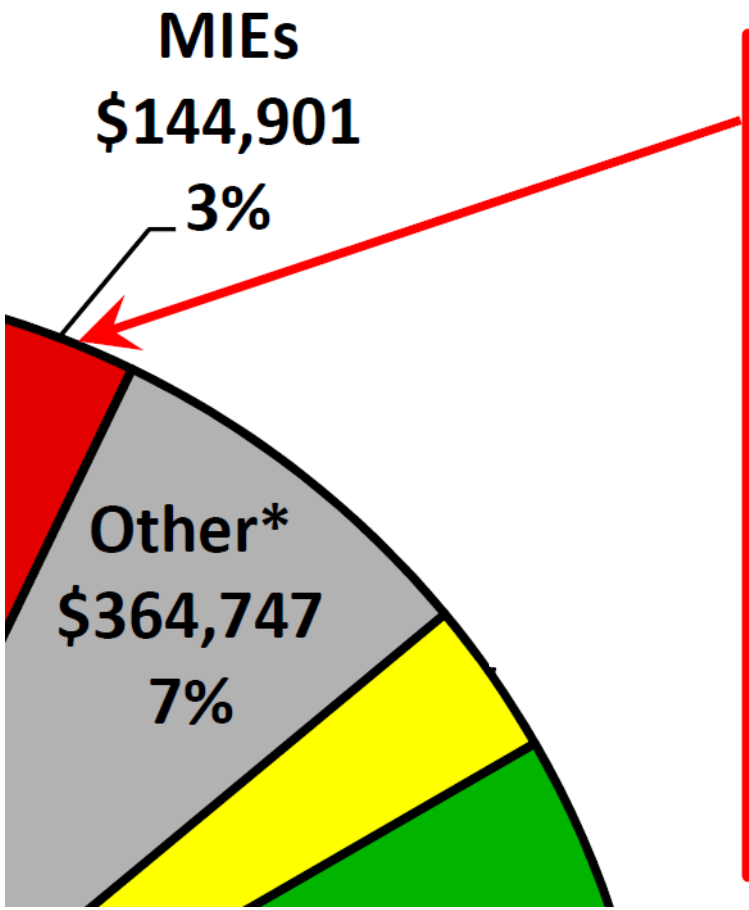
Construction

- BES: Linac Coherent Light Source-II continues and is in its peak funding year ($200,300K).
- FES: ITER – support for the USIPO, IO, and hardware fabrication continues ($150,000K).
- HEP: Long Baseline Neutrino Facility ($20,000K for PED); Muon to Electron Conversion ($40,100K).
- NP: FRIB continues and is at the peak of its funding profile ($100,000K); accelerator commissioning and detector construction of the CEBAF12 GeV upgrade continue ($12,000K).
- SLI: Materials Design Lab at ANL ($23,910K); Photon Science Lab Building at SLAC ($25,000K); Integrative Genomics Building at LBNL ($20,000K).



FY 2016 SC Budget Request by Category

Dollars in Thousands



Major Items of Equipment

- BES: Advanced Photon Source Upgrade (APS-U) ($20,000K) and NSLS-II Experimental Tools (NEXT) (15,500K).
- HEP: LHC Detector Upgrades (ATLAS and CMS) ($9,500K each); Large Synoptic Survey Telescope camera (LSSTcam) ($40,800K); Muon g-2 ($10,200K); LUX-ZEPLIN ($9,000K); SuperCDMS-SNOLab ($2,000K); Dark Energy Spectroscopic Instrument (DESI) ($5,300K).

SC is Contributing to Four DOE Crosscuts

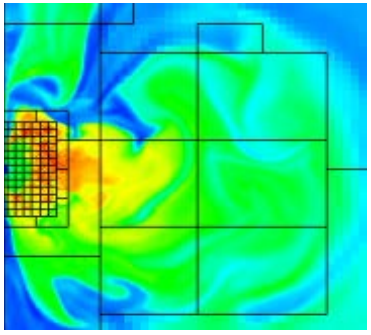
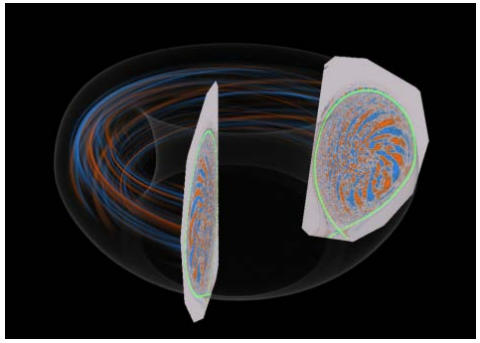
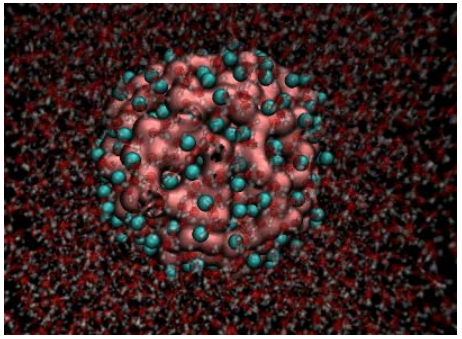
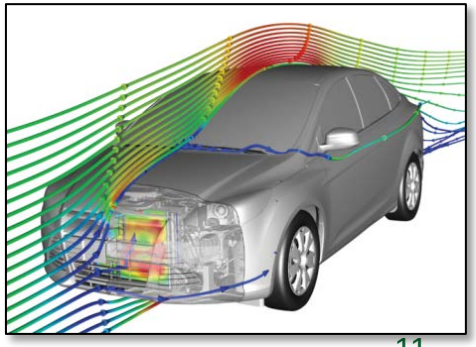
	Exascale Computing	Subsurface Engineering	Water Energy	Cyber Security	Total
Advanced Scientific Computing Research	177,894	0	0	0	177,894
Basic Energy Sciences	12,000	5,000	0	0	17,000
Biological and Environmental Research	18,730	0	11,800	0	30,530
Safeguards and Security	0	0	0	33,156	33,156
Total, Crosscuts	208,624	5,000	11,800	33,156	258,580

- **Exascale:** The advanced computing crosscut addresses the needs of SC, NNSA, and the energy technology offices in the development of advanced computing technologies to provide better understanding complex physical systems. BES funding for exascale is the FY 2016 request for Computational Materials Sciences; BER funding is for Climate Model Development and Validation.
- **Subsurface Engineering:** The subsurface crosscut addresses: intelligent wellbores using advanced sensors and adaptive materials; subsurface stress and induced seismicity to reduce risks associated with subsurface injection; permeability manipulation to control fluid flow; and new subsurface signals to enhance our ability to characterize subsurface systems.
- **Water – Energy:** The water-energy crosscut addresses RD&D; robust datasets; and integrated models to inform decision-making, aligning with SC's leadership in high-performance computing and in modeling and simulation.
- **Cybersecurity:** The SC request supports proper protection of the SC laboratories' computer resources and sensitive data. A review of the SC Cyber Security program recommended increased funding to protect the SC laboratories from cyber threats.

Advanced Scientific Computing Research

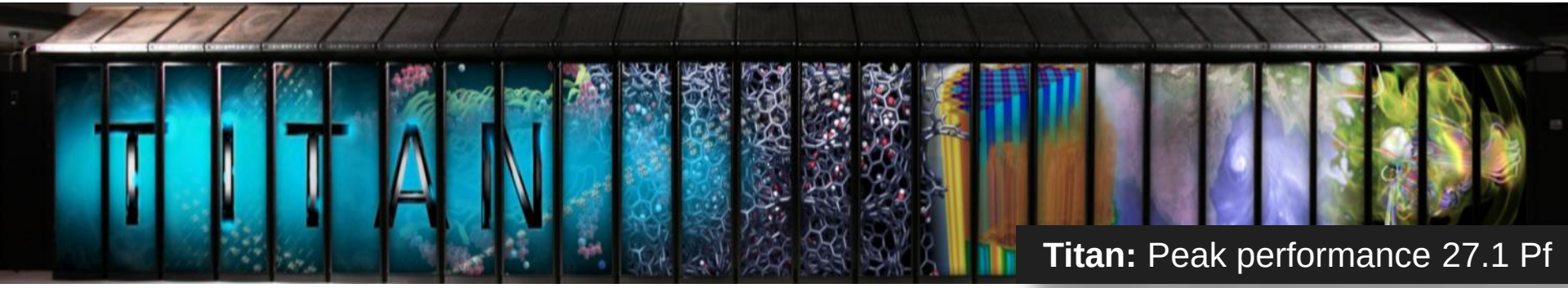
Computational and networking capabilities to extend the frontiers of science and technology

- **Exascale computing** – (Exascale Crosscut: FY 2015 = $91,000K; FY 2016 = $177,894K; Δ = +$86,894K) Exascale crosscut includes engagement with HPC vendors to design and develop exascale node technologies and exascale hardware and software computer designs at the system level (Δ = +$69,000K); hardware architectures and system software; programming for energy-efficient, data-intensive applications.
- **Facilities** operate optimally and with >90% availability; deployment of 10-40 petaflop upgrade at NERSC and continued preparations for 75-200 petaflop upgrades at the Leadership Computing Facilities.
- **SciDAC partnerships** continue to accelerate progress in scientific computing.
- The **Computational Science Graduate Fellowship** is restored at $10,000K to fully fund a new cohort.
- **Mathematics research** addresses challenges of increasing complexity and **Computer science research** addresses productivity and integrity of HPC systems and simulations, and supports data management, analysis, and visualization techniques.

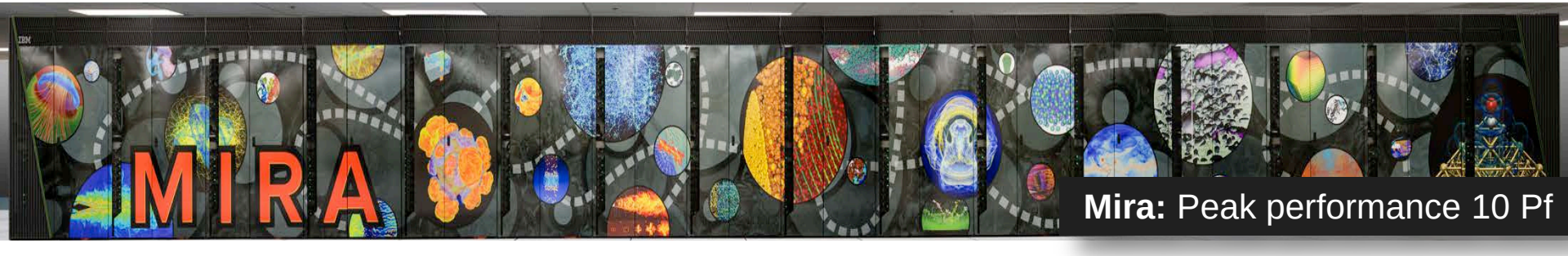





ASCR Production and Leadership Computing Facilities

Edison XC30: Peak performance 2.4 Pf



Titan: Peak performance 27.1 Pf



Mira: Peak performance 10 Pf

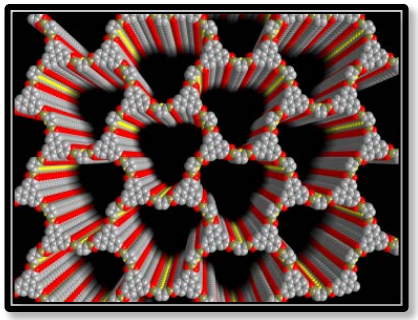
ASCR Computing Upgrades at a Glance

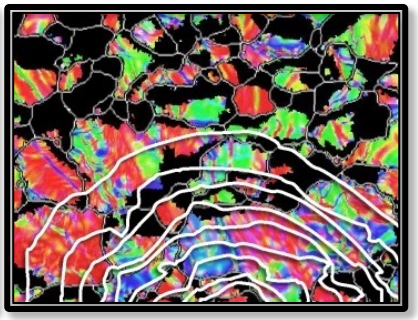
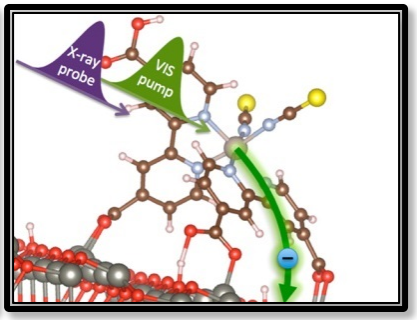
System attributes	NERSC Now	OLCF Now	ALCF Now	NERSC Upgrade	OLCF Upgrade	ALCF Upgrade
Name/Planned Installation	**Edison**	**TITAN**	**MIRA**	**Cori 2016**	**Summit 2017-2018**	**Aurora 2018-2019**
System peak (PF)	2.4	27	10	>30	150	>150
Peak Power (MW)	3	8.2	4.8	<3.7	10	~13
System memory per node	64 GB	38 GB	16 GB	64-128 GB DDR4 16 GB High Bandwidth	> 512 GB (High Bandwidth memory and DDR4)	TBA
Node performance (TF)	0.460	1.452	0.204	>3	>40	>15 times Mira
Node processors	Intel Ivy Bridge	AMD Opteron Nvidia Kepler	64-bit PowerPC A2	Intel Knights Landing many core CPUs Intel Haswell CPU in data partition	Multiple IBM Power9 CPUs & mulitple Nvidia Voltas GPUS	TBA
System size (nodes)	5,200 nodes	18,688 nodes	49,152	9,300 nodes 1,900 nodes in data partition	~3,500 nodes	~50,000 nodes
System Interconnect	Aries	Gemini	5D Torus	Aries	Dual Rail EDR-IB	TBA
File System	17.6 PB, 168 GBs, Lustre®	32 PB, 1 TB/s, Lustre®	GPFS™	28 PB, 744 GB/sec , Lustre®	120 PB, 1 TB/s, GPFS™	TBA

Basic Energy Sciences

Understanding, predicting, and controlling matter and energy at the electronic, atomic, and molecular levels

- Increased funding for additional **Energy Frontier Research Centers** (EFRCs) (Δ = +$10,000K)
- Increased funding for **computational materials sciences** research to expand technical breadth of code development for design of functional materials (Δ = +$4,000K)
- New funding for **mid-scale instrumentation** for ultrafast electron scattering (Δ = +$5,000K)
- **Energy Innovation Hubs**:
  - Joint Center for Energy Storage Research (JCESR) will be in its 4th year. (FY 15 = $24,175K; FY 2016 = $24,137K)
  - Joint Center for Artificial Photosynthesis (JCAP) is under review for renewal starting in September 2015. (FY 2015 = $15,000K; FY 2016 = $15,000K)
- **National Synchrotron Light Source-II** (NSLS-II) begins its 1st full year of operations.
- **Linac Coherent Light Source-II (LCLS-II)** construction continues.
- BES **user facilities** operate at near optimum levels (~99% of optimal).
- Two **major items of equipment**: NSLS-II Experimental Tools (NEXT) and Advanced Photon Source Upgrade (APS-U) are underway.



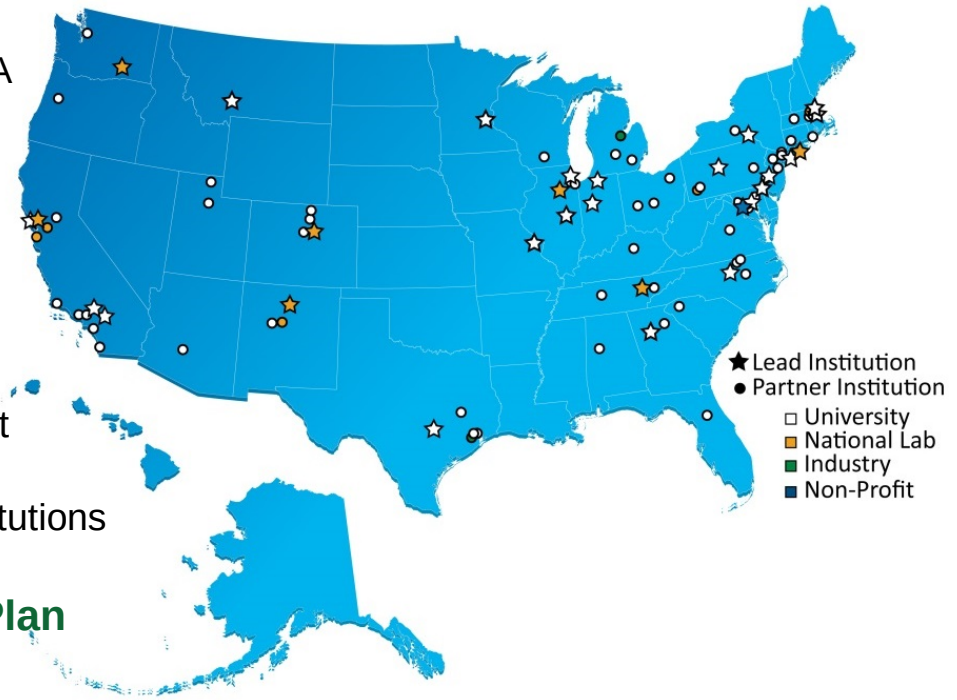
Energy Frontier Research Centers, 2009 - present

FY 2009 46 EFRCs were launched

- $777M for 5 years, $100M/year base + $277M ARRA

FY 2014 Recompetition Results

- $100M/year base
- 32 EFRCs in 32 States + Washington D.C.
  (22 renewals+ 10 new)
- Each $2-4M/yr for up to 4 years
- Led by 23 Universities, 8 DOE Labs, and 1 non-profit
- ~525 senior investigators and ~900 students, postdoctoral fellows, and technical staff at ~100 institutions



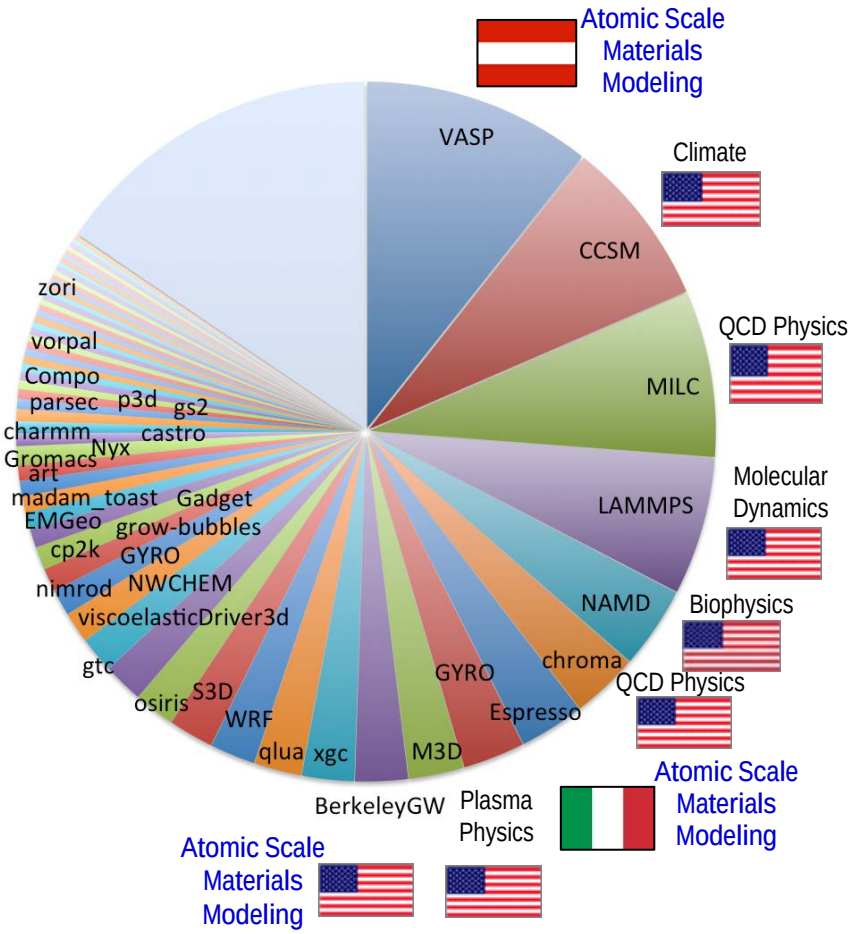
FY 2015 – FY 2016 Review and Management Plan

- Management review of new centers in FY 2015.
- Full mid-term progress review for all centers in FY 2016, with funding for final two years contingent upon review outcome.

FY 2016 Funding and New Solicitation

- Funding for EFRCs increases $10,000K (FY 2015 = $100,000K; FY 2016 = $110,000K).
- Call for new EFRC proposals with topical areas that complement current portfolio and that are informed by new community workshops.
- The EFRC program will transition to a biennial solicitation cycle starting in FY 2016.

Increase for Computational Materials Sciences



2013 Top Application Codes at NERSC

Funding

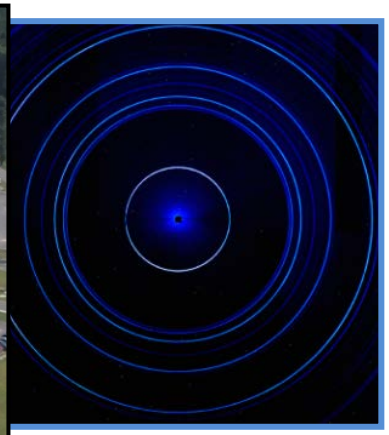
- FY 2015 included $8,000K for new awards. FOA announced January 26, 2015, for proposals to study functional materials; 4-year awards to be funded at $2,000-4,000K per year.
- FY 2016 Request of $12,000K will continue support for the 2015 awards and will fund additional awards to broaden the technical scope of the research.

Why computational materials sciences? The U.S. trails competitors in computational codes for materials discovery and engineering

- At NERSC, the most used code is VASP, a commercial Austrian atomic scale materials modeling code requiring purchase of license.
- (Quantum) Espresso, a popular materials modeling code, was developed by Italy.
- Top codes for other fields used at NERSC were developed in the U.S. and are all free, community codes.

National Synchrotron Light Source II

Successfully completed on time and within budget



First Diffraction Data

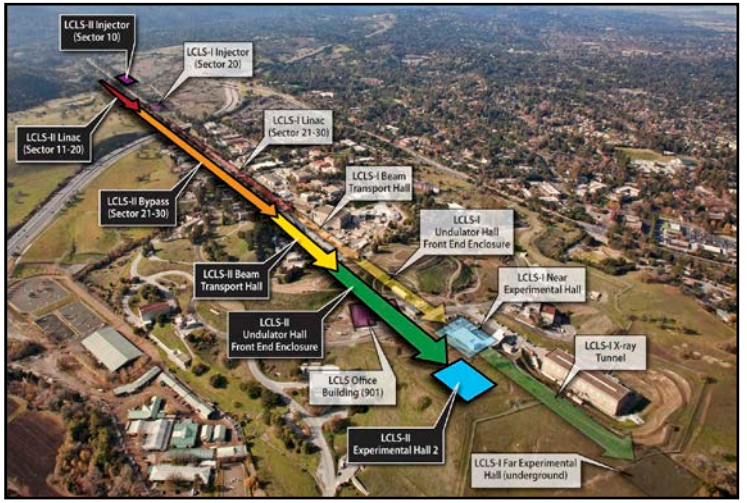
National Synchrotron Light Source-II (NSLS-II)

- First light was achieved on Oct 23, 2014. Six project beamlines were approved for commissioning by Oct 31, 2014. All key performance parameters and project scope were delivered by December 2014.
- NSLS-II provides over 600k square feet of space to house the 3 GeV storage ring and 5 lab and office buildings. The ring will be capable of 500 mA operation.
- NSLS operations ceased September 30, 2014, and it will transition to safe storage in FY 2015. NSLS-II FY 2015 operations is $90.4M. FY 2016 requests operations funding at $110,000K.

LCLS-II and APS-U Underway

Linac Coherent Light Source-II (LCLS-II)

- FY 2015 = $148,000K; FY 2016 = $200,300K for R&D, design, prototyping, long lead procurement, and construction of technical systems.
- LCLS-II will provide high-repetition-rate, ultra-bright, transform-limited femtosecond x-ray pulses with polarization control and pulse length control to ~1 femtosecond. The hard x-ray range will be expanded to 25 keV.
- Added are a 4 GeV superconducting linac; an electron injector; and two undulators to provide x-rays in the 0.2–5 keV energy range.



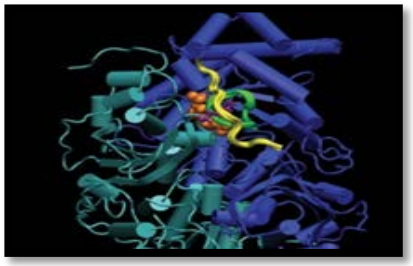
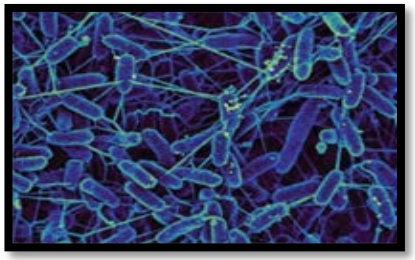
Advanced Photon Source Upgrade (APS-U)

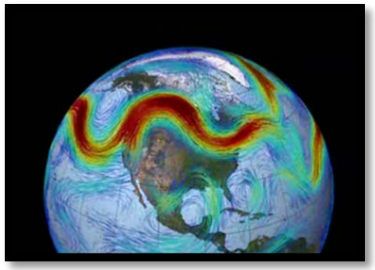
- FY 2015 = $20,000K; FY 2016 = $20,000K for R&D, design, and limited prototyping.
- APS-U will provide a multi-bend achromat lattice to provide extreme transverse coherence and extreme brightness.
- Initial conceptual design for the new lattice completed; conducting R&D and key component prototyping in support of the new design. Key performance parameters are being defined for the project and the new storage ring.

Biological and Environmental Research

Understanding complex biological, climatic, and environmental systems

- **Genomic sciences** supports the Bioenergy Research Centers and increases efforts in biosystems design for bioenergy and renewable bioproducts (Δ = +$2,145K).
- **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** develops physical, chemical, and biological model components to simulate climate variability and change at regional and global scales. (Δ = +$11,763K).
- A new activity in **Climate Model Development and Validation** combines code development and numerical methods with ARM data to design an Earth system model with sub-10 km resolution for use on next generation and exascale computers. (Δ = +$18,730K).
- **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. (Δ = +$2,066K).
- **User facilities operate at optimal levels: ARM** continues measurements at fixed sites, and mobile facilities deploy to the Arctic, Antarctic, and the Pacific Ocean. **JGI** provides genome sequence data, synthesis, and analysis. **EMSL** initiates work using the High Resolution and Mass Accuracy Capability.



Accelerated Climate Model for Energy (ACME)

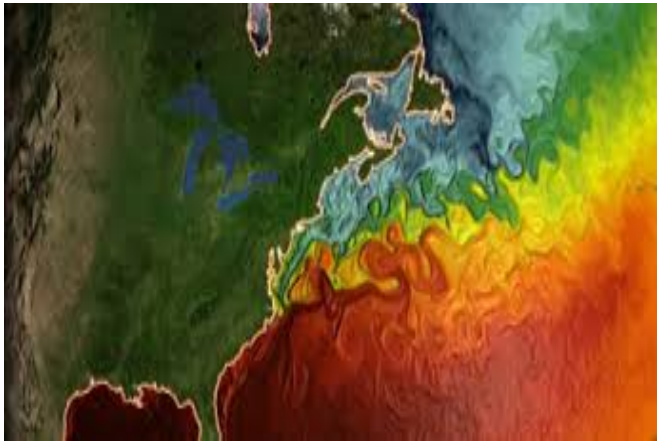
ACME is a DOE multi-laboratory climate modeling project designed to accelerate the assimilation of advanced software and numerical methods into a new model within the family of “Community Earth System Models” (CESM) that is more narrowly focused on science challenges important to DOE.

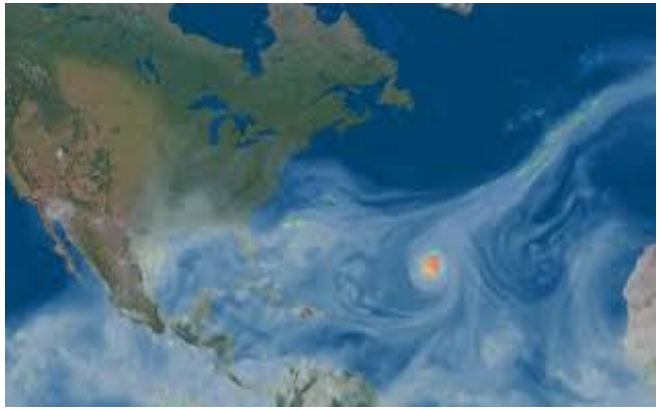
<u>Unique, world-leading capabilities</u>

- Will achieve highest spatial resolution of all climate models in US and international
  - Resolution at 15-25 km in fully coupled mode
  - Resolution below 10 km, using advanced adaptive-mesh for specific regions
- Will be the first climate model able to be ported to next generation computer architectures, as they become available.

<u>Science focus areas</u>

- Dramatically improved projections of future extreme weather events, droughts, water supply, ice sheets, sea level rise
- Carbon cycle, with dynamic ecology, biogeochemistry, and land-atmosphere fluxes
- Uncertainty quantification for full system and its components





Pacific Northwest National Laboratory · Oak Ridge National Laboratory · Argonne National Laboratory · Sandia National Laboratories · Los Alamos National Laboratory · Berkeley Lab · Brookhaven National Laboratory

Begun in 2014, involves 7 National laboratories and the National Center for Atmospheric Research (NCAR).

Climate Model Development and Validation

Model capabilities today

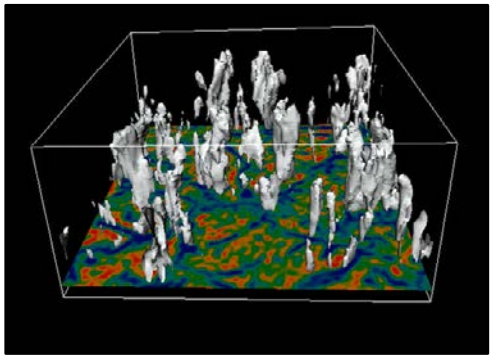
- Global and regional simulations to 50 km resolution in full integration mode; to 25 km with limited integration. *Unable to adequately represent extreme events, important to DOE and energy infrastructure*.
- No standard uncertainty quantification methodology applied to climate predictions. *Improved confidence in predictions is needed by scientists and stakeholders*.
- No common software infrastructure strategy in climate modeling community. *Current climate models will be unable to exploit DOE's next generation exascale computer architectures.*

FY 2016 Research Efforts

- Combine major upgrades in advanced software code development, downscaling methodologies, and validation against testbeds for sites in U.S. (Oklahoma, Alaska) using the Atmospheric Radiation Measurement Climate User Facility (ARM)
- Develop scale-aware physics appropriate for very high resolution phenomena extending 10 km to below 1 km.
- Integrate scale-aware physics into improved climate modeling codes for use on next generation and exascale computers.

ARM Oklahoma

Best-in-class software and hardware



First modeling of high-res extreme phenomena with Uncertainty Quantification methodologies

DOE's Role in Climate Change Research

- DOE has been a leader in climate science since the 1950s, beginning with atmospheric transport and the relationship between CO_2 and climate change.
- Today's research relies on unique SC user facilities, such as the Atmospheric Radiation Measurement (ARM) Climate Research Facility and the Leadership Computing Facilities, to develop predictive, systems-level understanding of climate change.
- DOE coordinates with other agencies through partnerships and through the U.S. Global Change Research Program.

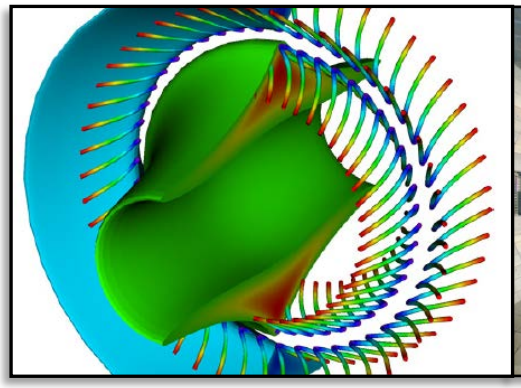
DOE/SC research addresses:

- The three important uncertainties in the earth's radiant energy balance—clouds, aerosols, and atmospheric greenhouse gases
- The relationship between climate change and critical ecosystems
- The climate-energy-water nexus through modeling

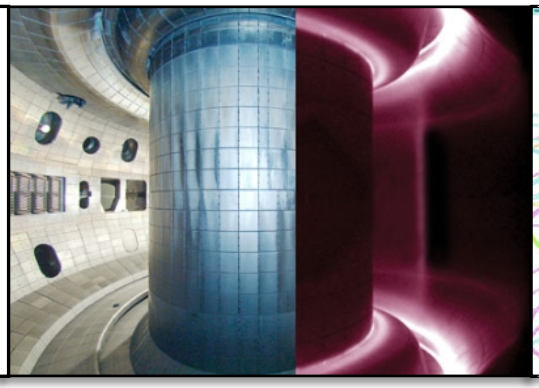
Fusion Energy Sciences

Matter at very high temperatures and densities and the scientific foundations for fusion

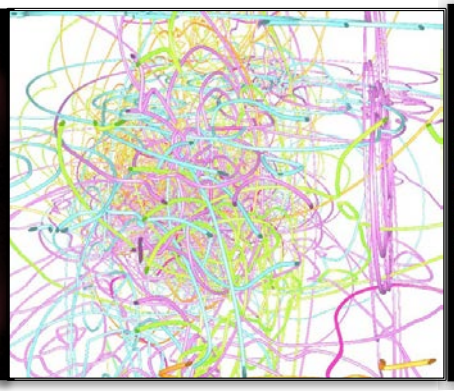
- Research is supported for the DIII-D and NSTX-U national programs.
- NSTX-U operates for 14 weeks; DIII-D operates for 12 weeks; and Alcator C-Mod operates for 5 weeks prior to facility close-out at the end of FY 2016.
- Support continues for U.S. research involvement on international machines EAST (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.
- 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.



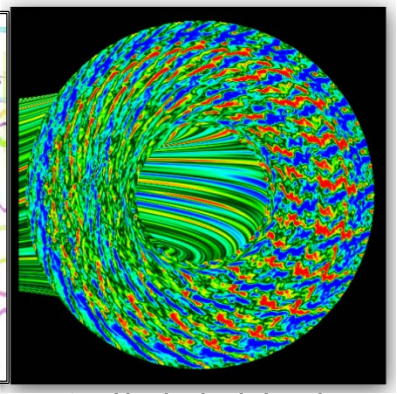
Magnetic reconnection on Swarthmore spheromak



Interior of DIII-D tokamak



Dislocation loops forming and moving inside fusion materials

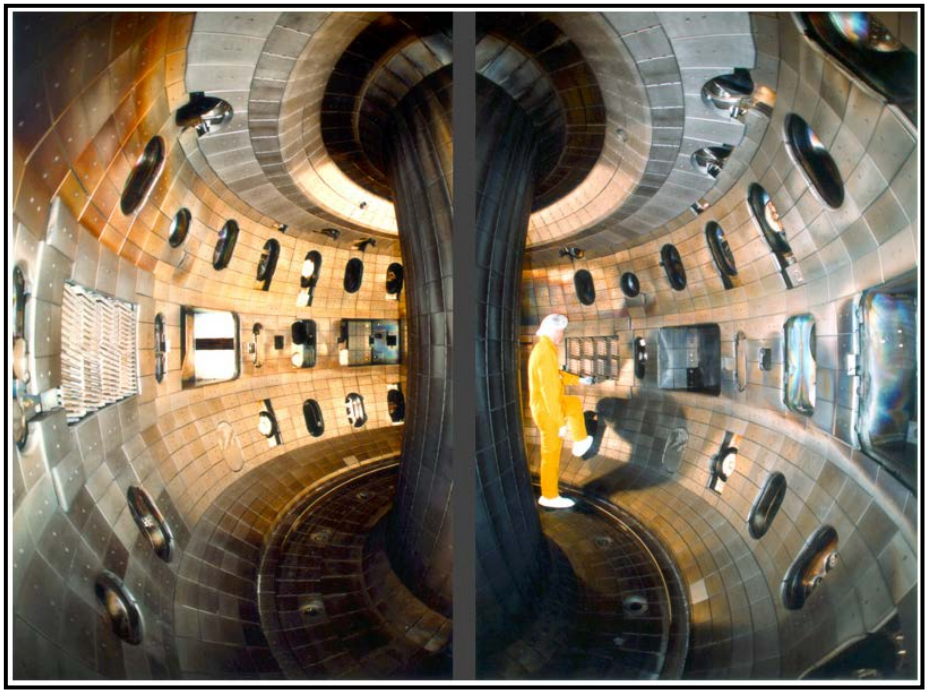


Gyrokinetic simulation of turbulent transport in tokamak plasma

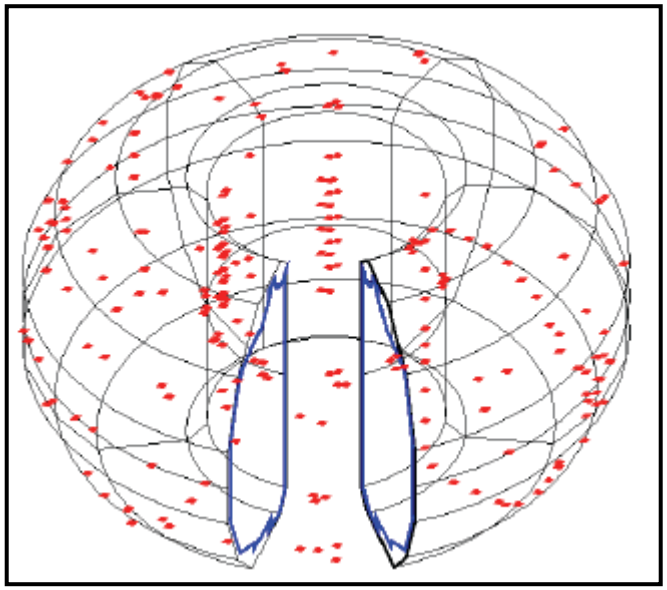
NSTX Upgrade at PPPL

- FY 2016 is the first full year of operation of NSTX-U after completion of the multi-year upgrade construction project in mid-FY 2015.
- Funding will allow 14 weeks of run time (up 4 weeks from the FY 2015 enacted budget).
- NSTX-U will extend its performance to the new full field and current values (both double what had been achieved prior to the upgrade) and address divertor heat flux mitigation, enhanced plasma confinement, and non-inductive discharge sustainment.
- In mid-FY 2016, a shutdown is planned for installation of a cryopump in the lower divertor and a row of tungsten tiles on the cryo-baffle.

DIII-D and its Upgrades at General Atomics



Interior of DIII-D vacuum vessel



Red dots are sensors on DIII-D tokamak for three-dimensional magnetic field structure measurements

- DIII-D will continue high-priority studies of transport, disruption physics and mitigation systems, methods to exploit three-dimensional magnetic field control for improved performance, and high plasma pressure operation.
- After 12 run weeks, DIII-D will have a planned outage for installation of upgrades, including an additional high-power microwave heating system, new magnet power supplies for the 3D coils and shaping coils, and improvements to the neutral beam heating control system. Also, design modifications necessary for a second off-axis neutral beam will begin.

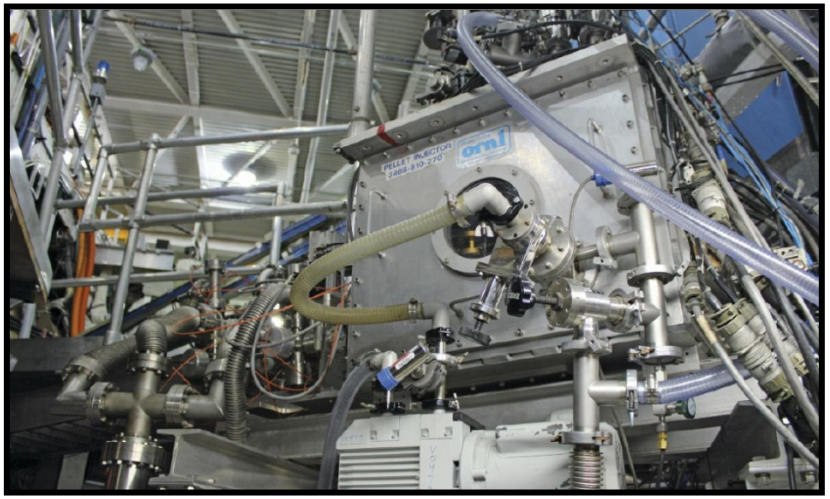
Community Engagement Workshops

- Following the FESAC *Strategic Planning and Priorities Report* (2014), FES will undertake a series of four technical workshops in May-June 2015. Workshop topics address the main recommendations of the FESAC report.
  - Workshop on Integrated Simulations for Magnetic Fusion Energy Sciences
  - Workshop on Transients
  - Workshop on Plasma Science Frontiers
  - Workshop on Plasma-Materials Interaction

- Each workshop will deliver a written report prepared by its steering committee (a group of community scientists selected for topical expertise who will lead/participate in the workshop). The reports will address scientific challenges and potential implementation options.

U.S. Fabrication of ITER Hardware Progressing

Toroidal field conductor jacketing at High Performance Magnetics (Tallahassee, FL)



Pellet injector to feed ITER with frozen fuel pellets, developed by ORNL (Oak Ridge, TN)

Toroidal field cable produced at New England Wire Technologies (Lisbon, NH)

Installation of the first winding station for the central solenoid at General Atomics (San Diego, CA)

High Energy Physics

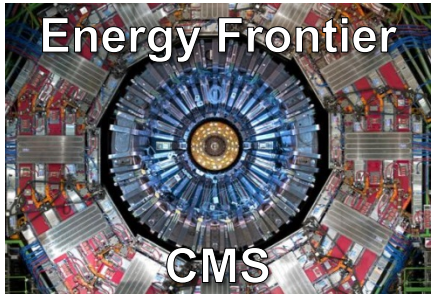
Understanding how the universe works at its most fundamental level

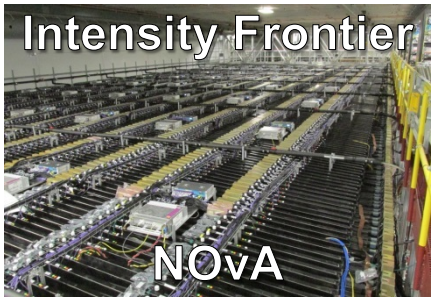
- HEP is implementing the strategy detailed in the May 2014 report of the Particle Physics Project Prioritization Panel (P5), formulated in the context of a global vision for the field
  - HEP Addresses the five compelling science drivers with research in three frontiers and related efforts in theory, computing and advanced technology R&D
  - Increasing emphasis on international partnerships (such as LHC) to achieve critical physics goals

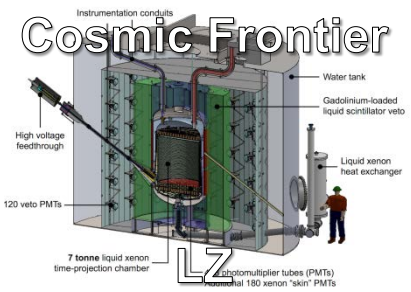
- Energy Frontier: Continue LHC program with higher collision energy (13+ TeV)
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis and the initial upgrades to the ATLAS and CMS detectors

- Intensity Frontier: Develop a world-class U.S.-hosted Long Baseline Neutrino Facility
  - Continue the design process for an internationalized LBNF and development of a short baseline neutrino program that will support the science and R&D required to ensure LBNF success
  - Fermilab will continue to send world's highest intensity neutrino beam to NOvA, 500 miles away

- Cosmic Frontier: Advance our understanding of dark matter and dark energy
  - Immediate development of new capabilities continue in dark matter detection with baselining of 2nd-generation experiments; and in dark energy exploration with baselining of DESI and fabrication of LSST camera.







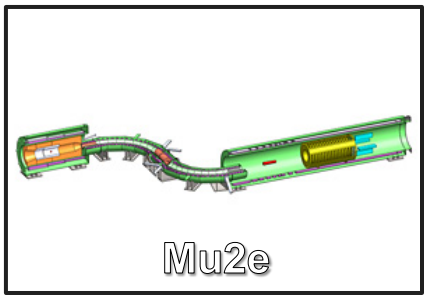
	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

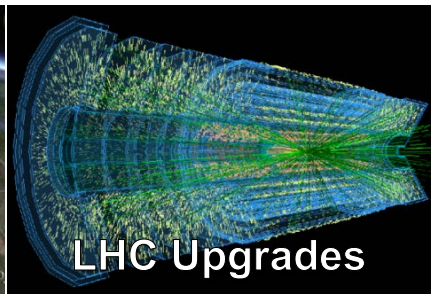
High Energy Physics

Understanding how the universe works at its most fundamental level

- Accelerator Stewardship
  - This subprogram focuses on the broader applications of accelerator technologies, including major thrusts in technology to enable ion-beam cancer therapy and R&D for high-power ultrafast lasers
  - The FY 2016 funding request provides support for a new research thrust in energy and environmental applications of accelerators and expands the open test facilities effort
  - The main facility supporting this subprogram, the Brookhaven Accelerator Test Facility (ATF), will undergo relocation and expansion in FY 2016 to accommodate more users

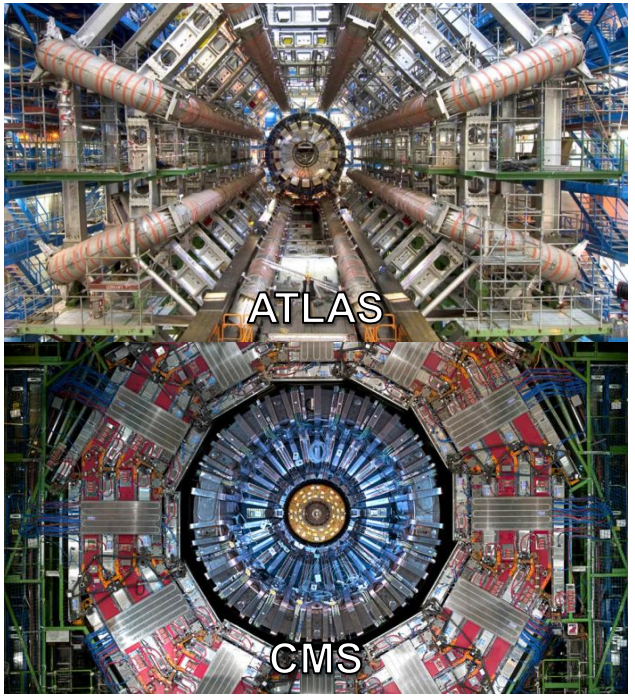
- Construction/Major Items of Equipment (MIEs) reflect P5 priorities:
  - The Long Baseline Neutrino Facility (LBNF) continues its design phase as the project baseline cost and technical scope are revised while incorporating international in-kind contributions
  - The LHC ATLAS and CMS Detector Upgrade projects continue fabrication
  - Muon g-2 continues accelerator modifications and fabrication of the beamline and detectors
  - LSSTcam fabrication support increases according to planned profile
  - Dark Energy Spectroscopic Instrument (DESI) will be baselined in 2016
  - Fabrication proceeds on the dark matter experiment MIEs: SuperCDMS-SNOLab and LZ
  - Construction continues for the Muon to Electron Conversion Experiment (Mu2e)

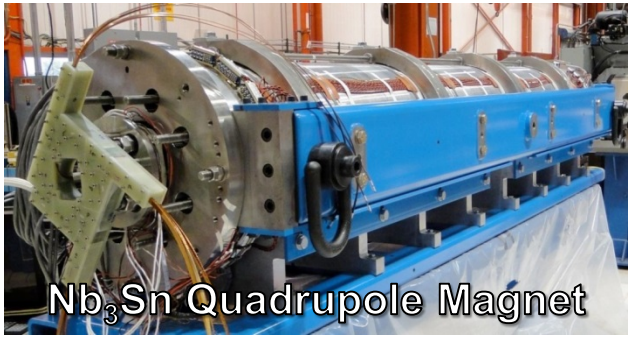




LHC – a Central Component of the Energy Frontier Program

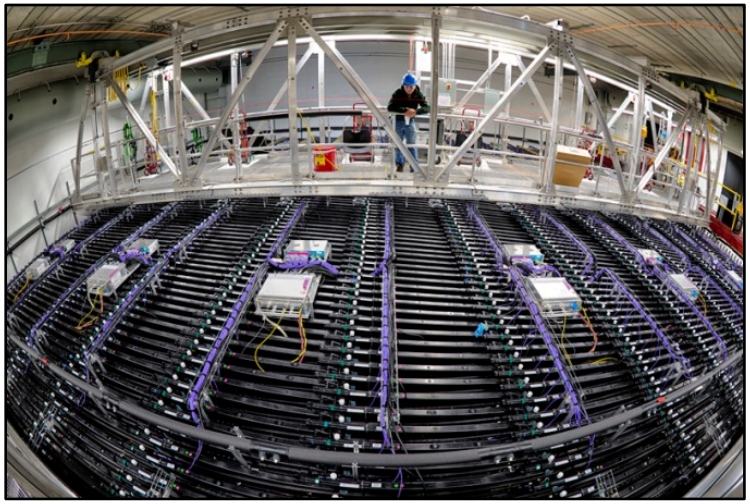
- U.S. investments enable leading roles in the global LHC physics collaborations
- P5 report identified LHC upgrades as the highest priority near-term large project and specifically recommends:
  - Complete in 2018 modest upgrades of ATLAS and CMS experiments to maintain performance.
  - Continue collaborations with the High-Luminosity LHC (HL-LHC) upgrades of the accelerator and the ATLAS and CMS experiments (2023-25)
    - HL-LHC upgrades will increase LHC luminosity by a factor of 10 beyond its design value and significantly extend discovery potential
- U.S. leadership in superconducting magnet technology in general, and with Nb_3Sn in particular, is widely recognized and acknowledged
  - U.S. LHC Accelerator Research Program (LARP) aims to leverage this expertise to serve needs of HEP community





Short- and Long-baseline Neutrino Experiments at Fermilab

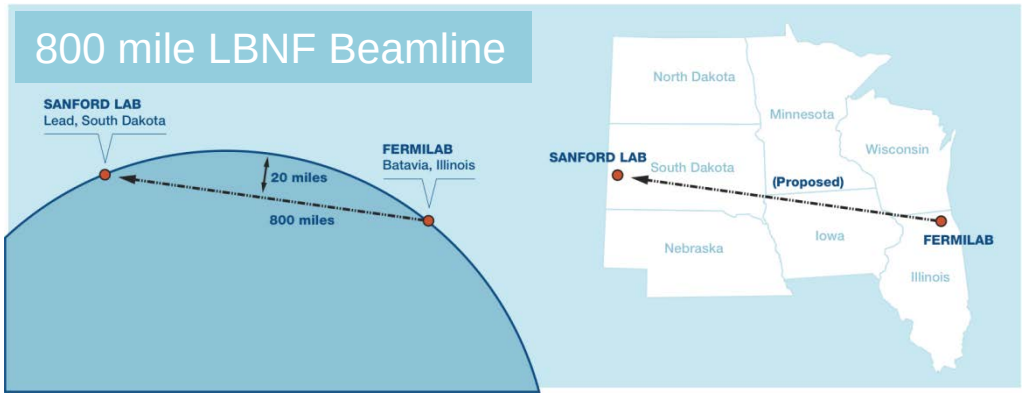
- NOvA taking data using the world's most powerful neutrino beam and the world's longest baseline
  - o World's highest intensity neutrino beam sent 500 miles from Fermilab to Ash River, MN
  - o Project completed on time and under budget in September 2014
  - o Currently operating as part of the planned six-year run

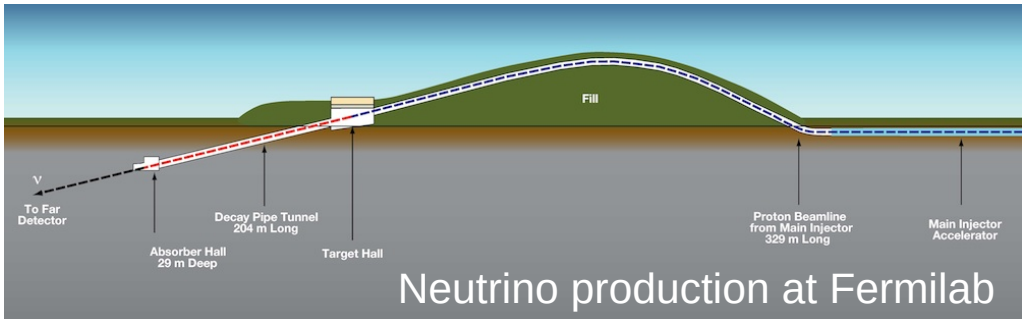


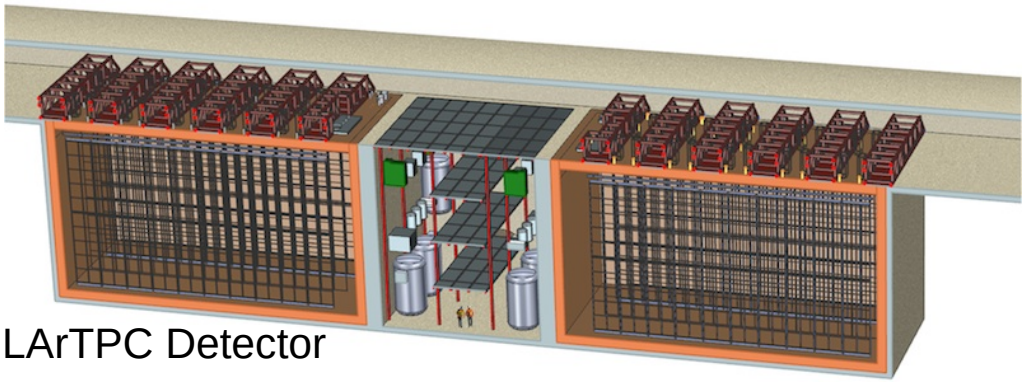
- MicroBooNE, a key first step in the Fermilab short baseline neutrino program, begins three year run in 2015
  - o Largest liquid argon based neutrino detector built in the U.S., at 170 tons of total liquid argon mass
  - o Important step in development of large-scale liquid argon technology for future Long Baseline Neutrino Facility detector

Long Baseline Neutrino Facility

- U.S.-hosted, world-class Long Baseline Neutrino Facility identified by P5 as “the highest-priority large project in its timeframe.”
- Community, led by Fermilab, is continuing the design process for an internationalized LBNF, with current design featuring:
  - New neutrino beam at Fermilab with over 1 megawatt of initial beam power
  - 800 mile distant large Liquid Argon Time Projection Chamber (LArTPC) detector deep underground at Homestake mine in Lead, SD



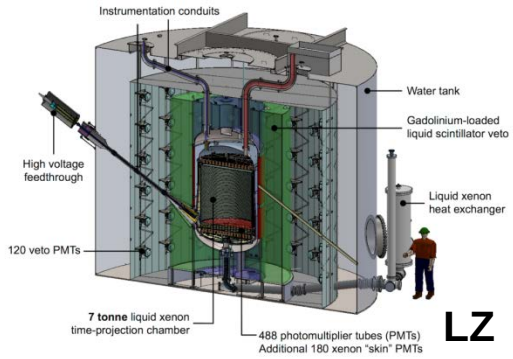




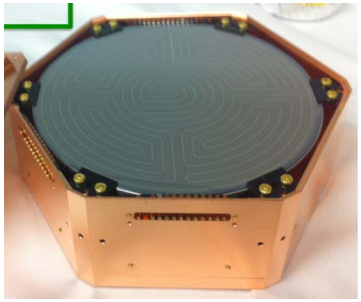
LArTPC Detector

Investments in Dark Matter and Dark Energy

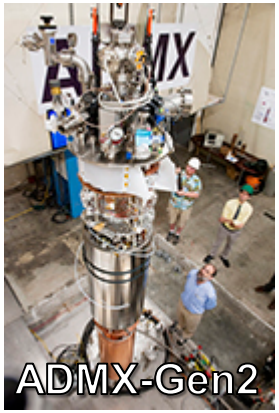
- P5 recommended strong immediate investments into the second generation dark matter direct detection program
  - 2015 MIEs, 2016 baselining for LUX-Zeplin (LZ) and SuperCDMS–SNOLab to collectively provide sensitivity to both low- and high-mass WIMPs
  - Small-scale ADMX-Gen2 supported to perform complementary search for axions
  - Program includes broad, coordinated R&D for future experiments



LZ



SuperCDMS-SNOLab



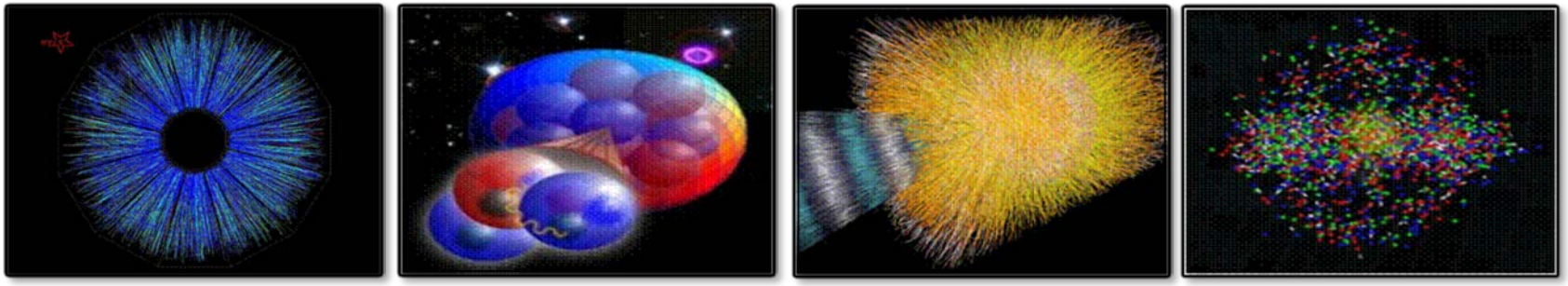
- P5 encouraged support for the Dark Energy Spectroscopic Instrument (DESI) as part of the dark energy program
  - DESI has MIE start in 2015 and will be baselined in 2016
  - Will provide spectroscopic complement to imaging-based LSST

DESI

Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

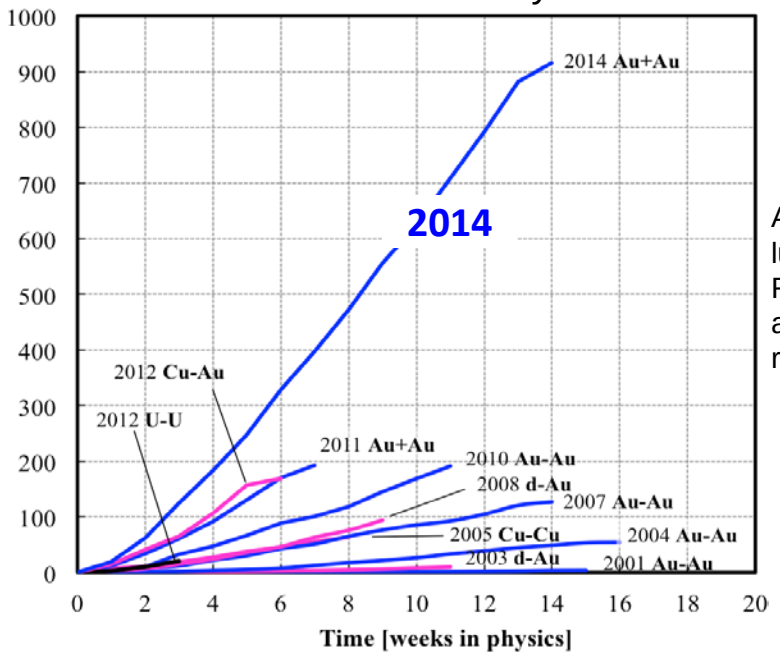
- Funding for **research** increases in every NP subprogram to support high priority research areas, e.g., in nuclear structure, nuclear astrophysics, the study of matter at extreme conditions, hadronic physics, fundamental properties of the neutron, and neutrinoless double beta decay. (Increase = +$13,843K or 8.1%)
- Research at **RHIC** capitalizes on record luminosity and new capabilities to probe the perfect Quark-Gluon liquid. The FY 2014 run commissioned the Heavy Flavor Tracker, (new microvertex detector); the FY 2015 run will generate baseline data from proton+proton and proton+Au collisions; the FY 2016 run will generate the definitive Au+Au data to inform our understanding of the perfect liquid, discovered at RHIC in 2005.
- The **12 GeV CEBAF Upgrade** continues beam development and commissioning activities in preparation for project completion and the full start of the 12 GeV physics program in 2017.
- Construction continues on the **Facility for Rare Isotope Beams** to provide unparalleled opportunity for research on nuclear structure and nuclear astrophysics.
- Upgrades of the **ATLAS** ion source and Booster Cyromodule provide new scientific capability for understanding nuclear structure and the origin of the elements in the cosmos.
- Research, development, and production of **stable and radioactive isotopes** is provided for science, medicine, industry, and national security.



Relativistic Heavy Ion Collider

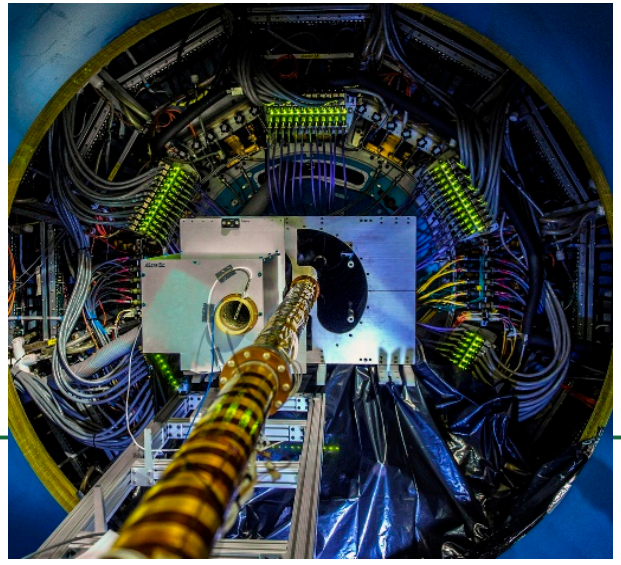
- RHIC operates for 22 weeks, the same as FY 2015.
- The FY 2016 run (Run-16) is essential to understand results on heavy quark propagation in the quark-gluon plasma discovered at RHIC.
- The high statistics data planned for Run-16 will address these phenomena and are required for researchers to interpret the data acquired from the last two years.
- Funds for experimental equipment, accelerator R&D, and materials and supplies are provided to optimize operations, maintenance, and support critical staff.

Record RHIC Luminosity Achieved

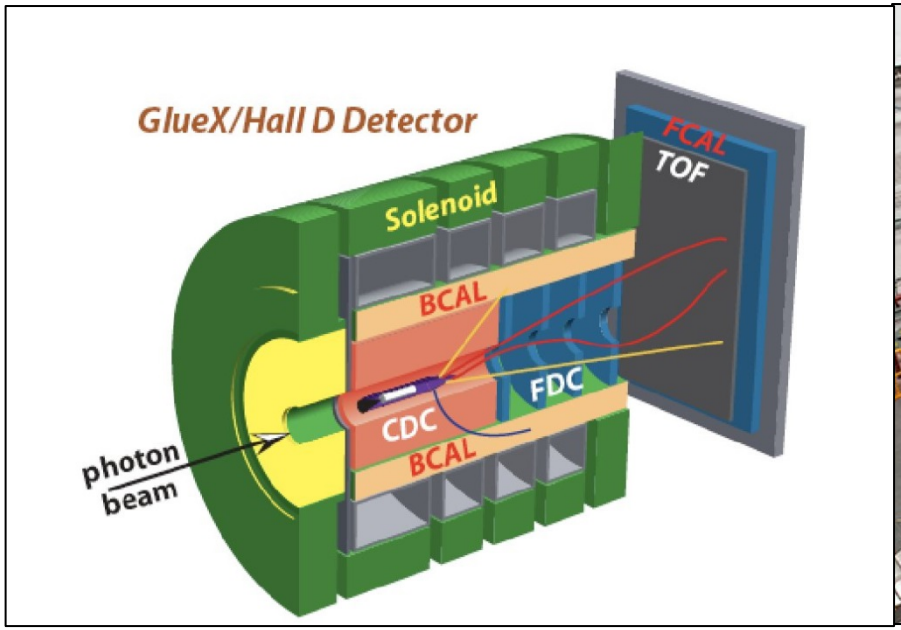


Au + Au integrated luminosity from Run 14 exceeded all previous Au+ Au runs combined

New micro-vertex detector (Heavy Flavor Tracker) will detect particles containing charm and bottom quarks to characterize the quark-gluon plasma



The 12 GeV Upgrade at CEBAF



- FY 2016 funding supports continued machine development and associated incremental power costs to support the 12 GeV research program, including engineering operations to Hall D and commissioning of newly installed hall equipment for physics running starting in FY 2017.
- Major milestones in FY 2016 will be establishing first beams to Halls B and C for commissioning activities.
- Increased funding for commissioning the upgraded CEBAF facility is provided for operations and experimental support for staff, incremental power costs, and experimental equipment for Halls B, C, and D as the 12 GeV CEBAF experimental program is initiated.

Facility for Rare Isotope Beams

FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000 and will provide world-leading capabilities for research on:

Nuclear Structure

- The limits of existence for nuclei
- Nuclei that have neutron skins
- Synthesis of super heavy elements

Nuclear Astrophysics

- The origin of the heavy elements and explosive nucleo-synthesis
- Composition of neutron star crusts

Fundamental Symmetries

- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

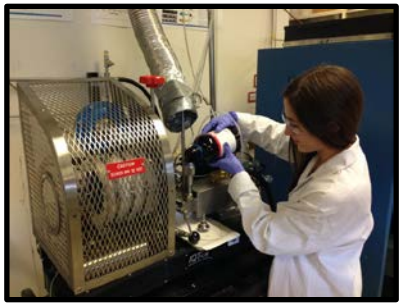
This research will provide the basis for a model of nuclei and how they interact.

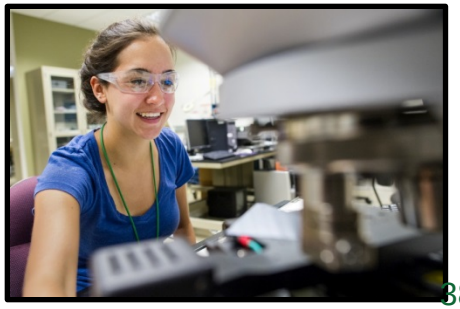
Concrete for the floor of the target area was placed December 1-2. It took around 30 hours and 300 concrete trucks to place the 2,700 cubic yards of concrete. FRIB received Critical Decision 3B, Approval to Start Technical Construction, on August 26, 2014.

Workforce Development for Teachers and Scientists

Ensuring a pipeline of STEM workers to support the DOE mission

- At DOE labs and facilities, WDTS will support ~1,000 students and faculty
  - 750 Science Undergraduate Laboratory Interns (SULI) placed at one of 17 DOE labs or facilities
  - 70 Community College Interns (CCI)
  - ~100 graduate students engaged in Ph.D. thesis research for 3-12 months at a DOE laboratory
  - 60 faculty and 25 students in the Visiting Faculty Program (VFP)
- Support for the National Science Bowl
  - More than 20,000 students, coaches, and volunteers participate in the regional and final competitions.
  - In FY 2015, there are 118 regional events, involving 14,000 students from all fifty states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. WDTS brings the regional winners, the top 4% of the teams, to Washington, D.C. for the final competitions.
- Support for 6 Albert Einstein Distinguished Educator Fellows
- Support for on-line business systems modernization
  - This activity modernizes on-line systems used to manage applications and review, data collection, and evaluation for all WDTS programs.
- Support for program evaluation and assessment
  - This activity assess whether programs meet established goals using collection and analysis of data and other materials, such as pre- and post-participation questionnaires, participant deliverables, notable outcomes, and longitudinal participant tracking.





Science Laboratories Infrastructure (SLI)

More than $600 million of line item investments on time, within budget since 2006

FY 2016 provides continued funding for:

- **Materials Design Laboratory (ANL)** to house research in materials science and related disciplines.
- **Photon Science Laboratory Building (SLAC)** to provide modern lab and office space for the expansion of SLAC's photon science programs, using SSRL and LCLS-II.
- **Integrative Genomics Building (LBNL)** to begin the consolidation of a significant fraction of the biosciences research currently now located in widely distributed commercially leased space.

Funding is also provided for:

- General purpose infrastructure: electrical upgrades at SLAC and ANL and facility improvements at FNAL.
- Continued funding of the New Brunswick Laboratory for infrastructure support and for transfer and shipment of material.
- Nuclear operations support at ORNL.

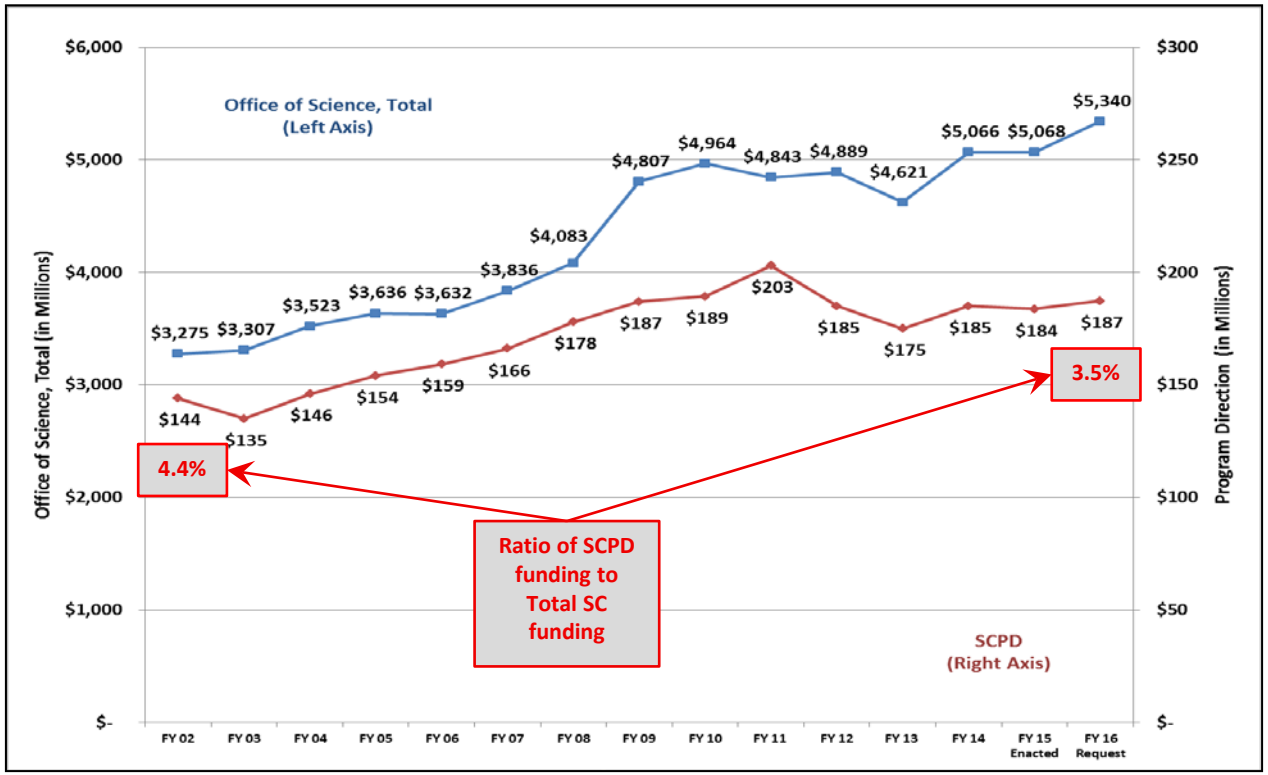
Safeguards and Security

Supporting protection against unauthorized access, theft, or destruction of assets

- Support to maintain adequate security for the special nuclear material housed in Building 3019 at the Oak Ridge National Laboratory.
- Increase in cyber security investments to ensure the Cyber Security Program has the funds needed to defend against cyber security compromises, minimize future losses of protected information, and detect repeated attempts to access information technology assets critical to support the SC mission.
- Support for the CyberOne strategy--DOE's solution for managing enterprise-wide cyber-security for incident response and identity management to mitigate the risk of intrusion.

Program Direction

The FY 2016 PD budget supports 945 FTEs



During the past 15 years, the ratio of the Program Direction budget to the SC appropriation has decreased from 4.4% to about 3.5% -- now the lowest ratio in DOE. This decrease has been accomplished through detailed analyses and execution of optimum staffing levels in both the SC Site Offices and the SC Headquarters program offices.

Support for:

- Management of the Office of Science programs, facilities, and projects;
- Business operations associated with portfolio management;
- Office of Science Information Technology Modernization Plan (ITMP) – the consolidation of data centers, IT support service contracts, and more efficient technologies;
- Federal travel for scientific program and laboratory operations oversight; and
- President's Council of Advisors on Science and Technology (PCAST).