The U.S. Department of Energy's Ten-Year Plans

for the

Office of Science National Laboratories

Fiscal Year 2011

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Table of Contents

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Introduction

The Department of Energy (DOE) Office of Science (SC) is responsible for the effective stewardship of ten national laboratories. The DOE national laboratories were created as a means to an end: victory in World War II and national security in the face of the new atomic age. Since then, they have consistently responded to national priorities: first for national defense, but also in the space race and more recently in the search for new sources of energy, new energy-efficient materials, new methods for countering terrorism domestically and abroad, and addressing the challenges established in the President's American Competitive Initiative (ACI) and the Advanced Energy Initiative (AEI).

Today, the ten national laboratories for which SC is responsible comprise the most comprehensive research system of their kind in the world. In supporting DOE's mission and strategic goals, the SC national laboratories perform a pivotal function in the nation's research and development (R&D) efforts: increasingly the most interesting and important scientific questions fall at the intersections of scientific disciplines—chemistry, biology, physics, astronomy, mathematics—rather than within individual disciplines. The SC national laboratories are specifically designed and structured to pursue research at these intersections. Their history is replete with examples of multi-and inter-disciplinary research with far-reaching consequences. This kind of synergy, and the ability to transfer technology from one scientific field to another on a grand scale, is a unique feature of SC national laboratories that is not well-suited to university or private sector research facilities because of its scope, infrastructure needs or multidisciplinary nature.

As they have pursued solutions to our nation's technological challenges, the SC national laboratories have also shaped, and in many cases led, whole fields of science—high energy physics, solid state physics and materials science, nanotechnology, plasma science, nuclear medicine and radiobiology, and large-scale scientific computing, to name a few. This wide-ranging impact on the nation's scientific and technological achievement is due in large part to the fact that since their inception the DOE national laboratories have been home to many of the world's largest, most sophisticated research facilities. From the "atom smashers" which allow us to see back to the earliest moments of the Universe, to fusion containers that enable experiments on how to harness the power of the sun for commercial purposes, to nanoscience research facilities and scientific computing networks that support thousands of researchers, the national laboratories are the stewards of our country's "big science." As such, the national laboratories remain the best means the Laboratory knows of to foster multi-disciplinary, large-facility science to national ends.

In addition to serving as lynchpins for major laboratory research initiatives that support DOE missions, the scientific facilities at the SC national laboratories are also operated as a resource for the broader national research community. Collectively, the laboratories served over 25,000 facility users and over 11,000 visiting scientists in Fiscal Year (FY) 2010, significant portions of which are from universities, other Federal agencies, and private companies.

SC's challenge is to ensure that these institutions are oriented to focus, individually and collectively, on achieving the DOE mission, that Government resources and support are allocated to ensure their long-term scientific and technical excellence, and that a proper balance exists among them between competition and collaboration.

This year, SC engaged its laboratories in a strategic planning activity that asked the laboratory leadership teams to define an exciting, yet realistic, long-range vision for their respective institutions based on agreed-upon core capabilities assigned to each.[1] This information provided the starting point for discussions between the DOE/SC leadership and the laboratories about the laboratories' current strengths and weaknesses, future directions, immediate and long-range challenges, and resource needs, and for the development of a DOE/SC plan for each laboratory. This document presents DOE/SC's strategic plans for its ten laboratories for the period FY 2011-2020.

[1] A table depicting the distribution of core capabilities across the SC laboratories is provided in Appendix A. Appendix B provides the definitions for each core capability category, Appendix C provides a listing funding sponsors, and Appendix D provides a listing of the DOE missions.

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Ames Laboratory

Mission/Overview

The Ames Laboratory (AMES) was formally established in 1947 by the United States Atomic Energy Commission as a result of AMES' successful development of the most efficient process to produce high-purity uranium metal in large quantities for the Manhattan Project. Situated on the campus of Iowa State University, the management and operating (M&O) contractor, the Laboratory's mission is to create materials, inspire minds to solve problems, and address global challenges. AMES is the premier DOE national laboratory for research on rare earths. AMES operates the Materials Preparation Center (MPC) which prepares, purifies, fabricates and characterizes materials in support of R&D programs throughout the world. AMES also performs research for the DOE's applied energy technology and nonproliferation programs and, through its Work for Others (WFO) program, provides research and materials to the National Institute of Justice, Department of Defense, various law enforcement agencies, and corporations. AMES researchers have won 17 R&D 100 Awards from R&D Magazine, which selects the 100 most significant technical products and innovations each year. Educating the next generation of scientists is a key component of the research at AMES; since 1947, over 3000 Masters and Ph.D. degrees in science and engineering have been awarded to ISU students working on DOE funded projects.

Materials design, synthesis and processing, including rare earths; analytical instrumentation/device design/fabrication; materials characterization; catalysis; condensed matter theory (including photonic band gap and other novel materials); and separation science are key areas of expertise at AMES. These areas enable AMES to deliver its mission and customer focus, to perform a core role in the DOE laboratory system, and to pursue its vision for scientific excellence and pre-eminence in the areas of:

- Materials research directed towards energy technologies including alternatives for rare earths, optical, magnetic, intermetallic, and catalytic materials; studies of high temperature materials and materials in extreme conditions; and
- Analytical techniques and instrument development.

Current Core Capabilities

The Office of Science (SC) has identified 3 core capabilities at the Ames Laboratory.

Lab-at-a-Glance

Location: Ames, Iowa

Type: Single-program Laboratory

Contractor: Iowa State University

Responsible Site Office: Ames Site Office

Website: www.ameslab.gov

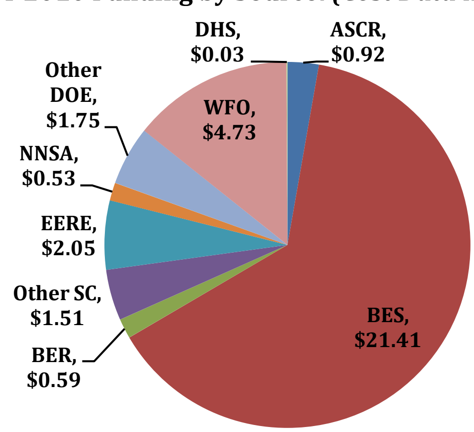
Physical Assets:

- 10 acres (lease–long term, no cost) and 12 buildings
- 327,664 GSF in buildings
- Replacement Plant Value: $73.1M
- Deferred Maintenance: $1.44M
- Asset Condition Index:
  - Mission Critical: 0.979
  - Mission Dependent: 0.967
  - Asset Utilization Index: 0.978

Human Capital:

- 307 Full Time Equivalent Employees (FTEs)
- 103 Joint faculty
- 53 Postdoctoral Researchers
- 70 Undergraduate Students
- 109 Graduate Students
- 0 Facility Users
- 1 Visiting Scientists

FY 2010 Funding by Source: ***(Cost Data in $M):***



FY 2010 Total Lab Operating Costs (excluding ARRA*)*: $33.5
FY 2010 Total DOE/NNSA Costs: $28.76
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $4.7
FY 2010 WFO as % Total Lab Operating Costs: 14%
FY 2010 Total DHS Costs: $0.032

ARRA Obligated from DOE Sources in FY 2010: $0.0
ARRA Costed from DOE Sources in FY 2010: $1.54

1. Condensed Matter Physics and Materials Science

The theory, design, synthesis, processing and characterization of innovative, energy-relevant materials comprise one of the Ames Laboratory's primary research foci. The Laboratory is widely recognized for its leading work on rare earth metals and alloys, photonic band gap materials, metamaterials, magnetic materials, high temperature superconductors, surfaces, and biomaterials. It is also widely recognized for its ability to grow high quality samples of unusual materials, which it distributes all over the world; one such example being the iron arsenic samples being supplied to research organizations worldwide. The Lab's condensed matter physics and materials sciences teams develop and use cutting-edge techniques to study these systems, including X-ray and neutron scattering, and solid-state nuclear magnetic resonance (SSNMR). Computational methods such as quantum Monte Carlo simulations, electronic structure calculations, and classical and quantum molecular dynamics simulations are continually being pushed to new limits for 'taming the complexity' of new chemistry and material problems.

The current resurgence of interest in rare earth materials, including their properties, processing and reclamation, has put the Ames Laboratory in the international spotlight. The DOE AMES is the only National Laboratory with the background intellectual property, expertise, know-how and world-class researchers to develop new cost-effective processing techniques, improved properties and new materials to replace the rare earth metals that are becoming difficult to obtain. To enable critical new alloys, the Laboratory is investigating the fundamental origin for properties of rare earths governed especially by *4f electron* element behavior during alloy modifications; society would benefit greatly if we can control valence states of more abundant early lanthanides needed, e.g., for higher Curie temperatures and saturation magnetization in magnets.

Major sources of funding for this core capability include: The Office of Science's Basic Energy Sciences and Advanced Scientific Computing Research programs, the Office of Energy Efficiency and Renewable Energy, and Work for Others.

2. Chemical and Molecular Science

DOE Ames Laboratory research teams develop and apply theoretical, computational and experimental methods to study biological processes, catalysts, chemical reactivity, energy conversion and surface dynamics. World-leading research is conducted at the interface between homogenous and heterogenous catalysis enabling the design of new catalysts that combine the best characteristics of both. The Laboratory improves understanding of molecular processes for energy and security decision-making, and molecular design using new simulation and modeling techniques. These methods are made available throughout the world, including GAMESS used by over 150,000 registered users.

The Ames Laboratory enables new discoveries through the development of new techniques to characterize a broad range of materials at time scales and lengths scales never before possible. Single-cell analysis is a forte of the Ames Laboratory. The Laboratory's work also involves the sensitive detection of chemicals, including chemical imaging within biomaterials. Recent developments, for example, enable an unprecedented look inside living cells. AMES is also developing novel probes for imaging within plants. The Ames Laboratory is internationally recognized for the development of new solid-state nuclear magnetic resonance (SSNMR) methods, optical spectroscopy, mass spectrometry and microscopy. The techniques can be used in applications ranging from bioenergy to bioremediation to national security.

Major sources of funding for this core capability include: The Office of Science's Basic Energy Sciences, Biological and Environmental Research, and Advanced Scientific Computing Research programs, and Work for Others.

3. Applied Materials Science and Engineering

Civilization advances with the capability to create new or improved materials. Applying the fundamental knowledge derived from the Laboratory's basic computational, theoretical and experimental research, researchers at AMES create diverse research teams to invent, design, and synthesize new materials with specific energy- and environment-relevant properties. The Ames Laboratory develops, demonstrates, and deploys materials that accelerate technological advancements in a wide range of fields; from a lead-free solder that is used virtually in all electronics to a nanotube with the potential to deliver drugs or other materials to a specific site within a living cell. The Ames Laboratory is world-renowned for developing materials that improve energy efficiency and conversion, and reduce environmental impact. Key impacts of the Ames Laboratory's work in applied materials science and engineering include catalysts, ultra-hard materials, low friction materials, special magnetic alloys, high temperature superconductors, light-weight high-strength materials and engineering alloys that are responsive to energy and environmental concerns.

Renewed interest in rare earths and rare earth replacements has brought several potential industrial partners to the Laboratory. In fact, AMES has several new projects underway funded by DOE or by U.S. industrial partners. Discussions started last year to set the direction for AMES continue as the interest in rare earths availability and alternatives remain a national issue. AMES is working towards solutions in rare earths science to help assure new economically viable rare earth processing techniques, new non-rare earth materials for national defense and improved energy technologies such as traction motors and magnets, and new techniques to recover these metals from waste and scrap. AMES is working with key industrial partners to assure the availability of these metals or to find acceptable alternatives to critical materials such as neodymium-iron-boron magnets.

Major sources of funding for this core capability include: The DOE Office of Energy Efficiency and Renewable Energy programs, specifically, Biomass, Vehicle, and Industrial Technologies, as well as Work for Others.

Science Strategy for the Future

DOE's vision is for AMES to be the nation's premier research institute in critical areas of condensed matter, its related technologies, and the strategic applications of advanced materials. Dramatic energy efficiency improvements require new ways of harvesting and converting energy from one form to another, enabled by new materials with enhanced functionalities. Over the next 10 years, AMES will focus its efforts on developing improved energy-conversion techniques, materials for energy efficiency, and new integrated methods to discover and process materials more efficiently with desired functionalities. AMES excels in the areas of materials processing methods, computational and theoretical materials science, rare earths, catalysts, magnetic and photonic materials, and analytical instrumentation development. AMES links basic and applied research across the scientific spectrum to achieve and maintain an impressive record of technology transfer success. AMES solves challenging problems by engaging multidisciplinary teams of world-renowned experts, including researchers from other National Laboratories and universities.

The Ames Laboratory's proposed initiatives are designed to transform the Nation's energy future and fill critical technological gaps. These initiatives build upon the Laboratory's core capabilities and components for excellence: people, inspiration, innovation, collaboration, agility, and safety. The Ames Laboratory's research will continue to help lead the way for the U.S. to reduce energy demand, innovate with new materials, control energetic processes, and use the Nation's biorenewable resources.

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

The Ames Laboratory is a Government-owned, contractor-operated facility located on the campus of and operated by Iowa State University (ISU) in Ames, Iowa. There is no federally owned land at the site (See The Ames Laboratory Land Use Plan, (https://www.ameslab.gov/content/land-use-plan). Instead, the Laboratory is situated on approximately 10 acres of state-owned land on the ISU campus under long-term, no cost lease. The lease line can be adjusted to accommodate new Laboratory facilities in the future (see Attachment C). The real property assets include 12 buildings that total 327,664 gross square feet. The three laboratory research buildings represent over 70% of the area and have an average age of 57 years. The newest research building in the inventory was constructed 50 years ago. The average age of the entire inventory (prorated by area) is 48 years. The buildings are highly utilized with an Asset Utilization Index (AUI) of 0.978. The buildings have been well maintained over their lifetimes and are currently in good condition as indicated by an Asset Condition Index (ACI) of 0.978. However, the research buildings were designed and built for the research needs and activities of the 1950's. As such, even though they are in good condition, they do not provide the effective and efficient infrastructure needed to support current and future research activities at the cutting edge of materials research. Staffing in FY2010 was 307 full time staff (FTEs). In addition there were also approximately 400 associates who perform research in the Ames Laboratory facilities. There are also two other real property assets defined in the Facility Information Management System (FIMS), an electrical switch pit and parking lot.

Being located on the University campus, allows the Laboratory to take full advantage of the infrastructure services provided by ISU, such as steam, chilled water, water and sewage service, compressed air, grounds maintenance, telecommunication systems, and roads without the need for Federal investment to construct, maintain, or recapitalize. The availability of these services allows the Laboratory to focus on maintaining and operating its research and support buildings. The relationship with ISU also enables the Laboratory to use space in University–owned buildings through a space usage agreement without investing in permanent space or long-term leases (33,000 nusf in 11 buildings).

No real estate actions are planned for FY 2011 or FY 2012.

Table 1. SC Infrastructure Data Summary

Replacement Plant Value ($M)		73.1
Total Deferred Maintenance ($M)		1.44
Asset Condition Index	Mission Critical	0.979
	Mission Dependent	0.967
	Non-Mission Dependent	N/A
Asset Utilization Index	Office	0.964
	Warehouse	1.000
	Laboratory	0.977
	Housing	N/A
Prior Year Maintenance ($M)		1.142

Facilities and Infrastructure to Support Laboratory Missions

The Ames Laboratory is dedicated to providing facilities and infrastructure that will effectively support its mission now and into the future. AMES also strives to be an effective steward of the DOE assets entrusted to it by managing them with a long-term view which is quality driven, looks at the life cycle of the assets, utilizes best industry practice, and is commensurate with the value and mission impact of the asset. This management links real property asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. Resources are directed to facilities and infrastructure in the context of the overall needs and operation of the Laboratory to carry out its mission.

The Mission Readiness tables (attached) provide a summary of the condition of the facilities from a mission readiness point of view, now and into the future. These tables list the core capabilities and the investments required to make the facilities and infrastructure fully capable to meet the mission needs within the 10-year planning window. In accordance with the definitions from the Mission Readiness Model, the research buildings are currently considered "Partial." This means that deficiencies require minor resources (work-arounds) to ensure achievement of mission; investments to return to mission ready, if capital, are within the GPP limit. The facility capital improvements are possible within the GPP limit of $10M per project but the current level of GPP funding does not allow the Laboratory to undertake those projects. Two mission critical needs identified during the mission readiness process are space for sensitive research instruments and scientific computation space. State of the art instruments, such as electron microscopes, demand infrastructure requirements for vibration, noise, temperature control, dust, power quality and electromagnetic interference to perform to their full potential. In the Laboratory's existing facilities, space for these sensitive instruments is not available without extensive modifications and, even then, they must be sited in locations that are marginally acceptable. Installation into marginal space compromises the ability to achieve optimal data results. Current scientific computation facilities are filled to capacity so that future expansion will require allocating new space for new systems within research bays while trying to provide adequate cooling and increased electrical demands in a room not designed for those increased requirements.

Strategic Site Investments

The Ames Laboratory embraced the Office of Science SLI Infrastructure Modernization Initiative that has the goal of the SC laboratories operating thoroughly modernized complexes by the end of the ten-year period (FY2010-FY2020). The Modernized facilities will encompass the following characteristics:

- Safe, Secure, and Environmentally Sound Infrastructure

- A Highly Productive Working Environment
- Efficient Operations and Maintenance

As part of this effort, the Ames Laboratory developed a modernization strategy. The primary component of the original plan was to replace the Metals Development Building with a new state of the art, LEED compliant building that would address the critical needs of the Laboratory. At last year's Lab Planning Meeting, it was suggested that Laboratory Management look for ways to meet the Laboratory's highest priority needs with smaller projects. The following portion of this plan will convey what the Laboratory sees as its highest priority needs for consideration by DOE's Office of Science. The Laboratory sees two options for funding the construction projects, SLI or GPP, and the Laboratory seeks advice as to how to package these requests.

1. Sensitive Instrument Facility

In this infrastructure initiative, AMES proposes a sensitive-equipment facility, especially for high-resolution TEM and STM, to resolve a critical issue with vibration and other environmental effects that limit the Laboratory's current characterization capabilities. This facility would consolidate several of the CĀM-2C special-use apparatus into a single facility and resolve these issues. This Facility will provide specialized space for current and anticipated state-of-the-art instrumentation such as high resolution transmission electron microscopes and scanning probe microscopes. This meets one of the critical gaps identified in AMES' mission readiness process.

The space that currently exists within Ames Laboratory is marginally adequate for instruments presently in use and is unacceptable for today's state-of-the-art instruments (see chart at right). In order to quantitatively assess the need for new space, a consulting firm was retained to measure floor vibration, electromagnetic interference (EMI) and acoustic intensity levels at ten locations in existing Ames Laboratory space that might be candidates for installations. Using the requirements for a current state-of-the-art transmission electron microscope, none of the ten locations met the installation criteria. While some of these locations might be made to work with extensive modification, the instruments would not be able to perform to their maximum ability.

Location	Vertical Vibration	Horizontal Vibration	DC EMI	AC EMI	Accoustic Vibration
MD #1	N	Y	Y	N	N
MD #2	N	N	N	N	N
MD #3	N	N	N	N	N
MD #4	N	N	Y	N	N
SPH #1	Y	Y	Y	N	N
SPH #2	N	N	Y	N	N
SPH #3	N	N	N	N	N
HWH #1	Y	Y	Y	N	N
HWH #2	N	N	Y	Y	N
HWH #3	Y	N	N	N	N

Figure 1. Identification of Building Floors that meet FEI Electron Microscope Requirements.

This project will build a facility with six instrument bays, sample prep lab, control rooms, and staff support space. The electron microscope bays will provide vibration isolation, acoustic separation and control, EMI control, strict control of air flow and strict ambient temperature and humidity control. The facility design has been organized to optimize the site and program elements. In a compact, space efficient envelope, the building is planned to be approximately 11,000 gross square feet and will provide 7,000 net square feet of usable space (i.e., 64% is usable space).

Total cost is estimated at $9.3M. Iowa State University has a proposal submitted to NIST to build a very similar facility on campus, and Ames Laboratory proposes to co-locate the DOE facility with the ISU facility. This will provide great synergy by encouraging greater collaboration and providing access to a broader set of resources in both capacity and capability. If ISU is not able to build their facility, a location adjacent to existing Ames Laboratory facilities will be selected. Ames proposes that GPP funds be used for the facility. With the aid of the Laboratory's Contractor, locations for the proposed building have been identified and conceptual architectural plans have been developed. AMES anticipates that construction cost savings could be obtained if AMES combines this facility with one proposed to be constructed by the Laboratory Contractor. Alternatively, this project could be combined with other facility and infrastructure mission needs such as the Scientific Computing Facility to develop a line item project if a lower level of SLI funds became available.

Figure 2. Architectural Sketch of Sensitive-Equipment "Pod" Building with instrumentation and control rooms on the ground floor and preparations and small instruments, data analysis and visualization equipment on the second floor.

2. Scientific Computing Facility

This project will build a dedicated scientific computing facility that will provide for the current and future computing facility needs of the Laboratory. AMES proposes to build a dedicated stand-alone facility to house AMES' computers, to address DOE's expanding computer needs, reduce energy consumption, improve heat management, consolidate cluster management, and free up usable lab space not designed for housing computers. The current computational facilities, developed due to critical need without having critical infrastructure, are filled to capacity and scattered throughout the Laboratory's facilities in space originally designed for bench science and lack the full complement of features that are part of modern computing centers, such as raised floors, redundant systems, or energy efficient components. Expansion requires remodeling additional bays to house new machines; including additional requirements for HVAC and electricity.

The new facility would be designed to utilize the latest techniques for energy efficiency that are not possible when modifying existing space. The facility would be approximately 10,000 square feet and provide approximately 5,000 square feet for computers and 2,000 square feet of ancillary space including offices for the cluster support staff. The estimated cost is $9.9M. Ames proposes that GPP funds be used for the facility, however, if a lower level of SLI funds became available, this project could be combined with other facility and infrastructure mission needs, such as the Sensitive Instrument Facility, to develop into a line-item project.

3. Center for Rare Earth and Energy Related Materials

As discussed in the Major New Initiatives section, a new initiative is being proposed for a Center for Rare Earth and Energy Related Materials (CREEM). The Center will require office space for administrative and scientific staff, general laboratory space and some high bay space. Significant space consolidation, reassignment and remodeling will be required to accommodate those needs within the existing footprint. Space in this Center will be a combination of assigned space, space vacated as a result of the proposed new facilities and from consolidation of existing space enabled by adoption of modern technologies. Existing space will have to be remodeled to accept these people, their equipment and research operations. The vacated space will then need to be prepared for the new center. As part of the mission readiness process, it became clear that there is a need for a more strategic way to deal with existing space. As is currently the case, a program may have space in several different buildings. The creation of a dedicated CREEM provides an opportunity to enable programs to consolidate their operations into a more efficient footprint and to consolidate space for the new center. Initiatives are already under way to remove unused equipment to free up space in existing labs. An example of this is the removal of an un-used extrusion press. Removing under-utilized equipment will allow the metal fabrication functions of both the Materials Preparation Center and the Engineering Services Group to be consolidated into one area. Providing a consolidated area for the new center will require that people be relocated out of targeted space. The facility renovation cost for the new center is estimated to be $6.5M.

AMES' infrastructure needs could be funded as individual GPP projects or consolidated into one improvement project under SLI. In discussion with key DOE individuals, AMES will develop an overall strategy (GPP vs. SLI; GPP and SLI; replace vs. refurbish) for meeting the Laboratory's infrastructure needs. There are several decisions points that affect AMES' strategy:

1) for the Sensitive Instrument Facility: if the Laboratory's Contractor decides to build a facility for their use, cost savings may be realized by the Laboratory by partnering on the design and construction of the facility;
2) the Scientific Computing Facility will help the Laboratory meet energy savings requirements;
3) the CREEM will help meet National critical needs; and
4) all three facilities impact Ames' contribution to DOE's missions.

4. New Research Building

If Ames experiences significant growth, then the facilities proposed above will meet some of the Laboratory's immediate needs for specialized space but will fall short of long-term facility needs. Ames Laboratory's present buildings are all more than half a century old. They have been well maintained over the years, but lack the features needed to accommodate modern research needs. Space utilized at the Laboratory continues to develop in a fragmented direction and fails to meet the needs of the researchers due to the constraints imposed by the Laboratory's existing buildings. A new facility will support collocation of research teams to work on common problems and allow better utilization of current buildings. It will provide a preferred work environment that will help attract and retain high quality staff and will also contribute to increasing staff productivity and facilitate the collaboration and teaming approach that characterizes research at AMES. A building with flexibility designed into it will allow space to be reconfigured quickly and efficiently when there are changes in research activities and technologies. There will be areas for collaborative meetings that have the technological tools to facilitate interactions both within the lab and with researchers working remotely.

The proposed building will have the capability to efficiently deal with the more stringent ventilation requirements of working with new and advanced materials that may be more toxic or reactive. It will include office, laboratory and conferencing space for the research staff. The building will be designed to achieve LEED Gold Certification and will utilize natural light and renewable energy where possible. The focused application of current technology and design will achieve energy savings (>50%) that would not be possible within the Laboratory's existing buildings. The staff housed in this building will have access to the resources housed in the Sensitive Instrument Facility and the Scientific Computing Facility which will reduce the need for specialized space in the new building. It is anticipated that AMES would be able to reduce the amount of space rented from ISU. AMES has not developed an estimate for size or cost of the facility, so for this year's IFI Crosscut the Laboratory has input the estimates for the MD Replacement Building contained in the SLI schedules. Ames Laboratory will need to update the Laboratory's gap analysis and design criteria as AMES and DOE further discuss and develop this plan.

5. Energy Savings Performance Contract

AMES was unable to utilize funding for energy savings projects through an Energy Savings Performance Contract (ESPC) due to beryllium contamination discovered in Spedding Hall and Wilhelm Hall. The ESPC partner had identified projects that would generate savings of 15% in energy consumption and 16% of water consumption. The project included stack lining, lighting upgrades and low-flow water fixtures. Though the ESPC was discontinued, AMES is using overhead and GPP funds to complete the conservation projects.

6. Current GPP Program

Historically, AMES' GPP funding level has been relatively constant in the range of $0.5 to $0.6M per year, which is less than 1% of AMES' replacement plant value. ARRA funding of $1.7M was received in FY2009 for Phase 1 of an improvement project that was completed in FY2010. The limited GPP funding requires that larger projects be phased in over several years. A heating, ventilating, & air conditioning (HVAC) upgrade project in Spedding Hall is currently in progress with existing GPP funding. This project will upgrade the existing systems of heating, ventilating and air conditioning (HVAC) and makeup air controls in Spedding Hall to improve the safety, reliability, energy efficiency and flexibility of the systems. The existing system has been in service for nearly 50 years and cannot provide the level of control, air balance, reliability and safety monitoring that is beneficial for laboratory activities. The HVAC system will be upgraded for variable air volume operation which will provide temperature control in each space independently. Because the size of the project is much greater than the annual GPP funding level, it is phased over several years using GPP funds into FY2013. Once the HVAC upgrade project is completed, GPP funding will be directed to other projects as defined by the Laboratory's planning process. Projects will include Energy Conservation Projects; Access Control; Upgrade Windows; Upgrade Electrical Distribution System in Spedding Hall; and Upgrade of Handicapped Access. Additional GPP projects for capital improvement projects in Metals Development Building will need to be incorporated into GPP plans. The space modernization project will systematically take out-of-date research space out of service and completely refurbish it to modern standards. This will provide the resources to restructure and reorganize space utilization to improve the work environment for research operations. Unused and underutilized space will be reclaimed and modernized. This will allow research programs to be housed for more efficient operations. It will also create the space needed to house new planned initiatives. The complete list of the GPP funding plan will be included in the Integrated Facilities and Infrastructure (IFI) Budget Crosscut.

7. Maintenance

The maintenance program consists of maintenance and repair activities necessary to keep the existing inventory of facilities in good working order and extend their service lives. It includes regularly scheduled maintenance, corrective repairs, and periodic replacement of components over the service life of the facility as well as the facility management, engineering, documentation, and oversight required to carry out these functions. Historically, the facilities have been well maintained so that the service lives of the buildings have been extended. The historical data shows that the Laboratory has been able to control and slightly reduce deferred maintenance levels with modest levels of indirect funded maintenance, allowing AMES to operate with a 1.8% target Maintenance Investment Index. Historical experience shows that the current levels of expenditures have been adequate to maintain the facilities. Therefore, future maintenance funding levels are projected by escalating the maintenance budget to continue this level of effort.

There are currently no excess facilities at the Ames Laboratory and none are planned.

Trends and Metrics

Performance measures are utilized to link facility and infrastructure performance to outputs and outcomes. Broad-based measures are used so that a small sample of key results can provide a high level, integrated grasp of the stewardship of DOE assets at the Ames Laboratory. The DOE corporate wide measures defined in the Real Property Asset Management Order are the Asset Condition Index and the Asset Utilization Index. These values are reported directly in the DOE Facility Information Management System (FIMS) as well as being incorporated in the Laboratory Performance Evaluation and Measurement Plan (PEMP). AMES continues to perform well in the measures with high values for Asset Utilization and Asset Condition that continue to improve, though it's important to note that even when old buildings are maintained in good condition, it does not guarantee that they can provide infrastructure that meets the mission needs of cutting-edge research. This observation certainly is reflected in an ACI of 0.978 but mission readiness ratings of "Partial" for Core Capabilities. In the 2010 EOY PEMP, Section 7, there were two notable outcomes identified; both of these outcomes met expectations resulting in an overall grade of B+.

The Ames Laboratory continues in the process of improving and documenting the Ames Laboratory Mission Readiness process. A peer review is scheduled for FY 2011. This year's mission readiness interviews with Laboratory Management, Program Directors, key researchers and Functional Managers were led by the Assistant Director for Scientific Planning, the Chief Operations Officer and the Facilities Services Manager. All three have participated as reviewers on peer reviews. The input and insight obtained from these interviews was incorporated into the Laboratory infrastructure plans. The process helps Laboratory management and facilities personnel to have an excellent understanding of the facility condition and needs. In addition to the mission readiness process, the preparation of the Mission Need Statement for the New Research Building utilized broad stakeholder input in the planning process. Key researchers provided valuable input into the limitations of existing facilities and the characteristics of a new facility that would enhance their effectiveness. A study committee with key researchers, the Budget Officer and the Facilities Services Manager was created by the Director to perform a needs analysis on scientific facilities. This work provided an excellent starting point for identifying the capability gaps in the Facilities and Infrastructure. It was this gap analysis that identified the need for both a Sensitive Instrument and a Scientific Computing Facility.

Table 2. Facilities and Infrastructure Investments (BA in $M) –Impact to Asset Condition Index

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance ($M)	1.1	1.9	1.1	1.2	1.2	1.4	1.6	1.6	1.7	1.7	1.8	2.4
Deferred Maintenance Reduction[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Excess Facility Disposition	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IGPP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GPP	0.6	0.6	7.1	9.9	10.4	2.2	1.3	1.2	1.2	1.2	1.2	1.2
Line Items	0	0	0	0	0	0	0	0	6.0	18.0	26.0	7.0
Total Investment	1.7	2.5	8.2	11.1	11.6	3.6	2.9	2.8	8.9	20.9	29.0	10.6
Estimated RPV		73.1	74.8	76.5	78.3	89.4	101.3	103.6	106.0	108.5	111.0	170.5
Estimated DM		1.47	1.49	1.51	1.36	1.38	1.40	1.41	1.43	1.45	1.47	1.48
Site-Wide ACI		0.980	0.980	0.980	0.983	0.985	0.986	0.986	0.986	0.987	0.987	0.991

Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		**Mission Ready, Current**				**Key Buildings**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N	M	P	C			**Laboratory**	**DOE**
Condensed Matter Physics and Materials Science	Now			X		SPH, HWH, MD	Note 1	▪ SPH. HVAC Upgrade (GPP) ▪ Remodel SPH. Auditorium (Indirect) ▪ Sensitive Instrument Facility (GPP) ▪ Scientific Computing Facility (GPP) ▪ Renovation for CREEM (GPP)	▪ SIF (SLI/>GPP) Note 2 ▪ SCF (SLI/>GPP) Note 2 ▪ CREEM (SLI/Program)
	In 5 Years				X	SPH, HWH, MD,			
	In 10 Years				X	SPH, HWH, MD			
Chemical and Molecular Science	Now			X		SPH, HWH, MD	Note 1	▪ SPH. HVAC Upgrade (GPP) ▪ Remodel SPH. Auditorium (Indirect) ▪ Sensitive Instrument Facility (GPP) ▪ Scientific Computing Facility (GPP) ▪ Renovation for CREEM (GPP)	▪ SIF (SLI/>GPP) Note 2 ▪ SCF (SLI/>GPP) Note 2 ▪ CREEM (SLI/Program)
	In 5 Years				X	SPH, HWH, MD,			
	In 10 Years				X	SPH, HWH, MD			
Applied Materials Science and Engineering	Now			X		SPH, HWH, MD	Note 1	▪ SPH. HVAC Upgrade (GPP) ▪ Remodel SPH. Auditorium (Indirect) ▪ Scientific Computing Facility (GPP)	▪ SCF (SLI/>GPP) Note 2
	In 5 Years				X	SPH, HWH, MD,			
	In 10 Years				X	SPH, HWH, MD			

N = Not M = Marginal P = Partial C = Capable
SPH = Spedding Hall HWH = Harley Wilhelm Hall MD = Metals Development Building

Note 1 The buildings are in good shape but are old and do not provide the modern infrastructure to serve current research paradigms. They cannot provide the flexibility, efficiency, environmental control, and preferred working environment that is possible with new research buildings. Specialized space is needed for increasingly sensitive instruments, such as electron microscopes. Existing space is not adequate because the vibration levels, noise levels and electromagnetic interference do not meet the installation requirements needed for the instruments to perform to their capability. The computation facilities are filled to capacity so that expansion requires creating new space or retiring existing computers to create space. Existing auditorium facilities limit the effectiveness of large group meetings and presentations due to outdated A/V, limited network access, inflexible space with fixed seating and outdated furnishings. It also presents a poor image of the laboratory for program reviews, visitors and staff.

Note 2 (SLI/>GPP) AMES has several projects that are needed in order to allow the facility to support the science planned for the next 10 years. The projects cost less than $10M each and would qualify for GPP funding. However, AMES' current level of funding ($610K/year) is inadequate to fund the proposed projects in a timely manner. Another option is to consolidate the projects into one SLI project and but fund them as separate milestones as funding becomes available.

Support Facilities and Infrastructure (Assumes TYSP Implemented)							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Capability Gap**	**Action Plan**	
	N	M[b]	P	C		**Laboratory**	**DOE**
Work Environment				X	▪ Services such as recreational/fitness, child care, cafeteria etc. are provided to the Ames Laboratory by Iowa State University in accordance with the operating contract. ▪ The age of the research buildings makes it difficult to provide modern energy efficient preferred office facilities.	Systematic Space Modernization (GPP)	
User Accommodations				X	▪ Visitor housing is available near the site by private enterprises. The size of the laboratory does not support a dedicated visitor center. Visitors are served by host personnel in existing laboratory facilities.		
Site Services				X	▪ Many site services such as fire service, emergency medical and library services are provided by offsite personnel or the contractor. ▪ Onsite services such as storage and shop facilities are capable.		
Conference and Collaboration Space			X		▪ Existing auditorium facilities limit the effectiveness of large group meetings and presentations due to outdated A/V, limited network access, inflexible space with fixed seating and outdated furnishings. It also presents a poor image of the laboratory for program reviews, visitors and staff. ▪ Adequate amount of conference room space is available but A/V and network capability is not uniformly available. Space for large gatherings is limited. ▪ Collaboration space is very limited and is not integrated architecturally.	Remodel Spedding Auditorium (Indirect) Systematic Space Modernization (GPP)	
Utilities				X	▪ Utility services are provided by the contractor, the municipality, and private enterprise. The Lab is working on projects designed to conserve energy and make the buildings more compliant with DOE's sustainability initiatives	Energy Conservation Projects (GPP/Indirect)	
Roads & Grounds				X	▪ Roads and grounds are provided and maintained by Iowa State University in accordance with the operating contract.		
Security Infrastructure				X	▪ Fifteen year old electronic access control has been upgraded to current proximity technology (FIPS 201 compliant). Coverage is being expanded on the site to begin replacing pin and tumbler locks.	Upgrade Access Control (GPP)	
N = Not, M = Marginal, P = Partial, C = Capable							

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Argonne National Laboratory

Mission/Overview

Located 25 miles southwest of Chicago, Argonne National Laboratory was the country's first national laboratory – a direct descendant of the University of Chicago's Metallurgical Laboratory where Enrico Fermi and his colleagues created the world's first controlled nuclear chain reaction. Appropriately, Argonne's first mission 65 years ago was to develop nuclear reactors for peaceful purposes. Managed by the University of Chicago for the DOE, Argonne has grown into a multidisciplinary laboratory with a unique mix of world-class scientists, engineers, and user facilities, creating new knowledge that addresses the most important scientific and societal needs of the nation.

Argonne's vision is to lead the world in discovery science and engineering that provides technical solutions to the grand challenges of our time: sustainable energy, a clean environment, economic competitiveness, and a secure nation. Toward this vision, Argonne's current major initiatives include hard x-ray science (a key and essential component being the upgrade of the Advanced Photon Source), leadership computing and computational science, energy storage, materials for energy, sustainable transportation, regional climate and biogeospheric interactions, nuclear energy, and national security.

These research initiatives are enabled by partnerships with academia, industry, and the government and the core capabilities in fundamental and applied science and engineering in which Argonne is a national leader: large-scale national user facilities and advanced instrumentation; condensed matter physics and materials science; chemical and molecular science; applied mathematics; advanced computer science, visualization and data; nuclear physics; particle physics; accelerator science and technology; applied materials science and engineering; chemical engineering; applied nuclear science and technology; and systems engineering and integration. The national user facilities include the APS, Argonne Leadership Computing Facility (ALCF), Center for Nanoscale Materials (CNM), Electron Microscopy Center (EMC), Argonne Tandem Linac Accelerator System (ATLAS), Atmospheric Radiation Measurement Climate Research Facility, and Transportation Research and Analysis Computing Center (TRACC).

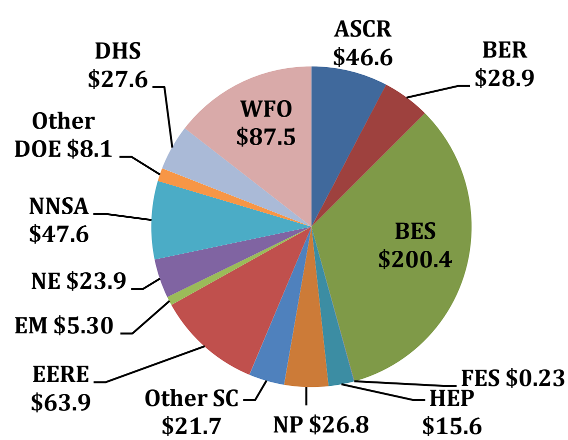
Lab-at-a-Glance

Location: Argonne, Illinois
Type: Multi-program Laboratory
Contractor: UChicago Argonne, LLC
Responsible Site Office: Argonne Site Office
Website: http://www.anl.gov

Physical Assets:
- 1,500 acres and 99 buildings
- 4.5M GSF in buildings
- Replacement Plant Value: $2.2B
- Deferred Maintenance: $111.8M
- Asset Condition Index:
  - Mission Critical: 0.951
  - Mission Dependent: 0.924
  - Asset Utilization Index: 0.944

Human Capital:
- 3,223 Full Time Equivalent Employees (FTEs)
- 126 Joint faculty
- 241 Postdoctoral Researchers
- 189 Undergraduate Students
- 776 Graduate Students
- 4,426 Facility Users
- 46 Visiting Scientists

FY 2010 Funding by Source: ***(Cost Data in $M):***



FY 2010 Total Lab Operating Costs (excluding ARRA): $604
FY 2010 Total DOE/NNSA Costs: $488.8
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $87.5
FY 2010 WFO as % Total Lab Operating Costs: 14.0%
FY 2010 Total DHS Costs: $27.6

ARRA Obligated from DOE in FY 2010: $22.0
ARRA Costed from DOE in FY 2010: $67.1

Current Core Capabilities

The DOE Office of Science has identified twelve core capabilities that distill the scientific and technology development excellence that Argonne researchers are known for. These capabilities cut across the scientific and innovation pipeline to create a powerful asset to serve the national need for advances in both basic science and technologies for energy, environment, and security needs. At its heart, the laboratory's scientific user facilities serve thousands of the nation's scientists and engineers every year in solving the most complex challenges of our time. Argonne takes full advantage of these facilities and core capabilities to create crosscutting initiatives that support the national interest and fuel the innovation pipeline for development and deployment of new energy technologies.

1. Large-Scale User Facilities/Advanced Instrumentation

Argonne is a leader in the conception, design, construction, and operation of world-class scientific user facilities. The laboratory's facilities collectively enable probing the most fundamental materials properties and chemical processes, advancing the understanding of nuclear matter, and delivering forefront computational and networking capabilities. Together, these facilities hosted over 4000 users in FY 2009.

The Advanced Photon Source (APS) is a unique national source of high-energy x-rays for scattering, spectroscopy and imaging studies of inorganic, organic, and biological materials. The pulsed nature of the x-rays allows time-resolved studies of dynamics over a wide range of time scales (seconds to ~100 ps) while the high energies make possible experiments at extremes of pressure and temperature or *in situ* observations during chemical reactions, for example. Continued enhancement of the APS (accelerator, beamlines, detectors, and infrastructure) is required to maintain this user facility at the state-of-the-art and globally competitive. Working closely with DOE/BES, Argonne is working on a significant upgrade of the facility (the APS-Upgrade Project) that would keep the APS at the world-class level. CD-0 for the APS-U Project was awarded in April 2010, a CD-1 review was completed in May 2011, and ANL is hoping for a CD-1 decision sometime in FY11. In parallel with APS-U, options for a 4th-generation hard x-ray source are being analyzed, with an expectation that this is for further in the future and beyond the APS-Upgrade. These plans will be developed in close cooperation with DOE and other National Lab partners. Also this year, the State of Illinois has acted on its pledge to fund the Advanced Protein Crystallization Facility (APCF), which will provide experimental space for structural biology adjacent to the APS. Preliminary design of the APCF is complete, final design is underway and will be complete in December 2011. Building construction will commence in late spring 2012.

The Argonne Leadership Computing Facility (ALCF) operates one of the largest open-science machines in the world. As a stepping-stone to the exascale, the facility, with its IBM Blue Gene/Q, will soon offer user access to petascale computing for the largest scientific applications, including research in energy systems, catalysis, life sciences, and environmental and basic sciences. In addition to the vibrant user base, the ALCF anchors a wide-ranging computational ecosystem that underpins every major research initiative the laboratory is pursuing. Expertise resident to the ALCF will be critical to overcoming the major technology and design challenges for movement to exascale level computing.

The Center for Nanoscale Materials (CNM) combines advanced scanning probe microscopy techniques with optical probes including an x-ray nanoprobe beamline at the APS that provides fluorescence, nanodiffraction and transmission imaging at a spatial resolution of 30 nm or better. These are combined with organic, inorganic, and digital synthesis, nanofabrication capabilities and theory and modeling. User and staff science are organized around three crosscutting theme areas: Materials Design and Discovery at the Nanoscale, Energy and Information Transduction, and Science of Nanoscale Devices. The Electron Microscopy Center provides state-of-the-art chromatic-aberration-corrected electron microscopy with applications to high-resolution and three-dimensional elemental imaging and is developing new capabilities for *in situ* environmental studies of catalysts and other nanoscale materials.

The Argonne Tandem-Linac Accelerator System (ATLAS) is a scientific user facility based on a superconducting linear accelerator that provides heavy ions in the energy domain best suited to study the properties of the nucleus, the core of matter, and the fuel of stars. The CAlifornium Rare Ion Breeder Upgrade (CARIBU), a rare-isotope injector based on a californium fission source and an RF gas stopper cell, is currently in its commissioning phase at ATLAS. It will deliver unique rare-isotope beams that cannot be produced through uranium fission and diffusion from a hot target. An efficiency and intensity upgrade of ATLAS has been initiated in 2010 with ARRA funding. Further upgrades are planned with the goal of providing roughly an order of magnitude higher intensity re-accelerated CARIBU beams and stable heavy ions over the full energy range available at ATLAS with 10-100 pμA intensities. Argonne also provides one-of-a-kind, custom-built detectors for use in high-energy and nuclear physics research worldwide.

Funding for these capabilities is provided primarily by the DOE/SC-BES, ASCR, and NP. Some instrumentation at the APS is funded by the National Institutes of Health and industry. The collection of these internationally renowned user facilities supports virtually the entire spectrum of DOE and federal agency S&T missions as enablers of the vital research performed at Argonne by both the user community and resident scientists and engineers.

2. Condensed Matter Physics and Materials Science

Argonne has a long tradition of expertise in the design, synthesis, fabrication, and characterization of advanced materials that address the Nation's critical needs for energy production, distribution, storage, and efficient usage. The portfolio of materials studied includes nanomaterials, complex oxides and other strongly correlated systems, and catalytic and electrocatalytic assemblies.

The objective across the portfolio is to create, explore, and control complex materials with tailored functionality for energy and environmental sustainability, and to develop the cutting-edge tools and expertise that enable Argonne to be a leader in this field. This capability encompasses multiple Argonne organizations across the continuum from basic to applied research. Argonne's strength is derived from an integration of strong programs in materials, chemistry, nanoscience, and biology that leverage DOE/SC funded user facilities for hard x-ray characterization (APS), nanoscale materials (CNM), electron microscopy (EMC), and leadership computing (ALCF).

The APS upgrade will provide new beamlines and greatly enhanced brilliance at hard x-ray energies for real-time imaging and scattering studies of materials synthesis and processing. Upgrades to the ALCF will enable an expanded program in computational materials design at the atomic and nanoscale, and in modeling and simulation of microstructure evolution at relevant length and time scales for the processing of advanced materials.

Argonne's materials science expertise includes theory and computation for materials design and insight into properties and phenomena; synthesis of new materials, including bulk crystals, bio-inspired materials, nanomaterials, films and superlattices; exploration of electronic, magnetic, and photonic behavior; patterning methods including self-assembly and electron beam lithography; and characterization utilizing scanning probes, ultrafast optical techniques, x-rays, photoemission, electrons and neutrons, with an emphasis on in situ studies. Specific materials research includes superconducting and magnetic bulk, thin film, and nanoscale materials; ferroelectrics; ionic, mixed, and electronic conductors; metal alloy and metal oxide nanoparticles and bio-nanoparticle hybrids; nanocarbons; molecular and nanoporous assemblies; granular and soft matter; and catalytic materials.

Funding for the core capability is primarily through DOE/SC-BES. This is complemented by WFO activities sponsored by DARPA, NASA and other agencies. DARPA support helps Argonne bridge the gap between discovery and use-inspired research and applied materials science and engineering activities, particularly with respect to integrating materials into unconventional architectures. NASA funding leverages fundamental research in surface chemistry and trace element analysis for application-specific purposes. The Condensed Matter Physics and Materials Science programs are Argonne's primary mechanism for delivering on a number of specific DOE missions: discover and design new materials and molecular assemblies; conceptualize, simulate and predict processes underlying physical transformations, particularly in complex materials with emergent behavior and materials far from equilibrium; probe, understand, and control the interaction of photons, electrons, and ions with materials; advance the scientific frontiers upon which Argonne's user facilities are based; and drive laboratory technology programs, particularly in energy storage, sustainable transportation, solar energy conversion, nuclear energy, and catalysts for alternative fuels production.

The SLI-funded Energy Sciences Building (ESB) will co-locate and consolidate much of the efforts associated with Condensed Matter Physics and Materials Science, Chemical and Molecular Science, and Chemical Engineering. An adjacent SLI building, the Materials Design Laboratory (MDL), planned for an FY2015 start, will enhance this consolidation and be the primary home for discovery and use-inspired research in the areas of materials synthesis, interfacial engineering for energy applications, materials under extreme conditions, and in-situ characterization and modeling.

3. Chemical and Molecular Science

Argonne's core capability in the synthesis, characterization, and control of molecules and chemical processes is targeted at transforming energy production and use. Thrust areas include artificial photosynthesis, catalysis, combustion, interfacial geochemistry, heavy-element and separations chemistries, ultrafast phenomena, AMO physics, and the conversion and storage of energy in batteries and fuel cells. In addition to scientific expertise, Argonne broadly leverages leading research tools at the Advanced Photon Source (APS), the Center for Nanoscale materials, and Argonne's Leadership Computing Facility (ALCF) to accomplish this work. The dramatic improvements in intensity and in time resolution to be enabled by the Advanced Photon Source Upgrade are essential to Argonne's in operando studies of catalysis and chemical dynamics, in-situ and real-time studies of reactions at solid-liquid interfaces, and to understanding excited states in molecular energy transduction. Notably, Argonne's catalysis programs benefit from strong collaborations between theoretical and computational chemists and experimentalists and have developed computational approaches for ground-breaking studies of electronic structures, as well as a unique set of in situ analytical tools for the APS that enable an improved understanding of catalytic systems under "real-world" operating conditions.

Other research priorities include photoinduced energy and electron transfer reactions in natural photosynthesis for a variety of biomimetic and synthetic systems. Studies are carried out on multiple spatial and temporal scales using techniques developed at Argonne, such as ultrafast x-ray structural determination, high-field electron paramagnetic resonance, and ultrafast laser spectroscopy/ microscopy imaging. Combustion research benefits from strong collaborations between theoretical and computational chemists and experimentalists. Experimental facilities to conduct combustion research include several unique instruments for studies of high temperature kinetics and dynamics. Atomic physics studies focus on understanding and controlling the electronic response to ultra intense x-ray radiation from the world's first x-ray free electron laser, the Linac Coherent Light Source at SLAC, and on developing high-precision, high-repetition-rate methodologies for ultrafast x-ray probes of molecular motion at the APS and the upgraded APS.

Interfacial science activities leverage the unique capabilities of the APS to probe interfacial structures and reactions with elemental- and chemical-specificity to understand the reactions at mineral surfaces that control transport of contaminants in Earth's near-surface environment. Housed in purpose-built radiological facilities, studies on transuranic systems aim to extend the fundamental understanding of the chemistry exhibited by these heaviest of elements. Their underlying bonding and energetics are targeted, within the context of separations relevant to nuclear energy, using a wide range of analytics, including state-of-the-art laser spectroscopy and x-ray techniques available through the APS.

Chemical, electrochemical, and molecular science has been the cornerstone of Argonne's advanced battery research programs. Basic understanding of the nature of complex solid-state and interfacial chemical interactions has resulted in breakthroughs that may ultimately enable significant penetration of hybrid, plug-in hybrid, and electric vehicles. Importantly, Argonne's battery research has successfully leveraged both the APS and advanced computational capabilities to develop new understanding of solid-state battery electrode systems, soluble electrolyte materials, and interfacial reactions that occur in advanced battery systems. A significant achievement in 2011 was licensing of Argonne materials for use in the Chevy Volt plug-in hybrid electric car battery.

Funding for Argonne's Chemical and Molecular Sciences program comes from DOE/SC-BES. Agency mission support leverages the capabilities above to deliver on advancement in chemical transformation processes, computational science, and the discovery and design of new molecular systems. The SLI-funded Energy Sciences Building (ESB) will co-locate and consolidate key elements of the research associated with Chemical and Molecular Science; it will also incorporate the Condensed Matter Physics and Material Science Core Capability and the smaller, yet synergistic components of ANL's Chemical Engineering core capability. Co-location of these programs will provide a platform for accelerated discovery in combustion, energy storage and catalysis.

4. Applied Mathematics

Applied mathematics, an Argonne core capability since the late 1970s, currently focuses on optimization, partial differential equations and algebraic solvers, and automatic differentiation. Argonne's optimization group has earned international renown for devising key concepts in optimization (trust-region methods, filter methods, complementarity, and performance profiles) and for developing the MINPACK, Network Enabled Optimization Systems (NEOS), and Toolkit for Advanced Optimization (TAO) toolkits. Work on NEOS and the filter methods won the 2003 Beale-Orchard-Hays Prize and the 2006 Lagrange Prize, respectively. Academic, commercial, and government institutions solved over 235,000 problems in 2010 using NEOS. TAO, the first toolkit for solving large-scale optimization problems on high-performance distributed architectures, was downloaded more than 800 times in 2010. In addition, Argonne is extending its expertise into novel areas of optimization such as stochastic, mixed-integer nonlinear, and derivative-free optimization.

Leaders of Argonne's partial differential equations and solvers group have written influential textbooks on domain decomposition and on spectral methods and their applications to complex simulations. The group has also gained recognition for its superb software. For example, the Portable, Extensible Toolkit for Scientific Computation (PETSc) is the most widely used parallel numerical software library for partial differential equations and sparse matrix computations, with over 15,000 downloads in 2010. In 2008, PETSc was identified as one of ten noteworthy breakthroughs in computational science funded by DOE/SC-ASCR, and in 2009 was awarded an R&D100 award for the release of version 3.0. Argonne researchers also developed Nek5000, considered the best code for high-order simulations of complex fluid flows on architectures with over 30,000 processors. Automatic differentiation, which originated at Argonne in 1989-1992, has been cited as one of the top ten developments in scientific computing for 1970-2000. Argonne's automatic differentiation group is considered the best in the world, and its three major toolkits (ADIFOR, ADIC, and OpenAD) are used for sensitivity analysis and uncertainty quantification in climate modeling and nuclear safety analysis. Argonne develops open-source libraries for representing CAD geometry (CGM) and unstructured and structured mesh (MOAB); the MeshKit library uses CGM and MOAB and provides a suite of open-source mesh generation algorithms.

Funding for Argonne's applied mathematics research is provided by the DOE/SC-ASCR. This research specifically supports the DOE mission for developing mathematical descriptions, models, methods, and algorithms. Work in these areas enables scientists to accurately describe and understand the behavior of complex systems involving processes that span vastly different time and length scales in energy and the environment. Argonne's research also promotes the mission to advance key areas of computational science and discovery through partnerships with applied programs and interagency collaborations. The Theory and Computing Sciences Building (TCS), completed in the fall of 2009 on the Argonne site, accommodates the needs of the Applied Mathematics program.

5. Advanced Computer Science, Visualization, and Data

Argonne's Advanced Computer Science, Visualization and Data core capability is built on leadership in finding new solutions to challenges surrounding parallel programming models and system software, distributed computing technology, and scientific visualization and analysis. Of particular note are the Access Grid – a revolutionary collaborative environment used worldwide for science and engineering applications; MPICH – the first portable implementation of the Message Passing Interface (MPI) standard, now considered the de facto standard for scientific research on parallel computers; and the Globus Toolkit – the de facto standard for Grid computing software tools that has made Argonne's name almost synonymous with the Grid. The Access Grid, MPICH2, and the Globus Toolkit have all won prestigious R&D 100 awards. Application groups worldwide use Argonne software, most notably in nuclear reactor simulation, computational biology, astrophysics, nuclear structure theory, and climate modeling. Argonne researchers develop software that enables science from the desktop to massively parallel machines and advanced heterogeneous clusters. Much of this research software is deployed at the Argonne Leadership Computing Facility (ALCF), which operates one of the largest open supercomputing resources in the world, as well as one of the first scientific cloud computing testbeds. These two user facilities support many of the Nation's scientific and engineering applications.

Funding for Argonne's advanced computer science, visualization, and data research activities are primarily from DOE/SC-ASCR, with additional support from the National Science Foundation through the Argonne/University of Chicago Computation Institute, in the areas of distributed computing, visualization, systems software, and data management. This work is supporting the mission to advance key areas of computational science and discovery through partnerships with DOE/SC, R&D integration efforts with the Department's applied programs, and interagency collaborations. The development of networking and collaboration tools is also enabling scientists worldwide to work together and share extreme-scale scientific resources.

Research teams for this core capability are located in the Argonne Theory and Computing Sciences Building, which brings together a broad array of computing and computational activities.

6. Nuclear Physics

Argonne's research in nuclear physics has a long proven track record in addressing the DOE mission for basic research in nuclear physics, and the scientific goals prioritized in Long Range Plans published by the DOE-NSF Nuclear Science Advisory Committee.

Argonne operates the Argonne Tandem Linac Accelerator System (ATLAS) as the premier DOE National User Facility for low-energy nuclear research, where stable ion beams and rare (e.g., radioactive) isotope beams are used: (a) to highlight aspects of nuclear structure that vary strongly with the proton-to-neutron ratio and are not readily apparent in stable nuclei; (b) to investigate reactions far from stability as the basis of astrophysical processes generating the chemical elements; and (c) to test nature's fundamental symmetries. This research addresses DOE mission areas such as understanding how protons and neutrons form atomic nuclei and how nuclei have emerged since the origin of the cosmos; understanding the fundamental properties of the proton and the neutron; and developing a better understanding of the neutrino. A unique new capability, the CAlifornium Rare Ion Breeder Upgrade (CARIBU) to ATLAS, was commissioned in 2011. Based on a californium fission source and a gas stopper, beams of rare isotopes not available anywhere else in the world are delivered at energies relevant for nuclear structure and astrophysics research. An efficiency and intensity upgrade of ATLAS was initiated in 2009 with ARRA funding. Following subsequent planned improvement projects, ATLAS will yield roughly one order of magnitude higher intensity re-accelerated CARIBU beams and will provide stable heavy ions over the full energy range at ATLAS with 10-100 pμA intensities. The facility is equipped with state-of-the-art instrumentation such as Gammasphere (the national gamma-ray facility), HELIOS (a spectrometer for the study of reactions in inverse kinematics), ion and atom traps, and a fragment mass analyzer.

Argonne's nuclear physics research program also strives for a deeper understanding of the underlying strong force and its basis in quantum chromodynamics (QCD) as it applies to protons and neutrons (addressing how quarks and gluons assemble into various forms of matter), and to the strongly coupled nuclear many-body system. Typically, as part of large collaborations, Argonne scientists design, construct, and operate instruments at JLab and Fermilab to carry out these investigations. Argonne's nuclear physicists have collaborated on key elements of the FRIB, including accelerator systems and detectors.

Argonne nuclear physics is also supported by strong theory efforts that leverage the advanced computer science visualization and data core capability and the ALCF, and by research in accelerator science and technology – particularly in superconducting radio-frequency technology and beam dynamics. Additional applications include: characterization of spent nuclear fuel for reactor design using accelerator mass spectrometry and total absorption spectrometry; radio-Krypton and radio-Argon dating with atom traps for geophysical, oceanography, and fundamental research; reconfiguration and repair of detection systems for Radiological Assistance Program teams nationwide; and new production techniques of isotopes for medicine.

The DOE/SC Office of Nuclear Physics supports this research, with some contributions from the DOE/SC-HEP, DOE/NNSA, and the Defense Threat Reduction Agency (DTRA) for accelerator R&D and detector development.

7. Particle Physics

Argonne's particle physics core capability supports the primary science mission of the DOE/SC-HEP office with a proven track record of significant contributions. The laboratory's particle physics research focus is on understanding the properties and interactions of the fundamental particles making up the universe and the symmetries underlying the fundamental forces of nature and the constituents of matter. Argonne's particle physics research teams are comprised of theoretical and experimental physicists, engineers, computing professionals, and technicians. Another important focus, research in accelerator science, is discussed in the Accelerator S&T core capability section. Specific activities in particle physics research thrusts are detailed below.

Argonne's efforts in developing new or extending existing theoretical models include theory of Higgs production, and MSSM and SUSY predictions. This effort is funded by DOE/SC-HEP, and supported by joint appointments with Northwestern University and University of Chicago. A new effort in Computational Cosmology has been initiated with two new hires that connect theoretical particle physics, cosmology and high performance computing needed for this area.

Argonne is pioneering the development of new large area photo-detectors with pico-second timing resolution, development of new digital hadron calorimeters for future experiments and wireless DAQ systems. This effort is funded by DOE/SC-HEP, and is supported by joint activities with Argonne's Materials Science Division and the University of Chicago, including joint appointments. A new senior scientist is leading a program developing new detectors and sensors for the Department of Homeland Security's Infrastructure and Geophysical Directorate.

The development of large detector systems to study particle interactions is an area of great success for Argonne. Of note, is the laboratory's design, construction, and commissioning of the large tile calorimeter for the ATLAS experiment at the Large Hadron Collider (LHC) at CERN in Switzerland, as well as prototyping of the NOvA detector for neutrino interactions, and development of new instrumentation for astrophysics experiments, such as transition edge sensor array detectors to be installed in the South Pole CMB experiment. Funding for these efforts comes from DOE/SC-HEP and is supported by collaborations world-wide.

In developing advanced acceleration techniques for future accelerators, Argonne has greatly improved its dielectric two-beam Wakefield accelerator and technologies for layered superconducting RF cavities for use in linear colliders. Processing of ILC SRF Nb cavities, in collaboration with Fermilab, is done in a specially designed Argonne facility. This work is supported by DOE/SC-HEP, and funding from DoD Office of Naval Research, and draws heavily on collaborations with Argonne's Materials Science and Physics Divisions and the Advanced Photon Source.

To support the design and creation of software and computing infrastructure for very large data sets, Argonne has supported creation of the ATLAS events and meta databases, as well as facilitating world-wide access to those databases. The laboratory also leads Tier-3 development for all U.S. institutions. Funding is from DOE/SC-HEP and is supported by Argonne's Decision and Information Science Division.

Argonne's expertise in analyzing experimental data for insights in particle physics is demonstrated through its work on MINOS analysis, CDF electroweak and B physics analysis, establishment of an ATLAS/LHC analysis center at Argonne, and filling the ATLAS/LHC physics coordinator position, all supported by DOE/SC-HEP.

As can be seen above, while funding is predominantly from DOE/SC-HEP, Argonne high energy physicists leverage WFO funding as well as expertise across the laboratory for improving instrumentation and accelerator techniques. While experimental space is currently adequate, Argonne is expanding the Argonne Wakefield Accelerator building, which is critical for accommodating planned and funded research, as well as other synergistic accelerator R&D activities, including those in superconducting RF cavities. Argonne's computational science strategy also includes plans for addressing the frontiers in accelerator and non-accelerator particle physics.

8. Accelerator Science and Technology

Argonne's accelerator science and technology research is a critical component to the development and improvement of the nation's accelerator-driven scientific user facilities. This capability uniquely leverages Argonne's strength in basic and applied materials research to support advances in accelerator science and technologies for hard x-ray science, high-energy physics, and nuclear physics. Significantly, the Advanced Photon Source Upgrade will leverage the accelerator S&T core capability to develop superconducting RF cavities for unique new capabilities in high energy and pulsed x-ray generation. Argonne will also leverage its strengths for current or proposed upgrade of its facilities in high energy and nuclear physics.

These efforts have helped Argonne develop a notable accelerator design and development expertise of strategic importance to the accelerator S&T community in the U.S. and abroad. For accelerator-based x-rays, Argonne has significant expertise in modeling, design, and operation of both electron accelerators and free electron lasers; undulator design, fabrication, and measurement; control systems; and vacuum chamber design and construction.

Codes developed at Argonne for x-ray facility design are used worldwide. Argonne is continuing development of a strong and unique R&D effort in support of x-ray optics, a critical need since an increasing number of hard x-ray sources are being developed, including the Advanced Photon Source (APS) upgrade. Furthermore, the APS has within its existing organization, a strong accelerator R&D capability. For high-energy physics, Argonne plays a significant R&D role for the proposed International Linear Collider, Fermilab's Project-X (which plans to use spoke resonators and other cavities originally developed for nuclear physics at Argonne), and FRIB at Michigan State University. The Argonne Advanced Wakefield Accelerator is the only facility in the world where two-beam acceleration techniques and dielectrically loaded structures (a promising concept for linear colliders) are being developed. Nuclear physics applications include the creation, acceleration, and manipulation of beams of rare isotopes and the development of high-performance, low-velocity superconducting accelerating structures. End-to-end simulations for hadrons and heavy ions are carried out with new codes that take advantage of the capabilities of the ALCF and will be further enabled by its upgrades. Argonne is a U.S. leader in the processing of superconducting RF cavities by techniques developed for ATLAS and its upgrades. There is considerable interest in the U.S. and elsewhere for applications of this technology applied to high-current hadron linear accelerators with energies in the MeV-GeV range.

Argonne's goal for Accelerator S&T is the successful continuation of the activities noted above, with a stronger focus of capturing unique Laboratory strengths to address accelerator S&T challenges. This has led Argonne to: (a) concentrate on "cavity"-based accelerating structures, either superconducting or warm, made from either metal or dielectric materials; (b) use materials science and other expertise at Argonne to understand surface phenomena that currently limit performance; (c) improve surfaces not only by standard surface treatments, but also through new materials synthesis technologies such as atomic layer deposition (ALD); (d) explore totally new techniques for cavity construction combining ALD and X-ray lithography; and (e) explore the technological challenges associated with the acceleration and manipulation of very high-intensity, high-power beams. It is the interdisciplinary character, and the materials and chemical science expertise of Argonne that makes this new approach possible.

Argonne, along with Fermilab, has developed a seminal program for introducing undergraduates to accelerator S&T. Argonne's accelerator S&T research maintains both the core capability and a trained accelerator workforce, while meeting the scientific needs of the DOE/SC community.

Funding for this core capability comes primarily from the DOE/SC Program Offices that utilize accelerators for research, namely BES, HEP, and NP. The DoD and international laboratories also contribute some funding. Future plans are being evaluated for other synergistic accelerator R&D activities, including those in assembly and testing of superconducting RF cavities.

9. Applied Materials Science and Engineering

Argonne's expertise in the development, synthesis, application, and engineering of scalable production technology for materials provides the foundation for advances in next-generation technologies for energy production, storage, distribution, and use. The applied materials science and engineering capability draws on expertise in multiple Argonne divisions, from discovery synthesis in the Materials Sciences, Chemical Sciences and Engineering, and Center for Nanoscale Materials Divisions, characterization at the Advanced Photon Source, and modeling and simulations at the Leadership Computing Facility. Argonne's applied materials science and engineering program fosters the integration of basic materials research with DOE-EERE technology programs in areas such as electrical energy storage, solar energy conversion, solid state lighting, catalysis, biofuels, and other applications to improve energy efficiency, and with DOE-FE technology programs for CO2 capture and sequestration. It also fosters broad collaborations with industry. The Advanced Photon Source Upgrade will provide new capabilities for real-time interrogation of scalable process technologies and thus shorten the time to deployment of novel, efficient materials production approaches.

Achieving cost and performance goals in traditional and transformational energy technologies requires innovations in both new materials as well as scalable processes for the production and application of those materials. For example, Argonne is developing superhard nanocomposite diamond and diamond-like carbon coatings to provide low friction and increased wear resistance for automotive drivetrain applications and wind turbine gearbox components, using modified plasma coating technology for volume production. Argonne's diverse program in atomic layer deposition includes extending this technology to applications ranging from high performance catalysts for the chemical industry to more efficient solar cells and solid-state lighting based on abundant materials, such as TiO2, ZnO, and Cu2S. Argonne bridges the gap between research and commercialization by advancing the process engineering research necessary to ensure that these materials and processes for coating large area planar substrates as well as micro- and nano-particles can be cost-effectively deployed. Argonne's applied materials science and engineering capabilities also include development of new materials for energy storage technologies, particularly advanced batteries and ultracapacitors focused on transportation applications, and organic and inorganic membrane materials and systems for gas- and liquid-phase separation for applications such as hydrogen production, carbon dioxide separation, and biofuels processing. Argonne is also advancing a nanomanufacturing capability as part of the DOE-EERE Industrial Technologies Nanomanufacturing for Energy Efficiency Initiative, with the objective of developing the engineering capability necessary to transition nanomaterials to commercial processes for applications including nanocatalysts, thermal nanofluids, nanolubricants, solar cells, flat-panel displays, large-area detectors, RF cavities for particle accelerators, and surface treatments for friction reduction and/or wear resistance.

While DOE/SC-BES funds development of basic materials, funding for Argonne's applied materials science and engineering research is primarily provided by DOE/EERE program offices, including the Industrial Technologies Program; the Vehicle Technologies Program; the Fuel Cell Technologies Program, and the Solar Program. DOE funding is often cost-shared by industrial companies and is complemented by funding from industry to enable a sustainable domestic manufacturing capability for advanced energy technologies. For example, funding is provided by the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) for research on scalable processes for advanced battery materials.

In FY 2010, Argonne received funding from DOE-EERE to equip a new 10,000ft^2 facility to conduct process-engineering research in support of the development of scalable processes for advanced battery chemistries. Construction of this new facility, within an existing building, is scheduled for completion in FY 2011.

10. Chemical Engineering

Chemical engineering research at Argonne is at the forefront of solving the energy and security challenges, by both receiving and informing ANL's basic energy research and demonstrating transformational technologies for electrochemical energy storage, nuclear energy, nonproliferation, radiological forensics, and chemical fuels production. Argonne's advanced battery program has been a hub of activity supporting an integrated innovation pipeline since the late 1960's and is responsible for a large portfolio of intellectual property; Argonne is recognized as one of the lead laboratories in the DOE complex for this field of research.

Argonne research programs are expanding capabilities in advanced battery chemistries for demonstration in internally-fabricated sealed cells with comprehensive post-test diagnostics. A key component of the Argonne battery research program is a state-of-the-art dry room which enables materials research on commercial-grade cells to both validate performance and understand materials transformations during use. Unique in the DOE complex is the coupling of basic materials R&D with the ability to scale materials to a pre-pilot level, incorporate the materials in commercial-grade cells, run them through a battery of tests, and then analyze the materials down to the molecular scale. This set of engineering capabilities is intended to be a quasi-user facility capability, i.e. materials developed elsewhere in DOE-funded or non-DOE-funded programs can capitalize on these capabilities, further enhancing U.S. competitiveness in the area of advanced battery developments and manufacturing.

A crosscutting combustion research program bridges first-principles chemistry efforts, largely supported by DOE/SC-BES, with combustion modeling and fundamental testing to anchor a full 'basic-to-applied' research program to ultimately advance chemical and biofuels. Argonne researchers are also developing the hydrogen production, storage, and utilization technologies necessary to realize the potential of fuel cells as clean, efficient power sources for automotive, stationary, and portable power applications. R&D in hydrogen production spans fuel reforming (catalytic conversion of natural gas to gasoline), high-temperature electrolysis, and thermochemical cycles. A crosscutting effort at the Laboratory is developing advanced membranes, electrodes, and electrocatalysts that reduce the cost and improve the durability of fuel cells based on both solid oxide and polymer electrolyte membrane technologies.

Researchers in the Argonne Chemical Engineering program also continue to pioneer separations chemistry for nuclear fuel processing and have become increasingly active in advancing the security of nuclear processing and the capability for responding to a radiological dispersal event. Argonne is a leader in the development of methods for medical isotope separation (e.g., Mo-99), is exploring alternative methods for isotope production, and is participating in the conversion of foreign and domestic test reactors from HEU to LEU fuel. In addition, Argonne brings its enormous expertise in separations chemistry to support novel approaches to nonproliferation and forensics.

Funding for these programs is provided by DOE Energy Programs in Vehicle Technologies, Fuel Cells, Solar Energy, Biomass, Nuclear Energy, the National Nuclear Security Administration, the Department of Defense, and the Department of Homeland Security. Collectively, these research activities support agency missions in isotope production, next generation nuclear energy technologies, safeguards by design, energy storage, vehicle technologies, energy systems optimization, nonproliferation, and chemical defense.

11. Applied Nuclear Science and Technology

Argonne has long led the development of advanced nuclear energy systems and their underlying technologies. Cumulative experience over many years of R&D in nuclear reactor design and development has positioned Argonne as a leader in the development of future-generation nuclear reactors and fuel cycles that advance the sustainable use of nuclear energy through waste minimization, enhanced resource utilization, competitive economics, and increased assurance of reliability, safety, and security.

Argonne's expertise in nuclear reactor physics, nuclear and chemical engineering, and fuel cycle analysis enables the laboratory to lead the assessment and conceptual development of innovative, advanced reactors operating with a variety of fuel types and fuel cycle schemes (once-through or modified open cycle, deep burn, transuranic recycle and consumption), and utilizing diverse coolants. The laboratory's research into the behavior of irradiated fuels and materials supports the NRC in the regulation of industry initiatives to extend the operational lifetime and optimize the operation of existing and evolutionary nuclear reactors. These capabilities, used in concert with expertise in systems analysis and modeling, uniquely position Argonne to assess the relative merits of different advanced nuclear energy systems and fuel cycles for various domestic and global scenarios of energy demand and supply.

Argonne's world-class capabilities in materials science, actinide chemistry, reactor physics, and separations science all contribute to an improved understanding of reactor and fuel cycle processes. Argonne's scientific user facilities, particularly the DOE/SC-BES funded Advanced Photon Source (APS) and Electron Microscopy Center (EMC), are major assets for discovery and improved understanding of phenomena and processes in nuclear reactors and fuel cycle facilities. They provide unique capabilities for in situ characterization of nuclear energy materials and processes, enabling increased understanding of phenomena needed to advance the design and operation of nuclear energy systems. Radiological laboratories at Argonne are used to conduct materials research and analytical chemistry on a range of activated materials and radioisotopes in various matrices.

The Argonne Leadership Computing Facility (ALCF), coupled with world-class expertise in nuclear engineering, computing, and nuclear computational science, uniquely positions Argonne to develop and validate modeling and simulation of future generations of nuclear reactors. The Simulation-based High-efficiency Advanced Reactor Prototyping (SHARP) code project at Argonne demonstrates the synergistic application of these disciplines and provides a recognized basis for future advancement and growth. Partnerships with institutions who have complementary modeling and simulation expertise (e.g., for advanced fuels and separations) provide a comprehensive modeling and simulation capability for current- and future-generation nuclear energy systems.

These broad capabilities in applied nuclear S&T are also applied to critical national security and nonproliferation needs, including the conversion of research reactors to low-enrichment fuels, technology export control, risk and vulnerability assessments, and information systems. These efforts are important for the national security and nonproliferation missions of the NNSA and other federal agencies.

Sensor and detector development expertise also supports national programs in border, cargo, and transportation security, as well as chemical, biological, radiological, and nuclear incident mitigation and management. Examples include millimeter wave technologies for remote detection and sensors and forensics to identify sources of nuclear and biological materials. These capabilities support the DHS, as well as the needs of the NNSA and several agencies of the DoD, including the DIA and the DTRA.

12. Systems Engineering and Integration

Crucial for demonstration and deployment of critical energy technologies is a strong applied research and development program. Argonne's capstone R&D programs are supported by the systems engineering and integration core capability to enable an integrated systems approach to ANL's research efforts. Argonne staff includes researchers spanning the spectrum from basic science through engineering to system deployment. Multidisciplinary research teams consisting of combinations of physical and biological scientists, engineers, computational scientists, social scientists, and decision analysts are routinely formed from among the organizations at the laboratory. In addition to a strong multidisciplinary staff, Argonne has a unique set of facilities that support integrated systems research such as: (a) the Advanced Photon Source is used to study the physics and chemistry of combustion in automotive engines, (b) high-performance computers are used to model engine function and performance, and (c) the Center for Transportation Research conducts experimental research on vehicle systems and life cycle analyses. Additionally, Argonne's agent-based modeling capability, a cross-cutting computational technology that has been used to address many problem domains related to energy systems analysis and national security, is world renowned for helping to solve some of the great challenges in electric power system behavior, market acceptance of advanced technology, and homeland security system operation.

Funding for Argonne's systems engineering and integration research comes from many sources, including DOE/BER, BES, and ASCR (e.g., for basic research on climate change, advanced materials, and high-performance computing, respectively); from DOE-NE's Generation IV, Fuel Cycle R&D, International, and Nuclear Hydrogen Programs (e.g., for research on the nuclear fuel cycle); from DOE-EERE's Biomass, Geothermal, Hydrogen, Vehicle, Wind and Hydropower, and Building Technologies programs (e.g., for research on transportation technologies, such as electrification, as well as wind and hydropower); from DHS's Science and Technology Directorate, National Protection and Programs Directorate, and FEMA (e.g., for research on critical infrastructure protection, on command and control systems for responding to weapons of mass destruction, and on the social dynamics of terrorist cell formation); and from DoD's Army, Navy, Air Force, DIA, DTRA, Joint Staff, and U.S. Transcom (e.g., for logistics planning, life cycle systems analysis, and information technology). Many of the products of this research have been operationally deployed by the supporting agencies both for their own use and for commercial applications. This work supports the mission of integrating research work across multiple DOE, DHS, and DoD organizations to advance their contributions to energy, environment, and national security missions.

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

Argonne National Laboratory is a 1,500-acre federally owned site, overseen by the DOE/SC, in DuPage County, Illinois. The site is located about 25 miles southwest of Chicago and accommodates approximately 4,500 persons (including DOE employees, contractors, facility users and guests). The Laboratory is surrounded by Waterfall Glen Forest Preserve, a 2,470-acre greenbelt. The Argonne site includes 99 buildings having 4.5 million total square feet of floor space. The site also includes New Brunswick Laboratory, a DOE-operated facility, as well as the University of Chicago operated Howard T. Ricketts Regional Biocontainment Laboratory. In addition, roughly 263,000 ft^2 of space is leased, approximately 240,000 ft^2 of which – Building 240, the Theory and Computing Sciences (TCS) facility – is located adjacent to the main entrance to the site.

As shown in *Table 2*, the replacement value of existing facilities and other structures at Argonne is estimated to exceed $2.2 billion. The average age of the facilities is 40 years, with over 62% of the facilities more than 40 years old. Argonne facilities are roughly 94% occupied. The asset utilization index (AUI) values related to use-specific measures exceed the DOE goals for the laboratory, warehouse and housing use types. The current overall asset condition index (ACI) is 0.949 ("adequate"). The ACI for buildings is 0.948 ("adequate"). The ACI for other infrastructure, including site utilities (electrical power, water, sewers, and steam) and civil infrastructure (roads, parking, and walks), is 0.982 ("good"). The ACI is based on identified deferred maintenance as it relates to the estimated plant replacement value.

Table 1. SC Infrastructure Data Summary

Replacement Plant Value ($M)		$2,218
Total Deferred Maintenance ($M)		$111.8
Asset Condition Index (ACI)	Mission Critical	0.95
	Mission Dependent	0.92
	Non Mission Dependent	0.98
Asset Utilization Index (AUI)	Office	0.91
	Warehouse	0.94
	Laboratory	0.94
	Housing	1.00
Prior Year Maintenance ($M)		$40.4

The current Land Use Plan has been provided to DOE/ASO. The only real estate action, including new (or renewal) leases of 10,000 ft^2 or more or disposals of DOE land via leasing, sale, or gift, planned for FY 2011 and FY 2012, was relocation of the Radiological Assistance Program offsite to accommodate space needs for the APS Upgrade. The Land Use Plan may be accessed via the Argonne Intranet.

Facilities and Infrastructure to Support Laboratory Missions

Argonne's ongoing challenge is to revitalize and reshape its existing facilities and infrastructure to meet the current and emerging needs of scientific missions. This challenge includes ensuring compliance with standards of environmental performance and safety and eliminating legacy waste and obsolete facilities, while optimizing operation and maintenance costs. The Argonne physical site has few constraints to expanding the laboratory's role in 21st century research beyond the need for modern agile research facilities and the elimination of outdated and legacy buildings. These actions are crucial to allow the laboratory to meet the functional and economic performance requirements associated with evolving programmatic needs and emerging technologies.

The 2009 Argonne Mission Readiness Peer Review found that "Argonne demonstrated a clear commitment to the implementation of the Mission Readiness principles and processes" and that the Mission Readiness process was being implemented. The challenge remains to sustain this process to ensure full Mission Readiness.

Argonne's mission is executed through twelve core capabilities and eight major initiatives with broad support from a professional operations staff. The tables included at the end of this section provide an overview of the condition evaluation of the existing facilities and infrastructure in the context of the core capabilities and identify the associated investments and actions needed to ensure mission readiness. For brevity, only larger investments are discussed.

Strategic Site Investments

Argonne has developed a structured modernization plan to provide a productive, safe, secure, and environmentally sound workplace to efficiently and effectively support its core capabilities. Needs identified in the plan were prioritized with the timing and sequencing of actions chosen to optimize the benefits and leverage the resources available for execution. The investments in the near term, i.e., the next five years, are discussed by program or funding type. The pre-conceptual locations of the recommended actions are summarized in the attached map titled "Projected 10-Year Status, FY 2011 Annual Laboratory Plan." Argonne's modernization program has evolved through a combination of laboratory strategic planning and mission readiness review. The modernization projects will replace or rehabilitate aging and inadequate facilities and infrastructure, which severely constrain the ability to deliver much needed innovative research and technologies.

Argonne requires significant recapitalization to replace many of the original multi-program scientific facilities and ensure the continued readiness of the facilities and infrastructure to support the core capabilities. The ten-year planning horizon includes initiation of four major DOE SLI-funded buildings, plus infrastructure rehabilitation, which will enable Argonne to move forward with the disposal of the most seriously outmoded and ineffective buildings in the 200 Area.

Concurrently, Argonne is continuing a successful partnership with the State of Illinois to realize specific business-line-focused buildings [Advanced Protein Crystallization Facility (APCF), the proposed Battery Test Facility Building, etc.] and to acquire leased facilities, such as the newly completed Theory and Computing Science (TCS). The plan relies on DOE-EM funding to disposition the buildings replaced by the DOE SLI projects (and other contaminated facilities) to avoid the continued high costs of operations and eliminate the deferred-maintenance backlogs associated with very limited operational lives. Where conventional funding sources are unavailable, Argonne will continue to actively pursue innovative approaches to acquire timely and adequate resources to ensure the laboratory's ability to meet the facility related mission needs.

- **SLI Modernization Initiative**

  In response to the DOE SLI Modernization Initiative, Argonne developed a proposed package of line item projects that were specifically timed and scoped to optimize the rehabilitation or replacement of programmatic facilities and upgrade of the associated infrastructure. Recent guidance from DOE-SC indicates that the funding timetable for the projects beyond FY 2010 has been significantly extended. The first project, ANL-001, Energy Sciences Building (ESB), received FY2010 initial funding and has achieved CD-3. Funding for the next project, ANL-002, Materials Design Laboratory (MDL), originally slated for FY 2012, is now planned for FY 2013 initiation. Initiation of the ANL-003, Biological Sciences Building (BSB) project has been deferred to 2015. Funding for the two remaining SLI projects has also been delayed beyond the planning timeline to FY 2020 and FY 2022.

  The three initial line-item projects, consistent with the approach identified in the laboratory's Modernization Plan, establish Argonne's path forward in the next ten years. The first project (FY 2010 start) is the 140-150,000ft^2 ESB (ANL-001, $95M) to co-locate and consolidate scientific efforts and eliminate excessive maintenance and operating costs associated with the most obsolete and inadequate buildings. The second project, the ~105,000ft^2 MDL (ANL-002, $95M), with an FY 2015 start, will continue consolidation within the three closely associated core capabilities (Condensed Matter Physics and Materials Science, Chemical and Molecular Science, and Chemical Engineering). The MDL will also provide the laboratory and infrastructure for the Materials for Energy major initiative detailed in Section 4. Argonne is requesting a third new project start to construct an additional new, ~140,000ft^2 building (ANL-003, $95M), to support research in sustainable energy technologies in the biology, environmental-science, and renewable-energy mission areas and facilitate additional disposal of vacated, obsolete, and deteriorated 200 area building space. The disposal efforts are proposed for EM-type funding.

  Comprehensive infrastructure modifications and upgrades are needed throughout the site in support of the significant changes associated with the construction of these new replacement facilities and the retirement of former key multi-program facilities. Where feasible, the project scopes for the new facilities will incorporate key infrastructure realignments and reliability upgrades and to serve projected load shifts associated with the reconfiguration of the site to best deploy the new generation of agile research buildings. Infusions of Institutional General Plant Project funds may be required to support this effort. Argonne's modernization planning projects include development of a new facility (SLI #5, FY 2020) to facilitate the removal of the additional legacy facilities in the 200 Area and rehabilitation of Building 362 (SLI #6) now slated for FY2022 initiation. These modernization projects will allow additional removals of obsolete facilities.

  The scopes of these projects — consistent with the Infrastructure Modernization Initiative screening and selection criteria — support the core infrastructure, benefiting the overall programmatic mission through co-location, synergy, and space optimization. Deferral of the SLI projects will result in increased total project costs due to escalation associated with the delays and the increased costs of maintenance and operation of obsolete, deteriorating facilities. For all five projects, alternative financing approaches are not economically viable, and costs are beyond the Institutional General Plant Project (IGPP) threshold. These projects directly support Argonne's core capabilities, are critical to the laboratory and DOE missions, and will enable reduction of deferred maintenance and elimination of excess space while providing a good return on investment (10-15 years). To supplement the SLI investments, the laboratory will support pre- and post-project implementation costs from its operating funds and is pursuing DOE/EM funding for the removal of the contaminated substandard facilities that will become surplus after these projects are implemented.

- **Programmatic Initiatives**

  Several smaller-scale programmatic projects are requested in support of the Large-Scale User Facilities/Advanced Instrumentation core capability. These include expansion of APS beamlines, build-out of the interior of LOM 437 in support of the new beamlines; a new APS Assembly and Fabrication Storage Building to house parts currently stored in the area of the future beamlines; and additions to the existing Laboratory Office Modules (LOMs) to house the support staff for the additional planned beamlines. Funding for these projects will require a determination as to the source of funds (Direct DOE funding or IGPP). A project is currently underway to expand Building 366 to accommodate the needed extension of the Argonne Wakefield Accelerator and provide space for an Accelerator Research and Development center to bring together accelerator R&D activities from several Argonne divisions.

  DOE is committed to continuing efficiency and intensity upgrades to the target and source beamlines of ATLAS/CARIBU, and is considering as part of these projects a dedicated CARIBU target transfer capability that will be utilized after closure of the Alpha Gamma Hot Cell Facility. Also, funding has been received from DOE/EERE for a new Materials Production Scale up Facility to be constructed within Building 370. Finally, a proposal for a new Battery Test Facility ($20M) is being developed for funding consideration by DOE/EERE and the State of Illinois.

- **Third-Party Financing**

  The recently completed and occupied TCS Facility was funded by State of Illinois revenue bonds, to be retired through the lease payments, and provided needed space and facilities support to build on Argonne's strengths in high-performance computing software, advanced hardware architectures, and applications expertise in support of the Applied Mathematics and Advanced Computer Science, Visualization, and Data core capabilities, as well as initiatives in Computational Science and Leadership Computing. To accommodate the need for state-of-the-art experimental space for structural biology work associated with Argonne’s Large-Scale User Facilities and Advanced Instrumentation core capability, the State of Illinois has pledged $33.5M for a 50,000ft^2 Advanced Protein Crystallization Facility (APCF), to be located adjacent to APS. To support core capabilities in Systems Engineering and Integration and Applied Nuclear Science and Technology, Argonne is evaluating non-traditional funding sources for mission-related multi-program facilities with specializations not currently included in the SLI modernization program. Additionally, the central heating plant requires upgrade/replacement, which will be third-party financed (TEC ~$18M) via an Energy Savings Performance Contract (ESPC). The project scope is currently under development for initiation in the FY 2011-2012 timeframe.

- **Projects Supported by Laboratory Operating Funds**

  Concurrent with the major construction projects discussed above, the Laboratory will devote IGPP and Major Repairs program funding to address pressing rehabilitation, upgrade, or maintenance needs in the other facilities and infrastructure and to support pre- and post-project implementation costs related to the SLI projects. The IGPP funding program will address minor facility upgrades in existing buildings and infrastructure (e.g., roof replacement, safety, fire protection, and mechanical/electrical systems), rehabilitate utility and site infrastructure, and support energy modification projects. IGPP projects are of a general institutional nature, under $10M and benefit multiple cost objectives that could be completed with indirect funding. Indirect funds will not be utilized for IGPP at the expense of maintenance or any other essential facilities program.

- **DOE/EM Funding**

  DOE/EM funding is being requested for removal of contaminated facilities that are or will become inactive. Argonne is currently consolidating the nuclear facilities and reducing the inventory of radiological materials, while preserving the capability to perform mission-important activities. Identification of funding paths is required for expeditious cleanup, material and waste disposition, and the ultimate disposition of these facilities. In conjunction with modernization planning, the laboratory has initiated efforts to transfer legacy waste and nuclear material and excess nuclear/radiological facilities to DOE-EM for disposition stewardship.

Removal of legacy facilities is consistent with the DOE/SC goal of achieving an AUI ratio of 1:1 for comparison of utilization-justified assets to current real property assets and to support DOE complex-wide requirements for overall footprint reductions via space banking. The demolition and disposal of these facilities will support responsible stewardship of nuclear material, contaminated equipment, and facilities; align infrastructure assets with mission performance; and reduce overhead costs associated with nuclear and radiological facilities. Receipt of DOE/EM ARRA funding of $79M and Omnibus funding of $29.5M allowed significant acceleration of the disposal activities. Nevertheless, current estimates indicate a total unfunded non-recurring liability of approximately $546M.

- **Deferred-Maintenance Reduction**

  Argonne is committed to reducing its maintenance backlog and with a target of ultimately achieving the DOE established ACI goals for "Mission Critical" and "Mission Essential" facilities. The laboratory's Mission Readiness Initiative closely aligns facility maintenance with anticipated facility uses. The management of deferred maintenance reduction involves multiple investment strategies. A major component is adequate funding of routine maintenance and Major Repairs programs, along with significant contributions from laboratory operating funds through the IGPP program and the SLI programs, as discussed above. The SLI modernization initiative will facilitate removal of the backlog of facility needs through replacement or modernization of maintenance-intensive, substandard existing facilities and infrastructure. Also contributing to the reduction of deferred maintenance is the use of third-party or alternative financing options where economically feasible. Office of Science ARRA funding ($15.1M) has allowed accelerated retirement of existing maintenance and replacement needs related to the electrical distribution systems.

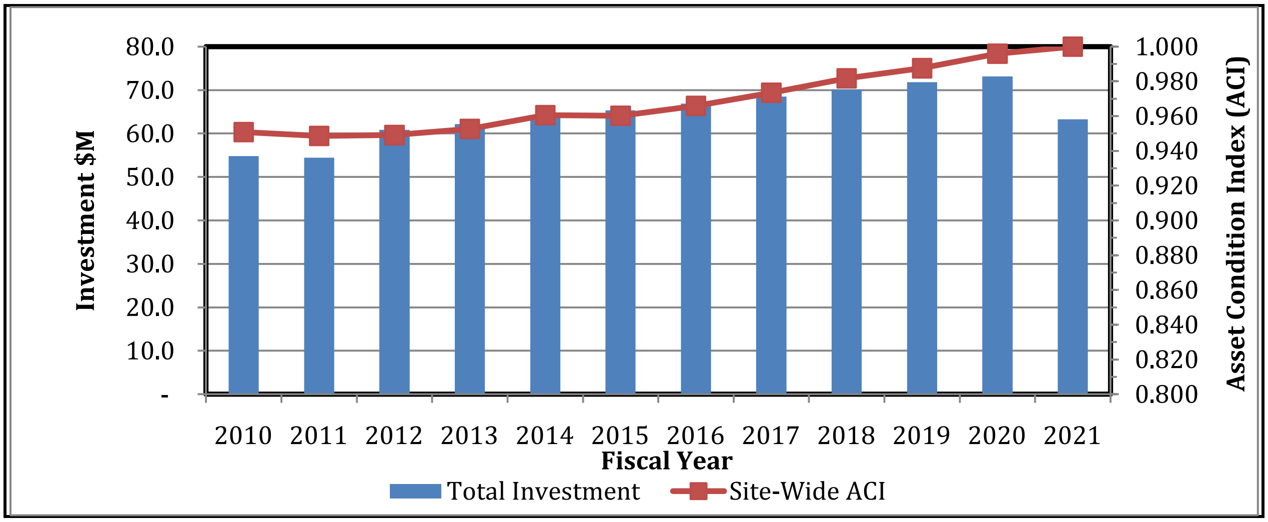
Trends and Metrics

As the Modernization Plan and Mission Readiness processes are executed, Argonne's facilities and infrastructure will become more efficient to maintain and operate and the elimination of surplus and substandard facilities will reduce the overall facility footprint. The laboratory will benefit with reduced operating costs, improved productivity, and improved performance in meeting AUI, ACI, and energy-related measures. A significant portion of the deferred-maintenance total is related to facilities that are slated for replacement as part of the modernization program. Argonne currently plans to meet all target maintenance investment index levels. *Table 3* shows that IGPP funds are projected to increase throughout the planning horizon. Forecasted operating budget reductions may slow or preclude achievement of the current maintenance targets and reduced funding levels for general facility support. *Figure 1* follows.

Table 2. Facilities and Infrastructure Investments ($M) - Impact to Asset Condition Index

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	40.4	39.8	40.8	41.7	42.7	43.8	44.8	45.9	47.0	48.1	49.3	50.5
Deferred Maintenance Reduction	4.8	5.0	10.0	10.2	10.7	10.9	11.4	11.6	11.9	12.2	12.5	12.8
IGPP	9.6	9.6	10.1	10.2	10.5	10.6	10.7	11.0	11.2	11.5	11.4	-
GPP	-	-	-	-	-	-	-	-	-	-	-	-
Line Items	-	-	-	-	-	-	-	-	-	-	-	-
Total Investment	54.8	54.4	60.8	62.1	63.9	65.3	66.9	68.5	70.1	71.8	73.2	63.2
Estimated RPV	2,129.2	2,264.7	2,298.5	2,353.7	2,443.2	2,596.8	2,659.1	2,723.0	2,788.3	2,855.2	3,018.8	3,091.2
Estimated DM	104.7	111.8	116.4	119.7	114.1	98.4	105.8	92.8	74.0	52.2	36.3	12.8
Site-Wide ACI	0.951	0.949	0.949	0.953	0.961	0.960	0.966	0.973	0.982	0.988	0.996	1.000

Figure 1. Facilities and Infrastructure Investments



Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
								Laboratory	DOE
Large-Scale User Facilities/ Advanced Instrumentation		N[a]	M[b]	P[c]	C[d]				
	Now			X		400, 401, 402, 411, 412, 420, 431 through 438, 450	Increased laboratory space required. Upgrade needed to transform APS storage ring and beamlines to meet needs of 21st-century science. Accommodation of user communities requires additional space at ends of beamlines and some extended beamlines. Major facilities upgrade initiative including compliance with Executive Order 13514 to meet mandated energy and greenhouse gas reductions	Advanced Protein Crystallization Facility in support of bioscience research (third-party – State of Illinois financed) APS Upgrade plan developed and 400 Area master plan in progress. Will identify options and resource needs to meet user requirements. Update existing facility lighting system and design and construct heat recovery system.	APS Upgrade funding requested. Upgrade plan will be funded through programmatic mechanisms.
	In 5 Years			X					
	In 10 Years				X				
	Now				X	IT Infrastructure	Currently providing in-house data center for scientific data storage. Future expansion may warrant consolidation into centralized data center.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Condensed Matter Physics and Materials		**N[a]**	**M[b]**	**P[c]**	**C[d]**				
	Now				X	212, 216	Vibration-free Microscopy Facilities – Completion of 212 D-Wing Upgrade will resolve microscopy issues for the present time.	Individual program-specific facility needs (i.e., reconfiguration or installation of specialized capabilities) will be addressed through programmatic operating funds.	
	In 5 Years				X				
	In 10 Years				X	216, new facilities	Expansion of electron microscopy capability (potential doubling in size) including replacement of 212 D-wing.	Explore options for replacement or rehabilitation of 212 D-Wing	
	Now				X	441	New scanning-probe facility to house state-of-the-art subatomic level microscopes.	Individual program-specific facility needs (i.e., reconfiguration or installation of specialized capabilities) will be addressed through programmatic operating funds.	
	In 5 Years				X	441			
	In 10 Years				X	441, new facilities	Expansion of scanning-probe microscopy capability (potential doubling in size).	Space options to be evaluated.	
	Now		X			200, 212, 223, 440	Environmental temperature, humidity, and electromagnetic interference control and clean power needed in all areas; current facilities generally inadequate. Current ventilation/hood/HEPA filter capability generally inadequate.	Rehabilitation of office and laboratory spaces and HVAC systems via Major Repairs or IGPP – see *Support Facilities and Infrastructure* table. Hood replacement program underway. Stack upgrade will be needed to accommodate construction of ESB facility	Argonne SLI-1 Project ESB (Argonne-001) $96M.
	In 5 Years				X	200, 223, 440, ESB			
	In 10 Years				X	ESB, MDL, 223, 440, new facilities		Individual program-specific facility needs (i.e., reconfiguration or installation of specialized capabilities) will be addressed through programmatic operating funds.	
	Now				X	IT Infrastructure	Currently providing in-house data center for scientific data storage. Future expansion may warrant consolidation into centralized data center.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Chemical and Molecular Science/ Chemical Engineering		**N[a]**	**M[b]**	**P[c]**	**C[d]**				
	Now			X		200, 205, 211	Modernization needed of radiological labs for heavy elements and separations science and applications in Bldgs 200 and 205. Post Test Analysis Facility for Energy Storage expansion, Bldg. 205 Synthesis labs with modern fume hood systems and upgraded electrical systems for buildings 200 and 205 Institute for Molecular Engineering initiative will require additional space. Need to relocate staff (20) from Bldg. 205 to Bldg. 200 to accommodate office and laboratory space for energy storage programs. Video teleconferencing in support of Energy Frontier Research Center web/grid access.	The most urgent general facility or infrastructure needs will be addressed via IGPP and Major Repair funds. (See Support Facilities and Infrastructure table for more information.) Programmatic operating funded activities: minor modernization of radiological labs, Bldg. 200. Modernization of some Bldg. 200 E-Wing labs funded by division funds. General facility upgrades for strategic lab programs in energy stroage and materials for energy - including the Institute for Molecular Engineering Battery Test Facility Building ($20M) Programmatic Funding - possible State of Illinois funding	DOE-EERE programmatic funded expansion of battery test laboratories in progress. Exploring State of Illinois funding.
	In 5 Years				X	200, 205, 211			
	In 10 Years				X	200, 205, 211			
	Now				X	IT Infrastructure	Currently providing in-house space for computer cluster and data center for scientific research. Future expansion may warrant consolidation into centralized data center.	Master IT plan and scientific support plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Applied Mathematics/ Adv. Computer Science, Visualization and Data		**N**[a]	**M**[b]	**P**[c]	**C**[d]				
	Now				X	240, 369	Chilling capacity provided by Argonne and Blue Gene/Q program as planned.	Complete construction of electrical substation and chilled water facility to accommodate Blue Gene Q computer program. Planning for Exascale resource needs.	Planning for Exascale resource needs.
	In 5 Years				X	240, 369	Accommodation of Exascale machine(s) contingent on emerging requirements, demand growth.	Utilize substation and chilled water facility capacity for growth to accommodate Exascale computer program, and data center storage. Provide funding for additional chiller upgrades.	Support for Exascale resource needs by 2018.
	In 10 Years				X	240, 369	Accommodation of Exascale generation machine(s) contingent on emerging requirements, demand growth. State of the art conference center needed	Expand infrastructure / facilities to accommodate Exascale program. Develop plans and identify potential funding sources for conference center.	Continued support for Exascale program effort.
	Now				X	IT Infrastructure	Facilities for ANL centralized data center storage.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X			100GB connection to APS needed.		

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Nuclear Physics		N[a]	M[b]	P[c]	C[d]				
	Now			X		203	Immediate upgrades to ATLAS/CARIBU to improve efficiency and intensity required (no change to facility footprint). Bldg 203 general office and admin and auditorium space needs significant rehabilitation. Dynamitron high bay general condition requires rehabilitation. New facility for Superconducting RF development required in 200 Area to replace existing site that must be used by ATLAS Electron Beam Ion Source(EBIS) upgrade and provide adequate space for resonator R&D and assembly in support of APS and ATLAS upgrades as well as HEP applications and work for others projects.	See facility rehabilitation, electrical, cooling (chilled water) projects in Infrastructure and Operations Support table. Evaluation and planning for highbay upgrades/construction required. Seek funds from outside ONP to support the infrastructure upgrades required for cross-cutting activities. Facility for SRF development to be utilized by PHY, APS and HEP	ATLAS efficiency and intensity upgrades ($50M). Replacement CARIBU target transfer capabilities will be required upon closure of AGHCF. ARRA Project includes increased 200 Area electrical capacity – underway ($15.1M ARRA).
	In 5 Years		X			200 Area	Required accelerator upgrades will increase need for electric power and cooling water.		Funds requested for ATLAS efficiency and Intensity Upgrade
	In 10 Years		X			200 Area	Conduct R&D on alternative production techniques of isotopes. Develop and work with partners to construct new light ion accelerator for development of isotopes for science and other applications such as Accelerator driven systems (ADS) for the processing of radioactive waste. Requires new buildings, electrical power, liquid helium refrigerator, chilled water cooling capacity.		
	Now				X	IT Infrastructure	Currently providing in-house data center for scientific data storage. Future expansion may warrant consolidation into centralized data center. Secure data transfer issues need to be addressed	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Particle Physics		N[a]	M[b]	P[c]	C[d]				
	Now				X	366	Assembly space is adequate, capable of supporting current level of experimentation. Accelerator (AWA) space will be adequate upon completion of building expansion currently underway.	Project underway to expand AWA facility in Building 366.	
	In 5 Years				X				
	In 10 Years				X	366 Area	Future growth would benefit from additional high-bay space in proximity to 360 area buildings. Further accelerator expansion may warrant below grade pits or above grade shielding blocks.	Future growth planning will be incorporated into long range facilities planning for entire 360 area.	
	Now				X	360, 362	Current office space is adequate, capable of supporting current and planned level of staffing. Laboratory space requires rehabilitation. Currently occupying space in 360 and 362. Plans call for future use of office and computing space in both 360. and 362,	Space rehabilitation underway for some 360 offices. Working with FMS to identify options for use of former IPNS control room in 360. Further 362 laboratory space rehabilitation will be addressed on a case by case basis as needs are identified.	
	In 5 Years				X				
	In 10 Years				X				
	Now				X	IT Infrastructure	Currently providing in-house data center for Divisional Linux clusters and scientific data storage. Future expansion may warrant consolidation into centralized data center.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Accelerator Science and Technology		**N[a]**	**M[b]**	**P[c]**	**C[d]**				
	Now				X	203, 208	Significant enhancement of the Superconducting RF (SRF) facility for nuclear physics and APS upgrade, R&D of international linear collider and work for other government agencies (DTRA) is required	Relocate high-bay SRF test facility. New clean-rooms, refrigeration, increased electrical power for the SRF facility – funding source and estimate tbd.	
	In 5 Years				X	208, 314, 366			
	In 10 Years				X				
	Now				X	IT Infrastructure		Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Applied Materials Science and Engineering		**N[a]**	**M[b]**	**P[c]**	**C[d]**				
	Now			X		212, 362, 369	Additional office space in Building 212 limits growth of funded programs and remains a constraint.	Evaluate options for additional office space. Relocate staff from Bldg. 212.	
	In 5 Years			X		362, 369	Flexible laboratory space including adequate ventilation is required to support program growth and ultimately for relocation of personnel from 212. Laboratory upgrades on 3rd floor of 362 could be made with program funds, but only if adequate ventilation can be provided (Fan Loft needed for 3rd floor). Additional highbay/experimental space is needed to allow relocation of Building 212 program and accommodate program growth.	The most urgent general facility or infrastructure needs will be addressed via IGPP and Major Repair funds. (See *Support Facilities and Infrastructure* table for more information.) Evaluate assignment of high-bay space to support current program growth New transformer and other building repairs being funded by Laboratory contingency funds. Lab supported cleanout of 360area high-bay areas; reassignment of high-bay space.	Buildout of new 10,000 sq. ft. H-Rated Battery Materials Engineering Facility within Bldg. 370 underway using DOE ARRA funding.
	In 10 Years				X	362			
	Now				X	IT Infrastructure	Currently providing in-house data center for scientific data storage. Future expansion may warrant consolidation into centralized data center.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years				X				
	In 10 Years				X				

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Applied Nuclear Science and Technology		**N[a]**	**M[b]**	**P[c]**	**C[d]**				
	Now		X			200, 205, 206, 208, 212, 308, 309, 315, 316, 370, 240, APS	Radiological Facilities – modern radiological laboratories provided through strategic renovation of space throughout the Argonne Complex. Hot Cell Facilities – capacity of existing facilities for programmatic work is limited – potentially required expansion to support mission needs. Existing nuclear facilities have transitioned to a de-inventory mission currently. Actinide research facility needed in APS area. Office/High Bay/Lab Space – aged facilities require upgrading or replacement to ensure continuity of programmatic work. Limited Area Office Space – currently space is inadequate for current need (inadequate space). Lack of a meeting room(s) cleared for classified discussion limits programmatic activities/growth. Current facility requires expansion or other suitable area renovated to support this need.	Individual program-specific needs (i.e., reconfiguration or installation of specialized capabilities) will be addressed using programmatic operating funds. The most urgent general facility or infrastructure needs will be addressed utilizing Major Repair and IGPP funds. (See Support Facilities and Infrastructure table for more information.) Suitable replacement facilities need to be identified before disposition of key buildings. Actinide research facility to be included in 400 area master plan.	
	In 5 Years		X						
	In 10 Years				X			Support consolidation and upgrade of office space and radiological facilities to support applied nuclear S&T programs	Support construction of appropriate radiological facilities to support applied nuclear S&T programs.
	Now				X	IT Infrastructure	Currently providing in-house data center for scientific data storage. Future expansion may warrant consolidation into centralized data center. Need for secure communication facilities.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure

Core Capabilities		Mis				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
Systems Engineering and Integration		N[a]	M[b]	P[c]	C[d]				
	Now				X	203, 221, 315, 316	Office desktop computing/ analytical capabilities and collaborative space was adequate for 180 staff w/o expansion capabilities. Additional office space(15-20 staff) now needed to accommodate program growth. Specialized contiguous office space/ conference facilities with Integrated Distribution Capabilities require enhanced secure communications and information capabilities	Rehabilitation of 221 and 203 space to be completed. Development of retrofit for on-site space to meet needs in the 300 Area (IGPP). Evaluating reconfiguration of existing space to accommodate staff growth.	
	In 5 Years			X			General office space needed to continue to accommodate projected growth of programs in related research areas.	Continued relocations/ development/retrofit of on-site space to meet needs in the 200 Area (IGPP). Investigating funding options to expand Department of Homeland Security and Department of Defense work.	
	In 10 Years			X			Expanded collaborative space needed to accommodate program growth for National Security and Energy Programs that require collaborative computing and enhanced information sharing capabilities, including space requiring specialized security. Some classified work can not be co-located with non-classified work.		Seek funding from DOE and other federal agencies to support development of collaborative space expansions.
	Now			X		IT Infrastructure	Currently providing in-house data center for scientific data storage. Future expansion may warrant consolidation into centralized data center. Specific concern for system redundancy. Needs additional video, remote computing and collaborative capabilities.	Master IT plan development underway. Will incorporate IT needs into future planning	
	In 5 Years			X					
	In 10 Years			X					

Support Facilities and Infrastructure							
Assumes TYSP Implemented							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Capability Gap**	**Action Plan**	
						Laboratory	**DOE**
Work Environment	N[a]	M[b]	P[c]	C[d]			
Office & Lab/Office Buildings & Systems			X		Older buildings have obsolete mechanical & electrical systems and roofing & envelope issues.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. • Elevator Modernization Program, $1,500K/yr • Roof Replacement Program, $1,000-$2,000/yr – IGPP • Fire Safety Improvements Program, $500K/yr – IGPP • Hood Upgrade Program – Sitewide, $100K/yr – IGPP • Space Rehabilitation Program, $1,000/yr – IGPP • Site wide Tuckpointing Program, $50K/yr – MR • Steam and Chilled Water Coils Replacement and Chiller Overhaul Programs, $500K/yr – MR • Window and Door Replacement Program, $200- $400/yr – MR • Restroom Rehabilitation Program, $250K-$650K/yr, FY 10-14 – MR • Foundation Repair Program, $50K/yr – MR • Asbestos Abatement Program, $150K/yr – OPER • Demolition Program, $100K/yr, FY 10-14 – OPER	• SC-SLI Modernization plan to construct/ refurbish various buildings.Continue EM program for D&D and disposal. (Bldgs. 310) • Funding (EM, SC, NNSA) for Waste removal & disposal • SC IPNS Transition • Nuclear Footprint Reduction • Potential for some direct programmatic funding
High-Bay Industrial Buildings/Space			X		The demand for high-bay space exceeds availability.		
Cafeteria				X	Lighting& HVAC system controls are generally adequate		
Recreational Facilities				X	Generally adequate except in 600-area		
Child Care				X	Generally good condition. Some playground remodeling needed. Siding replacement needed.		
User Accomodations							
Visitor Housing (Short Term)				X	No apparent gaps.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	
Visitor Housing (Student)			X		Additional refurbishment needed in student housing (600-area).		
Visitor Information Center				X	No apparent gaps.		

Support Facilities and Infrastructure

Assumes TYSP Implemented

Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan: Laboratory	Action Plan: DOE
Site Services							
Library				X	No apparent gaps	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	
Medical				X	Continue to maintain/upgrade equipment and offices.		
Shipping & Receiving				X	No apparent gaps.		
Fire Station			X		Inadequate training and equipment storage space; gender non-specific dormitory, locker room and shower. Building envelope and systems require updating.		
Security				X	No apparent gaps.		
Storage			X		Limited storage; programmatic space and highbays inefficiently used to warehouse experimental apparatus.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	
Conference and Collaboration Space							
Major Conference/Auditorium - 401 & TCS				X	No apparent gaps.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	
Auditorium – 200, 203& 362			X		Asbestos, fire protection, access and electronics issues.		Total rehabilitation of Building 362 is included under Modernization Initiative.
Conference Room – General				X	Communication/electronic upgrades needed. Some aesthetics.		Improved conference facilities included in buildings being constructed under Modernization Initiative.
Collaborative Spaces – General			X		Acceptable, but significant improvements warranted. More spaces needed.		Additional collaborative space is included in buildings being constructed under Modernization Initiative.

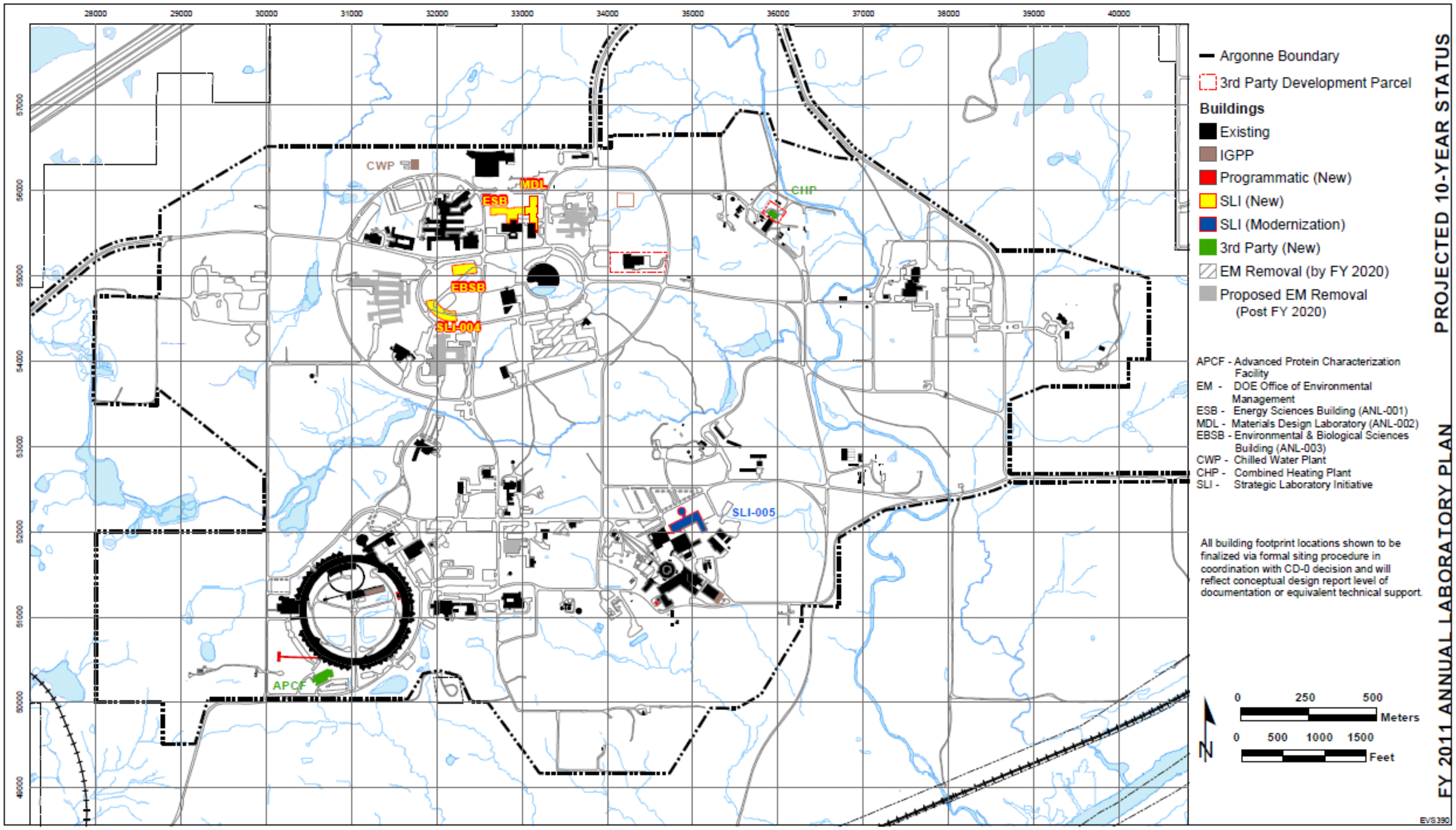
Support Facilities and Infrastructure							
Assumes TYSP Implemented							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Capability Gap**	**Action Plan**	
						Laboratory	**DOE**
Utilities							
Communications			X		Mass notification systems integration and upgrade needed	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	
Central Heating Plant			X		Existing facility requires modernization to meet latest environmental standards;	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	
					New combined heat/power plant for base load.	Major modifications to existing plant, Combined Heat and Power Plant $17M –3rd party financing.	
Electrical				X	System upgrades and expansion needed. Replace obsolete equipment. New major substation underway.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	ARRA funding $15.1M addressing electrical distribution issues – FY 09-11.
Water (potable and lab.)			X		Water systems controls and elevated tanks require refurbishment – Capability to operate water pumps/towers for backup supply questionable.		Modernization Initiative includes major utility system upgrades.

Support Facilities and Infrastructure

Assumes TYSP Implemented

Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
						Laboratory	DOE
Utilities							
Natural Gas				X	No apparent gaps.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	Modernization Initiative includes major utility system upgrades.
Wastewater Treatment (sanitary)			X		Plant requires modernization and equipment upgrades/replacement.		
Wastewater Treatment (lab waste)				X	No apparent gaps.		
Sewer (Sanitary & Lab)			X		200 area sewers require lining. Combined effluent conduits deteriorated and leaking.		
Sewer (Storm)			X		Sewers in less than desirable condition. Many culverts with corroded/deteriorated bottoms. Some areas in failure.		
Water (Chilled)			X		Expansion of central chilled water capacity and distribution in the 200-area - underway		
Steam Distribution			X		Steam distribution lines require some upgrading of anchorage, traps, etc. East Area feeder trunk to be removed.		
Flood Control				X	No major gaps.		
Roads & Grounds							
Parking (surfaces & structures) Roads, Sidewalks & Paths			X		Parking lots and some roads require some degree of maintenance, replacement or resurfacing.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above.	Modernization Initiative includes several new parking areas (associated with reconfiguration of campus).
Grounds			X		Lack of certified wetlands bank may jeopardize expansions of existing or new facilities due to on-site impacts to numerous wetlands.	Continued routine maintenance & improvements using the major repair and IGPP programs (including stewardship programs) as required to address current and emerging needs. – see above. Wetland Management Program, $100K/yr – OPER	

Argonne Site Map



Brookhaven National Laboratory

Mission/Overview

Established in 1947, Brookhaven National Laboratory (BNL) originated as a nuclear science facility. Today, BNL maintains a primary mission focus in the physical, energy, and life sciences, with additional expertise in environmental sciences, energy technologies, and national security. BNL brings specific strengths and capabilities to the Department of Energy (DOE) laboratory system to produce excellent science and advanced technologies, safely, securely, and environmentally responsibly, with the cooperation and involvement of the local, national, and scientific communities. With a long-standing expertise in accelerator science and technology (S&T), BNL conceptualizes, designs, builds, and operates major scientific facilities available to university, industry and government researchers, in support of its Office of Science (SC) mission. These facilities serve not only the basic research needs of the DOE, but they reflect BNL and DOE stewardship of national research infrastructure that is made available on a competitive basis to a wide range of university, industry, and government researchers. While the Relativistic Heavy Ion Collider (RHIC) complex and the National Synchrotron Light Source (NSLS) are the two facilities that account for most of the 4200 scientists/year served at BNL, the Center for Functional Nanomaterials (CFN) served nearly 300 users in FY 2010 and that number is expected to grow. To date, seven Nobel Prizes have been awarded for discoveries made at the Laboratory.

BNL's strong partnerships with Stony Brook University (SBU) and Battelle Memorial Institute are important strategic assets in accomplishing the Lab's missions. Beyond their roles in Brookhaven Science Associates (BSA), which manages the Laboratory, Stony Brook and Battelle are key partners in all of BNL's strategic initiatives, from basic research to the commercial deployment of technology, and figure prominently in BNL's energy research and development (R&D) strategy.

Current Core Capabilities

Twelve core technical capabilities underpin activities at Brookhaven National Laboratory:

1. Particle Physics
2. Nuclear Physics
3. Accelerator Science and Technology
4. Condensed Matter Physics and Materials Science

Lab-at-a-Glance

Location: Upton, New York

Type: Multi-program Laboratory

Contractor: Brookhaven Science Associates

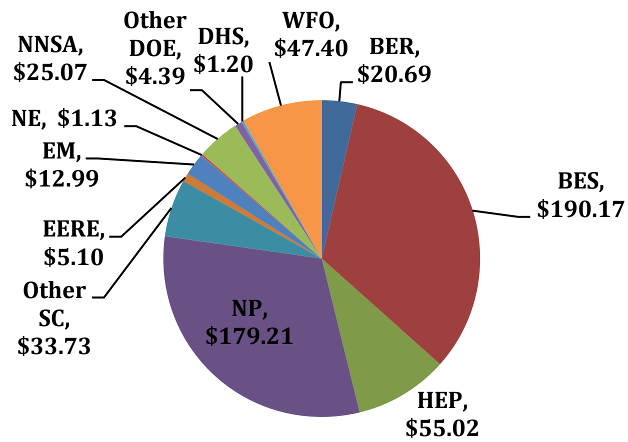
Responsible Site Office: Brookhaven Site Office

Website: http://www.bnl.gov

Physical Assets:
- 5320 acres and 331 buildings
- 4.0M GSF in buildings
- Replacement Plant Value: $1.65B (for buildings)
- Deferred Maintenance: $92M
- Asset Condition Index:
  - Mission Critical: 0.942
  - Mission Dependent: 0.950
  - Asset Utilization Index: 0.980

Human Capital:
- 2,945 Full Time Equivalent Employees (FTEs)
- 21 Joint Faculty
- 160 Postdoctoral Researchers
- 328 Undergraduate Students
- 124 Graduate Students
- 4,223 Facility Users
- 1,052 Visiting Scientists

FY 2010 Funding by Source: ***(Cost Data in $M):***



FY 2010 Total Lab Operating Costs (excluding ARRA): $576.0
FY 2010 Total DOE/NNSA Costs: $527.4
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $47.4
FY 2010 WFO as % Total Lab Operating Costs: 8.2%
FY 2010 Total DHS Costs: $1.2

ARRA Obligated from DOE Sources in FY 2010: $32.1
ARRA Costed from DOE Sources in FY 2010: $131.6

5. Chemical and Molecular Science
6. Climate Change Science
7. Biological Systems Science
8. Applied Nuclear Science and Technology
9. Applied Materials Science and Engineering
10. Chemical Engineering
11. Systems Engineering and Integration
12. Large Scale User Facilities/Advanced Instrumentation

Each of these core capabilities is comprised of a substantial combination of facilities, teams of people, and equipment that has a unique and often world-leading component and relevance to national needs that includes the education of the next generation of scientists from grades K – 12 through graduate school. These core capabilities enable BNL to deliver transformational science and technology that is relevant to specific DOE/Department of Homeland Security (DHS) missions.

1. Particle Physics

BNL provides technical and intellectual leadership in key particle physics experiments that seek answers to seminal questions about the composition and evolution of the universe, i.e., the source of mass, the nature of dark matter and dark energy, and the origin of the matter-antimatter asymmetry in the universe. BNL's major roles are: host institution for U.S. contributions to particle physics with the ATLAS detector at the Large Hadron Collider (LHC); leadership in neutrino oscillation experiments with moderate (Daya Bay) and long (Deep Underground Science and Engineering Lab-DUSEL) baselines, to complete measurement of the neutrino mixing matrix, including possible CP-violation; and development of a program of observational cosmology (Large Synoptic Survey Telescope-LSST and precursor efforts, the Dark Energy Survey and the Baryon Oscillation Spectroscopic Survey). These roles are enhanced by BNL theory efforts and by BNL's international leadership in critical detector and advanced accelerator research and development (AARD) for next-generation facilities, including a possible energy-frontier Muon Collider. Detector R&D at BNL is strongly leveraged by Laboratory support for the Instrumentation Division, which has made world-leading contributions to radiation detectors of various types and to low-noise microelectronics (see core capability 12 – CC 12). BNL's expertise in Nuclear Chemistry provides world-leading development of metal-loaded liquid scintillator materials critical to contemporary neutrino experiments. BNL operates a unique national user facility for AARD, the Accelerator Test Facility (ATF), largely with Office of High Energy Physics (OHEP) funding (see CC 3).

BNL develops advanced software and computing facilities for applications in high energy experiments and theory. Key expertise has been developed in the management and processing of petabyte-scale data sets generated at high rates and distributed computing for analysis, facilitated by the RHIC-ATLAS Computing Facility (RACF) and US-ATLAS Analysis Support Center. Lattice Quantum Chromodynamics (QCD) simulations utilize high performance computing facilities that include New York Blue (NYB), Quantum Chromodynamics on a Chip (QCDOC), and soon to be installed BlueGene/Q machines at BNL to explore theoretically the properties of elementary particles. Particle physics software and computing development for both experiment and theory benefit very strongly from synergies with RHIC facilities funded by Nuclear Physics and with the RIKEN-BNL Research Center (RBRC), funded by the Japanese RIKEN Institute.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Host institution for U.S. particle physics with ATLAS	HEP	SC: 21,22,24,26,35
Neutrino oscillation experiments	HEP	SC: 22,23,24,26,29,35
Theory, including lattice QCD on NYB and QCDOC	HEP: Theory, QCDOC New York State (NYS), BSA: NYB RIKEN: Theory, QCDOC, BlueGene/Q	SC: 21,22,23,24,29,35
AARD for next-generation facilities	HEP	SC: 24,25,26,35
Observational cosmology	Laboratory Discretionary Funds (LDF), HEP, LSST project	SC: 23,26,34,35
Software & computing facilities for theory and experiment, facilitated by RACF and US-ATLAS Analysis Support Center	HEP, BNL General Plant Projects (GPP)	SC: 4,5,35

2. Nuclear Physics

BNL conducts pioneering exploration, guided by theory, of strongly interacting nuclear matter in regimes sensitive to unique many-body QCD effects. Heavy-ion collisions at RHIC probe matter at temperatures and densities representative of the early universe, mere microseconds after its birth. Such collisions are used: to quantify the fluid properties of the quark-gluon plasma (QGP) and transitions within the QGP leading to local violations of fundamental symmetries as revealed in RHIC measurements to date; to search for a predicted critical point in the QCD phase diagram; and to search for predicted fundamental transformations of the QCD vacuum at extreme temperatures. Collisions of polarized protons (uniquely available at RHIC) are used to elucidate the spin structure of the proton. Future addition of an electron accelerator to RHIC would facilitate quantitative study of a regime of saturated gluon densities, present in all ordinary matter and featuring the strongest fields in nature. RHIC offers a synergistic environment for collaboration with universities, other National Labs, and industry. To date, RHIC has produced over 200 Ph.D. nuclear physicists. Nuclear theory efforts at BNL guide and stimulate planning and interpretation of RHIC experiments and include world-leading programs in high-temperature lattice QCD computation and the treatment of matter at high gluon density. Experimental, theoretical, and QCD computational work is enhanced by the presence of the Japanese-funded RBRC.

BNL develops advanced software and computing facilities for applications in nuclear physics experiments and theory. Key expertise has been developed in the management and processing of petabyte-scale data sets generated at high rates and distributed computing for analysis, facilitated by the RACF. Lattice QCD simulations utilize high performance computing facilities at BNL (including NYB, QCDOC, and the soon-to-be-installed BlueGene/Q machines) to explore theoretically the phase diagram of QCD.

Development and enhancement of RHIC accelerator facilities benefits from a first-rate program of advanced accelerator R&D (see CC 3), while enhancement of the RHIC detector capabilities benefits from the BNL support of the Instrumentation Division (see CC 12).

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Relativistic heavy ion physics and polarized proton spin studies	Office of Nuclear Physics (NP), LDF	SC: 21,22,25,27,30,35
Scientific case and R&D for an Electron Ion Collider	NP, LDF	SC: 27,30,35
Nuclear theory, including high-temperature lattice QCD on NYB	NP, LDF, Scientific Discovery through Advanced Computing (SciDAC): Theory BSA, NYS: NYB	SC: 21,22,26,27,35
Theoretical (including QCDOC and BlueGene/Q) and experimental studies at the RBRC	RIKEN	SC: 21,22,26,27,35
Software and computing facilities for theory and experiment, facilitated by RACF	NP	SC: 4,5,35

3. Accelerator Science and Technology

BNL has long-standing expertise in accelerator science that has been exploited in the design of accelerators around the world, beginning with the Cosmotron in 1948 and now including RHIC and NSLS. Among the now "standard" and widely-used technologies developed at BNL are strong focusing, the Chasman-Greene lattice, high brightness electron guns, and high gain high harmonic generation. Innovative BNL designs of superconducting magnets are in use at worldwide accelerator facilities, including LHC. Expertise in high temperature superconducting magnets is expected to be of central importance to future facilities, including the Facility for Rare Isotope Beams (FRIB). Complementing the above is BNL's core capability in Advanced Instrumentation (CC 12).

With the construction of National Synchrotron Light Source II (NSLS-II), the Laboratory began adopting high energy accelerator technology to achieve unprecedented brightness, integrating damping wigglers in a unique configuration. BNL's development and implementation of stochastic cooling for high-energy bunched beams is making possible an earlier and less costly completion of the RHIC-II luminosity upgrade. Full implementation of stochastic cooling will enhance RHIC heavy-ion collision luminosities by about an order of magnitude. The Lab's developing competencies in superconducting RF technology, high-brightness high-energy Energy Recovery Linacs (ERL), and innovative electron cooling techniques, together with its established world leadership in acceleration of spin-polarized beams to high energy, fuel plans for a future Electron Ion Collider.

BNL scientists have provided leadership from the outset in international R&D efforts toward development of a future Neutrino Factory and/or Muon Collider. BNL operates the ATF, a unique national user facility for beam physics experiments, which also provides training for the next generation of accelerator scientists in cutting-edge tests of advanced accelerator concepts. One specialty of the ATF is the interaction of high-power fast pulsed lasers with high-brightness electron beams. The development of such lasers at long wavelengths (~10 μm) has led to recent breakthroughs in the generation of monoenergetic ion beams from laser bombardment of gas jets, with game-changing potential for radiotherapy. Shorter-term collaboration with industry for improved ion beam therapy facilities is being driven by recent patents building on BNL expertise in developing synchrotrons and Fixed-Field Alternating Gradient accelerators for nuclear and particle physics projects.

With the selection of Experimental Physics and Industrial Control System (EPICS) as the backbone of the NSLS-II control system, BNL has become the center for development and maintenance of EPICS and its applications software.

BNL possesses strength as a world class accelerator laboratory, which is the backbone of the Laboratory and DOE's research programs. As part of the Blueprint, the Lab is promoting the establishment of an Accelerator Science and Technology Center that will foster cross-fertilization between the hadron sector under the Nuclear and Particle Physics Directorate and the photon sector under the Photon Sciences Directorate. Accelerator science and technology drives all of the projects, both internally and externally, that will sustain the Laboratory, which underscores the creativity, breadth, and flexibility of BNL's expertise in this area. In order to extend BNL's strong tradition of creative accelerator design, a joint BNL-SBU Center for Accelerator Science and Education (CASE) was recently established. The mission of CASE is to educate and train the next generation of accelerator scientists and technologists, who will support the growing needs, not only of BNL, but also of the community at large.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Accelerator design, including RHIC, NSLS, and NSLS-II	NP: RHIC Office of Basic Energy Sciences (BES): NSLS, NSLS-II	SC: 9,24,25,26,30(NP),35(NSLS,RHIC)
High temperature superconducting magnets	HEP, NP, LDF, Advanced Research Projects Agency-Energy (ARPA-E)	SC: 24,25,26,30,35 Energy Security (ES): 10
Development of stochastic cooling	NP	SC: 26,30,35
Superconducting RF technology, energy recovery linacs, innovative electron cooling techniques, and high-intensity polarized electron sources	NP, Department of Defense (DOD), BSA, LDF	SC: 25,26,30,35
Tests of advanced accelerator concepts at the ATF and research in high brightness beams	HEP, BES: ATF	SC: 24,25,26,35
R&D toward development of muon collider/neutrino factory	HEP	SC: 24,25,26,35
Joint BNL/SBU CASE	SBU Seed Grant, LDF, HEP	SC: 25,35
Electron Beam Ion Source (EBIS)	NP, National Aeronautics and Space Administration (NASA)	SC: 26,27,30,32
Development of next generation hadron therapy facilities	NP, Cooperative Research and Development Agreement (CRADA) with industrial partner	SC: 25 (medical aspect)

4. Condensed Matter Physics and Materials Science

BNL conducts world-leading fundamental research in Condensed Matter Physics and Materials Science focusing on new and improved complex, nano-structured, and correlated-electron materials for renewable energy, energy storage, and energy efficiency. This is accomplished through interdisciplinary and tightly coupled research programs in materials synthesis, advanced characterization, and theory. The Brookhaven research approach leverages core scientific, university, and industry expertise, including that in chemical and molecular science, with BNL's unique suite of complementary facilities that include NSLS, NSLS-II, the CFN, the NYB supercomputer, and BNL's Institute for Advanced Electron Microscopy. An emerging aspect of these programs is research at the gap between basic and applied science to provide an environment where research innovations may be developed to the point of deployment more rapidly. The Condensed Matter Physics and Materials Science Department is the lead institution in the Center for Emergent Superconductivity, an Energy Frontier Research Center (EFRC) that involves collaboration with Argonne National Laboratory and the University of Illinois. BNL is also partnering in the EFRCs on Excitonics and Photovoltaic Efficiency, led by the Massachusetts Institute of Technology and Columbia University, respectively. Since several of the BNL Principal Investigators are from the CFN, the expectation is that the EFRCs will lead to new CFN users involved in high-impact research on energy-related topics.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Fundamental studies of complex materials through materials synthesis, advanced characterization, and theory	BES, LDF	SC: 6,7,8,10,26,33,34,35
Research at the gap between basic and applied science	BES, LDF	SC: 6,7,8,10,26,33,34,35
BNL-led Center for Emergent Superconductivity and EFRCs on excitonics and photovoltaic efficiency	BES	SC: 6,7,8,10,26,33,34,35
Unique and complementary tools (NSLS, NSLS-II, CFN, NYB, Institute for Advanced Electron Microscopy) to facilitate the research	BES: NSLS, NSLS-II, CFN BSA, NYS: NYB	SC: 6,7,8,9,26,35

5. Chemical and Molecular Science

In the chemical and molecular sciences, BNL focuses on fundamental experiments, theory, and computation that provide the scientific underpinning for the development of new energy sources, energy storage, and more efficient utilization of energy. Areas of highly-recognized expertise include: heterogeneous-, electro-, and photo-catalysis, chemical dynamics, and radiation chemistry.

The heterogeneous catalysis science effort links *in situ* studies of powder catalysts under reaction conditions, particularly using synchrotron X-ray techniques, with systematic studies of model nanocatalysts and computation to develop deeper understanding of catalyst active sites and reaction mechanisms. This effort focuses on improved catalysts for clean fuels (desulfurization), sustainable fuel synthesis from abundant small molecules such as CO_2 and H_2O, and alternative fuels such as hydrogen.

Electrocatalysis research builds on world leadership in synthesis and characterization of nanostructured core-shell metal and metal oxide electrocatalysts to develop improved fuel cell catalysts for hydrogen and liquid fuel cells, as well as electrocatalysis of water splitting and fuel forming reactions. This effort is strongly linked to the CFN, NSLS, and computational efforts in developing strong fundamental understanding of structure-activity relationships in electrochemistry.

Photocatalysis addresses sustainable energy sources such as conversion of solar energy to fuels (artificial photosynthesis) through national leadership in mechanistic inorganic chemistry, including photochemical and computational studies of reaction mechanism. This effort is also closely linked to radiation chemistry as a unique tool for time-resolved mechanistic studies of oxidation and reduction reactions.

Chemical dynamics groups are leaders in the development of advanced, time-resolved laser spectroscopy methods for characterization of molecular dynamics in the gas phase important in combustion processes, and for study of molecule-surface interactions underlying catalytic and photocatalytic processes. These efforts combine leading experimental capabilities along with state-of-the-art computational methods in quantum molecular dynamics.

Radiation chemistry research addresses fundamental chemical events arising from ionizing radiation, including study of chemical transformations that arise for materials and processing media that are important in actinides processing, such as in advanced nuclear energy cycles. The methods also provide a powerful method to study singly oxidized or reduced molecular systems for mechanistic studies of redox chemistry important in electrical-chemical or solar-chemical energy conversion, as well as the unique ability to study single-molecule electron transfer and conductivity important, for instance, in organic photovoltaic materials.

This research makes extensive use of the NSLS and NSLS-II, the CFN, NYB, and the Laser Electron Accelerator Facility (LEAF) and leverages expertise in core programs, including those in condensed matter physics and materials science, with collaborations from universities, other National Labs, and industry.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Fundamental experiments, theory, and computation in heterogeneous-, electro-, and photo-catalysis, electrochemistry, chemical dynamics, and radiation chemistry	BES, LDF, BSA	SC: 6,7,8,10,26,33,34,35
Unique and complementary tools (NSLS, NSLS-II, CFN, NYB, LEAF) to facilitate the research	BES: NSLS, NSLS-II, CFN, LEAF BSA, NYS: NYB	SC: 6,7,8,9,26,35

6. Climate Change Science

BNL's world-class climate change programs seek to understand the role of greenhouse gases, aerosols, and clouds on Earth's climate. Research includes partnering on the Atmospheric Radiation Measurement (ARM) Climate Research Facilities; designing and conducting global change experiments that explore the effects of increased CO_2 on the biosphere; studying the formation, growth, and optical properties of clouds and aerosols; providing three dimensional (3-D) cloud reconstructions; developing and testing physics-based representations of important climate-related atmospheric processes for implementation in large-scale climate models; and probing the consequences of CO_2 sequestration on molecular scale geology at the NSLS.

This research utilizes climate and climate-related models that have been implemented on NYB and leverages BNL's expertise in the core programs including experimental studies of clouds and aerosols and skills in the development of theory needed to understand the relevant processes with collaborations from universities and other National Laboratories and institutions.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Partnership in the ARM Climate Research Facilities	Office of Biological and Environmental Research (BER)	SC: 12,14,24,26,33,34,35
Designing and conducting global change experiments	BER	SC: 12,14,24,26,33,34,35
Formation, growth, and optical properties of clouds and aerosols and 3-D cloud reconstructions	BER, Office of Advanced Scientific Computing (ASCR), LDF BSA, NYS: NYB	SC: 12,14,15,16(part),26,33,34,35
Physics-based representations of climate-related atmospheric processes	BER, LDF BSA, NYS: NYB	SC: 12,14,15,16 (part),26,33,34,35
Climate change impact on plant systems	BER, LDF	SC: 12,14,15,16(part),24,26,33,34,35
Consequences of CO_2 sequestration on molecular scale geology at NSLS	LDF	SC:14,35

7. Biological Systems Science

The goal of BNL's programs in the biological sciences is to understand complex biological systems, from the molecular to the organism level at different temporal and spatial scales. BNL emphasizes applications in plants of interest to missions of the DOE in energy and environment. Expertise ranges from investigating structures of individual proteins, elucidating the structures and multi-dimensional interactions within protein complexes, measuring and modeling metabolic fluxes in single cells and tissues, to studying epigenetic mechanisms in plants. In all cases, the objective is to relate structure and function, so that desired manipulations, such as increasing growth rates, altering metabolic pathways to enable the accumulation of desired products, environmental adaptation or detecting disease can be carried out easily and reliably. The tools used include structural biology in a wide variety of forms, molecular biology, and biological imaging.

Macromolecular interactions are the main focus of an interdisciplinary effort between investigators in the Biology Department and the CFN, who develop novel biomimetic approaches that use bio-programmable self-assembly for the creation of well-defined hierarchical nanoscale structures that are built from inorganic nano-objects and biological molecules (see CC 9). This work has great potential to impact a broad range of nanotechnologies related to the fabrication of nanomaterials and devices for energy conversion, single molecular detection, and catalysis. Moreover, these efforts are among the building blocks for an emerging focus at BNL on biodesign, i.e., understanding and exploiting the design principles of biological systems for engineering systems of great impact to DOE missions in energy and environment.

BNL conducts world-leading research in developing radiochemical tracers for monitoring biological processes including plant metabolism using Positron Emission Tomography (PET) and better detectors based on the Lab's advanced instrumentation capability in detector physics. Using the beamlines at the NSLS, cryo-electron microscopy (EM), and fluorescence resonance energy transfer, BNL performs structural analysis on complex biological systems.

The biofuels/biofeedstocks program has a unique expertise in engineering plant oils. Methods for defining epigenetic change in plants are being applied to changes initiated by climate change. The low dose radiation program characterizes the effects of radiation on living systems. The radiation biology program at BNL also features a flagship facility supported by NASA, the NASA Space Radiation Laboratory (NSRL).

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Structure/function relationships using molecular biology and structural biology and biological imaging (NSLS, NSLS-II, CFN, and cryo-EM)	BER, LDF: molecular biology BER, National Institutes of Health (NIH): Biology beamlines at the NSLS NIH, BSA: cryo-EM	SC: 11,24,26,33,34,35
PET radiochemical tracers and imaging technology for monitoring biological processes, including plant metabolism	BER, NIH, CRADAs, BSA, LDF: radiotracers BER: technology	SC: 11,14,26,35
Metabolic engineering of plants for biofuels and bio-based products	BES, LDF, CRADA: plant oils LDF, BSA, Inter-lab: endo-phyte/plants BER, LDF: plant cell walls LDF, BER: epigenetic changes	SC: 11,14,26,33,34,35
Effect of radiation on living systems, including NSRL	BER, NASA NASA: NSRL	SC: 24,26,35

8. Applied Nuclear Science and Technology

BNL's nuclear science programs span the gamut from medicine to national security. At the Brookhaven Linear Isotope Producer (BLIP), BNL plays a critical role in preparing radioisotopes for the nuclear medicine community and industry that are unavailable commercially. This work continues BNL's long leadership tradition in radiotracer development. A 2011 highlight is the first combined PET/Magnetic Resonance Imaging (MRI), carried out with ^{52}Fe-labeled nanoparticles developed at the Lab. This role could be amplified if the BNL-proposed Cyclotron Isotope Research Center (CIRC) were to be constructed at the Lab. BNL's expertise in accelerator development has led to a recent patent for a Rapid Cycling Medical Synchrotron (RCMS) and for low-mass beam delivery gantries, viewed as technologies of choice for the next generation of proton- and ion-based cancer therapy centers.

BNL also has extensive expertise in nuclear safeguards, security policy, and energy policy, including MARKAL (Market Analysis Modeling) that has broader applications in materials and chemical sciences; nuclear nonproliferation; materials protection and control; advanced radiation detector R&D; and scientific and technical assistance to the Radiological Assistance Program (RAP). BNL is a critical player in the New York Energy Policy Institute (NYEPI), a new institute headquartered at the Advanced Energy Center at SBU. NYEPI will assist government agencies and officials with critical energy decisions.

BNL develops cadmium zinc telluride (CZT) prototype radiation detectors for nonproliferation and homeland security applications, starting from the conceptualization and design phases to assembly, testing, and characterization of the prototypes. BNL is developing a special expertise in growing large CZT and other detector crystals in-house. An innovative application of the detectors developed for national security purposes at BNL is a CZT camera, marketed as ProxiScan, which is designed for high-resolution imaging of prostate cancer.

BNL operates the National Nuclear Data Center (NNDC), an international resource for dissemination of nuclear structure, decay, and reaction data that serves as the focal point for the U.S. nuclear data program and reactor design. BNL supports the development of next generation reactors through its research on alternative fuel cycles, materials in extreme environments, and its assessment of the role of nuclear energy in our Nation's energy future.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Medical applications: BLIP, RCMS, and possibly CIRC in the future	NP: BLIP CRADA: RCMS	SC: 25(medical aspect),31,35
Nuclear safeguards and security	Department of State (DOS)	National Security (NS): 2
Nuclear nonproliferation, materials protection and control, advanced radiation detector R&D, including CZT prototype detectors	National Nuclear Security Administration (NNSA), LDF: nonproliferation NNSA: materials protection and control NNSA, Defense Threat Reduction Agency (DTRA), DHS, LDF: detectors	NS: 1,2 Homeland Security (HS): 2,3
RAP	NNSA: RAP DHS Domestic Nuclear Detection Office	NS: 4 HS: 9
Energy policy	Offices of Energy Efficiency and Renewable Energy (EERE)-Solar & Renewable Resource Technologies, Fossil Energy (FE)-Coal Research & Development, and Nuclear Energy, Science & Technology (NE)–Nuclear Energy Research & Development	ES: 1,2,7
NYEPI	NYS	Enhances all DOE Missions in Energy Security
NNDC	NP	SC: 5,26,31,32,35
Next generation reactors, materials in extreme environments, and assessment of nuclear energy in the U.S. energy future	Nuclear Regulatory Commission (NRC), Department of Commerce: reactors LDF: materials NE: U.S. energy future	ES: 2 NS:2

9. Applied Materials Science and Engineering

This capability is an extension of BNL's effort in condensed matter physics and materials science that is concentrated on materials for energy technologies including strongly correlated/complex materials and nanomaterials (including bio/soft/hybrid materials), which are at the heart of renewable energy technologies. In order to understand the route to superconductors with improved critical properties (e.g., critical temperature, critical current, critical field), BNL conducts experimental and theoretical research to design, synthesize, understand, predict, and ultimately enhance the properties of strongly correlated/complex materials, particularly for electrical energy transmission and electrical energy storage applications. Among its tools for synthesis, BNL uses its state-of-the-art molecular beam epitaxy (MBE) capability to prepare exceptionally high quality films of cuprates and other oxides. Typical methods of characterization include neutron and X-ray scattering, electron spectroscopy, electron microscopy at the Institute for Advanced Electron Microscopy, and scanning tunneling spectroscopy, supported by theory. Similarly, BNL synthesizes and characterizes materials for energy storage and nanomaterials for enhanced solar fuel production and solar electricity generation and for incorporating new functionalities. BNL supports electrical energy storage technologies including General Electric's sodium battery technology, through its facilities and expertise in photon sciences and electron microscopy. BNL is a partner in the SBU-led Energy Storage EFRC and in several successful battery proposals funded by the New York Battery and Energy Storage (NYBEST) Consortium. In conjunction with theory and modeling, characterization methods include electron microscopy, electron and X-ray diffraction, nanoprobes, and studies of nanoscale ordering and assembly at the CFN.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Strongly correlated/complex materials (including films grown by MBE) and nanomaterials for renewable energy technologies	BES, Office of Energy Delivery & Energy Reliability (OE)-Office of Electric Transmission & Distribution, LDF	SC: 6,7,8,10,26,33,34,35 ES: 10
Materials and nanomaterials for energy storage and solar fuels	BES, EERE-Solar & Renewable Resource Technologies; Vehicle Technologies, LDF	SC: 6,7,8,10,26,33,34,35 ES: 1,10,12,15
Electrical energy storage technologies	BES: EFRC, LDF NYBEST, LDF: batteries	SC: 6,7,8,10,26,33,34,35 ES: 10,15
Characterization by neutron and X-ray scattering at NSLS and NSLS-II, electron -spectroscopy,-microscopy, and –diffraction, scanning tunneling spectroscopy, and nanoprobes, supported by theory and modeling, and studies of nanoscale ordering and assembly at the CFN	BES, LDF: characterization, theory, modeling, studies of nanoscale ordering and assembly BSA, NYS: NYB	SC: 6,7,8,9,26,35

10. Chemical Engineering

BNL has a small, but emerging effort in applied chemical research that translates scientific discovery into deployable technologies. Basic research in surface electrochemistry and electrocatalysis, using a variety of characterization techniques, including atomic-level surface characterization with X-rays at the NSLS has matured into the design of efficient catalysts for fuel cells. BNL has developed various innovative catalysts that have the potential to solve two main problems of existing technology: low efficiency of energy conversion and high Pt loading. In the future, since the catalysts contain smaller amounts of precious metal, they could be used in fuel cells that convert hydrogen to electricity in electric vehicles. Scale-up of some of these materials is underway. The Synchrotron Catalysis Consortium at NSLS offers the opportunity for advanced characterization and testing of real world catalysts to universities, industry, and other National Laboratories.

Elements	Major Sources of Funding	Tie to Mission (Appendix D)
Design of efficient catalysts for sustainable chemical conversions	BES, EERE-Solar & Renewable Resource Technologies, CRADAs	SC: 6,7,8,10,26,33,34,35 ES: 1
Characterization at the NSLS (including using the tools of the Synchrotron Catalysis Consortium), NSLS-II, CFN, NYB	BES BSA, NYS: NYB	SC: 6,8,9,35

11. Systems Engineering and Integration

BNL solves problems holistically and across multiple disciplines on several levels in order to deliver Large-Scale User Facilities/Advanced Instrumentation. Individual facility components (accelerators, detectors, beamlines, etc.) that are conceived, designed, and implemented at BNL are complex entities, requiring broad integration for their successful performance and, in turn, for their coupling with other systems. BNL's approach applies not only to engineering at the various stages of a single project, but also to developing cutting-edge technology that fuels multiple large projects at the Laboratory. One example is BNL's development of noble liquid detectors from concept, through demonstration, to implementation within enormous detectors at D0 at Fermilab and ATLAS at LHC, and accompanied by continuing R&D to develop the very large liquid argon time projection chambers that might serve a future long baseline neutrino experiment (LBNE). A second example involves application of high-brightness electron beam technology developed at BNL to NSLS-II and the proposed future electron-ion collider (eRHIC). A third example involves collaboration between condensed matter physicists at BNL, the Superconducting Magnet Division, and commercial partners to develop high-temperature superconducting materials and magnets for prototyping Superconducting Magnet Energy Storage systems.

Recently, BNL has been focusing its expertise in the engineering analysis of energy systems toward developing an Advanced Electric Grid Innovation and Support (AEGIS) Center for electric network monitoring, analysis, and modeling. This emerging capability will serve East Coast utilities, technology developers, research institutions, emergency management organizations, and the DOE and DHS as a fully-functional grid monitoring and control center, test-bed for transmission and distribution technologies and strategies, and a research and development center that supports the controlled separation plans and assessments for NYS and others. This Center will also reach-back to BNL's applied research efforts in materials and storage for grid applications (see CC 9).

Elements	Major Sources of Funding	Tie to Mission* (Appendix D)
Components which combine to deliver NSLS, CFN, ATF, and in the future, NSLS-II	BES: NSLS, NSLS-II, CFN BER: NSLS NIH, National Institute of Standards and Technology (NIST): NSLS, NSLS-II BES, HEP: ATF	SC: 9,24,26,35 SC (NSLS): 34,35
Components which combine to deliver RHIC, and in the future, RHIC-II and eRHIC	NP: RHIC, RHIC-II DOD, LDF, BSA: eRHIC	SC: 24,26,30,35
Components which combine to deliver international facilities (LHC, Daya Bay)	HEP: LHC HEP, LDF: Daya Bay	SC: 23,24,29,35
Components which combine to deliver future facilities (LBNE, LSST, Muon Collider)	HEP: LBNE, Muon Collider LDF, HEP, LSST project: LSST	SC: 23,24,26,29,35
AEGIS Center	LDF	ES: 10,16 HS: 9, 10
Superconducting Magnet Energy Storage systems	ARPA-E	ES: 10

*The facilities enable additional mission ties that are shown in core capabilities 1-10.

12. Large-Scale User Facilities/Advanced Instrumentation

Since its creation as a National Laboratory to promote research in the physical, chemical, biological, and engineering aspects of the atomic sciences, BNL's ability to provide facilities that individual institutions could not afford and would not have the range of expertise required to develop on their own has been a key element of its mission. In FY 2010, BNL served more than 4200 users at its DOE designated user facilities, i.e., NSLS, RHIC (including NSRL, the Alternating Gradient Synchrotron (AGS), and the Tandems), CFN, and ATF, as well as those users at the RACF and US ATLAS Analysis Support Center. BNL is constructing NSLS-II, the newest member of DOE's suite of advanced light sources, which is expected to serve more than 3500 users annually when fully operating. BNL envisions a future major upgrade of RHIC (eRHIC) that will attract a new generation of users interested in using high-energy electron-ion collisions to study cold nuclear matter at extreme gluon densities. BNL also makes important contributions to international facilities – the LHC, Daya Bay, regional facilities such as the New York Center for Computational Sciences (NYCCS), and such future facilities as DUSEL, LSST, and a Muon Collider. This core capability is strongly tied to those in *Accelerator Science and Technology*, *Systems Engineering and Integration, Advanced Instrumentation* (CC 3, 11, 12), and world-leading computation efforts for data capture, storage and analysis, and is enhanced by infrastructure support to users. Some smaller user-oriented facilities of the future that will be helpful to NYS include access to testing the 32 MWe solar array and the AEGIS Center.

BNL conceptualizes, designs, and constructs state-of-the-art optics, detectors and electronics that are used for experiments at RHIC, NSLS, LHC, LSST, and in accelerator-based facilities around the world. The BNL Instrumentation Division is especially noteworthy for its leadership in noble liquid detector technology, low-noise Application-Specific Integrated Circuit design, state-of-the-art silicon detector development, and R&D on photocathodes and ultra-short pulse lasers. BNL also engages in pioneering development of gamma ray spectrometers, neutron imaging and directional detectors, as well as long-range detection of special nuclear materials for homeland and national security applications.

Elements	Major Sources of Funding	Tie to Mission* (Appendix D)
NSLS, CFN, ATF, and in the future, NSLS-II	BES: NSLS, NSLS-II, CFN BES, HEP: ATF BER: NSLS NIH: NSLS, NSLS-II	SC: 9,24,26,35 SC (NSLS): 34,35
RHIC/AGS, and in the future, RHIC-II and eRHIC	NP: RHIC/AGS DOD, LDF: eRHIC	SC: 24,26,30,35
RHIC-ATLAS Computing Facility and Analysis Support Center	NP, HEP	SC: 4,5,35
NSRL	NASA	SC: 24,26,35
NYCCS	NYS, BSA	SC: 6,7,11,12,21,22,23,27,33,35
International facilities (LHC, Daya Bay)	HEP: LHC HEP, NP: Daya Bay	SC: 24,35
Future facilities (LBNE, LSST, Muon Collider, solar array, AEGIS)	HEP: LBNE, Muon Collider LDF, HEP, LSST project: LSST LDF: solar array, AEGIS	SC: 24,35
State-of-the art detectors and electronics	LDF, and through NP, HEP, BES, BER programs NNSA, DTRA, DHS, LDF: detectors for national and homeland security	SC: 24,26,30,35 NS: 2 HS: 2,3

*The facilities enable additional mission ties that are shown in core capabilities 1-10.

The Office of Science believes that these twelve core capabilities will enable BNL to deliver its mission and customer focus, to perform a complementary role in the DOE laboratory system, and/or to pursue its vision for scientific excellence and pre-eminence in the following areas:

- Relativistic heavy ion and spin physics research to understand the essence of nuclear matter
- Photon sciences for advanced characterization of functional nanomaterials for energy technology applications, and more broadly for tackling grand challenge questions in condensed matter, materials, chemical and nano-sciences, as well as in life and environmental sciences, that will lead to breakthroughs needed to address global energy and climate challenges
- Energy-related R&D to enable breakthroughs in the effective use of renewable energy through improved conversion, transmission, and storage
- High energy physics at the energy, intensity, and cosmology frontiers, supported by theory and advanced accelerator R&D
- Understanding and dealing with the impact of natural phenomena and human activity on climate, the environment, and local ecosystems, from the molecular to the biological system level.

Science Strategy for the Future/Major Initiatives

Anticipated scientific discoveries at Brookhaven will drive U.S. competitiveness, inspire America, and transform the technologies that meet the Nation's energy requirements. The Laboratory's major activities for the coming decade are in three principal and inter-related areas: the advancement of fundamental research in nuclear and particle physics to gain a deeper understanding of matter, energy, space, and time; the application of photon sciences and nanomaterials research to energy sciences; and emerging cross-disciplinary research to understand the relationships between climate change, sustainable energy, and Earth's ecosystems.

In order to reap the potentially transformational benefits of these missions, Brookhaven is pursuing the evolution of its two largest user facilities – the NSLS and RHIC. NSLS, a pioneering user facility, is an accelerator-based light source for photon sciences. It remains productive after more than 25 years of operation. The discovery potential of BNL photon sciences will be enormously expanded by replacing NSLS with NSLS-II, a new light source, by 2015. It will deliver the world's finest capabilities, ~10 times brighter than any other synchrotron now operating or under construction, and exquisite sensitivity. Together with the newly completed CFN, NSLS-II will transform Brookhaven's research in energy sciences. RHIC is an accelerator that collides beams of atomic nuclei at unprecedented energies, where quarks and gluons can be released from their normal confinement inside protons and neutrons. Since the start of operations in 2000, RHIC experiments have transformed our understanding of the matter that forms the visible universe, including the form and behavior of that matter at the extreme temperatures reached a tiny fraction of a second after the Big Bang. To pursue these fundamental studies on a more comprehensive scale, RHIC will be evolved first to upgrade the collider luminosity and detector precision, to facilitate quantification of the properties of the quark-gluon plasma, searches for the onset in energy of quark deconfinement, and elucidation of possible changes in fundamental symmetry properties in the excited QCD vacuum assessed at the extreme temperatures of the matter produced in RHIC collisions.

The five major activities that will extend and evolve BNL's current core capabilities to support the DOE Strategic Themes in Energy Security, Nuclear Security, Scientific Discovery and Innovation, and Environmental Responsibility and build on core strengths and capabilities of the Laboratory, are presented below. These are areas in which BNL envisions that it will substantially distinguish itself by offering new capabilities. In their order of priority, these activities are as follows:

1. Photon sciences
2. QCD Matter
3. Discovery to Deployment: A Path to 21st Century Energy Security
4. Physics of the Universe
5. Climate, Environmental, and Bio-Sciences

BNL has also developed and is now implementing a comprehensive, multi-year plan, called the Blueprint, which will enable BNL to realize its long-term vision and goals. Reaching across BNL's science and technology directorates, operations, and stakeholder relationships, the Blueprint seeks to expand BNL's applied sciences portfolio, especially in energy and climate sciences, address leadership capabilities and expectations, revitalize the Laboratory's infrastructure, improve safety, and enhance operational performance including lowering/optimizing the cost of business. BSA is strongly committed to the success of the Blueprint. Both BSA partners (Battelle and SBU) are providing significant help with its implementation in order to ensure its success.

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

BNL is located in Upton New York in central Suffolk County approximately 75 miles east of NYC. The BNL site, former Army Camp Upton, lies in both the Townships of Brookhaven and Riverhead. BNL is situated on the western rim of the shallow Peconic River watershed. The marshy areas in the site's northern and eastern sections are part of the Peconic River headwaters. Approximately thirty percent of BNL's 5,320 acre site is developed. There are 344 buildings totaling 4.19M square feet (sf) (including 13 Environmental Management (EM) buildings totaling 165k sf and 331 SC buildings totaling 4.02M sf). In addition, there are 44 real property trailers totaling 23k sf, and 131 other personal property portable structures, totaling 33k sf. The average age of active buildings is 46 years (49 years for EM and 46 years for SC). Sixty-eight buildings (749k sf) date back to World War II and most major permanent science facilities, excluding those constructed for NSLS, RHIC and the CFN, are DOE-SC facilities built in the 1950s and 1960s. Other than several GPP, IGPP and operating-funded laboratory rehabilitation projects and the current RSL-I project under the SLI program, these facilities have not received any major renovation and many building systems are original.

The current Land Use Plan can be found on the BNL intranet: http://intranet.bnl.gov/mp/im/ . Construction of the NSLS-II is underway and will add 590,000 sf by FY14. Included in this Plan is the 14 ksf expansion of the Chilled Water Plant which will be completed this fiscal year. In addition, construction of ISB-I began this fiscal year and the baseline project will add 87,701 sf by FY12. Under an easement arrangement, DOE has provided approximately 200 acres of land to construct the LISF, a 32 MWe solar power plant. Table 2 provides key infrastructure data for SC conventional real property only.

Table 1. SC Infrastructure Data Summary

Replacement Plant Value ($M)*		2,070
Total Deferred Maintenance ($M)*		105
Asset Condition Index	Mission Critical	0.95
	Mission Dependent	0.95
	Non-Mission Dependent	0.96
Asset Utilization Index	Office	0.98
	Warehouse	1.00
	Laboratory	0.99
	Housing	1.00
FY10 Actual Maintenance ($M)*		45.0
**Excludes program real property (OSF 3000 series)*		

Facilities and Infrastructure to Support Laboratory Missions

The major issue confronting BNL and the mission readiness of its core capabilities is the need for capital renewal and new facilities where existing buildings cannot meet the required functionality. Since many of BNL's permanent science buildings are in excess of 45 years old, they require substantial investments in mechanical and electrical system upgrades. Typical upgrades to research labs include new fume hoods and casework and creation of "clean rooms", some of which cannot be achieved by renovating existing facilities. In addition, many research labs need state-of-the-art upgrades including stringent environmental and vibration control. BNL has identified those "permanent" facilities that will form the platform for current and future core capabilities. In addition to routine maintenance, BNL has invested over $30M of GPP and operating funds in them over the past ten years. The current RSL-I project has invested an additional $18M in these facilities and the RSL-II project, now completing design, will invest an additional $50M. As part of the Recovery Act, BNL received $18.5M in GPP funds for projects focused on capital renewal and upgrades to mission critical buildings. These permanent facilities are well-designed and structurally sound. With the planned investments indicated, their ability to support world-class science can be extended significantly. Some capabilities of existing programs are hampered by the lack of high-accuracy labs. The proposed ISB-I, ISB-II, and ISB-III projects will help address these needs, however, delays in project funding for the latter two will require intermediate projects supported by IGPP and operating to ensure program needs are met and anticipated growth supported. BNL's direct investment in conjunction with Line Item support through the SLI program will ensure BNL's leadership roles within the SC Laboratory Complex.

The mission readiness needs of BNL's technical facilities and infrastructure now, in 5 years, and in 10 years and the current mission readiness of support facilities and infrastructure are summarized in the tables contained in Appendix D. Mission Critical facilities continue to be evaluated against Mission Readiness needs. An infrastructure study that focused on near and mid-term IGPP and operating-funded projects was performed. It concluded that waiting for the future SLI projects to be constructed is not a viable solution and intermediate actions will be needed. The Lab will continue to work with NYS to maintain low cost power for operation of its facilities.

- **Particle Physics:** The Physics Department, Building 510 (B510), is a key facility for major activities in particle physics at LHC-ATLAS, studies of neutrino properties, theory, and development of a program in observational cosmology. The 49 year-old 200k sf building, comprised mainly of labs, offices, shops, and high-bay assembly space, has major capital renewal needs. These needs will be addressed by the RSL-II SLI Line Item, BNL IGPP, and operating funds. In addition, the SLI Line Item will provide needed clean room space and clean power for detector development. At the conclusion of the line item project, most major needs are expected to be addressed. B515 houses the RACF and the US-ATLAS Analysis Support Center, as well as QCDOC and NYB. A main gap for B515 is the continuing need for additional power and cooling as existing computers are replaced with more powerful ones. Associated electrical infrastructure needs will be addressed with IGPP over the planning period. The Instrumentation Division (B535), which builds detectors for observational cosmology and low-noise electronics and other innovative detectors for particle physics, nuclear physics, and photon sciences is 47 years-old and has issues with capital renewal and lack of clean room and other dedicated lab space. These needs will be addressed during the ten-year planning period with either IGPP or operating funds or potentially as a part of the proposed ISB-III project. Plans to provide the needed clean room space in alternate locations continue to be evaluated. B901 (advanced accelerator development for next-generation facilities) and B902 (accelerator upgrade to the LHC) do not have major issues.

- **Nuclear Physics:** B510, B515, and B535 are also key facilities for experimental and theoretical nuclear physics research including relativistic heavy ion and polarized proton spin studies, developing the scientific and technical case for eRHIC, and designing and constructing advanced detector instrumentation and electronics. The RBRC is located in B510. The gaps and actions are the same as for Particle Physics. The main experimental facilities are a series of buildings mostly in the 900 and 1000 series range, collectively known as RHIC, housing the accelerator and its support facilities that include research dedicated toward RHIC improvements and eRHIC. The primary gap is operational efficiencies which have begun to be addressed through consolidation of functions which, in turn, will result in several run-down buildings becoming vacant for future demolition. IGPP and operating funds will be used to renovate and upgrade existing facilities such as B911, B912, and B924 in order that the consolidation can occur.

- **Accelerator Science:** R&D related to this capability in accelerator design, development and implementation of high brightness guns, stochastic cooling, superconducting RF technology, advanced beam cooling, energy recovery linacs, and a future Neutrino Factory/Muon Collider, and fabrication of high Tc magnets occurs in several facilities previously discussed, such as B510, 515, 535 and 901, 902, 911 & 912 (part of the Collider-Accelerator Department). Other buildings including B817, 703, 725, 830, 832, and 902 support NSLS-II R&D, design, and construction. B820 houses the ATF. Most of the labs in B703 have been renovated and some major buildings systems have also been upgraded. Additional rehab of remaining labs and buildings systems will need to be accomplished during the planning period. There are no major gaps other than those previously described.

- **Condensed Matter Physics & Materials Science (CMPMS):** The current key facilities for CMPMS research that focuses on new and improved materials for renewable energy, energy storage, and energy efficiency are B480, 510, and 703 as well as at the NSLS (B725), the CFN (B735), and NYB (B515). The renovation of B480, part of RSL-I project, will be completed this year. This project will make B480 fully capable. The CMPMS functions in B510 and B703 will be relocated to the ISB-I in FY13, which will provide the high quality/high accuracy space needed to support the program. While the renovations in B480 take place, some materials work is being performed in B555 (Chemistry). The un-renovated areas of B480 will continue to be upgraded using operating and IGPP funds. The CFN and NYB do not have any major gaps or planned actions.

- **Chemical & Molecular Science:** Laboratories for fundamental energy-related research, theory, and computation in the chemical and molecular sciences are located in B555 (Chemistry). Approximately 40% of the building will be renovated under the RSL-II project. The remaining areas have already been and will continue to be renovated with operating and IGPP funds. As part of the Infrastructure Blueprint Project, BNL has identified these needs and will propose a time-phased plan to address them. Other key enabling facilities are the NSLS, the CFN, and NYB. The CFN and NYB do not have any major gaps or planned actions and NSLS experiments will transfer to the NSLS-II, when completed.

- **Climate Change Science:** Key facilities for research in clouds and aerosols, physics-based representations of climate-related atmospheric processes, and the impacts of climate change on plant systems and for developing and implementing ARM and BER global change experiments are B490 and B815. Portions of B490, constructed in 1958, have been converted for this use. B490 needs major capital renewal or replacement. Options will be explored at the later part of the ten-year planning period. In the interim, capital renewal such as HVAC replacement will be accomplished, as needed, to keep the facility operational. B815 was constructed in 1961 and expanded in 1995. Major capital renewal in B815 has been funded over the years through GPP and will essentially be completed this FY by the SLI Line Item, RSL-I, making B815 essentially fully capable.

- **Biological Systems Science:** B463 (Biology) is a key facility for structural analysis of biological systems, monitoring and engineering metabolic processes in plants for biofuels and bio-based products, and studying the effects of radiation on living systems. B490 (Medical) and B555 (Chemistry) are important for development of radiotracers and instrumentation and for monitoring biological processes. Radioisotope preparation takes place in B901. All three facilities have major capital renewal needs. B463 was constructed over a period of 40 years with the initial phase going back to World War II (WW-II). Laboratories in the older phases are not suitable for major renewal and the space will need to be replaced or repurposed. The Plant Science groups are slated to move to the ISB-II building, but funding delays will require intermediate improvements of existing space and the replacement of some greenhouses to address immediate needs. In addition, room for expansion of Plant Science will be provided by consolidating current NASA labs in B463 into B490. B490 and B901 require major capital renewal of building systems which will be addressed through IGPP and operating funds. Imaging studies are performed in B560 (MRI) and B906 (PET) which have no major infrastructure gaps. However, the existing facilities to produce the associated short-lived isotopes for these studies require a new Research Cyclotron, which will be located in B901. A site prep project has started and will complete in FY12. Instrumentation for monitoring biological processes is also developed in B510 and B535 (discussed above). Supporting experimental facilities are B725 (NSLS), B958 (NSRL), and B735 (CFN), none of which has major infrastructure gaps impeding the science.

- **Applied Nuclear Science & Technology:** Key office buildings are B197, which houses the NNDC and programs in nonproliferation, global nuclear security, and detector development for national and homeland security and B130, home to programs in nuclear energy and infrastructure systems. Both are WW-II era wood buildings in need of replacement. Current plans are to pursue an office building, potentially alternate-financed, which could address this gap. Other work is performed in small portions of several buildings including B750 Annex (RAP), B815 (detectors), and B902 and B911 (applications of accelerator physics to medicine). Radioisotopes for national needs are produced at the BLIP (B931), which could be replaced by the CIRC (if built at BNL). In addition, some detector work requiring high-accuracy labs will be carried out in the ISB-I building.

- **Applied Materials Science & Engineering:** Key buildings supporting this work are described in the core capability on Condensed Matter Physics & Materials Science.

- **Chemical Engineering:** Key buildings for this effort are discussed in the Chemical and Molecular Science core capability.

- **Systems Engineering & Integration**: This area encompasses many buildings that enable BNL to deliver Large-Scale User Facilities and Advanced Instrumentation. All have been mentioned previously. They include: B510, 535, 703, 725, 817, 830, 832, 901, 902, 911, and 912. This area will benefit from buildings in design and under construction, including NSLS-II. AEGIS, a Center which BNL is planning to develop, will focus on the unique problems and opportunities in the Northeast electrical grid, is likely to be located off-site.

- **Large-Scale User Facilities & Advanced Instrumentation:** Facilities for this capability include those for systems engineering and integration (above) as well as the user facilities themselves, and for development of state-of-the art detectors and electronics. They include: B197, 515, 535, 725, 735, 815, 820, 911, the AGS, and RHIC, all of which have been discussed previously and also involve buildings in design and under construction, including ISB-I, NSLS-II, and potentially ISB-III. A study of the Collider-Accelerator complex upgrades that would improve operational efficiency and right-size its space identified a series of projects to be implemented over the next several years. Beginning with key mission critical buildings, additional studies are being performed to refine the needs and develop time-phased implementation plans. A study to evaluate the potential future reuse of the NSLS building once operations fully transfer to the NSLS-II was performed.

Support Facilities and Infrastructure

The most significant issue facing the support divisions is that many are still located in WW-II era wood buildings. To address this, a project to construct modern office buildings potentially using alternative financing or leased space is being explored. In addition, re-alignment of support shops under the Integrated Facility Management (IFM) model will help to right-size these facilities by reducing maintenance costs and increasing operational efficiency. While BNL's utilities are fairly reliable, they are aging and issues impacting reliability are likely to increase. BNL has commissioned a study to evaluate its utilities and to recommend a strategy for addressing needs. It is anticipated that the study will confirm the most immediate need is for additional central chilled water, which will be addressed by a currently funded IGPP project and by the NSLS-II project which will fund its chilled water needs. The Lab expects the study to confirm that the aging water, electric, and steam distribution system components also need replacement and will have to be addressed with a combination of IGPP and maintenance funds.

A Mission Readiness Peer Review occurred in August 2009. The Peer Review team, consisting of members from other SC National Labs, validated BNL's planning processes as being robust and capable of identifying and addressing Mission Readiness needs.

Strategic Site Investments

In order for the Laboratory to continue as a world leader in science and technology, it will be necessary to address critical infrastructure concerns. Paramount to this objective is implementation of infrastructure renewal, i.e., upgrades and enhancements needed to support the expanding scientific and technological base as well as to meet the expectations of premier staff and providing reliable uninterrupted utility services with sufficient reserve capacities to support future planned growth. In addition, the Laboratory must provide world-class facilities that will support the recruitment and retention of a premier staff.

Many of the current buildings and laboratories are of 1950s and 1960s vintage, and can continue to support future science needs when renewed. In other cases, the needed scientific capabilities (high accuracy temperature controlled labs, vibration isolation, rf shielded spaces, etc.) cannot be developed within existing buildings and new laboratory buildings will be needed.

To meet the infrastructure challenges, BNL has formulated the following strategies to address the immediate needs of its staff and facility users:

- Construct new state-of-the-art research facilities (e.g., high-accuracy labs) that facilitate collaboration and support interdisciplinary research teams, where existing buildings cannot be retrofitted feasibly or economically.

- Maintain quality workplaces for employees and users through rehabilitating, renovating, and upgrading those permanent buildings that can readily support current and future missions.

- Continue to defer major investments in 65+-year-old wood buildings (mostly used by support staff) while performing minimum maintenance to keep these buildings safe and operational. When opportunities arise, consolidate staff from these old wood structures and demolish them.

- Employ new business models to reduce space needs, right-size and consolidate when possible into better facilities, and use selective off-site leasing when possible. This has allowed BNL to demolish approximately 310,000 sf of substandard space on the BNL site.

- Pursue alternative financing for new buildings. BNL continues to investigate alternative financing and/or leasing opportunities to relocate staff from the WW-II era wood office buildings into a modern office building. In addition, BNL has begun preliminary investigations to consolidate national security programs requiring secured facilities, many of which are in substandard buildings, into a new modern secure office/lab building.

- Use planning teams composed of engineering and site maintenance staff to identify and recommend strategies for maintaining utility system reliability at minimum cost.

- BNL and DOE will continue to work with NYS and the New York Power Authority (NYPA) to obtain electric power at a reasonable cost. A 10 year extension of the NYPA electric contract, which now includes 15 MW of hydro power, was approved in December 2010. This extension continues the annual savings of over $20 million compared to the local utility source and is estimated to provide additional savings of over $4M per year.

- Work with DOE, local, and state regulators to prioritize environmental liability issues.

- Prioritize all proposed investments in infrastructure and ES&H and program them to maximize the value of BNL's infrastructure, reduce risk, and support the science and technological programs.

In response to the Laboratory's scientific and technological priorities, infrastructure projects were formulated and will be included the Integrated Facilities and Infrastructure Crosscut in order to maintain and upgrade mission-essential facilities and to provide new ones, where warranted. Completing these projects will enable BNL to realize its mission and to meet the goals expressed in the *Department of Energy's Strategic Plan 2011*. BNL expects that these projects will be funded from the following sources:

- Infrastructure-related Line Items. Over the next ten years as part of the SC Infrastructure Modernization Initiative, BNL has proposed projects that will help to achieve the goals identified as part of its Site Master Plan process. The projects can be categorized as those providing new modern facilities where it is not cost effective to rehabilitate and upgrade existing ones; those which will rehabilitate and upgrade permanent buildings where the functional layout meets current and anticipated program needs; and those which will modernize utilities to ensure continued high-reliability.

  - New facilities: BNL has proposed an ISB complex consisting of three buildings to be constructed in phases. ISB-I received CD-3B in 6/2010 and has a total estimated cost (TEC) of $66M; ISB-II, with a proposed project FY16 start, has a TEC of $70M; ISB-III, with a proposed project start in FY19, has a TEC of $62M.

  - Rehabilitation and upgrade of BNL's major lab/office buildings: BNL proposed phasing this work over three projects (RSL-I, -II, and -III). RSL-I (TEC $18M) which impacts portions of B480 and B815 will complete this FY. Design will be completed this FY for RSL-II (TEC $50M) and CD-3 scheduled for May 2011. The project will impact B510 and B555. Phase III (TEC $74M) is scheduled to start in FY20; current planning is to continue the upgrade of B510 and B555, but addressing other needs will also be explored, such as the repurposing of the NSLS building.

  - BNL had planned to replace and consolidate its support shops, which were housed in WW-II era wood buildings, using SLI funds. However, the Lab's recent reorganization into a distributed support model, known as IFM, will allow the needs of the support shops to be met with smaller facilities distributed around the site which can be constructed with IGPP funds.

  - A Utilities Improvement Project was removed from the modernization initiative planning period. The Project which would have resolved a number of capital renewal needs relating to BNL's utility distribution systems (water, steam, electric, and communications) will now be addressed with IGPP and deferred maintenance (operating) funds. To ensure the highest priority needs are clearly identified with clear scope and cost, a Utilities Master Plan was commissioned to develop a recommended implementation schedule.

  - In addition to SLI-funded Line Items, BNL is constructing the BES program-funded NSLS-II project (conventional facilities portion at a cost of ~$278M, adding 590k sf). This project includes funds to improve infrastructure as required, so as not to have a negative impact on existing infrastructure.

- IGPP projects will average $10.5M per year for the planning period (FY12-FY17). They will help meet the immediate needs of BNL's core capabilities and reduce the backlog of non-line item capital construction needs. Several projects will support and complement the proposed line items initiatives.

- The indirect-funded maintenance investment which includes regular maintenance, maintenance projects, and deferred maintenance reduction (DMR) for FY12 will be $36.7M. This will rise to $43.2M by FY17 which represents a 3.5% average yearly increase during that period. BNL's Asset Condition Index (ACI) is expected to steadily increase and should reach 0.965 in FY15. In addition, direct program funded contributions to building maintenance are expected to average $5.9M/yr from FY11-17.

- Environmental Liabilities. EM has committed to incorporating several SC assets into its clean-up program for disposition, but the timeline is uncertain. Included are B491, 650, 701, 810, & 811. Additional cleanup work will be accomplished in B801 and 830. The long-term funding of Long Term Response Action costs, currently direct funded by EM, is uncertain. If left for BNL overhead to fund in future years, this could impact the availability of overhead to meet mission readiness needs.

- A lease-to-ownership contract award, expected this FY, will be used to procure a new telecommunication system to replace the technologically obsolescent existing system and allow expansion to meet projected site growth.

Appendix E contains the Site Master Plan vision for 2021. The plan is divided into two maps for clarity; an overview of the entire site and an expanded view of the core area.

Trends and Metrics

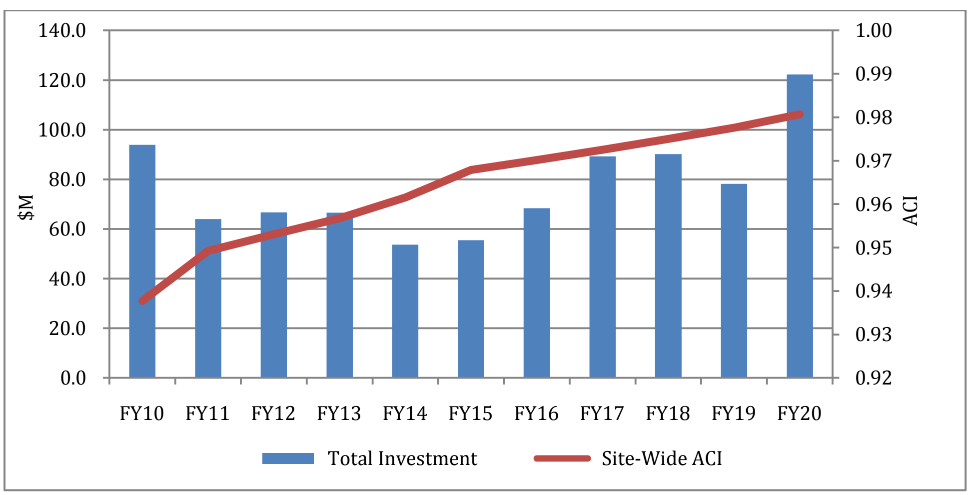
Brookhaven has achieved and often exceeded Maintenance Investment Index goals. In FY10, BNL achieved 108% of its goal. BNL maintenance investment plans show a steady increase in ACI up to 2015 after which it levels off (Figure 1). Maintenance funds are focused mainly on Mission Critical assets (Table 3).

BNL expects to achieve a site wide ACI of 0.965, the long term Federal Real Property Council target, in FY15 and maintain that level or higher. Mission needs are considered in the project prioritization process and favor Mission Critical facilities in funding decisions. With the focus on Mission Critical Facilities, the ACI for those facilities will be even higher. Using its mission readiness evaluations, BNL will determine if it makes sense to direct some indirect funds normally used for DMR to IGPP to reduce rehab and improvement cost once the ACI reaches the DOE target level. Current and projected future states of Mission Readiness are discussed above in the Facilities and Infrastructure to Support Laboratory Missions section.

Table 2. Facilities and Infrastructure Investments ($M) - Impact to Asset Condition Index

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance (all)	29.5	30.6	31.3	32.1	33.1	34.2	35.4	36.5	37.7	39.0	40.3	41.6
DMR	10.8	9.9	9.9	9.9	10.2	10.6	10.9	11.3	11.7	12.0	12.4	12.9
EFD (Overhead)	0	0	0	0	0	0	0	0	0	0	0	0
IGPP	9.3	8.5	10.0	10.0	10.3	10.7	11.0	11.4	11.8	12.2	12.6	13.0
GPP	0	0	0	0	0	0	0	0	0	0	0	0
Line Items (SLI)	44.3	15.0	15.5	14.5	0.0	0.0	11.0	30.0	29.0	15.0	57.0	72.0
Total Investment	93.9	64.0	66.8	66.5	53.7	55.5	68.3	89.2	90.2	78.2	122.3	139.4
Estimated RPV	1,972	2,070	2,149	2,268	2,336	2,692	2,773	2,856	2,905	2,992	3,154	3,248
Estimated DM	122.8	105.1	100.8	98.1	89.9	86.6	82.8	78.5	72.5	67.1	61.0	54.3
Site-Wide ACI	0.938	0.949	0.953	0.957	0.962	0.968	0.970	0.973	0.975	0.978	0.981	0.983

Figure 1. Investment and ACI Trend



Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	Mission Ready	N[a]	M[b]	P[c]	C[d]	Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan Laboratory	Action Plan DOE
Particle Physics	Now		x			• 510	• Host institution for U.S. particle physics with ATLAS; neutrino oscillation experiments; RIKEN; theory, including lattice QCD; observational cosmology • QCDOC; RACF Computing Facility; NYB; BlueGene/Q • Detectors development and low-noise microelectronics • ATF • AARD for next generation facilities • LHC upgrade	• B510 capital renewal, such as electrical & mechanical system end-of-life replacements & rehabilitation and upgrades to labs, are needed to meet program needs. Clean rooms are needed for detector R&D and fabrication (Note 1) • B515 expansion and an associated infrastructure upgrade were made to service the anticipated increasing demands on CPU power and disk storage capacity for both programs through ~2020. Continuing power and cooling infrastructure needs to support increased computing capacity throughout the coming decade may well exceed BNL infrastructure funding levels; reliable alternate power feeder also needed (Note 2) • B535 facility upgrades or replacement, such as clean rooms and general capital renewal, are needed to support detector fabrication, etc. (Note 3) • B820 ATF program expansion is limited, new space being sought • B901&902-no major gaps	**IGPP** • Brookhaven Computing Facility (BCF) Power & Cooling Upgrades, B515 (FY11,13) (Note B) • HVAC Improvement for Clean Room, B535 (FY11) (Note C) • Temperature & Humidity Control PC Lab, B535 (FY15) (Note C) • Upgrade Printed Circuit Board Facility, B535 (FY18+) (Note C) • Semiconductor Detector Develop Lab, B535 (FY18+) (Note C) • Sensor Characterization & Special Projects Lab, B535 (FY18+) (Note C) **Operating** • B510 Air Handler AC-3 Replacement (FY11-12) (Note A) • RSL-II Companion Project, B510 (FY10-12) • B510 Move-In Support (FY13) (Note A)	**SLI** • RSL-II, B510 (FY10) (Note A) • ISB-III (FY18) • RSL-III (FY19) • Central Computing Building (FY20) (Note B)
	In 5 years			x		• 515 • 535				
	In 10 years				x	• 820 • 901 • 902 • ISB-III				

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	**Mission Ready**	**N[a]**	**M[b]**	**P[c]**	**C[d]**	**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan Laboratory**	**Action Plan DOE**
Nuclear Physics	Now		x			• 510,535	• Relativistic heavy ion physics & polarized proton spin studies; scientific case & R&D for EIC; nuclear theory, including high temperature lattice QCD; RBRC • High temperature lattice QCD computing; RACF; NYB; QCDOC; BlueGene/Q • RHIC experimental complex	• B510-Note 1 • B515-Note 2 • B535-Note 3 • B911-renovation of several areas to improve operations (Note 4) • B912-needs new roof, project completing in FY10 (Note 5) • RHIC-consolidate older facilities into upgraded & more efficient facilities; needed to improve operational efficiency & reduce Deferred Maintenance (DM).	• B510-Note A • B515-Note B **IGPP** • B924 Upgrade for Operational Efficiency (FY09-13) • Renovate East Exp. Bldg. Addn. Ext., Tech Shop & Clean Room, B912 (FY11-13) • B510 Lab/Office Renovation, Former CMP Area (FY13-17) **Operating** • B911 Renovation (FY13-15) Note D • B930 Chiller Replacement (FY15)	**SLI** • RSL-II, B510 (Note A) • ISB-III (FY18) • RSL-III (FY19) • Central Computing Building (FY20) (Note B) **Program Line Item** • eRHIC-I project (TBD)
	In 5 years			x		• 515 • 900& 1000 Bldgs.				
	In 10 years				x	• ISB-III				
Accelerator Science	Now		x			• 510,703, 725,817,832 820,902 • 535,911,912	• Accelerator design, including RHIC, NSLS, and NSLS-II • Develop high brightness guns; stochastic cooling; superconducting RF technology, energy recovery linacs, advanced beam cooling techniques & high-intensity polarized electron sources; next generation hadron therapy facilities • Advanced accelerator concepts at the ATF & research in high brightness beams.	• B510-Note 1 • B535-Note 3 • B911-Note 4 • B912-Note 5 • B901,902 & 820-no major gaps • B703-No major gaps • B725-no major gaps • B817-No major gaps • B820-Relocate ATF, plan is for future EM cleanup & demo • B832-No major gaps • B930 major capital renewal needs	• B510-Note A • B535-Note C • B911-Note D	• B510-Note A • B912-Note E **SLI** • ISB-III (FY18)
	In 5 years			x		• 820				

Technical Facilities and Infrastructure (Assumes TYSP Implemented)

Core Capabilities	Mission Ready	N[a]	M[b]	P[c]	C[d]	Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan: Laboratory	Action Plan: DOE
	In 10 years				x	• 901 • 902 • 930 • Various • ISB-III	Development of next generation Hadron therapies • R&D toward future muon collider/neutrino factory • High temperature superconducting magnets • Electron Beam Ion Source • Joint BNL/SBU Center for Accelerator Science and Engineering (CASE)			
Condensed Matter Physics & Materials Science	Now			x		• 480,510, 703,ISB-I • 725 • 735 • 515 • 480, CFN • NSLS-II	• Fundamental studies of complex materials through materials synthesis, advanced characterization, and theory; research at the gap between basic and applied science; EFRCs • NSLS • CFN; EFRCs • NYB • Inst. for Adv. Electron Microscopy • NSLS-II	• B480-gaps being addressed in ISB-I & STM project • B703-recent rehabs closed gap • B725-no major gaps • B735-no major gaps • B515-no gaps for NYB • ISB-I-new bldg., construction started FY10 • NSLS-II, new bldg., construction started FY09	**Operating** • Relocation Support for CMPMS move to ISB-I (FY13)	**SLI** • RSL-I, B480 (FY07)
	In 5 years			x						
	In 10 years				x					
Chemical and Molecular Science	Now			x		• 555 • 725 • 735 • 515 • NSLS-II	• Fundamental experiments, theory, and computation in heterogeneous-, electro-, and photo-catalysis, electrochemistry, chemical dynamics, and radiation chemistry; LEAF • NSLS • CFN • NYB • NSLS-II	• B555-significant capital renewal & fire protection upgrades needed. In addition, space to consolidate computers and swing office and lab space is needed to facilitate the RSL-II SLI project (Note 7) • B725-no major gaps • B735-no major gaps • B515-no gaps for NYB • NSLS-II, new bldg., construction started FY09	**IGPP** • RSL-II Companion Project –IGPP B555(FY10-11) **Operating** • RSL-II Companion Project – OE B555(FY10-12) (Note F) • B555-Move-In Support Post RSL-II (FY13)	**SLI** • RSL-II, B555 (FY10) (Note F) • RSL-III, B555 (FY19)
	In 5 years			x						
	In 10 years				x					

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	Mission Ready	N[a]	M[b]	P[c]	C[d]	Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan Laboratory	Action Plan DOE
Climate Change Science	Now		x			• 490	• Partnership in the ARM Climate Research Facilities; designing and conducting global change experiments • Formation, growth, and optical properties of clouds and aerosols and 3-D cloud reconstruction • Physics-based representations of climate-related atmospheric processes • Climate change impact on plant systems • Consequences of CO_2 sequestration on molecular scale geology at NSLS • NYB	• B490-needs major capital renewal (e.g. elect & mech. systems). Need better computing space. • B815-most gaps being addressed in RSL-I • B725-no major gaps • B515-no gaps for NYB	**Operating** • Replace Roof "C" Wing, B815 (FY13) **IGPP** • Computer Room Upgrade, B490 (FY12-13) • Hood Upgrades, B815 (FY12)	**SLI** • RSL-I B815 (FY07) • ISB-II (FY16)
	In 5 years		x			• 490				
	In 10 years			x		• 490, 815 • 490,815 • 815, 725 • 515 • ISB-II				
Biological Systems Science	Now		x			• 421,463,7 5,73NSLS-II • 490,555,901,906,560, 535 510 • 463,ISB-II	• Structure/function relationships using molecular biology & structural biology and biological imaging (NSLS, NSLS II, CFN, cryo-EM) • PET radiochemical tracers and imaging technology for monitoring biological processes, including plant metabolism • Metabolic engineering of plants for biofuels and bio-based products	• B421-68 years old, needs replacement • B463-needs major capital renewal including replacement of greenhouses • B555- Note 7 • B725–no major gaps • B735-no major gaps • B490-needs major capital renewal • B901-no major gaps • B906-no major gaps • B560-no major gaps • B535-Note 3	• B535-Note C • B510-Note A **IGPP** • Greenhouse Replacement (Partial) (FY12) • Site Prep For Cyclotron, B901 (FY11-12) • B463 Phase II Lab/Office Renovations for Plant Science (FY14-17+)	• B535-Note A • B510-Note C • B555-Note F **SLI** • ISB-II (FY16)
	In 5 years		x			• 463,490,958				

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	Mission Ready	N[a]	M[b]	P[c]	C[d]	Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan Laboratory	Action Plan DOE
	In 10 years			x			• Effects of radiation on living systems, including NSRL	• B510-Note 1 • B958-no major gaps	• B490 Low Temp. Freezer Farm (FY12) • B555 Lab/Office Renovation, East Wings (FY13-17+) **Operating** • B555-Note F **Under Evaluation** • Research Cyclotron site prep, B901	
Applied Nuclear Science & Technology	Now		x			• 931,902,911	• Medical applications: BLIP, RCMS (conceptual), possibly CIRC • Nuclear safeguards & security, nuclear nonproliferation, materials protection & control, NNDC • Advanced radiation detector R&D, including CZT prototype detectors • RAP • Energy policy, next generation reactors, materials in extreme environments, and assessment of nuclear energy in the U.S. energy future • NYEPI	• B462- Conversion to High Bay labs needed • B931-no major gaps, some DMR needs • B902-no major gaps, some DMR needs • B911-Note 4 • B197-68 year old wooden bldg., needs replacement, move staff to Alt. Financed Nat'l Security Bldg. • B421-68 years old, needs replacement • B815-gaps being addressed in RSL-I • B750-annex portion, no gaps • B130-68 year old wooden bldg, needs replacement. Move staff to Alt Fin Office building	• B911-Note D **IGPP** • Solar Energy Research Support Labs, B526 (FY11-14) • Convert B462 to HB Labs (FY14-16) **3rd Party** • Alt Financed Office Building (FY14) • Alt Financed National Security Building (TBD) **Under Evaluation** • CIRC site	**SLI** • ISB-I (FY09)
	In 5 years			x		• 197 • 197,815 ISB-I				
	In 10 years				x	• 750,197 • 130 • At SBU				
Applied Materials Science &	Now			x		• 480,510 703,815, ISB-I	• Strongly correlated/complex materials (including films grown by MBE) and	• See Condensed Matter Physics & Materials Science and Climate Change Science	• See Condensed Matter Physics & Materials Science	• See Condensed Matter Physics & Materials Science

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	**Mission Ready**	**N[a]**	**M[b]**	**P[c]**	**C[d]**	**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan: Laboratory**	**Action Plan: DOE**
Engineering	In 5 years			x		• 515, 480,725 735,NSLS-II	nanomaterials for renewable energy technologies; materials and nanomaterials for hydrogen storage and solar fuels • Characterization by X-ray & neutron scattering at NSLS & NSLS II, electron – spectroscopy, -microscopy, & -diffraction, scanning tunneling spectroscopy, and nanoprobes, supported by theory and modeling, and studies of nanoscale ordering & assembly • Solar energy generation & electrical energy storage technologies	(B815) • B526 –most labs need major rehab • B815 – select labs need rehab	**IGPP** • Solar Energy Research Support Labs, B526 (FY11-14)	
	In 10 years				x	• 526,815				
Chemical Engineering	Now			x		• 526,555	• Design of efficient catalysts for sustainable chemical conversions • Characterization at the NSLS, including using the tools of the Synchrotron Catalysis Consortium • NSLS-II, CFN, NYB	• B526 –most labs need major rehab • B555-Note 7 • B725-no major gaps • B735-see above • B515-Note 2	• B555-Note F **IGPP** • Solar Energy Research Support Labs, B526 (FY11-14) • B555 Lab/Office Renovation, East Wings (FY13-17+)	• B555-Note F
	In 5 years			x		• 725				
	In 10 years				x	• NSLS-II, 735,515				
Systems Engineering & Integration	Now		x			• 725 • 735 • 820 • 703,725,817 830,832,902	• Components for: NSLS • CFN • ATF • NSLS-II • Components for RHIC, RHIC-II, eRHIC	• See above for details (gaps for all buildings already listed)	• See above for details (Lab plans already shown) **Under Evaluation** Advanced Electrical Grid Innovation & Solution Center (AEGIS)	• See above for details (DOE plans already shown)
	In 5 years			x		• 510,535 902,911,91	• Components for International			

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	**Mission Ready**	**N[a]**	**M[b]**	**P[c]**	**C[d]**	**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan Laboratory**	**Action Plan DOE**
	In 10 years				x	2 • 510,902,480 • 510,535,ISB-III • 901 • Possible off-site location	Facilities (LHC, Daya Bay); Superconducting Magnet Energy Storage Systems • Components for Future Facilities (LBNE, LSST) • Components for Muon Collider/Neutrino Factory • AEGIS Center			
Large-Scale User Facilities/ Advanced Instrumentation	Now		x			• 725 • 735 • NSLS-II • 820 • 900 & 1000 Bldgs. • 515	• NSLS • CFN • NSLS-II (future) • ATF • RHIC/AGS; RHIC-II, eRHIC future	• See above for details (gaps for all buildings already listed) • Need for low cost power	• See above for details (Lab plans already shown) **Operating** • Rehab Motor Controller Centers	• See above for details (DOE plans already shown)
	In 5 years			x						

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities	Mission Ready	N[a]	M[b]	P[c]	C[d]	Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan Laboratory	Action Plan DOE
	In 10 years				x	• 958 • 535,197 815,ISB-I,ISB-III	• RACF, NYCCS • NSRL • See sys. engin. & integ. for objectives related to Particle Physics R&D & planning • State-of-the-art detectors & electronics		(FY10-15) • Replace Outdoor Dist Panels (FY13-16) • Rehab AGS Pwr. Dist Sys Fan House A (FY13-15) • Rehab AGS Pwr. Dist Sys Fan House B (FY13-15) Rehab AGS Pwr. Dist Sys Fan House C,D,E (FY14-16) **3rd Party (NYS & other sources)** • Alt. Financed Office Bldg. (FY14) • Continue to work with NYS to maintain low cost power • LISF **Under Evaluation** Advanced Electrical Grid Innovation & Solution Center (AEGIS)	

Technical Facilities and Infrastructure (Assumes TYSP Implemented)						
Core Capabilities	**Mission Ready N[a] M[b] P[c] C[d]**	**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan Laboratory**	**DOE**

General Notes

N[a] = Not M[b] = Marginal P[c] = Partial C[d]= Capable

Capital renewal is (replacement like-in-kind) of bldg. systems such as roof, HVAC, electrical equipment, & interior finishes, including ceilings & flooring

Key Building Notes

ISB-I Interdisciplinary Science Building -I - Will be B540
ISB-II Interdisciplinary Science Building-II - Will be B541
ISB-III Interdisciplinary Science Building -III - Will be B542
AGS A series of buildings all in the 900s
RHIC A series of buildings all in the 1000s & AGS & B901A
NSLS-II National Synchrotron Light Source (NSLS)-II - Will be B740

Gap Notes

1. 510 - capital renewal, such as electrical & mechanical system end-of-life replacements & rehabilitation and upgrades to labs, are needed to meet program needs. Clean rooms are needed for detector R&D and fabrication
2. 515 - expansion and an associated infrastructure upgrade were made to service the anticipated increasing demands on CPU power and disk storage capacity for both programs through ~2020. Continuing power and cooling infrastructure needs to support increased computing capacity throughout the coming decade may well exceed BNL infrastructure funding levels; reliable alternate power feeder also needed
3. 535 - facility upgrades or replacement, such as clean rooms and general capital renewal, are needed to support detector fabrication, etc
4. 911 - renovation of several areas needed to improve operations
5. 912 – no major gaps, building being repurposed
6. RHIC- consolidation from older less desirable facilities into upgraded and more efficient facilities is needed to improve operational efficiency and reduce DM
7. 555 - significant capital renewal, part will be addressed in RSL-II

Action Plan Notes

A See Particle Physics for details of 510 projects
B See Particle Physics for details of 515 projects
C See Particle Physics for details of 535 projects
D See Nuclear Physics for details of 911 projects
E See Nuclear Physics for details of 912 projects
F See Chemical and Molecular Science for details of 555 projects

Support Facilities and Infrastructure							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Gap**	**Action Plan**	
	N[a]	**M[b]**	**P[c]**	**C[d]**		**Laboratory**	**DOE**
Work Environment							
Post Office	x				1941 wood building, location of future ISB-II	**IGPP** • Upgrade B462 for Post Office/Mail Room (FY15-16)	None
Offices			x		Many support groups remain in WW-II era wood buildings	**3rd Party** • Alt. Financed Office Building (FY14)	None
Cafeteria				x	General maintenance-related backlog	**Operating** • Primary Electrical Equipment (FY11-12) • Asbestos Abatement B488 (FY17+)	None
Recreational/Fitness				x	General maintenance-related backlog	**Operating** • Roof replacement, Gym (FY11)	None
Child Care			x		With expanding staff and guests due to NSLS-II and CFN, need more capacity	**IGPP** • Child Care Ph II (FY17+)	None
Safety & Health			x		Physical improvements needed for full compliance and to meet Best Management Practice	**IGPP** • Eyewash & Safety Shower Improvements ((FY09-13) **Operating** • OSHA Corrective Actions (FY11-17) • Identification of Asbestos Containing Materials (FY10-17) • Electrical Panel Labeling FY09-17) • Disposal of Legacy Radioactive & Nuclear Material (FY09-17)	None
ADA Modification			x		Improvements to meet ADA standards in public areas and as needed for specific accommodation	**Operating** • Misc. Modifications for ADA (FY11-17)	None
User Accommodations							
Visitor Housing		x			WW-II era buildings with general maintenance-related backlog. Right-size housing by implementing the recommendations of the Housing Study which was part of the Infrastructure Blueprint Project	**Other** • Looking for partnering opportunities off-site	None
Site Services							
Library		x			WW-II era building, annex in separate location should be consolidated	**3rd Party** • Alt. Financed Office Building (FY14)	None
Medical				x	General maintenance-related backlog	No major projects	None
Examination & Testing				x	General maintenance-related backlog	No major projects	None

Support Facilities and Infrastructure							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Gap**	**Action Plan**	
	N[a]	**M[b]**	**P[c]**	**C[d]**		**Laboratory**	**DOE**
Maintenance & Fabrication			x		• Need to consolidate and right-size facilities, adjust for new Integrated Facility Management model. Phase I consolidate B244, 405 & 422 • General maintenance-related backlog and further consolidation needed	No major projects	None
Fire Station/Alarm Station			x		General maintenance-related backlog. Small addition to provide better cleaning facilities for infection control. Security alarm station building is a fifty-eight year-old wood building operated 24/7 and will require replacement	**IGPP** • B50 (Security) Replacement or possible consolidation with Fire Station. Further evaluation needed	None
Storage			x		General maintenance-related backlog	**IGPP** • Warehouse Office Addition, B98 (FY10-11)	None
Conference and Collaboration Space							
Auditorium/Theater				x	General maintenance-related backlog	No major projects	None
Conference Facility		x			Facility upgrades and expansion of central conferencing facility needed	**IGPP** • Conference Center Addition B488 (FY17+)	None
Collaboration Space		x			No dedicated facilities	No major projects	**SLI** • ISB-I (FY09) & ISB-II (FY16) - spaces incorporated
Utilities							
Communications		x			New telephone system needed to allow for expansion and obsolescence. Additional fiber-optic needed in several buildings	**Capital Lease-to-Ownership** • New Phone System (FY11) **IGPP** • Fiber Network Upgrade (FY09-17)	None

Support Facilities and Infrastructure							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Gap**	**Action Plan**	
	N[a]	**M[b]**	**P[c]**	**C[d]**		**Laboratory**	**DOE**
Electrical			x		Equipment is beyond its normal service life. Some, due to system changes, is also over-dutied based on recent system evaluation. Equipment such as low and medium voltage (MV) circuit breakers has low operations and can be maintained as long as trip units are replaced. Remote tracking of these breakers in some locations is needed to reduce arc-flash exposure operational risks. Some underground 13.8kV distribution cable beyond useful life	**Operating** • Rehab 480V & MV Circuit Breakers (Various) (FY11-17) • Remote Racking Equip, Substation 603, BUS 1&3 (FY16+) • Replace Over-Dutied Electrical Equipment (Various) (FY11-17)	None
Water			x		Some improvements to iron reduction system are needed at the Water Treatment Plan; elevated water tanks require painting to extend service life. In addition, some of the older iron water mains require replacement	**IGPP** • Well 12 (FY12-13) • Replace Well 4 (FY14-15) **Operating** • Paint 300,000 Gal. Elevated Water Tank B49 (FY15) • Well 11 Emergency Generator Replacement (FY15)	None
Petroleum/Oil				x	No major gaps	No major projects	None
Gases				x	No major gaps	No major projects	None
Waste/Sewage Treatment			x		Address new standards concerning metals removal in discharge	**IGPP** • New Ground Water Recharge Basins, Sewage Treatment Plant (FY11-13)	None
Storm Water			x		Some areas flood in heavy rains	**IGPP** • Storm Water Improvements (FY14-15)	None
Chilled Water			x		Additional capacity estimated at 2,000 tons is needed to meet new planned loads. Existing central plant equipment is nearing end of service life. Distribution system can be expanded to additional buildings as an alternate to chiller replacement as they reach service life	**IGPP** •Central Chilled Water - Phase II (FY10-11) •Chilled Water Tower Addition (FY12-13) • Chiller Addition, B600 (FY13-14) • Chiller Water Line Improvements B515 (FY15) **Operating** • Replace Chillers, B600 (FY11-16) • Replace Central Chilled Water Facility Cooling Tower (FY17+)	None

Support Facilities and Infrastructure							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Gap**	**Action Plan**	
	N[a]	**M[b]**	**P[c]**	**C[d]**		**Laboratory**	**DOE**
Steam			x		Some upgrades and repairs needed to BNL's oldest boiler, 1A. Steam plant exterior shell needs rehabilitation. Sections of steam distribution system and associated condensate return system are leaking and need replacement. Some steam distribution manholes need to be rehabilitated	**IGPP** • Convert Boiler 1A To Natural Gas (FY17+) **Operating** • Steam System Rehab Site wide (FY09-17+) • Boiler 1A Retube Front Half (FY17+)	
Flood Control			x		See Storm Water	See Storm Water	None
Road & Grounds							
Parking (surfaces and structures)				x	General maintenance-related backlog	**Operating** • Repaving (Various) (FY11-17+)	None
Roads & Sidewalks (improved & paved surfaces)			x		General maintenance-related backlog, some additional sidewalks needed to improve safety, new main entrance road, and associated Police Guard Stations	**IGPP** • Main Gate & Access Roadway (FY17+) **Operating** • Repaving (Various) (FY11-17+)	None
Grounds				x	None	No major projects	None
Security Infrastructure							
Main Gate			x		Current facility functionally capable, but improvements needed including improved protection for guards, additional lighting and improved electrical service	**IGPP** • Main Gate & Access Roadway (FY17+)	None
Visitors Center		x			Current facility is a trailer with no facilities	Options under evaluation	None
Police Headquarters			x		Current facility is a WW-II era wood building	**IGPP** • Security Building (FY17+)	None
Site Security			x		Needed improvements to address potential physical security vulnerabilities	**IGPP** • Hazardous Material Protection Security Improvements (FY11-12) • Security Alarm & Video At Central Steam Facility (FY13-14) • Alarms Electrical Distribution Centers (FY14) • Security Communications Towers (FY15)	None

[a]N = Not [b]M = Marginal [c]P = Partial [d]C = Capable

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Fermi National Accelerator Laboratory

Mission/Overview

Fermi National Accelerator Laboratory (Fermilab) advances the understanding of matter, energy, space and time by providing leadership and resources for researchers to conduct research at the frontiers of particle physics and related disciplines. As the only U.S. national laboratory primarily devoted to particle physics, Fermilab helps maintain U.S. global leadership in science and engineering, and achieves the high-level goal identified in the strategic plan of the Department of Energy's Office of High Energy Physics (HEP).

Fermi Research Alliance manages Fermilab for the Department of Energy. FRA is an alliance of the University of Chicago and the Universities Research Association, a consortium of 86 universities. FRA combines the depth and commitment of the University of Chicago with the broad involvement of URA universities for the benefit of Fermilab, the particle physics community and the nation.

Fermilab's 1,925 employees and 2,300 scientific users carry out a world-leading program of discovery at the three interrelated frontiers of particle physics. At the Energy Frontier, particle accelerators produce high-energy collisions that signal new phenomena. Fermilab operates the Tevatron collider, supports the U.S. community engaged in research at the Large Hadron Collider, and carries out R&D on future colliders. At the Intensity Frontier, scientists use intense beams from particle accelerators to explore neutrino interactions and ultra-rare processes in nature. Fermilab produces the world's most intense beams of neutrinos. At the Cosmic Frontier, scientists use the cosmos as a laboratory to investigate the fundamental laws of physics. Fermilab scientists investigate dark matter, dark energy, and ultra-high energy cosmic rays using underground experiments, ground-based telescopes, and Cerenkov-fluorescence detectors.

The laboratory's core skills include experimental and theoretical particle physics, astrophysics, and accelerator science; R&D and development of accelerator and detector technologies; the construction and operation of large-scale facilities; and high-performance scientific computing. The laboratory operates particle accelerators and particle detectors; test beams for detector development; test facilities for accelerator research and development; and large-scale computing facilities such as a Tier-1 computing center for the CMS experiment at the LHC, the Lattice QCD center, and the Grid Computing Center. In FY 2010, more than 100 Ph.D. degrees were

received based on work done at Fermilab and about 38,000 K-12 students either participated in activities at Fermilab or were visited in their classrooms by Fermilab staff.

Lab-at-a-Glance

Location: Batavia, Illinois

Type: Single-program laboratory

Contractor: Fermi Research Alliance, LLC

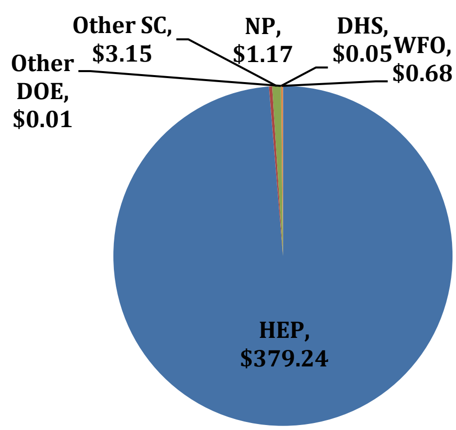
Responsible Site Office: Fermi Site Office

Website: http://www.fnal.gov/

Physical Assets:
- 6,800 acres, 356 buildings, other structures and facilities
- 2.4 Million GSF in buildings
- Replacement Plant Value: $1,699M
- Deferred Maintenance: $44.7M
- Asset Condition Index:
  - Mission Critical: 0.91
  - Mission Dependent: 0.98
  - Asset Utilization Index: 0.99

Human Capital:
- 1,925 Full Time Equivalent Employees (FTEs)
- 10 Joint Faculty
- 250 Postdoctoral Researchers
- 200 Undergraduate Students
- 540 Graduate Students
- 2,300 Facility Users
- 50 Visiting Scientists

FY 2010 Funding by Source: *(Cost Data in $M)*



FY 2010 Total Lab Operating Costs (excluding ARRA): $384.3
FY 2010 Total DOE/NNSA Costs: $383.6
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $0.7
FY 2010 WFO as % Total Lab Operating Costs: 0.00
FY 2010 Total DHS Costs: $0.05

ARRA Obligated from DOE Sources in FY 2010: $19.1
ARRA Costed from DOE Sources in FY 2010: $35

Fermilab’s 6,800-acre site is located 42 miles west of Chicago in Batavia, Illinois. The laboratory was designated a National Environmental Research Park in 1989, and much of the site is open to the public.

Current Core Capabilities

As the national particle physics laboratory, Fermilab’s mission is to enable the U.S. scientific community to tackle the most fundamental physics questions of our era, and to integrate universities and other laboratories fully into national and international particle physics programs. Fermilab provides the only accelerator facilities in the United States for particle physics research. Particle physics is a central component of the physical sciences, focused on the fundamental nature of matter, energy, space and time. Discoveries in particle physics change our basic understanding of nature. The Standard Model of particle physics provides a remarkably accurate description of elementary particles and their interactions. However, experiment and observation strongly point to a deeper and more fundamental theory that breakthroughs in the coming decade will begin to reveal. To address the central questions of particle physics and thus to deliver on the missions of the DOE’s Office of High Energy Physics, Fermilab uses a range of tools and techniques at the three interrelated frontiers of particle physics:

- **The Energy Frontier**, where high-energy particle colliders are used to discover new particles and directly probe the architecture of the fundamental forces of nature.

- **The Intensity Frontier**, where intense particle beams are used to uncover properties of neutrinos and observe rare processes that will tell us about new physics beyond the Standard Model.

- **The Cosmic Frontier**, where underground experiments and ground-based telescopes are used to reveal the natures of dark matter and dark energy, and high-energy particles from space are used to probe new physics phenomena.

These three approaches ask different questions and use different techniques, but answers to challenging questions about the fundamental physics of the universe will come from combining powerful insights and discoveries at each of the three frontiers. Three core capabilities (Particle Physics, Accelerator Science, and Large Scale User Facilities / Advanced Instrumentation / Computing) support activities at Fermilab and enable Fermilab to deliver the DOE OHEP’s mission.

1. Particle Physics

Fermilab’s scientific program supports the U.S. scientific community with world-leading research at all three interrelated frontiers of particle physics.

At the Energy Frontier, after a very successful 26 year program, Fermilab’s Tevatron collider and the CDF and DØ experiments will end data taking in September 2011. Despite a fast ramp up of the LHC collider at CERN in Geneva, Switzerland, the Tevatron remains the leader in a number of high profile analyses. Fermilab’s accelerator, detector, computing and physics facilities support the ongoing LHC program. Fermilab is the principal U.S. contributor to the LHC accelerator and the CMS detector. Fermilab’s Remote Operations Center and LHC Physics Center make the participation of U.S. institutions in the LHC and in CMS more effective. Fermilab is a world-leading institution in the development of accelerator technologies for future lepton colliders such as the International Linear Collider and the Muon Collider.

Experiments at the Intensity Frontier provide critical and unique tools to address some of the central questions in particle physics that cannot be answered at the Energy Frontier. **Fermilab experiments at the Intensity Frontier** aim to uncover properties of neutrinos and to probe new physics from rare processes in muons, kaons, and nuclei, and they are the laboratory’s primary focus in the short and intermediate term. The discovery of neutrino oscillations was the first experimentally observed phenomenon that departed from the very successful Standard Model of particle physics. This discovery strongly suggests a connection between neutrino physics and physics on a very high mass scale and identifies a number of key questions that could open a path to new discovery. Using the NuMI neutrino beam, the most powerful in the world driven by 120 GeV protons from the Main Injector accelerator, Fermilab’s long-baseline neutrino experiments MINOS (on-going / short term), NOvA (intermediate term – under construction), and then LBNE (under development) address the masses, mixings, mass ordering, and matter-antimatter asymmetry of the three known neutrinos in the neutrino Standard Model. The 8 GeV Proton Booster Ring drives a second beam of neutrinos for short-baseline experiments MiniBooNE (on-going / short term) and MicroBooNE (intermediate term – under development) to probe questions beyond the neutrino Standard Model. The current MINERvA experiment with the NuMI beam focuses on precision measurements of cross sections for neutrinos and anti-neutrinos that are critical to extract physics of long-baseline and short-baseline experiments. The Booster Ring will also provide beams of muons for two future experiments: Mu2e, a major new experiment that searches for the conversion of muons to electrons, a critical signature for any unified theory of particle physics; and the g-2 experiment to precisely measure the muon anomalous magnetic moment. Fermilab is developing a multi-megawatt proton accelerator, *Project X*. This accelerator would provide a neutrino beam for the LBNE and beams of muons, kaons and nuclei for rare-process experiments simultaneously. It will be the most powerful and flexible facility at the Intensity Frontier anywhere in the world.

At the Cosmic Frontier, Fermilab is a critical partner in a number of world-leading experiments. Fermilab manages the construction and operation of the Cryogenic Dark Matter Search (CDMS) and the Chicagoland Observatory for Underground Particle Physics (COUPP) that search for particles of dark matter; the Sloan Digital Sky Survey (SDSS) and the Dark Energy Survey (DES) that probe the properties of dark energy; and the Pierre Auger Observatory that studies the source and nature of ultra-high-energy cosmic particles.

Theoretical work in particle physics and particle astrophysics are an essential part of the laboratory. Theorists guide the development of experiments and elucidate their results, emphasizing the connection between theory and experiment to advance cutting-edge science. As Fermilab addresses the defining questions in particle physics and delivers the DOE's high energy physics mission, it pays special attention to educating future generations of scientists. Fermilab trains about 250 postdoctoral fellows and 540 graduate students each year, resulting in more than 100 Ph.D. degrees awarded each year based on research performed at laboratory facilities. Fermilab contributes to science, technology, engineering and mathematics (STEM) education with a broad program for undergraduate university students and K-12 students and teachers.

This core capability enables the laboratory to support the DOE's Scientific Discovery and Innovation mission (SC 4, 5, 21, 22, 23, 24, 25, 26, 27, 29, 34, and 35).

2. Accelerator Science

Particle accelerators are key resources for DOE's program of scientific discovery. Fermilab's accelerator science capabilities—operation, design, development and research—form the foundation of the present and future accelerator-based activities at the lab and in the U.S. particle physics community. Fermilab is home to one of the largest accelerator facilities in the world, including a complex of nine accelerators, test accelerators, and infrastructure for the development of accelerator technologies. Nearly half of the lab staff are directly engaged in accelerator activities.

Fermilab's world-leading accelerator R&D efforts focus on the areas of superconducting radio-frequency (SCRF), superconducting-magnet, ionization-cooling, high-intensity proton accelerator and advanced beam manipulation technologies. Fermilab's unique capabilities in superconducting magnet development are currently focused on upgrades to the LHC and the development of high-field solenoids for the Muon Collider. Fermilab provides U.S. leadership in the development of high-gradient SCRF technology for a future multi-megawatt proton source, *Project X*, and for the ILC, and Fermilab develops integrated design concepts and technologies for *Project X* in support of world-leading neutrino and rare-process experiments. Fermilab leads U.S. technology development for ionization cooling required for muon-storage-ring based facilities, supplies integrated design concepts for the Muon Collider and a neutrino factory, and advances fundamental understanding of beams and their manipulation in dedicated test facilities. In addition, Fermilab pursues comprehensive integrated theoretical concepts and simulations of complete future facilities at both the Energy and Intensity Frontiers of particle physics. These activities, while focused on particle physics, can be applied widely across other fields of science, serving the broader goals of the DOE's Office of Science.

Advanced accelerator R&D activities, currently centered at the A0 PhotoInjector, will move to the new AARD (Advanced Accelerator R&D) Users' Facility that is being created in conjunction with the new SCRF test facility. These activities include novel beam manipulation techniques, high-performance electron source and diagnostics development, and advanced beam cooling tests, conducted in collaboration with other laboratories and universities.

Activities in accelerator and beam physics include advanced beam studies at the laboratory's operating accelerators in support of optimizing accelerator performance; energy deposition simulations, including the upgrade, maintenance and distribution of the MARS code, a resource to the worldwide community; theory of beam instabilities in current and future accelerator facilities; development of new techniques for compensation of beam-beam effects; experimental studies of ground motion effects in accelerators and electron cloud effects in high-intensity proton beams; as well as theory and experimentation on new collimation and cooling methods.

Fermilab, together with BNL, LBNL, and the SLAC, provides joint leadership of the national Muon Accelerator Program. MAP manages the development of future facilities including a neutrino factory at the Intensity Frontier and the Muon Collider at the Energy Frontier. Fermilab is developing design concepts and major subsystem technology simulations and demonstrations for these muon-based facilities. This work also features strong cooperation with companies funded by the DOE's Small Business Innovation Research (SBIR) program.

Fermilab leads the ComPASS (Community Petascale for Accelerator Science and Simulation) collaboration which develops a comprehensive computational infrastructure for accelerator modeling and optimization and advances accelerator computational capabilities from the terascale to the exascale to support DOE priorities for the next decade and beyond. This project is funded by the DOE's Offices of HEP, NP, BES and ASCR.

Fermilab carries out a comprehensive program for training of the next generation of accelerator scientists and engineers. The program includes hosting the U.S. Particle Accelerator School, a national consortium, which holds two sessions a year for undergraduate and graduate students; the Lee Teng Internship in accelerator science and technology for undergraduate students; a Joint University-Fermilab Accelerator Ph.D. program; the Bardeen Fellowship in accelerator engineering for M.S. and Ph.D. students; and the Peoples Fellowship in accelerator science for post-graduates. The new Illinois Accelerator Research Center, to be constructed in 2011 and 2012 with funds from a State of Illinois grant, will significantly enhance the accelerator science education program at Fermilab.

This core capability enables the laboratory to support the DOE's Scientific Discovery and Innovation mission (SC 4, 5, 24, 25, 26, and 35).

3. Large Scale User Facilities, Advanced Instrumentation, and Computing

Large Scale User Facilities

For more than four decades, Fermilab has conceived, planned, designed, constructed, managed and operated large-scale user facilities and hosted international scientific collaborations for particle physics and particle astrophysics. Research at these facilities has led to many discoveries, including the top quark, the bottom quark, the tau neutrino, and the matter-antimatter transition in the B_s system, and numerous precision measurements. Current user facilities include the Tevatron, the world's highest energy proton-antiproton collider, and the CDF and DØ experiments at the Tevatron; NuMI and Booster, which create the world's highest-power neutrino beams, and the MINOS, MINERvA, and MiniBooNE neutrino experiments. NOvA, a second-generation long-baseline neutrino experiment, and the Dark Energy Survey, a third-generation dark energy experiment, are currently under construction. Fermilab has established design concepts and begun technology development for the next generation of world-leading particle physics facilities including longer baseline (>1000 km) neutrino beams and LBNE experiment; Mu2e and g-2 experiments to study rare processes with muons; *Project X*, a multi-megawatt proton facility for Intensity Frontier physics; and the ILC. Efforts are underway to establish design concepts for a multi-TeV Muon Collider and a neutrino factory.

Advanced Instrumentation

Fermilab develops cutting-edge particle detector technologies and applies them to the construction of detectors for a variety of scientific disciplines. In the area of semiconductor-based detectors, Fermilab employed dedicated-readout integrated circuits and pioneered the construction of very low-mass silicon detectors for the Tevatron and LHC collider experiments. Fermilab currently pursues three-dimensional vertical integrated silicon technology and silicon-based multi-pixel photon detectors. In the area of cryogenic detectors, Fermilab uses an ultra-cold bolometric detector for dark matter searches and is developing liquid argon technology for neutrino and dark-matter detectors. The laboratory made additional innovative contributions to the development of scintillators and their applications, now used in a wide array of particle physics experiments. Fermilab's test beam facility, operated simultaneously with the collider and neutrino program, is used by the international particle physics community for the development of detector technologies. The laboratory advances the instrumentation of its test beams through the development of picosecond time-of-flight systems and versatile, integrated data acquisition systems.

Computing

Fermilab's computing leadership and resources enable the particle physics community to deliver scientific results at the Energy, Intensity and Cosmic Frontiers. Fermilab has internationally recognized experts in programming languages, high-performance computing and networking, distributed computing infrastructure, petascale scientific data management, physics simulations and scientific visualization. Fermilab supports large-scale computing, data management, and data analysis facilities for CDF and DØ experiments; the CMS experiment and the LHC Physics Center; the Sloan Digital Sky Survey; the Dark Energy Survey; neutrino and rare-process experiments; and computational cosmology. Fermilab hosts the CMS Tier-1 center, the U.S. Lattice QCD computing project, the campus grid FermiGrid, leads the ComPASS collaboration for accelerator modeling and simulation, and is a leader in the Open Science Grid.

- *CMS Tier-1 Center*: The scientific challenges of particle physics require data storage, networks and processing power on an extreme scale. The CMS experiment uses a distributed computing model, in which seven national Tier-1 centers and more than 40 university- and laboratory-based Tier-2 computing and storage facilities distribute, process, and serve data. Fermilab's CMS Tier-1 center is the most powerful Tier-1 center for the CMS experiment. US CMS scientists make use of the LHC Physics Center's Tier-3 facility for analysis of CMS datasets.

- *Lattice QCD Computing*: Quantum Chromodynamics describes how quarks and gluons interact via the strong force and predicts the properties of hadrons. Such predictions require the numerical simulation of QCD on a lattice of space-time points, known as Lattice QCD, which uses substantial computing resources. Fermilab builds and operates large clusters of computers for Lattice QCD as part of the national computational infrastructure for the Lattice QCD project established by DOE. Fermilab is also a participant in a DOE SciDAC-2 program devoted to the improvement of software for lattice gauge computing.

- *FermiGrid*: Grid computing evolved as an extension of distributed computing to satisfy growing computing needs from science, industry, government and commerce. Grid computing involves the distribution of computing resources among geographically separated sites, thus creating a "grid" of computing resources. Fermilab operates a large Grid Computing Facility with shared computing and storage resources provided to the Fermilab experiments for data processing, storage and analysis. The laboratory makes these computing facilities available to other scientific organizations in a secure manner through the Open Science Grid.

This core capability enables the laboratory to support the DOE's Scientific Discovery and Innovation mission (SC 4, 5, 21, 22, 23, 24, 25, 26, 27, 29, 34, and 35).

Science Strategy for the Future/Major Initiatives

Fermilab will continue its program of research at all three frontiers of particle physics and enable the U.S. particle physics community to tackle the most fundamental physics questions of our era. For the U.S. to remain among the leaders in this field of science, it must maintain a laboratory that builds and exploits new facilities in partnership with universities and other national and international laboratories. Facilities for particle physics are global and ever more challenging to design, build and operate. A laboratory with a singular focus and consolidated particle physics facilities will give the U.S. a competitive advantage in the future.

In designing the laboratory strategy for the post-Tevatron era Fermilab needs to meet the following criteria:

- Address critical and exciting questions
- Be bold and establish world leadership in at least one domain
- Attract partners to leverage DOE/SC investments through international collaboration
- Fit within a global strategy for the field and within reasonable U.S. funding
- Be broad enough to be resilient against physics discoveries and funding fluctuations

An analysis of the world's particle physics program leads us to the conclusion that the greatest opportunity for U.S. leadership lies in experiments driven by high intensity proton beams. In this area the laboratory is sensitive to physics beyond the Standard Model up to energies much greater than reachable at the LHC directly. Whether the LHC is physics "rich" or physics "poor" Fermilab needs to connect the interpretation of the LHC results to quark and lepton processes where the effects are visible, namely in very rare transitions. In addition, the most intense proton source enables the best set of neutrino experiments. These neutrino experiments would greatly increase the understanding of this still mysterious sector. Thus the centerpiece of the Fermilab strategy is to build a high intensity continuous wave superconducting linac and to couple it to the rest of the existing Fermilab accelerator complex. The laboratory calls it *Project X*.

The design and construction of *Project X* will take at least the rest of the decade. When completed it will drive a long baseline neutrino experiment (LBNE) with ten times the flux of the present Fermilab NuMI beam, short baseline neutrino experiments with ten times current fluxes, and kaon, muon and EDM experiments with fluxes that are two orders of magnitude greater than the current capabilities. To get there Fermilab needs to manage the transition from 26 years of Tevatron Collider operations to the world's leading program at the Intensity Frontier. An important element of the strategy is to exploit the present complex for a set of world-class experiments before *Project X* is available. They are current and near-future neutrino and muon experiments, and the simultaneous running of these experiments requires us to improve the injection chain of the current complex to increase the beam intensity by a factor of two. During the *Project X* era the beam intensity up to 3 GeV would be a factor of a hundred greater than the present complex.

Project X would substantially re-use existing facilities such as the Main Injector and Recycler Ring, infrastructure that would be very costly to reproduce elsewhere. Fermilab has aligned the technology of *Project X* to the ILC superconducting technologies so that the project benefits from the advances developed by the ILC community. The Laboratory has also placed a requirement that it should be usable with well understood improvements as the front end of a neutrino factory or a muon collider, thus allowing for the very long range development of the complex. The alignment of technology with the ILC also means that by developing *Project X* Fermilab will be in a position to take a leadership role if the ILC is eventually built.

Infrastructure/Mission Readiness

Overview of Site Facilities & Infrastructure

Fermilab is sited on 6,800 acres of land located 42 miles west of Chicago in Batavia, Illinois. Laboratory assets include 356 buildings and 74 real property trailers comprising 2.4 million gross square feet and hundreds of miles of utility infrastructure including roads, electrical, natural gas, industrial cooling water, potable water and sanitary systems. The total real property replacement plant value (RPV) is $1.7B, including the laboratory's programmatic accelerator and tunnel assets. The detailed property information associated with all assets is maintained in the DOE's Facilities Information Management System real property database. All of the laboratory's buildings are used and owned by DOE; the usage is predominately divided among research and development space and administrative areas. Fermilab's most significant infrastructure needs are the underground piping systems and electrical distribution system, with their overall conditions categorized as poor. Investments over the next several years have been proposed through GPP, SLI and third-party investments. The delay of SLI funding for the Utility Upgrades initially slated to start in FY 2011 has for the first time in Fermilab history created a mission readiness status of "Partially Capable" for utility infrastructure.

Table 1. Fermilab Infrastructure Data Summary

Total Replacement Plant Value ($M)		$1,699
Conventional Replacement Plant Value excluding OSF 3000 facilities ($M)		$846
Total Deferred Maintenance ($M)		$44.7
Asset Condition Index	Mission Critical	0.91
	Mission Dependent	0.98
	Non-Mission Dependent	N/A
Asset Utilization Index	Office	0.99
	Warehouse	0.94
	Laboratory	1.00
	Housing	1.00
FY2010 Actual Maintenance ($M)		$15.7

Fermilab's Conventional Equivalent RPV, used as the baseline RPV in this Plan, is $846M, for buildings, real property trailers, utilities and the conventional portion of the accelerator (OSF 3000) assets. Additional RPV data and discussion, including projections for the 10-year planning period, is included in the table in Trends & Metrics.

Fermilab's Ecological Land Management (ELM) Plan (available electronically at http://www.fnal.gov/cgi-bin/ecology/frame?TYPE=PLAN&YEAR=NOW) is updated annually. The ELM Plan identifies near-term goals and long-term objectives for cost-effective planned management and fulfillment of Fermilab's stewardship responsibility for the undeveloped portions of the laboratory's 6,800-acre campus.

Facilities and Infrastructure to support Laboratory Missions

The core capabilities identified in this Plan represent the current mission whose specific needs are being met within the existing facilities, and whose condition is excellent based on real property criteria considering deferred maintenance. The size and scope of most proposed large experimental projects at Fermilab will likely require considerable additional investment in new facilities and infrastructure, and improvements to existing infrastructure. Future mission programs will evolve based on developments in the high energy physics field, and will continue to provide upgrades and improvements to facilities and infrastructure as required. In support of future programs reuse of existing facilities will also be considered. SLI funding previously identified to address the most critically required upgrades to the Industrial Cooling Water system and High Voltage Electrical System is no longer in the Office of Science budget plan that if not reinstated will require significantly increased GPP levels. The major facility consolidation project remains part of the SLI funding program at some point in the future. Other work is expected to be accomplished with GPP funds and third party agreements.

The existing building facilities are meeting the current operational and experimental needs of the site, which is currently operating with a building Asset Utilization Index of 99.0% (Excellent). Work at a number of buildings has successfully enabled facility reuse to meet programmatic needs. The CZero Experimental Hall was recently converted to a programmatic storage facility, complete with electrical, fire protection and overhead crane enhancements. The reconfigured space will house the NuMI experimental focusing horns, allowing for remote repair of this equipment. Other successful reuse efforts include: a series of enhancements at the Meson Detector Building to house a test beam for Superconducting Radiofrequency cavities; the former Wide Band Counting House Building enlarged and converted to a state of the art computing facility, the Grid Computing Center; the former Muon Lab expanded to serve as the superconducting radio frequency (SRF) cryomodule testing center at the new Cryomodule Test Facility (CMTF). In each of these situations, Laboratory management identifies and meets facility needs through re-assignment and modernization. However, as future mission opportunities continue to develop, additional new experimental facilities will likely be needed.

Similarly, the laboratory's utility infrastructure may require expansion as future mission is identified. When siting future projects, Fermilab's Facilities Engineering Services Section (FESS) works closely with experimental planning groups, the Lab's Master Planning Task Force and the Directorate's newly-created Office of Integrated Planning to efficiently utilize existing utilities or easily expand such facilities. Deferred maintenance requirements of the laboratory's utility infrastructure currently comprises 78% of the site's total FY 2010 Deferred Maintenance backlog, or $34.8M of the $44.7M. Most notably, the underground piping and electrical systems are in need of additional significant investment. While substantial GPP efforts are identified in the Lab's five year infrastructure budget plan, investment via the Office of Science's SLI Modernization Initiative would have provided improved reliability of the most critical utility systems. In 2010, Fermilab initiated work on the SLI Utilities Upgrade Project for Industrial Cooling Water and High Voltage Electric, called the Utilities Upgrade Project, achieving CD-1 in November 2010, though the project was absent from the FY 2012 President's Budget Request in February 2011. The laboratory is hopeful that this project scope will be reinstated in the SLI program. In the interim, attempts will be made to mitigate the most significant vulnerabilities by use of GPP or other investments.

The following tables depict the Mission Readiness status of Facilities and Infrastructure in support of the laboratory core capabilities. The status reflects the overall results of the Facility Mission Matrix, in which Division/Section management evaluate the technical facilities and infrastructure capabilities based on the known and projected mission and the five and ten year investment plan. Through discussions with the input of the Directorate, capability gaps are identified for management consideration and mitigation. The mission readiness status of all core competencies is summarized as mission "Capable". However, loss of SLI funding for the Utility Upgrades initially slated to start in FY 2011 has for the first time in Fermilab history created a mission readiness status of "Partially Capable" for utility infrastructure.

Strategic Site Investments

Facilities and Infrastructure needs are identified by a variety of mechanisms, including the annual effort accomplished on the Facility Mission Matrix (FMM). Distributed to each division/section facility landlord, the FMM provides alignment of core capabilities to each asset (building, trailer, OSF) current and projected use. The Directorate analyzes the landlord input to create the mission readiness scores identified elsewhere in this Plan. Identified capability gaps are evaluated and programmed for accomplishment via appropriate funding mechanisms, including SLI, GPP, 3rd Party investment or operating funds.

- **SLI Modernization Initiative**

  Two Fermilab projects had been slated for funding as part of the Office of Science initiative to address infrastructure modernization needs at its laboratories. Each of these projects helps to satisfy general infrastructure requirements and would help solidify Fermilab's current and future mission capabilities.

  - Utility Upgrade Project (UUP); TPC of $34.9M with FY 2011 start – delayed

    The UUP is needed to improve the site's industrial cooling water system (ICW), a critical system that provides fire water supply for building sprinkler systems and hydrants. The ICW system also provides water for experimental cooling. The project also improves the high voltage electric system by replacing legacy oil switches with air switches. Unit substations would also be replaced since much of the equipment is at the end of life and replacement parts are not available. It is hoped that this project will be reinstated as part of the SLI program.

  - Industrial Facilities Consolidations; TPC of $33.8M with FY 2014 proposed start

    This project consolidates multiple machine shops into one state of the art machine shop and demolishes legacy Butler buildings that housed the existing shops. This facility also allows modernization and relocation of crucial accelerators and detector technology development activities.

- **GPP**

  The five year infrastructure budget plan summarizes the laboratory's best understanding of outyear GPP funding levels based on information from the HEP program office and the laboratory's planning for infrastructure improvements. As part of the 2009 American Recovery and Reinvestment Act (ARRA), three building additions are currently in the final phases of construction at Industrial Building 3 (IB3A), MI-8 Service Building, and New Muon Laboratory. Computing enhancements at the Feynman Computing Center and an upgrade of the Wilson Hall Emergency Generator are also underway and funded by ARRA. The ARRA-funded Crymodule Test Facility (CMTF) is under construction and will allow testing of state-of-the-art full scale cryomodules to be used for future development of accelerators. Small programmatic enhancements continue to be funded through the GPP program as prioritization decisions are made with the HEP office.

Projects funded with FY 2011 and FY 2010 funds include and ICW Sectionalization project, a road reconstruction & paving project, improvements to the Wilson Hall Atrium and west parking lot, and a sanitary sewer improvement project in the vicinity of the Feynman Computing Center. A project to upgrade the Batavia Road gate funded by Safeguards & Security monies was closed early in FY 2011.

Requests for GPP facility and infrastructure alteration and improvement funding are submitted annually through the Fermilab internal budgeting process and the FMM. Additional urgent requests are also considered throughout the year. Upon receipt, needs are prioritized based on regulatory compliance and risk to safety, mission, environment, and operational efficiency.

In addition to mission requirements, the prioritized infrastructure needs and plans, FY 2010 through FY 2016, are summarized in Lab's five year infrastructure budget plan. GPP investments are directed toward the utilities which present the highest vulnerability to the scientific operation as well as those in the greatest need of repair. Future infrastructure budget plans include additional projects as planning continues for future mission. Historically, significant GPP investment has been directed toward expanded computing capacity. There are projected to be $9.8M of GPP level projects necessary over the next 5 years in support of expanding data center requirements. Currently, less than $3M has been planned within the 5-year budget planning window based on projected overall lab funding levels. This situation will continue to be monitored.

- **Third-Party Investments**

Fermilab, in conjunction with DOE, has received a grant from the State of Illinois Department of Commerce and Economic Opportunity (DCEO) for construction and ownership of the Illinois Accelerator Research Center (IARC). The IARC's basic goal is to make northern Illinois a center for accelerator development and to initiate, promote, and support related industry in Illinois.

IARC is conceived of as a center of excellence for accelerator research and development in northern Illinois. Located on the Fermilab site, IARC will bring together scientists and engineers from Fermilab, Argonne National Laboratory, Illinois universities, and industry with the goal of encouraging development of accelerator based industry and accelerator projects in Illinois and at Fermilab. In collaboration with nearby universities, IARC would also serve to educate and train a new generation of scientists, engineers, and technical staff in accelerator technology. The opportunities for Illinois are many and several companies and university groups have already expressed their interest in IARC.

The 2010 Illinois Capital Bill included $20M to be provided via a DCEO grant to fund a portion of the costs of constructing the IARC building. In addition, Fermilab expects from the Office of High Energy Physics (OHEP) in DOE $13M of Federal funding to be used for project initialization, site preparation, project oversight, and outfitting of the newly constructed state building. Fermilab plans to refurbish an existing heavy assembly building (CDF) for use as an integral part of IARC.

The project is well-aligned with both the accelerator-based research mission of the laboratory as well as the mission of the OHEP as the "stewards" of accelerator technology within the Office of Science. Risks include differences in state and federal requirements, coordination of Federal funding with State funding, and the normal risks associated with the construction of any building. The project is currently in the design phase.

- **Maintenance**

Facilities at Fermilab are assigned to a program, including responsibility for maintenance, recapitalization, and the process operations. In a hybrid maintenance program, the Facilities Engineering Services Section provides preventive and corrective maintenance for Fermilab's conventional electrical and mechanical equipment and the occupant organizations identify, fund, and accomplish the remainder of facility sustainment requirements, including those activities accomplished in concert with other GPP or line item projects. . Centralized maintenance data scheduling and tracking activity, end-of-life replacements, and no maintenance zone identification ensure coordinated and consistent application of lab maintenance.

Future maintenance expenditures may continue to exceed 2% of conventional replacement plant value and will be adjusted based on overall facility condition evaluations. Maintenance plans for conventional components of the Tevatron are still in development and will evolve as the work of the Tevatron decommissioning task force makes determinations about the future of the facilities and their contents.

- **Deferred Maintenance**

  Fermilab's total deferred maintenance (DM) increased by $9.1M from $35.6M reported in FY 2009 to $44.7M for FY 2010. Seventy-five percent of FY 2010 DM rests with Mission Critical Other Structures and Facilities (OSF), and 54% of the total site DM, $24M, is in the electric and industrial water distribution systems.

  Fermilab recognizes that continued additional reinvestment will be required to control deferred maintenance growth. Many of the GPP projects identified in the Lab's five year infrastructure budget plan, reflect the current plans for this reinvestment, which will maintain the overall condition of building components and infrastructure systems. As a single-program laboratory with a single source of funding, Fermilab's GPP infrastructure expenditures support general purpose assets. The Lab's five year infrastructure budget plan also reflects a reduced GPP expenditure profile based on outyear budget constraints.

  Routine maintenance responsibilities for OSFs are assigned to specific system owners, typically the Facilities Engineering Services Section. OSF assessments are periodically updated to represent their current operating condition. This ongoing process considers system or component age, efficiency, safety, environmental impacts, maintainability, failure history, locations and conditions found during repairs, current mission needs, and future requirements. Utility system deferred maintenance is due in large part to end of life conditions identified during ongoing inspections validating increased deterioration of these systems. Requirements for deferred maintenance are identified and scoped by the system owner, and, if appropriate, prioritized for GPP funding, based on risk levels associated with safety, mission, and environment and the probability of operational impacts from a particular system.

  The cancellation of the SLI UUP will not allow for a reduction of utility deferred maintenance of $16M over the next three years. Further, the cancellation of the SLI project will require increased operating funds to satisfy urgent repair projects to enable experimental operations.

- **Excess Facilities**

  Fermilab is considering the operational needs of many of its buildings following the end of collider operations. As plans develop further, they will be vetted within the Lab, Office of High Energy Physics, Office of Science and documented in future laboratory planning documents.

Trends and Metrics

The Mission Readiness Assessment Process was initiated at Fermilab during FY 2008. An initial overview assessment was conducted with the Directorate to evaluate technical facilities and infrastructure capabilities relative to the planned mission. The assessment results, with consideration for the currently planned investments, are shown in the tables titled, *Technical Facilities & Infrastructure* and *Support Facilities and Infrastructure* below.

Fermilab's mission is evolving with the imminent cessation of the Tevatron accelerator operations in FY 2011. With the mission readiness initiative, Fermilab is integrating long term facility planning with mission planning, both at the overall laboratory level, as well as the Division and Section level. As new mission is identified, this process will help assure that facility and infrastructure needs are considered early in the process. Fermilab's Mission Readiness peer review is scheduled for July 2011 and will highlight the planning associated with new mission developments. Fermilab has participated in each Mission Readiness peer review at other labs, including serving as team members in five reviews.

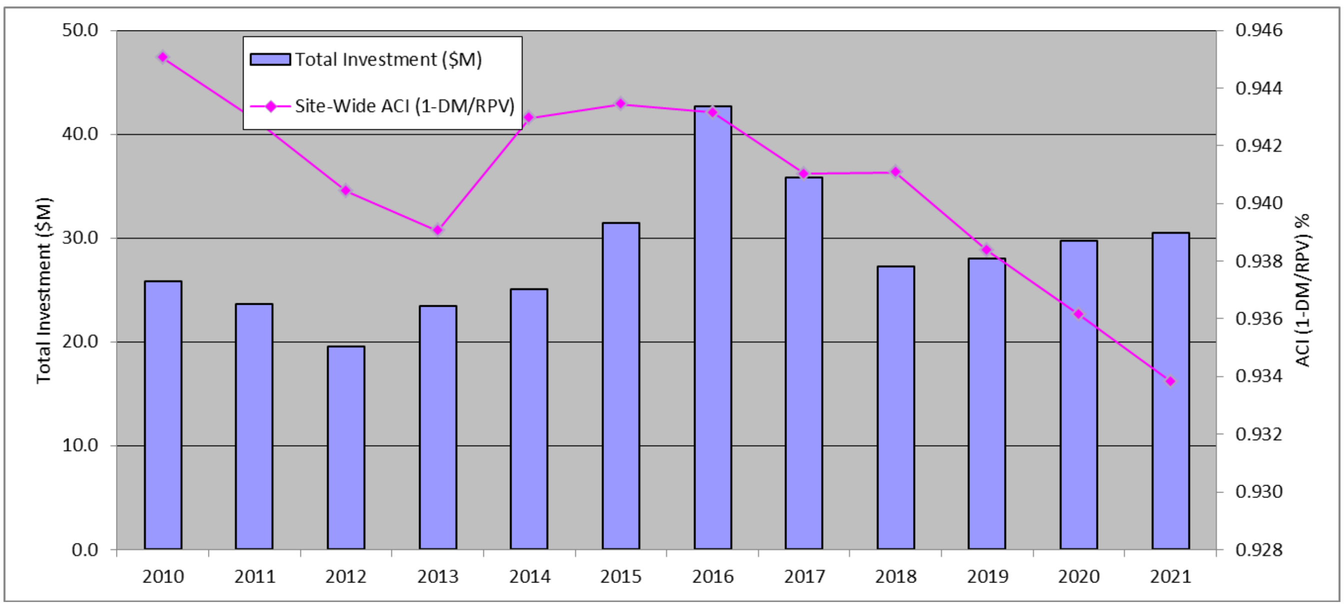
Building management responsibilities are assigned to landlord organizations at Fermilab a cost effective and accurate means to insure facility management investments are well-aligned with mission need, while fulfilling the stewardship responsibility of efficiently managing, using, and preserving real property assets. Extension of the new mission facility planning by use of the Facility Mission Matrix to the landlord organization level strengthens the effectiveness of the overall planning effort.

The projected trends for infrastructure investments and asset condition are presented in Table 3 as summarized in the Lab's five year infrastructure budget plan.

Table 2. Facilities and Infrastructure Investments

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	15.0	15.7	14.9	16.3	16.9	17.3	17.9	19.0	19.4	19.9	20.4	21.9	22.4
DMR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Excess Facility Overhead	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
IGPP	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	29.0	10.1	2.9	2.9	6.2	6.3	6.5	6.6	6.8	7.0	7.2	7.4	7.6
Line Items						1.1	6.7	16.7	9.3				
Total Investment ($M)	44.0	25.8	23.6	19.5	23.5	25.0	31.5	42.7	35.8	27.3	28.0	29.7	30.5
Estimated RPV	745.0	813.8	846.0	865.5	897.4	948.0	969.8	997.1	1,020.0	1,092.5	1,117.6	1,143.3	1,169.6
Estimated DM	36.0	44.7	48.3	51.6	54.7	54.1	54.8	56.7	60.2	64.4	68.9	73.0	77.4
Site-Wide ACI (1-DM/RPV)	0.952	0.945	0.943	0.940	0.939	0.943	0.943	0.943	0.941	0.941	0.938	0.936	0.934

Figure 1. Facilities and Infrastructure Investments



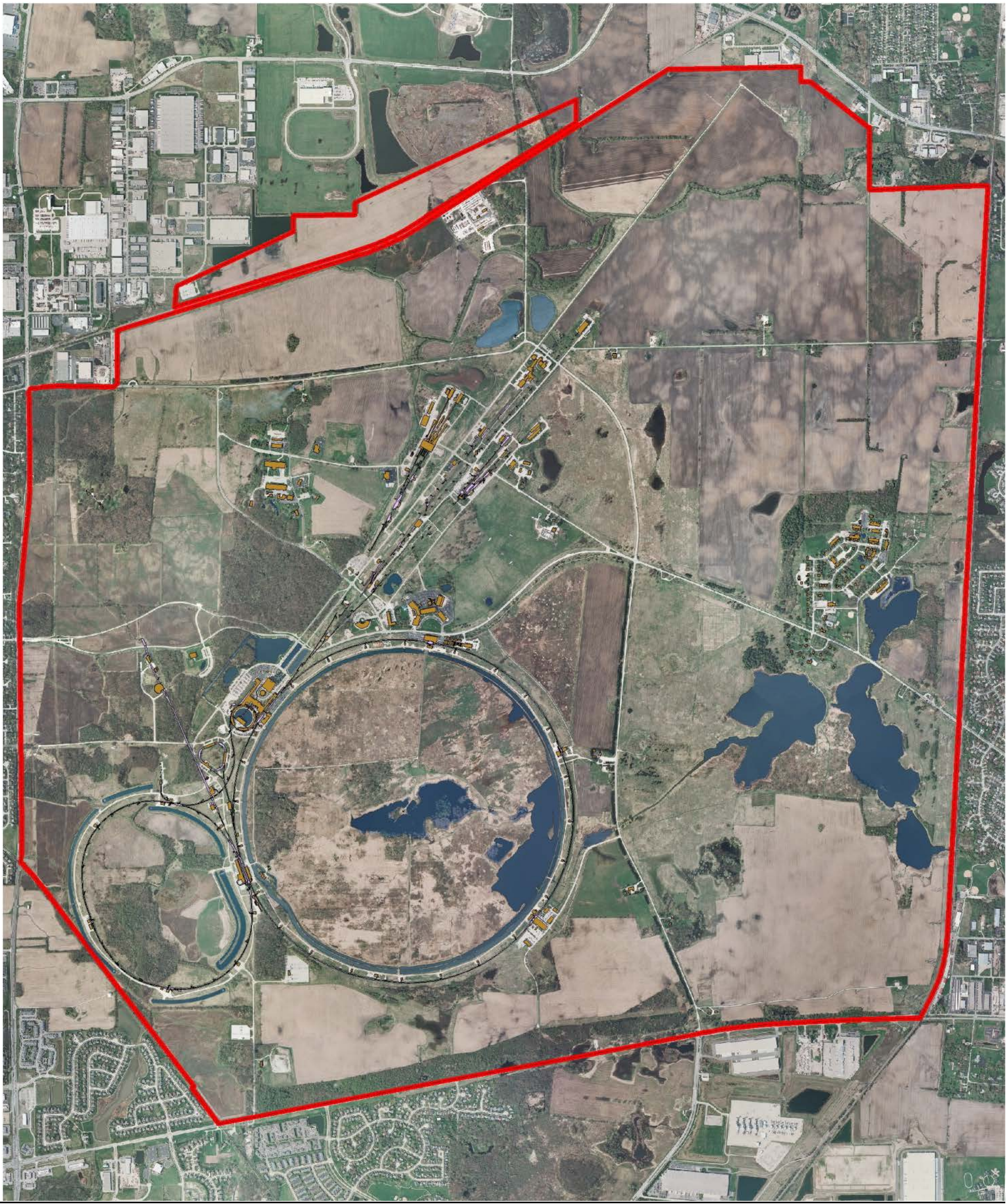
Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
Particle Physics	Now				X	CDF, DØ, MI65 & MINOS, NOvA, miniBooNE	Establish world-class scientific research capacity to advance high-energy physics	The facilities and infrastructure in support of this area are considered adequate. Additional investment in supporting infrastructure (both new and restoration or expanded capacity of existing systems) will be included in each new experiment project scope.	• As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas.	• No dedicated line item infrastructure investments necessary at this time, related facility and infrastructure investments will be needed for future experiments and will be included in future plans
	In 5 Years				X					
	In 10 Years				X					
Accelerator Science	Now				X	Meson Detector Building, New Muon Lab, CMTF, Wide Band, Industrial Facilities	Develop the technology & design for future accelerators to expand the research capacity of high energy physics	The facilities and infrastructure in support of this area are considered adequate. Additional investment in supporting infrastructure (both new and restoration or expanded capacity of existing systems) will be included in each new experiment project scope.	• As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas. Third-party investment will construct IARC.	• ARRA GPP at IB-3, NML & CMTF underway. Industrial Facilities Consolidation SLI will solidify R&D capability. Related facility and infrastructure investments will be needed for future experiments and will be included in future plans.
	In 5 Years				X					
	In 10 Years				X					
Large Scale User Facilities / Advanced Instrumentation	Now				X	Accelerator complex, beamlines, FCC, GCC & LCC computing facilities	Establish world-class scientific research capacity to advance high-energy physics including high-performance computing to	Tevatron decommissioning and development of mu2e, LBNE and *Project X* will usher in a new era of accelerator operations. Planning is underway to assure support facilities associated with managing and maintaining the accelerator complex	• As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas.	• ARRA GPP at MI-8 and FCC is underway. No additional dedicated line item infrastructure investments necessary at this time, facility and infrastructure investments will be needed for future experiments and will be included in future plans.
	In 5 Years				X					
	In 10 Years				X					

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
							attach highly non-linear problems in lattice QCD, and collective effects in beams and cosmological simulations	are either incorporated into each project, or identified for other funding. The real property assets are considered adequate including the conventional portions of the underground asset.		

N[a] = Not, M[b] = Marginal, P[c] = Partial, C[d] = Capable

Support Facilities and Infrastructure (Assumes TYSP Implemented)							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
Work Environment	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE
User Accommodations				X			
Site Services				X			
Conference & Collaboration Space				X			
Utilities			X		Industrial Cooling Water system piping, valves & pumping capacity; Electrical oil switches & unit substations; Domestic Water System piping & valve replacements; Sanitary distribution system piping & lift stations	GPP	Capability gaps can be closed by reinstatement of the SLI UUP
Roads & Grounds				X	Reconstruction & resurfacing	GPP	
Security Infrastructure				X			
N[a] = Not, M[b] = Marginal, P[c] = Partial, C[d] = Capable							

Fermilab Site Map



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Lawrence Berkeley National Laboratory

Mission and Overview

Founded in 1931, Lawrence Berkeley National Laboratory (LBNL) has grown from a pioneering particle and nuclear physics laboratory into a multidisciplinary research facility with broad capabilities in physical, chemical, biological, and Earth systems research, including energy supply, efficiency, and storage; and environmental science. LBNL researchers conduct experiments in ultrafast soft X-ray science to engineer systems at quantum, atomic, and molecular scales; fabricate nanostructured materials and devices; gain new insight into particle physics, nuclear physics, and cosmology; apply computational science to the solution of scientific problems of scale; and study and engineer complex biosystems. As a Department of Energy (DOE) national laboratory with international impact, LBNL strives to continually strengthen its core capabilities, intellectual creativity, and rigorous safety culture. LBNL applies these strengths to address the greatest scientific and technical challenges of our time to transform the world energy economy and to provide a sustainable future for humankind.

LBNL provides critical national scientific infrastructure for university, industry, and government researchers. Major facilities include the Advanced Light Source (ALS), a world center for ultraviolet and soft X-ray synchrotron-based science; the Molecular Foundry, a nanoscale-science user facility; the National Center for Electron Microscopy (NCEM) for materials science; the Joint Genome Institute (JGI); the National Energy Research Scientific Computing Center (NERSC), with high-performance computational science capabilities; the Energy Sciences Network (ESnet), the Office of Science (SC) data and connectivity backbone; and the 88-Inch Cyclotron, for nuclear science. LBNL also hosts two DOE sustainable-energy research centers, the Joint BioEnergy Institute (JBEI) and the Solar Energy Research Center (SERC); and co-leads (with the California Institute of Technology [Caltech]) DOE's Joint Center for Artificial Photosynthesis (JCAP).

LBNL fosters the creativity of outstanding individuals working collectively across disciplines to deliver solutions to DOE challenges of scale and urgency. Founder Ernest Lawrence was the Laboratory's first Nobel laureate; following that tradition, 11 Nobel laureates have worked or are working at LBNL, and many more have had significant research associations. Eighty current members of the National Academies of Science, Engineering, and the Institute of Medicine are affiliated with LBNL.

Lab-at-a-Glance

Location: Berkeley, California

Type: Multi-program laboratory

Contract Operator: University of California

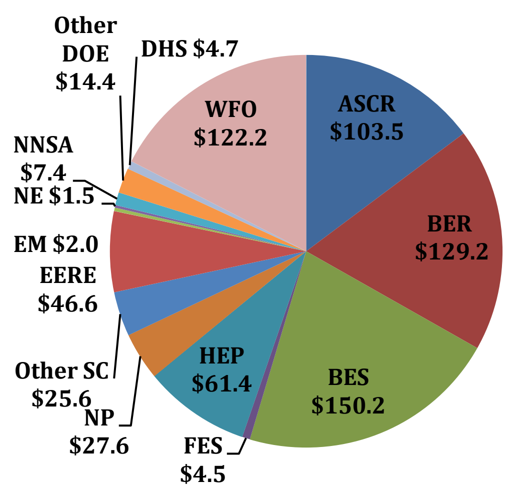
Responsible Site Office: Berkeley Site Office

Website: http://www.lbl.gov/

Physical Assets:
- 202 acres (leased) and 106 buildings
- 1.55M gsf in active operational buildings
- Replacement plant value: $1.006B
- Deferred maintenance: $46.1M
- Asset Condition Index
  - Mission critical: 0.95
  - Mission dependent: 0.98
  - Asset Utilization Index (overall): 0.95

Human Capital:
- 3,223 Full Time Equivalent Employees(FTEs)
- 267 Joint Faculty
- 491 Postdoctoral Researchers
- 328 Graduate Students
- 194 Undergraduate Students
- 8,025 Facility Users
- 1,612 Visiting Scientists

FY 2010 Funding by Source (*Costs $M*):



FY 2010 Total Lab Operating Costs (excluding ARRA): $700.69
FY 2010 Total DOE/NNSA Costs: $573.8
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $122.2
FY 2010 WFO as % Total Lab Operating Costs: 17%
FY 2010 Total DHS Costs: $4.7

ARRA Obligated from DOE FY 2010: $87.8
ARRA Costed from DOE FY 2010: $96.2

Current Core Capabilities

Each of LBNL's core capabilities involves a substantial combination of people, facilities, and equipment to provide a unique or world-leading scientific ability to safely support DOE missions and national needs. Each capability is executed safely, with minimal impact on the environment and surrounding community. The descriptions below summarize the core capabilities, their targeted missions, and sources of funding. The core capabilities crosscut missions and are mutually supportive to allow an exceptional depth and breadth in LBNL's research portfolio, all the while maintaining an integration of efforts across core capabilities to better support DOE targeted outcomes. These core capabilities are grouped loosely into the following categories: Biosciences; Energy and Environment Sciences; Computational Sciences; High-Energy, Nuclear Fusion, and Accelerator Science; and large-scale facilities.

1. Biological Systems Science

LBNL has pioneered and sustains leading capabilities in systems biology, genomics, synthetic biology, structural biology, and imaging at all length scales (from protein structure to tissues). LBNL is also a national leader in microbial biology, cell biology, plant biology, microbial community biology, and computational biology. The Laboratory's biological systems science capability is further enhanced by instrumentation at ALS, JGI, Molecular Foundry, JBEI, and smaller-scale facilities for the study of metabolomics and proteomics. LBNL has the capability for the characterization, in detail, of complex microbial community structure and function, the management of highly complex biological data, the visualization of biological structure, and large-scale gene annotation.

These foundational capabilities enable biological systems science in bioenergy, global environmental analysis, and environmental remediation. In bioenergy science, LBNL leads JBEI and is a partner in the University of California (UC) at Berkeley-led Energy Biosciences Institute. These institutes provide complementary work in the development of energy crops, enzyme and microbial discovery, and microbial engineering for the production of transportation biofuels. The newly constructed Advanced Biofuels Process Development Unit (ABPDU), an Energy Efficiency and Renewable Energy (EERE) funded user facility, provides the capability for scale-up of biofuels pretreatment, saccharification, and fermentation methods. LBNL's terrestrial carbon sequestration and ecosystem modeling seeks to enhance models of carbon cycling for better predictions of soil carbon, including the study of grasslands, from genomes to ecosystem function. The LBNL-led Foundational Sciences Focus Area — Ecosystems and Networks Integrated with Genes and Molecular Assemblies (ENIGMA) — which is funded by DOE's Office of Biological and Environmental Research (BER), targets the biological remediation of contaminated sites, and has developed numerous methods for the analysis of biological systems, from molecules up to whole microbial communities, and via the MicrobesOnline system provides computational genomic and metabolomic analysis for the greater scientific community.

LBNL's JGI and Biological Data Management and Technology Center developed the Integrated Microbial Genomes (IMG) data management and data analysis system, a community resource for comparative analysis and annotation of genomes, along with the Integrated Microbial Genomes with Microbiome. Additionally, DOE JGI continues to improve its main portal, which provides the global user community easy access to all genomes that DOE JGI has sequenced. Other DOE JGI bioinformatics assets include Phytozome, a collaboration with the UC Berkeley Center for Integrative Genomics, to facilitate comparative genomic studies among green plants; MycoCosm, which integrates fungal genomics data and analytical tools; and Metazome, which organizes the proteomes of 24 metazoans into gene families defined at nine ancestral nodes on the metazoan evolutionary tree.

The LBNL radiochemistry and instrumentation competencies include radiochemistry, novel scintillators, probe development, and data analysis. Radioisotope production makes use of the Biomedical Isotope Facility, and LBNL Positron Emission Tomography (PET) radiochemists transform radioisotopes into forms usable labeling agents and develop imagers for positron tracers in plants. LBNL Low Dose Radiation capabilities integrate cell and molecular biology, genomics, epigenomics, proteomics, metabolomics, 4D imaging, and bioinformatics to determine responses to low-dose radiation; these include adaptive responses, nontargeted responses, genomic instability, genetic susceptibility, and epigenetic regulation in relation to cancer.

The primary sponsor of this core capability is BER; other key sponsors include the National Institutes of Health (NIH), the Department of Defense (DOD), industry, and other Work for Others (WFO) sponsors. The core capability supports DOE's mission to: a) obtain new molecular-level insight into the functioning and regulation of plants, microbes, and biological communities for cost-effective biofuels; b) make fundamental discoveries at the interface of biology and physics to address DOE's needs in climate, bioenergy, and subsurface science; c) develop advanced molecular- and systems-level mechanistic understanding of the interaction of low doses of ionizing radiation with biological systems to provide a scientific underpinning for future radiation protection standards; d) leverage DOE computational capabilities across BER programs and coordinate bioenergy, climate, and environmental research across DOE's applied technology offices as well as other agencies; and e) provide high-throughput genomic sequencing and analysis for the DOE science community and collaborating agencies.

2. Climate Change Science

LBNL has developed a highly integrated climate program to understand the forcing and response of the Earth's climate system. LBNL scientists collect comprehensive measurements of CO_2 and CH_4, the two most important anthropogenic greenhouse gases, and employ these field data together with observations from DOE's Atmospheric System Research (ASR) Program to accelerate the development of DOE's new Community Earth System Model (CESM). LBNL is also one of the primary science centers studying terrestrial carbon cycling and is leading two current and one proposed Scientific Focus Areas (SFAs) for BER: Atmospheric Systems Research, Terrestrial Ecosystems Science, and Climate and Earth System Modeling. This lab-wide effort unites researchers from nine scientific divisions and national user facilities at LBNL, including the Computational Research Division, Earth Sciences Division, Environmental Energy Technologies Division, Material Sciences Division, Life Sciences Division, ALS, and NERSC.

The Climate and Carbon Sciences Program at LBNL has a leading role in national and international scientific assessments and programs. LBNL scientists served as principal authors of the highly visible Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC), which was awarded the Nobel Peace Prize in 2007; the Fifth IPCC assessment, which will be published in 2013; and two of the Synthesis and Assessment products commissioned by the U.S. Climate Change Science Program (CCSP). LBNL scientists served on science steering groups for the North American Carbon Program (NACP) under the Carbon Cycle Interagency Working Group of the CCSP, and the National Soil Carbon Network. LBNL carbon cycle observations and analysis constitute valuable components of national synthesis products and national carbon inventories for NACP.

LBNL heads a multi-laboratory consortium to advance DOE's modeling of the mechanisms and risks of abrupt and extreme climate change. LBNL and its partners are developing world-leading capabilities to simulate the dynamics of the Greenland and Antarctic ice sheets and to project the feedbacks among the terrestrial and oceanic methane cycles and global climate change. In support of these projects, LBNL leads the deployment of advanced numerical methods for ultra-high-resolution ice-sheet models and uses its benchmark subsurface models for methane/climate studies. LBNL is leading the technical integration of DOE's flagship integrated assessment models and the CESM1 with the goal of creating the first integrated Earth System Model capable of projecting the future of energy/climate interactions with state-of-the-science treatments of physical, chemical, and biogeochemical processes. The Laboratory's research on soil biogeochemistry, utilizing the LBNL Center for Isotope Geochemistry, ALS, and microbial genomics laboratories is supporting a leadership role in the development of new soil carbon and methane modules for CESM1. LBNL has ensured that CESM is the first model worldwide to adopt all of ASR's internationally recognized parameterizations of greenhouse gas forcing and radiative processes to enable more accurate IPCC climate-change simulations. Finally, LBNL is advancing DOE's measurement and modeling of interactions among ecosystems, permafrost, and climate change. LBNL is one of the lead laboratories of the Oak Ridge National Laboratory (ORNL)-led, DOE Next Generation Ecosystem Experiment (NGEE) initiative on climate-ecosystem feedbacks in the Arctic. NGEE marshals LBNL expertise in geophysics, microbial ecology, biogeochemistry, biometeorology, and modeling in the Climate Change Science and Environmental Subsurface Science Core Capabilities.

The primary support for this core capability at LBNL comes from DOE BER and Advanced Scientific Computing Research (ASCR). Additional research in Earth observations from space is obtained through the National Aeronautics and Space Administration (NASA).

3. Environmental Subsurface Science

LBNL has an internationally recognized capability to quantify, simulate, and monitor subsurface processes and their couplings over a hierarchy of scales, ranging from nanometers to kilometers.

LBNL uses recognized capabilities in geophysics, geochemistry, hydrology, and microbiology to advance five key components required for a predictive understanding of subsurface systems relevant to energy and the environment:

a) the quantification of coupled subsurface processes and associated rates (hydrological, biological, geochemical, thermal, mechanical) using theoretical and laboratory-to-field scale experimental approaches, including the coupling of microbial growth and metabolism with geochemical speciation and fluxes in groundwater and quantifying thermal-chemical mechanisms relevant to long-term waste repositories and optimized waste forms; b) imaging and monitoring subsurface processes from cell and pore scales using synchrotron approaches as well as to aquifer and reservoir scales using geophysical methods; c) developing, advancing, and implementing subsurface multiphysics flow and transport simulations. Examples include improving the predictability of biogeochemical reaction rates and mixing in subsurface materials and simulating CO_2-brine multiphase system modeling coupled to geomechanics; d) advancing and implementing novel subsurface characterization and interpretation approaches, including microarray technologies to track pathogens in surface waters or to quantify microbial community responses to in situ remediation treatments; e) developing advanced approaches to manipulate subsurface fluids and reactions for sustainable remediation as well as energy production and storage. Examples include methods to enhance: energy production from hydrothermal/thermal systems and fossil energy systems, to sequester CO_2 in geologic formations, and to sustainably immobilize metal and radionuclide subsurface contamination. A hallmark of this core capability is the multidisciplinary and multi-scale approach used to quantify fundamental processes and their impact on overall environmental and energy system behavior.

LBNL's work in this area primarily comprises several large, multidisciplinary projects, supported by DOE SC and Energy Programs with additional funding from WFO sponsors. The BER-supported Sustainable Systems Scientific Focus Area includes 26 investigators and tackles the challenges described above relevant to metal and radionuclide contamination; it is the second largest Subsurface Biogeochemical SFA in the complex. Basic Energy Sciences (BES) Geosciences supports 21 investigators involved in three core efforts addressing geophysical imaging, isotope geochemistry, and experimental/theoretical geochemistry. These three clusters of research constitute the largest BES Geosciences effort across the DOE Lab complex. In addition, BES also supports an Energy Frontier Research Center (EFRC) at LBNL to address geologic carbon storage research at the molecular scale. DOE Fossil Energy and Environmental Protection Agency (EPA) support LBNL as a leading geological carbon sequestration laboratory, where LBNL leads one of the seven regional sequestration partnerships and performs research on trapping mechanisms and longevity as well as CO_2 leakage risks and impact. The DOE Geothermal program supports 17 LBNL geoscience research projects where theory, field, experimental, and numerical approaches are used to explore for and develop Enhanced Geothermal Systems (EGS). LBNL is one of three labs leading the development of the DOE Environmental Management Advanced Scientific Computation for Environmental Management (ASCEM) platform for providing consistent subsurface flow and transport across the DOE complex using computational scales from laptops through high-performance computers. A team of 15 multidisciplinary investigators is quantifying the potential of the *in situ* microbial ecology for sustainably degrading the oil spilled from the Deepwater Horizon well with support from the Energy Biosciences Institute. The DOE Nuclear Energy program supports research at LBNL focused on the evaluation of the behavior and long-term performance of waste forms and ecological disposal systems using coupled experiments and multiphase numerical simulation capabilities.

A variety of unique facilities are used to support research in this core capability, including the Center for Environmental Biotechnology; the ALS suite of environmental beamlines, the Center for Isotope Geochemistry, the Geosciences Measurement Facility, the Center for Computational Geophysics, the Environmental Applied Geophysics Laboratory, the Geochemical-Geophysical Computing Cluster, the Molecular Foundry, NCAM, and NERSC.

4. Condensed Matter Physics and Materials Science

LBNL focuses world-class efforts in synthesis, characterization, theory, and simulation to discover and understand novel forms of matter and harness new properties to address global challenges in energy-related science such as energy efficiency, conversion, storage, and carbon capture. The Laboratory's focus areas for this core capability include: a) nanostructures and nanoscale assemblies; b) strongly-correlated, coherent, and topologically protected materials; c) ultrafast processes in matter; d) soft/organic materials; e) catalysis, surface, and interface science; and f) the development of new characterization tools along with the associated theory for imaging, understanding, and controlling complex materials at atomic- and electronic-length scales.

As a DOE national laboratory, LBNL's efforts in nanoscience include the development of nanocomposite proton conductors; thermoelectrics to extract electrical energy from heat; synthesis of nanocrystals as novel biosensors; biomimetic polymer design, catalysts, hybrid materials that convert solar energy (photovoltaics, artificial photosynthesis, etc.), graphene nanoelectronics, nanowires and nanotubes, the contacting of individual molecules to macroscopic electrodes, plasmonics, and nanophotonics. Strongly correlated materials include multiferroics and spin-polarized oxides; spin transport; magnetism and superconductivity, including Bardeen-Cooper-Schrieffer (BCS), cuprates, pnictides, and others. Soft/organic materials include organic photovoltaic materials, biomimetic materials, and hybrid bio- and polymer materials. In catalysis and interface science, the Laboratory's focus is on the study of the physical and chemical properties of surfaces and nanocrystals. New characterization tools include custom scanning probe tips etched with plasmonic tips for near-field sub-wavelength imaging of heterogeneous materials at unprecedented length scales.

LBNL has leading capabilities in use-inspired basic research in advanced materials, including the development and characterization of novel materials for solar-energy, the production of carbon-neutral fuels, for hydrogen and energy storage, and for carbon capture and sequestration studies. LBNL leads the Helios Solar Energy Research Center (SERC), the first center funded by BES in the area of solar-fuels research. Jointly with Caltech, LBNL leads the Joint Center for Artificial Photosynthesis (JCAP), the only energy hub in the nation with a focus on using artificial, environmentally benign, abundant materials for conversion of sunlight into carbon-neutral chemical fuels. World-class user facilities include the Molecular Foundry, NCEM, ALS, the Center for X-Ray Optics, and NERSC.

This core capability is primarily supported by BES with important contributions by ASCR, EERE, the Department of Homeland Security (DHS), and DOD as well as other WFO sponsors. The capability supports DOE's missions to discover and design new materials and molecular assemblies with novel structures, functions, and properties through deterministic design of materials and atom-by-atom and molecule-by-molecule control, as well as other scientific discovery and innovation missions in energy technology and homeland security.

5. Chemical and Molecular Science

LBNL has world-leading capabilities in fundamental research in chemical and molecular sciences in support of DOE's mission to achieve transformational discoveries for energy technologies and develop advanced transportation fuels for the optimization of internal combustion engines in an economically sustainable manner while preserving human health and minimizing the impact to the environment. LBNL has integrated theoretical and experimental core capabilities and instrumentation that enable the understanding, predicting and ultimately control of matter, and energy flow at the electronic and atomic levels and over time scales that span from the natural timescale of electron motion to the intrinsic time scale of chemical transformations.

LBNL has core capabilities and instrumental expertise in gas phase, condensed phase and interfacial chemical physics in the form of laser systems; soft X-ray sources; photon and electron spectrometers, imaging capabilities to advance understanding of key chemical reactions and reactive intermediates that govern combustion processes in realistic environments such as flames and engines. LBNL is a world leader in multicoincidence imaging instrumentation that probes how photons and electrons transfer energy to molecular frameworks and provide critical knowledge in atomic, molecular, and optical sciences needed to understand and ultimately control energy flow in light-harvesting systems. LBNL is a leader in attosecond chemistry, enabling studies of the motion of electrons that may lead to reaction engineering at the atomic scale.

The LBNL catalysis core capability includes basic research on chemical conversions fundamental to new concepts of energy storage and on environmentally benign synthesis that minimizes energy consumption. This core capability that combines experimental, theoretical, and computational modeling components seeks to establish fundamental principles in catalysis and chemical transformations at the molecular level that will advance the field from catalyst discovery to catalyst design.

LBNL is a world leader in actinide and heavy element chemistry. The Heavy Element Research Laboratory (HERL) has a core capability to perform transuranic and actinide chemistry. LBNL has a unique resource in its scientific personnel and instrumentation to characterize, understand, and manipulate rare earth complexes for separation and discovery of alternative elements and critical materials, including materials for energy storage, motors, solid-state lighting, and batteries. LBNL has exceptional capabilities in solar photochemistry, photosynthetic systems, and the physical biosciences. Collectively, the photosynthesis and photochemistry capabilities elucidate the structure and elementary mechanisms of biological and artificial photon-conversion systems through the development of novel spectroscopies and imaging methods covering the range from X-rays to infrared at high temporal resolution. New capabilities for understanding natural photosynthesis will form a basis for the design of efficient engineered solar-conversion systems. In addition, LBNL leads the scientific community in the control and manipulation of the interaction of living and nonliving molecular systems by addressing the communication between live cells and organic/inorganic surfaces at the molecular level. The Chemical Dynamics and Molecular/Environmental Sciences Beamlines at the Laboratory's ALS provide the pioneering application of vacuum ultraviolet and soft X-ray synchrotron radiation to critical problems in chemical dynamics and interfacial chemistry. The Ultrafast X-Ray Science Laboratory (UXSL) develops laser-based ultrafast X-ray sources for chemical and atomic physics experiments and contributes to the knowledge base for future powerful FEL-based attosecond light sources.

LBNL also has preeminent capabilities in molecular and isotopic geochemistry. Research is focused on fundamental aspects of liquid-solid and liquid-liquid interactions, employing synchrotron X-ray and mass spectrometric analysis, including molecular dynamics and *ab initio* computational approaches. Molecular-scale studies are complemented by experimental and modeling studies of larger scale systems, and include the physics as well as the chemistry of Earth materials. The Center for Nanoscale Control of Geologic CO_2 is an EFRC, managed by the Laboratory, in which research is directed specifically at the molecular, nanoscale and pore scale to reveal properties and processes that affect the transport of supercritical CO_2 in subsurface environments.

This core capability is supported primarily by BES with important contributions from ASCR. Other DOE contractors and WFO enable this core capability. This capability supports DOE's mission to probe, understand, and control the interactions of phonons, photons, electrons, and ions with matter, to direct and control energy flow in materials and chemical systems, as well as other scientific discovery missions.

6. Chemical Engineering

At LBNL, this core capability links basic research in chemistry, biology, and materials science to deployable technologies in support of energy security, environmental stewardship, and nanomanufacturing. Leading capabilities are provided in the fields of chemical kinetics, catalysis, molecular dynamics, actinide chemistry, electronic, biomolecular, polymeric, composite, and nanoscale materials, as well as surface chemistry, ultrafast spectroscopy, crystal growth, mechanical properties of materials, metabolic and cellular engineering applied to recombinant DNA techniques that create new chemical processes within cells, and new methodologies for genomic and proteomic analysis in high-throughput production that enable gene libraries that encode enzymes for metabolic engineering.

The Laboratory's expertise in carbon cycling, reactive-flow transport in porous media, mineral kinetics, and isotopic signatures are applied to programs in carbon capture, environmental remediation, geothermal energy, and oil and gas production. Other components of the program provide the capability to translate fundamental research in catalysis, chemical kinetics, combustion science, hydrodynamics, and nanomaterials into solutions to technological challenges in energy storage and efficiency as well as environmental monitoring. LBNL has expertise in chemical biology and radionuclide decorporation needed to characterize mammalian response and develop sequestering agents for emergency chelation in humans in case of heavy element or radioactive contamination.

As a DOE national laboratory, LBNL's user facilities provide unique national assets to the chemical engineering community. The Molecular Foundry enables synthesis, fabrication, characterization, assembly, and simulation of nanostructured materials, linking knowledge discovery to the engineering of advanced manufacturing processes and device development. ALS provides spectroscopic characterization of materials and reactions highly useful to design and engineering. The unparalleled imaging capabilities of NCEM are used to characterize the impact of materials processing on structure, and the SofTEAM microscope will extend these capabilities to both soft materials and soft-hard interfaces for high-value materials and device manufacturing. LBNL's expertise in applied mathematics and energy technologies has resulted in groundbreaking 3D simulations of laboratory-scale flames that closely match experiments. These simulations, with innovative mathematics, are unprecedented in the number of chemical species included, the number of chemical processes modeled, and size of the flames.

This core capability is supported by BES, ASCR, BER, EERE, and WFO, including DOD, universities, and industry. The capability supports DOE's missions to foster the integration of research with the work of other organizations in DOE and other agencies. This research applies directly to DOE's energy security and environmental protection mission, including solar energy, fossil energy, biofuels, and carbon capture and storage.

7. Applied Materials Science and Engineering

LBNL's research program in this area emphasizes the design and synthesis of advanced materials for energy, electronic, structural, and other applications in a wide range of physical environments. The capability provides a basis for the development of materials that improve the efficiency, economy, environmental acceptability, and safety for applications including energy generation, conversion, transmission, and utilization. The capability is enabled through core investments in computing, physical sciences, engineering, and environmental sciences. Areas of expertise include nanoscale phenomena, advanced microscopy, physical and mechanical behavior of materials, materials chemistry, and bimolecular materials.

LBNL has leading capabilities in materials for advanced battery technology, focusing on the development of low-cost, rechargeable, advanced electrochemical devices for both automotive and stationary applications. The related field of fuel-cell research capabilities is enabling the commercialization of polymer-electrolyte and solid-oxide fuel cells for similar applications. Research in this area involves advanced materials and nanotechnology for clean energy, including hydrogen storage and nanostructured organic light-emitting diodes. LBNL has world-leading expertise in the tailoring of the optical properties of window materials, including the characterization of glazing and shading systems, the chromogenics of dynamic glazing materials, and low-emittance coatings for solar performance control. LBNL also leads the scientific community in the development of plasma-deposition processes to enable improved window coatings at minimized production costs and energy consumption.

LBNL's development program for advanced sensors and sensor materials for the control of industrial processes is intended to reduce the waste of raw materials on manufacturing lines, increase the energy efficiency of manufacturing processes, and minimize waste products. LBNL's studies of high-temperature superconductors for electrical transmission cable could substantially reduce losses during transmission. The Laboratory's capabilities in this area include the analysis of the mechanical behavior of novel materials and the design of novel materials with enhanced mechanical properties. LBNL has extensive expertise in the utilization of waste heat for electricity and was recently recognized with an R&D 100 Award in this area. Largely sponsored by industry, LBNL also conducts next-generation lithography and supports the development of tools and metrology for the size reduction in the next generation of microelectronic chip manufacturing.

This core capability is sponsored by EERE, DHS, and WFO programs, including DOD and industry. The core capability contributes to DOE missions in energy, environment, and national security. The applied research capabilities benefit from LBNL use-inspired basic research in materials science, computing, and other capability areas. This work provides a benefit to the DOE's technology programs such as solar-energy conversion, electrical-energy storage and transmission, solid-state lighting, energy efficiency, and the study of materials in extreme energy environments.

8. Systems Engineering and Integration

LBNL's demonstrated abilities to engineer, construct, and integrate complex systems underpin many of the core competencies described in this section. The breadth of large-scale user facilities designed, built, and operated at LBNL would not be possible without the ability to address complex instrumentation challenges of scale. The internationally recognized skills in advanced instrumentation at LBNL (such as accelerating structures, detectors, lasers, magnets, and optics) enable many of the scientific advances described in this Plan.

In addition to LBNL's demonstrated abilities to engineer and integrate complex systems (as described in *Large-Scale User Facilities and Advanced Instrumentation*, below), as a DOE national laboratory, LBNL is the recognized leader in energy efficiency in commercial and residential buildings and industrial facilities. In this capacity, LBNL transfers new energy-efficient building and industrial technologies from the laboratory to the real world, both domestically and internationally, and stimulates the use of underutilized, high-performance technologies through innovative deployment programs. LBNL has a strong record of working with industry to evaluate, develop, and implement new cost-effective technologies for buildings, including high-energy-intensity buildings such as data centers that increase energy efficiency and improve the comfort, health, and safety of building occupants. LBNL is in the process of designing and building a novel User Test Bed Facility (UTBF) for Low-Energy Integrated Building Systems. The Facility comprises a set of "test beds" and simulation platforms intended for the research, development, and demonstration of building technologies, control systems, and building systems integration strategies. Integrated commercial building systems explore ways to assimilate research in building demand-response systems, windows, lighting, indoor air quality, and simulation tools with the goal of developing coherent and innovative building construction and design techniques.

LBNL is a leader in the development of cool surface materials for roof, pavement, and architectural glazing, and in understanding large-scale urban heat-island effects that impact energy consumption and smog formation.

LBNL also performs integrated research on domestic and international energy policies to help mitigate carbon emissions and climate change. In addition, the economic impact is investigated and evaluated for the implementation of energy-efficiency performance standards in industrial systems and for a wide range of consumer products. LBNL provides technical assistance to federal agencies in evaluating and deploying renewable, distributed energy, and demand-side options to reduce energy costs, manage electric power grid stability, and assess the impact of electricity market restructuring, e.g., employing large-scale electric energy storage systems. LBNL is a leader in the research and development of battery systems for automotive and stationary applications, and is applying its extensive experience in subsurface science to underground compressed-air energy storage. Research in battery systems encompasses the development of new materials, theoretical modeling, and systems engineering, while research in large-scale subsurface energy storage encompasses numerical simulation of coupled processes in the porous reservoir. Novel integrated solutions to materials and sensor problems that are relevant to fields of interest to DOE and/or DHS (see *Applied Nuclear Science and Technology*, below) are also actively pursued.

These efforts support DOE's mission to achieve the integration of basic research with applied science, technology development, demonstration, deployment, and policy implementation in areas such as electrical energy generation, transmission, storage, and energy efficiency. LBNL also assists DOE missions to develop and assess opportunities and risks of carbon dioxide capture and storage (CCS), and to better understand complex Earth ecosystems and the impacts that climate change will have on these systems.

LBNL contributes significantly to several technology research programs funded by EERE, Fossil Energy (FE), Electricity Delivery and Energy Reliability (EDER), Advanced Research Projects Agency-Energy (ARPA-E), and the DHS Chemical and Biological Security program. LBNL leverages DOE's investment in systems engineering and integration efforts by working with the state of California as well as other states, and other federal and WFO sponsors, including the Federal Energy Regulatory Commission, the California Energy Commission, the New York State Energy Research and Development Agency, the Western Governors' Association, energy utilities, the Electric Power Research Institute (EPRI), the Carbon Capture Project, and programs within DOD's Defense Threat Reduction Agency. LBNL works with standards organizations such as the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), and the International Organization for Standardization (ISO) to support the development of technical standards.

9. Applied Mathematics

Through its capacity as a DOE national laboratory, LBNL has world-leading capabilities for the development of mathematical models, algorithms, tools, and software for high-performance computing. These have resulted in breakthroughs in several mathematics fields, with a strong impact in many computational science areas. LBNL has a large pool of nationally and internationally recognized experts in applied mathematics, including members of the National Academy of Sciences, members of the National Academy of Engineering, Society for Industrial and Applied Mathematics (SIAM) Fellows, and numerous other professional society awardees. Recent awards include Sloan Research Fellowships, the International Council for Industrial and Applied Mathematics (ICIAM) Lagrange and Pioneer Prizes, U.S. Air Force Young Investigator Research Program, The National Science Foundation (NSF) Faculty Early Career Development Award, and the SIAM Junior Scientist Prize.

The Adaptive Mesh Refinement (AMR) capability is recognized worldwide. LBNL's Chombo framework for block-structured local AMR has resulted in computational simulations that run 100 times faster than uniform mesh simulations. LBNL has unsurpassed expertise in algorithms for modeling and simulating compressible, incompressible, and low Mach number flows in many applications, such as combustion and nuclear flames in supernovae. The Laboratory's hierarchical, structured-grid finite difference capabilities, coupled with AMR algorithms, can solve turbulent flow problems 10,000 times faster than previous techniques. LBNL and UC Berkeley have developed fast-marching and level-set methods, numerical techniques that can follow the evolution of moving interfaces and boundaries for problems in fluid mechanics, combustion, computer-chip manufacturing, robotics, biomedical and seismic image processing, and tumor modeling. LBNL's expertise in partial-differential equations yields new algorithms to describe the evolving wave front of seismic disturbances, resulting in improved 3D seismic images. In numerical linear algebra, LBNL has the only SC lab researchers with expertise in large-scale eigenvalue calculations and direct solutions in sparse matrix computation.

Drawing on the wealth of experience developed in these more traditional science domains, LBNL's applied mathematics research groups aim to push the frontier of designing new mathematical techniques and applying them to both existing models and emerging areas of simulation.

These capabilities and their applications are sponsored primarily by ASCR, with support from other SC program offices and WFO. These capabilities support DOE missions in fusion energy science, biological and environmental research, high energy physics, nuclear physics, and basic energy sciences. They support DOE's missions to develop mathematical descriptions, models, and algorithms to understand the behavior of climate, living cells, and complex systems for DOE missions in energy and environment; and to advance key areas of computational science and discovery for SC science partnerships, DOE applied programs, and interagency research and development.

10. Computational Science

LBNL is a leader in connecting applied mathematics and computer science with research in many scientific disciplines, including biological systems science, chemistry, climate science, materials science, particle and nuclear physics, subsurface science, and all of the core capability areas described in this Plan.

LBNL has a well-proven record of effectively using high-performance computing resources to obtain significant results in many areas of science and/or engineering. The Carbon Capture Simulation Initiative (CCSI) is a new project that will develop and deploy state-of-the-art computational modeling and simulation tools to accelerate the commercialization of carbon capture technologies from discovery to development, demonstration, and ultimately the widespread deployment to hundreds of power plants. By developing the CCSI Toolset, a comprehensive, integrated suite of validated science-based computational models, this initiative will provide simulation tools that will increase confidence in designs, thereby reducing the risk associated with incorporating multiple innovative technologies into new carbon capture solutions. In addition, the Laboratory has begun development of an Advanced Simulation Capability for Environmental Management (ASCEM). The ASCEM program will develop a state-of-the-art high-performance computing simulation code that will enable new science-based approaches for predicting contaminant fate and transport in natural and engineered systems. This initiative supports the reduction of risks associated with DOE Environmental Management's (EM's) environmental cleanup and closure programs through a better understanding and quantification of uncertainties in the subsurface flow and contaminant transport behavior in complex geological systems. The simulator will provide a flexible computational engine to simulate the coupled processes and flow scenarios described by the conceptual models, eventually coupling hydrological, biogeochemical, geomechanical, and thermal processes within one framework.

Several other key projects connected with DOE's Energy Frontier Research Centers (EFRCs) were also started this year, targeting carbon capture and sequestration, solar energy, and combustion efficiency. However, the mathematical methods and computational tools developed here will also have applications in many other scientific domains, such as the search for improved catalysts for hydrogen fuel cells and storage.

Although a lead source of support for this core capability is ASCR, all SC offices sponsor computational applications and software development for their respective areas of science. The notable examples above are High Energy Physics (HEP) and BES, but the development of theoretical, simulation, and analytical science applications occur throughout SC and the technology programs; with other federal agencies such as NASA and DOD; and other interagency partners. This core capability supports all of DOE's science, energy, environmental, and security missions. For SC's discovery and innovation mission, it provides the mathematical descriptions, models, methods, and algorithms to enable scientists to accurately describe and understand the behavior of the Earth's climate, living cells, and other complex systems involving processes that span vast time and length scales.

11. Advanced Computer Science, Visualization, and Data Management

LBNL is a leader in computer architecture research, with expertise in low-power parallel processor design, optical interconnects, and memory systems, which are unique within DOE. The design and deployment of a highly usable, energy-efficient exascale system has research challenges in hardware, software, and algorithms. With its hardware emulation capabilities, co-design experience from the Green Flash project and roles as both a leader and participant in multiple co-design centers, LBNL will play a critical role in an exascale program. LBNL has been a leader in performance analysis and modeling for several years, with multiple award-winning papers on application performance analysis and use of emerging computer architectures for scientific applications. LBNL and UC Berkeley established and continue to lead the field of automatic performance tuning research.

LBNL is a world leader in programming languages and compilers for parallel machines and is taking a leadership role in programming models for exascale systems. The lab's Unified Parallel C (UPC) compiler and its GASNet runtime system are broadly deployed by computing system vendors, government agencies, and academic institutions. The Berkeley Lab Checkpoint Research (BLCR) project provides support for tolerating faults, which is increasingly important as systems scale. LBNL is also a leader in developing software tools and libraries for easier programming of high-performance scientific applications. LBNL is a pioneer in scientific data management, including development of FastBit, an indexing method that won an R&D 100 Award for dramatically speeding up data searches. LBNL and DOE JGI develop genome databases as community resources for comparative analysis and genome annotation. NERSC provides shared storage resources for several scientific communities. LBNL leads in the development of remote, distributed, and query-driven visualization and collaborative visual analytics systems, while NERSC provides visualization systems and support for its users. LBNL is a leader in troubleshooting and performance-analysis tools for complex, distributed applications, such as the perfSONAR application. ESnet and LBNL computer scientists work with scientists around the globe to meet the distributed computing and networking needs of the next generation of DOE science experiments. ESnet's Science Data Network operates like a dynamic expressway, creating uncongested paths between endpoints.

The primary source of support for this core capability is ASCR, and the benefits accrue for all SC offices and other elements of DOE. The capability supports SC's mission to deliver computational and networking capabilities that enable researchers to extend the frontiers of science and to develop networking and collaboration tools and facilities that enable scientists worldwide to work together and share extreme-scale scientific resources. In addition, this core capability contributes to all of the missions described in *Applied Mathematics*, above.

12. Particle Physics

As a DOE national laboratory, LBNL has a long record of leadership in projects at the three frontiers of particle physics: the energy frontier, the intensity frontier, and the cosmic frontier. The Laboratory's capabilities in cosmology, collider physics, and detector innovation build on LBNL core competencies in computing and engineering.

As its contributions to the energy frontier, LBNL provides significant support to the detector hardware, computing and software systems, and physics analysis for the ATLAS Experiment at CERN. LBNL pioneered the use of silicon tracking detectors at hadron colliders in the Collider Detector at Fermilab (CDF) and D0 experiments at Fermi National Accelerator Laboratory, enabling the discovery of the top quark. LBNL contributed to the construction of both the Silicon Tracking Detectors (SCTs) and the pixel detectors at the ATLAS facility. The pixel project is a critical new technology that provides precision tracking with radiation tolerance; LBNL pioneered the pixel development and led the international ATLAS pixel project through construction, installation, and commissioning. Working closely with computer scientists and software engineers in the LBNL Computing Sciences directorate, the LBNL ATLAS group led the development of the software framework for that experiment. LBNL scientists have more than 20 years of experience in theory, simulation, and data analysis for collisions at high-energy hadron colliders and are taking leadership roles in all aspects of the ATLAS experiment.

In neutrino physics, which is central to the intensity frontier program, the Laboratory provides scientific and computing leadership and project management to the Daya Bay reactor-based neutrino oscillation experiment. Construction of the first phase of this experiment is scheduled for completion in 2011 enabling commissioning and early data taking to begin.

The LBNL Theory Group, which is closely integrated with the UC Berkeley Center for Theoretical Physics, plays a crucial role in the Laboratory's particle physics program, working with experimentalists to define future programs and develop strategies for data analysis. The LBNL Particle Data Group provides a unique service to the international physics community through its compilation and analysis of data on particle properties.

On the cosmic frontier, LBNL core competencies have had a very large impact on the DOE program in cosmology. LBNL pioneered and continues to lead the research on dark energy with studies of distant supernovae and with the more recent technique of baryon acoustic oscillations, for which LBNL leads the Baryon Oscillation Spectroscopic Survey (BOSS) project. This survey was successfully commissioned in 2009 and is now partway through its four-year program to map dark energy. A follow-on program, BigBOSS, is under development and has recently been approved by the National Optical Astronomy Observatory for 500 nights of observations with the Mayall 4m Telescope at Kitt Peak, Arizona, conditional on funding. LBNL has also been a leader in the development of advanced instrumentation for cosmology research. LBNL-invented deep-depletion charge-coupled devices (CCDs) are the technology of choice for a range of optical detectors for both space- and ground-based astronomical imaging. LBNL also developed integrated detectors for cosmic microwave background (CMB) measurements and provided integrated detectors to search for CMB polarization in the POLARBEAR project, which was funded by NSF and commissioned in the spring of 2010.

Data analysis at the Laboratory's NERSC is critical to these capabilities, confirming the discovery of dark energy from supernova data and the discovery of the flat geometry of the universe from CMB data. LBNL astrophysicists and computer scientists have automated both supernova discovery and analysis, and the Laboratory's computational scientists have made significant contributions to the simulation of supernova explosions.

The DOE's HEP program office is the primary sponsor of this core capability, with important contributions from ASCR, BES, the National Nuclear Security Administration (NNSA), NASA, NSF, and DHS. This capability supports DOE's missions to understand the properties of elementary particles and fundamental forces at the highest energy accelerators, to understand the symmetries that govern the interactions of matter, and to obtain new insight on matter and energy from observations not requiring accelerators.

13. Nuclear Physics

Since its founding, LBNL has had a core competency in nuclear science. Current programs at the Laboratory now provide world leadership in neutrino research, heavy-ion physics, nuclear structure, and nuclear chemistry. Recent accomplishments include a key role in the Sudbury Neutrino Observatory and KamLAND for the discovery and confirmation of neutrino oscillations; the discovery of jet quenching and almost perfect liquid behavior in collisions of gold ions at Brookhaven National Laboratory's (BNL's) Relativistic Heavy Ion Collider (RHIC) (the STAR detector at RHIC); and new insights into the chemical and physical properties of the heaviest elements.

This core capability includes innovations for the search for neutrinoless double-beta decay to better understand the neutrino sector (Cryogenic Underground Observatory for Rare Events [CUORE] and MAJORANA), leadership in next-generation instrumentation for nuclear structure (Gamma-Ray Energy-Tracking In-Beam Nuclear Array [GRETINA] and Gamma-Ray Energy Tracking Array [GRETA]), in the CERN A Large Ion Collider Experiment (ALICE) Electromagnetic Calorimeter (EMCal) project, and in the conceptualization and physics effort for an underground physics laboratory. Leadership in both detector technology and fabrication underpins all of these contributions. LBNL's Electron Cyclotron Resonance ion source and related technologies are also important for advanced accelerator facilities. The success of the nuclear physics program draws heavily on the core capabilities of the Laboratory in Computational Science, Advanced Instrumentation, Engineering, and Accelerator Science. Theoretical physicists are crucial for experimental design and precise model testing. This includes a growing competency in the use of high-performance computing to study nuclear physics, in particular in the subfields of quantum chromodynamics and supernovae.

Support for this capability is primarily from the Office of Nuclear Physics (NP) with some contributions from ASCR, NSF, DOD, and DHS. This capability supports DOE's missions to understand how quarks and gluons assemble into various forms of matter; how protons and neutrons combine to form atomic nuclei, the fundamental properties of neutrons and neutrinos; and to advance scientific user facilities that reveal the characteristics of nuclear matter.

14. Accelerator Science and Technology

Born as an accelerator laboratory, LBNL has maintained a leading capability in accelerator development for seven decades. With core expertise in the areas of insertion devices, ion sources, superconducting magnet technology, linear accelerators, and synchrotron radiation sources, the Laboratory's research efforts support revolutionary approaches to science, energy, health, national security, environment, and industry.

LBNL is the world leader in ultrahigh-gradient laser-driven plasma wakefield acceleration technology, where it is producing high-quality GeV electron beams with compact accelerators and is on the verge of creating a new paradigm for high-energy particle accelerators. The Berkeley Lab Laser Accelerator (BELLA) project, to be completed in 2012, will enable laser-plasma acceleration technology in discrete 10 GeV modules. This system will lay the groundwork for a future in which laser-based accelerators will provide much shorter wavelengths and time structures as well as improved beam control at nearly $1/100^{th}$ of the physical size of existing particle accelerators. In addition to high-energy physics applications, this technology will also enable the scientific community to probe matter as well as chemical and biological systems at their most fundamental level.

LBNL's Ion Beam Technology (IBT) group has significant expertise in developing both ion sources and low-energy beam transport systems. The group is providing world-class accelerator front-end systems, such as that in the recently built Spallation Neutron Source at ORNL, and the Laboratory plans to deliver front-end systems for future SC projects such as the Facility for Rare Isotope Beams (FRIB) at Michigan State and the proposed Project X at Fermi National Laboratory. The IBT group has developed novel, high-yield neutron generators recognized by R&D 100 Awards as well as numerous patents, and has recently extended its research to include gamma-generating devices for national security applications.

LBNL's superconducting materials program is a center of excellence, pioneering novel design and fabrication techniques for high-field magnets employed in accelerator applications. The high-energy and nuclear physics communities are dependent on the Laboratory's expertise in this area and a recent successful application includes the first isolation of a significant mass of antimatter. Future applications will include neutrino science and the proposed development of a muon collider. LBNL's state-of-the-art superconducting magnet capability is well integrated across all aspects of magnet development, including conductors, fabrication, and testing. This expertise is being applied across SC programs, most notably in support of the U.S. ITER Project.

LBNL is a leading partner in the Heavy-Ion Fusion Science Virtual National Laboratory (with Lawrence Livermore National Laboratory [LLNL] and Princeton Plasma Physics Laboratory [PPPL]), providing leadership expertise in high-current induction linac accelerator technology for inertial fusion energy research via its ARRA-funded Neutralized Drift Compression Experiment II (NDCX-II) facility. This facility will commence with experimental research by March of 2012 and will study the beam and target interaction physics needed to facilitate the design of optimized heavy-ion targets capable of significant fusion energy production.

A complimentary program at LBNL in diagnostics and instrumentation is now allowing the synchronization of accelerator and laser systems to the femtosecond regime and has been applied to large-scale facilities outside the Laboratory such as the Linac Coherent Light Source (LCLS) at SLAC. Other applications include a leadership role in the design of the FERMI@Elettra Free-Electron Laser (FEL) facility in Trieste, Italy, and a novel storage ring design that has kept LBNL's ALS at the forefront of synchrotron light sources. In addition, the Laboratory's superconducting undulator design capability has the potential to greatly extend the performance of existing synchrotrons, thereby enabling a new suite of fourth-generation facilities that will provide brighter sources at reduced capital and operating costs.

The Accelerator Science and Technology core capability at LBNL is supported primarily by the HEP, Fusion Energy Sciences (FES), and BES programs, with further sponsorship from the ASCR program, NE, NNSA, DHS, DOD, and other federal agencies. The research associated with this capability at LBNL supports SC's missions to conceive, design, and construct scientific user facilities, to probe the properties of matter; to advance energy, national, and homeland security; and to support DOE's other scientific discovery and innovation missions.

15. Applied Nuclear Science and Technology

LBNL's capabilities in this area include fundamental nuclear measurements; actinide chemistry; the irradiation of electronic chips for industry and the government, including post-irradiation and materials characterization; the design, development, and deployment of advanced instrumentation; compact neutron and gamma-ray sources for active interrogation; and substantial modeling and simulation expertise. Work for DOE SC includes actinide chemistry with application to chelating agents, and subsurface science related to nuclear-contamination transport.

LBNL is a world leader in the development of instrumentation for the detection and measurement of ionizing radiation. It develops fundamental radiation- detection materials, including both scintillators and solid-state detectors that combine high-density and excellent energy resolution, and high-performance electronics (including custom integrated circuits) to read out the detectors, as well as complete detection and imaging systems that are used for a variety of purposes including nuclear medical imaging, homeland security, and fundamental explorations of high energy and nuclear physics. Unique materials-screening capabilities enable optimized high-throughput development and design of semiconductor and scintillation-detector materials (supported by DHS and NNSA). Detector development work is performed for DOE NP (e.g., MAJORANA, GRETA/GRETINA), HEP, DHS, NNSA, and the DOD (Defense Threat Reduction Agency [DTRA]). Core competencies include germanium detector development, with an emphasis on low-noise systems, and gamma-ray imaging using coded aperture masks, Compton scattering telescopes, as well as other methods. Detectors and techniques are being developed for a wide variety of applications, including homeland security, nonproliferation, medical imaging, and nuclear science.

The Air Force and the National Reconnaissance Office support the testing of electronic components by the National Security Space Community, using heavy-ion beams at the Laboratory's 88-Inch Cyclotron. The use of "cocktail beams" composed of a mixture of elements that mimic the composition of the cosmic rays encountered by satellites provides a unique national asset that greatly speeds the testing of critical space-based electronic components. In addition, the 88-Inch Cyclotron is also employed to develop surrogate reaction techniques of interest to advanced fuel cycles for nuclear reactors.

LBNL's research in this area in support of SC includes the development of high-field ion sources for use by nuclear accelerators, such as the FRIB at Michigan State and the 88-inch Cyclotron at LBNL.

This core capability is sponsored by the Office of Civilian Radioactive Waste Management (OCRWM), DHS, NNSA, DOD, NRC, NP, BES, and NE. This core capability contributes to DOE missions to integrate the basic research in SC programs with research in support of the NNSA and DOE technology office programs.

16. Large-Scale User Facilities and Advanced Instrumentation

Since its inception, LBNL has had a core capability of designing, constructing, and operating leading scientific facilities for large user communities, both on the Berkeley site and elsewhere across the globe, including the deep oceans, and up into space. (Current efforts of scale are taking place in Europe, North America, Asia, and Antarctica.) Berkeley Lab's highly recognized and experienced managers continue a record of success in handling $100 million-plus construction projects, and assembling experts in design and implementation of systems to support large-scale capital acquisitions. Below is a list of the Laboratory's large-scale user facilities at or near the main Berkeley site; above, in the discussion of the core capabilities, are numerous references to LBNL's support to partner facilities including contributions to project design and management as well as advanced systems and instrumentation.

- LBNL's ***Advanced Light Source (ALS)*** is the nation's premier light source for high-brightness soft X-ray and ultraviolet science, with additional world-class performance in the hard X-ray spectral region. The scientific challenges investigated at the ALS involve the understanding, predicting, and ultimately control of matter and energy at the electronic, atomic, and molecular levels to improve our understanding of nearly all of the DOE core capability areas including biological processes and systems. The ALS has roughly 2,032 users per year, with an annual budget of approximately $63M per year and is funded primarily by DOE/BES.

- The Laboratory's ***National Center for Electron Microscopy (NCEM)*** houses, among other instruments, the world's two most powerful electron microscopes, each having the resolution of nearly 50 pm (roughly the radius of a hydrogen atom). The NCEM conducts fundamental research relating microstructural and microchemical characteristics to material properties and processing parameters, greatly advancing our understanding of defects and deformation; mechanisms and kinetics of phase transformations; nanostructured materials; surfaces, interfaces and thin films; and microelectronic materials and devices. The NCEM has roughly 255 users per year, with an annual budget of approximately $6M per year and is funded primarily by DOE/BES.

- The ***Molecular Foundry*** at LBNL is a state-of-the-art nanoscience user facility providing significant advances in human health, economic well-being, and national security through leadership in nanoscience and nanotechnology, with particular emphasis on combinatorial nanoscience, nanointerfaces, multimodal in situ nanoimaging, and single digit nanofabrication. The Molecular Foundry has roughly 275 users per year, with an annual budget of approximately $20M per year and is funded primarily by DOE/BES.

- LBNL's ***Joint Genome Institute (JGI)*** is the world's largest producer of plant and microbial genomes with programs focused in three areas that include the generation of DNA sequences, the development of innovative DNA analysis algorithms, and a large yet rapidly accessible repository of functional genomics information. The JGI is a key element in providing the foundation for the Laboratory's bioscience core capabilities, in particular in areas of biofuels, bioremediation, and climate change science. The JGI has roughly 1170 users per year, with an annual budget of approximately $70M per year and is funded primarily by DOE/BER.

- The ***National Energy Research Scientific Computing Center (NERSC)*** is the flagship scientific computing facility for SC, serving more than 4,000 researchers worldwide whose scientific impact is enormous, with more than 1,500 scientific publications per year. This year, the first system at NERSC with peak performance over 1 petaflop/s will enter production. As part of the Magellan Cloud Computing testbed, NERSC is evaluating the use of cloud computing resources for scientific computing. The total FY 2010 funding for NERSC was $55 million, plus $16 million in ARRA funds for Magellan. The primary funding organization for the NERSC is DOE/ASCR.

- The ***Energy Sciences Network (ESnet)*** is a high-speed network enabling DOE scientists and collaborators worldwide to address some of the most important scientific challenges by providing direct connections to all major DOE sites and to more than 100 other networks. The network has many tens of thousands of users and sees nearly 1016 bytes of data flow per month. As the first part of the Advanced Networking Initiative (ANI), a testbed for a 100 gigabit-per-second prototype network has been deployed. A planned nationwide 100 G prototype network that is slated to link three of DOE's major supercomputing centers, and MAN LAN, the international exchange point in New York, is due to be operational this year. FY 2010 funding totaled $30 million, plus $62 million in ARRA funds for ANI. The primary funding organization for the ESnet is DOE/ASCR.

Science Strategy for the Future

LBNL's science strategy focuses on solving the most pressing and profound scientific problems facing humankind, with particular emphasis in the areas of basic science for a secure energy future; an understanding of living systems to improve the energy supply, the environment, and human health; and the fundamental understanding of the nature of matter and energy in the universe.

The Laboratory's portfolio of research in each of these areas is steered by a balance between the scientific art-of-the-possible and the needs of the Laboratory's funding supporters, in particular DOE SC, DOE Technology Offices, and WFO sponsors such as NIH.

Team science is essential to the successful execution of the grand challenges laid out above, so the Laboratory adopted two new overarching initiatives to both speed the pace of scientific progress and to ensure that a high-quality, relevant product is delivered to its sponsors. The first of these two initiatives is the Next Generation Light Source (NGLS), which LBNL believes will transform the field of attosecond science, thereby having enormous impact across the material and chemical sciences with particular applications in both the biological sciences and the development of energy-efficient technologies. The second of the two new initiatives is Carbon Cycle 2.0, which enables the Laboratory to integrate much of its work for DOE/BES, DOE/Technology Offices, and WFO sponsors in the areas of energy-efficient science and technology. The Laboratory's energy-efficient science and technology (S&T) portfolio is very broad, encompassing everything from basic chemistry and materials, to the development of technologies such as energy-efficient windows, to the development of energy-efficiency standards for the federal government and local municipalities. The Carbon Cycle 2.0 initiative enables the Laboratory to make critical connections across this diverse portfolio, enabling a more rapid pace of scientific discovery and a more rapid response to the needs of its funding agencies.

Infrastructure / Mission Readiness

Overview of Facilities and Infrastructure

The LBNL Mission Readiness infrastructure strategy has two primary goals:

- Seismically upgrade or replace deficient LBNL buildings, ensuring the safety of the Laboratory's staff
- Maintain, modernize, and obtain facilities and infrastructure to ensure Mission Readiness

This Mission Readiness approach ensures that infrastructure investments support the core capabilities for DOE described in this Plan. Table 6A and Figure 6A below summarize the generally good and functional condition of LBNL buildings and infrastructure; however, this data does not convey the fact that significant older space is not suitable for modern science mission use and must be either modernized and seismically upgraded or replaced with safe, modern research facilities. The Berkeley Lab 2020 facilities and infrastructure strategy discussed in this Plan has been developed to address this issue and provides a road map for both short- and long-term mission readiness. LBNL's Berkeley Lab 2020 strategy is aligned with two goals above, is based on space efficiency, and makes both maintenance and upgrade/replace decisions based on cost effectiveness and mission requirements.

LBNL's main site is located in the San Francisco Bay Area on 202 acres of University of California (UC) land (87 acres are leased to DOE). The main site comprises approximately 1.7 million gross square feet (gsf) in permanent facilities and temporary trailers (active and inactive). All but 27,500 gsf of these buildings are owned by DOE. Sixty-nine percent of LBNL's active facilities were constructed more than 30 years ago, when LBNL was primarily a high-energy physics, nuclear chemistry, and nuclear medicine laboratory. The *LBNL Land Use Plan* can be viewed within the Berkeley Lab Long-Range Development Plan at http://www.lbl.gov/Community/LRDP/index.html.

Approximately 30% of the active space had been identified as seismically deficient with seismic performance ratings of "Poor" or "Very Poor," according to the UC Seismic Policy, and, given the probability of a major seismic event in the Bay Area, represents a major infrastructure rebuilding priority. Today, the seismically deficient space figure is approximately 22%, as approximately 8% of the seismically deficient space has been upgraded or vacated. Significant progress, but a job not yet complete.

LBNL also leases approximately 365,894 sf in surrounding cities and occupies 50,576 sf of space on the UC Berkeley campus for research and administrative purposes. LBNL completed five lease transactions in FYs 2010 and 2011: 1) the lease at 717 Potter Street in Berkeley was expanded from approximately 60,000 sf to approximately 95,369 sf to accommodate Life Sciences; 2) approximately 15,448 sf of space was leased at 5885 Hollis Street in Emeryville, California, at the third floor of that premise to accommodate the ABPDU; 3) approximately 23,500 sf of space was leased at 2929 Seventh Street in Berkeley to accommodate the JCAP program; 4) approximately 30,770 sf of space was leased to accommodate the off-site move of Office of the Chief Financial Officer (OCFO) department into 6401 Hollis Street in Emeryville; and 5) the lease for 40,200 sf of high-performance computing and office space at the Oakland Scientific Facility was renewed. In November 2010, the Regents of the University of California purchased the Oakland Scientific Facility building from the private landlord. LBNL intends to review its receiving/warehouse lease in 2011.

LBNL's utility infrastructure ranges from 6 to 51 years old. Infrastructure Fitness for Service Evaluations and Capacity Assessments were conducted in the past year. Overall, the surveyed utility systems were determined to be in relatively good shape. A few upgrades and replacements are recommended by the consulting engineers. These are addressed in Table 6F. Some building systems in a few buildings will be approaching the end of their expected useful lives within the term of this plan, including in some cases energy-management control systems, electrical transformers and service panels, and network and telephone systems. LBNL intends to continue to provide good and functional buildings for the evolving research missions, and to meet the facilities requirements of modern science. Toward this end, maintenance and modernization of building infrastructure and space is ongoing, and discussed in the following subsections.

Table 1. SC Infrastructure Data Summary

Replacement Plant Value ($M)		1,060.22
Total Deferred Maintenance ($M)		46.10
Asset Condition Index	Mission Critical	0.95
	Mission Dependent	0.98
	Not Mission Dependent	n/a
Asset Utilization Index	Office	0.99
	Warehouse	n/a
	Laboratory	0.96
	All Other	0.91
FY 2010 Maintenance ($M)		21.56

Facilities and Infrastructure to Support Laboratory Missions

LBNL and UC have developed the following facilities and infrastructure strategy, Berkeley Lab 2020, as a road map to address space shortages and infrastructure needs. This strategy comprises two elements: an Infrastructure Modernization Initiative and the Strategic Space Initiative. The Infrastructure Modernization Initiative provides a framework to make existing buildings safe and efficient, replace buildings that cannot be modernized or made safe, and add new buildings on previously developed sites where necessary. The Strategic Space Initiative addresses the need to provide adequate space and program consolidation resulting from expanded research activities over the past several decades as well as the more recent program growth for DOE missions in energy and environmental research.

The Strategic Space Initiative is being implemented in an overlapping two-stage process, involving near-term and longer-term solutions. In the first stage, off-site leases are being extended and expanded, and on-site space is being more efficiently and aggressively managed. These actions are relieving shortages of space and enabling a reorganization and programmatic consolidation of space allocations in existing buildings. In the second stage, the main site will be further renewed and a second campus site, to be established within five years, will consolidate the current off-site programs and offer the potential for future growth. SLI Infrastructure Modernization Initiative projects are concurrently addressing seismic life-safety issues, and the building replacement and renewal scope of these five line item projects is a key baseline aspect of the Berkeley Lab 2020 Plan.

Main LBNL site structures are at full occupancy, and the growth of programs in the past three years continues. LBNL currently has six major facilities in off-site leases: 1) the Joint Genome Institute (JGI), 2) the Joint BioEnergy Institute (JBEI), 3) the supercomputer facility, the National Energy Research Scientific Computing Center (NERSC), 4) the Advanced BioFuels Process Development Unit (ABPDU), 5) the Joint Center for Artificial Photosynthesis (JCAP), and 6) the Office of the Chief Financial Officer (OCFO). Significant numbers of staff from seven divisions are housed at separate off-site locations in four East Bay cities: Life Sciences, Physical Biosciences, Genomics, Computational Research, NERSC, Material sciences, and Operations. Current occupancy at those locations makes up roughly 13% of the Laboratory, counted either by FTEs or programmatic funding.

SC has provided critical funding for the ALS User Support Building and the Molecular Foundry, as well as through the SLI program, which enabled seismic upgrades and modernization of existing buildings, and will provide for the construction of two general-purpose laboratories. SLI program support for demolition of legacy facilities has been, and will continue to be critical. SLI program support to demolish legacy facilities in Old Town and in the former Bevatron area are critical path facilities management issues.

Laboratory management has recognized the urgency of the space problem at Berkeley Lab, and worked with the University of California to secure UC financing for three new buildings on the main LBNL site: a Guest House (completed in 2009) for users of LBNL's scientific facilities such as the ALS, a Computational Research and Theory building (estimated completion: 2013), and a Solar Energy Research Facility (estimated completion: 2013). Laboratory management is also working with UC regarding development of a second site.

The Laboratory's Mission Readiness infrastructure strategy takes into account the concerns of the local community on growth and environmental protection. LBNL, DOE and UC are addressing these concerns in several ways: 1) by focusing future development in previously built areas, primarily the Old Town and Bevatron sites; 2) by exploring the concept of a second campus in recognition of the space limitations of the main site; and 3) by reaching out to the local community with the establishment of a Community Advisory Group and through greatly increased communications with neighbors, local organized groups, and elected officials. This approach is working well, leading to an improved dialogue and greater support. LBNL will ensure environmentally sensitive development of the main LBNL site by clearing already developed sites (e.g., Bevatron, Old Town) of old, inefficient, seismically deficient structures and replacing them with safe, modern, and energy-efficient purpose-built laboratory and office buildings, minimizing energy consumption and environmental risks.

Laboratory management is working with UC to explore second campus options within a radius that allows effective collaboration with the main site and UC Berkeley (estimated 20- to 25-minute drive from the main site), with first occupancy anticipated likely in ~2016. A number of potential sites offering 500,000 square feet for a first phase occupancy, and an additional 1.5 million sf subsequently have been identified by local communities and organizations. These preliminary proposals have been vetted with DOE SC. It is anticipated that biological research, currently located in off-site leased space, will be consolidated at the second campus, including JGI, JBEI, and the Life Sciences Division as well as related programs. One or more potential sites could also serve as an alternative location for the proposed Next Generation Light Source (NGLS).

There are many possibilities for the second campus that appear to fulfill the general criteria outlined above, and LBNL, working closely with the University of California, will undertake a systematic vetting and selection process over the next year. Some second campus sites offer pre-existing buildings that can be modified, to enable a lower cost and more rapid entry point, while others have greater long-term potential in terms of future expansion. As this process unfolds, there will be a continual dialogue with DOE. Table 6B below outlines the elements and current status of a) the Strategic Space Initiative and b) the Infrastructure Modernization Initiative.

Contributing to the development of LBNL's Infrastructure Modernization Initiative has been the four-year program that evaluated the structural seismic life safety of all occupied buildings and large trailers at the main LBNL site. The surveys were completed by nationally recognized structural engineers experienced in field investigations and analyses of damage in earthquakes. These analyses were examined in terms of the standards for "Good," "Fair," "Poor," or "Very Poor" structures, consistent with UC Seismic Safety Policy. LBNL developed plans for mitigating the risks in all structures rated either "Poor" or "Very Poor." All "Very Poor" structures on the site are now unoccupied and, in every case, slated for demolition. All "Poor" structures will either be demolished or structurally upgraded, either through the SLI program or using Institutional General Plant Project (IGPP) funds.

In this *Annual Plan*, LBNL proposes a series of integrated investments to ensure that the facilities and infrastructure are safe and meet the needs of the Laboratory's current *Core Capabilities* found in Section 3 of this document and the needs of the Research Initiatives described in Section 4. Table 6B, below, identifies the facilities that house research for each core capability, the condition of those facilities, and the planned investment to achieve seismic safety and mission readiness. Most buildings and investments benefit multiple core capabilities; each investment is detailed once and then cross-referenced in the core-capability sections that follow. Building numbers are also identified on the Berkeley Lab FY11-FY21 Projects map at the end of this section. LBNL's Mission Readiness strategy was successfully Peer Reviewed in 2009 and the support programs were found to include best-in-class programs. LBNL's Mission Readiness strategy will undergo Peer Review again in 2012.

Table 2. LBNL 2020 Strategy: Strategic Space Initiative and Infrastructure Modernization Initiative

A. Strategic Space Initiative

Stage 1: Expansion of leased space off of the main LBNL site and more efficient use of space on the main site will allow reorganization of space on the main site into more functional domains, allowing programs to be consolidated.	
DETAILS	**SPECIFIC ACTIONS ALREADY UNDER WAY**
1. Leases	• The lease of JGI in Walnut Creek will be extended. • Office of the Chief Financial Officer (OCFO) functions in Building 90 will be transferred to leased space in Emeryville in July 2011. • Additional portions of the Life Sciences Division still on the main site were consolidated with portions that are off site through an expanded lease at the West Berkeley Potter Street location.
2. Reorganization of space	• Earth Sciences Division will move to Buildings 74 and 84. (Previously occupied by the Life Sciences Division.) • The Environmental Energy Technologies Division, which has grown significantly in the past several years, will expand into space in Building 90 vacated by HR and OCFO units and the Earth Sciences Division. This makes way for the new User Test-Bed Facility program and other related new programs.
3. Assess the entire existing stock of laboratory space and ensure more efficient and effective use moving forward. Repeat assessments on a biennial basis.	• Assessments of all LBNL laboratories at the main site have been completed. A regular, ongoing cycle for review of laboratory space has been implemented. In addition, an annual review of office space at LBNL is being planned.
4. Create an effective space-governance model with centralized planning and management.	• A new governance model has been implemented with appointment of a Space Manager, in the Office of the Chief Operating Officer (OCOO), and chartering of a Space Planning and Advisory Committee (SPAC). New office space standards, managed within the OCOO, have been introduced.
5. Modernize and make more efficient, using new space standards, creating additional spaces to meet needs.	• SPAC is involved in reviewing space requests and in working with the Space Manager on implementing the standards to optimize space use.
6. Consolidate both distributed “area” shops and data centers/cluster rooms.	• These projects are in the opportunity assessment phase.
7. Reduce storage of unnecessary materials, equipment; reduce paper generation; digitize files; archive; excess, etc.	• The Information Technology Division has developed a strategy for reducing, archiving, and digitizing materials and is engaged in the initial stages of implementation. LBNL is reviewing equipment and research materials stored in an off-site warehouse.

Stage 2: Renewal of the main site and establishment of a second campus.	
DETAILS	**SPECIFIC ACTIONS ALREADY UNDER WAY**
1. Create a second campus, initially for co-location of bioscience-related programs, but with capacity for significant expansion.	• A project team has been assembled to coordinate a 4- to 6-year effort to complete the following steps: 1) identify user needs, 2) identify and evaluate potential sites, 3) select a short list of sites, 4) perform further evaluation of the short-listed sites, 5) select a preferred site, 6) complete the environmental review process, 7) determine the financial structure, 8) achieve UC Regents approval, 9) design and construction, 10) move and occupancy. DOE will be appropriately engaged throughout the process, and all necessary DOE approvals will be obtained as appropriate. The target completion date for co-location of bioscience-related programs is calendar year 2016, which may be improved depending on final site selection.
2. Investigate alternatives for NGLS.	• CD-0 for the Next Generation Light Source has been approved. In developing alternatives, potential sites include both the main LBNL site and the possible second campus. Factors include cost and schedule of construction, geological conditions, environmental effects, distance from the main site and from the closest major airport, community concerns, existing and/or nearby infrastructure/utility capacity, etc. LBNL has conducted comparative studies of four sites: the UC Richmond Field Station, the former Concord Naval Weapons Station, the former Alameda Naval Air Station, and the LBNL main site, and continues to review these results and consider additional options. The site decision will be made in CD-1.
3. Modernize research labs with IGPP and noncapital alteration projects prioritized by the UniCall.	• LBNL's Mission Readiness program is lab-wide is scope, it includes an ongoing lab-wide annual process to identify, rank, and fund priority facility and infrastructure modifications in support of mission readiness. In FY11, LBNL's Mission Readiness UniCall process is funding over $6 million of lab renovation and modernization projects. Work is under way on these projects.
4. Continue the SLI program, focusing on seismic safety deficiencies – building upgrades where feasible and replacement new general-purpose lab buildings.	• Seismic Phase 1 project was finished in FY10 making two lab/office buildings seismically safe: Buildings 50 and 74. Seismic Phase 2 is under way to provide seismic repairs, demolish structures that are not cost-effective to upgrade, modernize Bldg. 74, and construct a new general-purpose Laboratory building. Seismic Phases 3-5 have been coordinated with DOE to continue this life-safety Line Item work throughout the term of this Plan with project starts in FY13, FY16, and FY19, respectively.

B. Infrastructure Modernization Initiative

Modernize and make safe and efficient existing buildings and infrastructure and add new buildings on previously developed sites where necessary.	
DETAILS	**SPECIFIC ACTIONS ALREADY UNDER WAY**
• Produce a Strategic Utility Infrastructure Master Plan, including an existing-condition assessment and capacity analysis, and identify future requirements.	• A Strategic Utility Infrastructure Master Plan has been completed. Capacity requirements have been developed through LBNL's site master planning and mission-readiness process.
• Modernize infrastructure consistent with Master Plan data with IGPP and noncapital alteration projects as prioritized through the UniCall.	• Master Plan data will support enhanced integration of infrastructure modernization in LBNL's ongoing lab-wide annual program to identify, rank, and fund priority facility and infrastructure modifications in support of mission readiness. Priority needs have been identified and are being proposed for FY 2012 funding.
• D&D of Old Town to create space for future on-site development.	• The D&D of Old Town has started. The following buildings are being removed in Seismic Phase 2: Buildings 25, 25A, 25B, 40, 41, 52, and 52A. In addition, the following buildings will be removed through overhead funds in FY11: Buildings 44, 44A, and 44B. A proposal has been submitted to SC for funding to remove remaining Old Town structures.
• Generate true dialogue with LBNL's local community, including neighbors, elected officials, and community representatives, around LBNL space issues and plans.	• A Community Advisory Group has completed its first year of close and productive engagement with LBNL on growth and development plans. The LBNL Director regularly meets with local elected leaders and plans meetings with regional elected officials as well. A community perception survey has revealed the importance of science education to voters, prompting plans for a lab-wide volunteer education effort, in partnership with local schools, based on cool-roof and cool-surface science.
• Develop integrated solution for parking and increasing use of public transportation, vanpools, and LBNL shuttle services.	• Workforce transportation options are being reviewed, including restarting a vanpool program, subsidies for mass transit use, leasing off-site parking lots and busing in employees. A trial period with Zimride, a casual carpooling service, was initiated.

Strategic Mission Readiness Facilities and Infrastructure Investments

LBNL's plan integrates actual and proposed investments by SC (SLI and program offices), DOE's Office of Environmental Management (OEM), the University of California, and IGPP, as well as alterations and maintenance from the Laboratory's funds. These investments ensure mission readiness and support for the core capabilities, and fully address safety commitments. Near-term investments (the next five years), including some conceptual projects in early stages of planning, are summarized below.

Office of Science Investments (SLI and Program Offices)

The SLI Modernization program at LBNL corrects seismic deficiencies and modernizes facilities for mission readiness. New buildings and major renovation projects are expected to meet Leadership in Energy and Environmental Design (LEED) Gold certification and exceed ASHRAE Standard 90.1-2004 energy-efficiency requirements by approximately 30%.

- **Anticipated SLI:**
  - Old Town Demolitions and Environmental Remediation. This non-capital investment is a priority, as it will demolish approximately 55,000 gsf of old, outdated structures and remediate approximately 1 acre

of legacy soil and groundwater contamination under the structures. Pre-project planning activities including characterization and conceptual design are planned to continue in FY 2012 and Project Engineering Design (PED) is planned for completion in FY 2013. Deferred maintenance will be reduced by approximately $0.5 million.

- o SLI Seismic Phase 3 Project. This investment is a priority for LBNL, as it will remedy particularly serious seismic life-safety deficiencies in DOE structures occupied by approximately 220 staff and approximately 900 daily visitors. A number of seismically deficient structures that cannot be cost-effectively upgraded will be demolished. Square footage of demolished structures will offset the new facilities on this project. This project constructs a new 40,000 to 46,000 gsf general-purpose lab/office building, an approximately 4,500 gsf fire station truck garage, and will upgrade and modernize two seismically poor-rated institutional facilities (approximately 10,600 gsf medical services building and an approximately 15,400 gsf cafeteria). PED is planned to begin in FY 2013. Deferred maintenance will be reduced by approximately $2.5 million and productivity improvement will be greater than $2 million.

- o SLI Seismic Phase 4 Project (B70) Project. This investment is a priority for LBNL, as it will remedy seismic life-safety deficiencies in DOE Building 70, occupied by 160 staff and visitors. This project will replace Building 70 with a modern, approximately 55,000 gsf lab/office building. PED is planned to start in FY 2016. Deferred maintenance will be reduced by $2.3 million and productivity improvement will be greater than $1 million.

- o SLI Seismic Phase 5 Project. This investment is a priority for LBNL, as it will remedy particularly serious seismic life-safety deficiencies in DOE structures totaling over 100,000 gsf and occupied by roughly 400 staff and visitors. This project will upgrade and modernize the final seismically unsafe facilities that can be cost-effectively upgraded and modernized. In addition, this project constructs an approximately 55,000 gsf replacement general-purpose lab/office building. Structures that are seismic and operational liabilities and that cannot be cost-effectively upgraded will be demolished. PED is planned to start in FY 2019. Deferred maintenance will be reduced by $5 million and productivity improvement will be greater than $2 million

- **SLI in Progress:**

  - o SLI Seismic Phase 2 Project. This FY 2009 project start is remedying seismic life-safety deficiencies in DOE buildings occupied by 250 staff and visitors. This project will also modernize about 45,000 gsf of laboratory space. A modern, roughly 43,000 gsf general-purpose lab/office building will be constructed to replace structures that are seismic and operational liabilities and that will be demolished. An ancient landslide under Building 85 will be stabilized in the Building 85 area. PED was started in FY 2009. Deferred maintenance will be reduced by $6.1 million, and productivity improvement will be equivalent to $2.5 million.

  - o SLI ARRA GPP Projects. The initial scope of the five FY 2009 GPP project starts is completed. These projects 1) increase energy efficiency in Building 2, 2) replace the main air-handling units for ALS, 3) upgrade the main substation, 4) modernize general-purpose laboratory and office space in Building 62 for energy and materials sciences research, and 5) modernize general-purpose laboratory and office space in Building 66 for energy and materials sciences research. Construction completion of all initial scope was achieved as of FY11. Approximately $2.6 million of ARRA GPP funding is expected to be released from the initial five projects during 2011, and which, if approved by DOE, will be utilized to modernize additional general-purpose laboratory space in Building 62.

SC Programs and other DOE offices provide essential support for mission-specific facilities and infrastructure. SC Program projects and those of the OEM that are in progress or anticipated are outlined as follows:

- **SC Program Office in Progress:**

  - o NGLS (BES). Site planning and pre-conceptual designs and estimates for this investment are a priority as they enable the construction of the Next Generation Light Source, including associated experimental and user facilities and utility infrastructure. Pre-Critical Decision Zero (CD-0) assessments have been completed, and CD-0 was approved in 2011.

- Berkeley Lab Laser Accelerator (BELLA) (HEP). This project began in 2009. This investment is adapting portions of Building 71 to accommodate the BELLA experimental laser system and provide experimental facilities to employ the BELLA laser for accelerator science experiments. CD-1 and CD-2/3A were approved in September 2009. The laser system subcontract was awarded in November 2009 and conventional construction began in August 2010.

- **Other DOE Office Investments**

  - Advanced Biofuels Process Development Unit (EERE). This project began in 2010. This ARRA investment will allow for the development of processes by which scientific breakthroughs in advanced biofuels can be scaled up to lay the groundwork for eventual mass commercialization. The project obtained beneficial occupancy in a leased facility in January 2011, became baseline operational in April 2011, and is on track to become fully operational prior to the September 2011 milestone.

  - User Testbed Facility (EERE). This ARRA investment will contain a set of testbeds for building systems integration. It will be designed to address key technical challenges for low and net-zero energy buildings and will be located near and within Building 90.

- **Contractor Investments**

  The University of California has further demonstrated its commitment to research and education by arranging over $178 million of funding for three significant facility investments, and is working with LBNL to identify additional funding for a fourth facility.

  - Berkeley Lab Guest House. This investment is a priority for visitors to LBNL's national user facilities, as it provides overnight accommodations for up to 70 guests. The roughly 20,000 gsf project was funded in 2007 and became operational in 2009.

  - Computing Research Theory Facility. This investment is a priority, as it will provide a new, approximately 128,000 gsf computing science facility. The project is proposed for occupancy in 2014.

  - Solar Energy Research Center. This investment is a priority, as it will provide a new, roughly 38,000 gsf facility to support sustainable energy research. The project funding was authorized in FY 2007 and this facility is scheduled for occupancy in 2014.

  - Science, Technology, Engineering, and Mathematics Education Facility. UC is seeking gift funding to finance a 9,500 gsf educational facility at LBNL to serve K-12 and undergraduate students and teachers in the science education community. Preliminary discussions have been held with potential donors.

- **Laboratory Investments**

  LBNL focuses its direct investments, including maintenance funding of approximately $20 million/year and IGPP funding in excess of $5 million/year, to ensure that facilities are maintained effectively to serve the mission. Funding needs are identified annually in a lab-wide UniCall process, and are reviewed by LBNL leadership to ensure funds are allocated to the highest overall priority facility and infrastructure projects. Of particular note are three one-time near-term projects:

  - Building 44-complex Demolition. This is a $1.5 million LBNL institutionally funded project that was started in FY 2011 and will demolish three underutilized, inefficient, seismically marginal facilities, and in addition will perform underground characterization and environmental restoration within the Old Town area. This work is coordinated with the not-yet-approved SC SLI Old Town demolition project and together will create room for future modern research facilities.

- Temporary Consolidation of Research Programs in Off-site Lease Space. The preceding leasing and space-planning discussions noted LBNL's intent to lease additional research space pending development of the Second Campus. The Laboratory is mindful that these moves need to provide adequate research space as well as improve communication among researchers and defragment research and administrative groups, and LBNL is planning accordingly. Projects to relocate these programs are well under way and are planned to be completed in the FY 2011 time frame.

- Development of a Second Campus. The preceding space-planning discussions included the basis for and intent to develop a Second Campus. A detailed development and funding plan will be prepared in conjunction with UC over the next year, and further details will be vetted with DOE during the year and incorporated into the 2012 Annual Plan.

- Old Town Move-out. The Laboratory is working to vacate legacy buildings in the Old Town area in an orderly and coordinated manner prior to the SLI demolition and restoration project described above. Relocation planning, and some moves, are now under way.

Additional Excess Facilities and Plans to Achieve Asset Condition Index (ACI) Targets

About 5% (roughly 86,600 gsf) of DOE building space at LBNL is nonoperational. This includes Building 74 (45,382 gsf), which is currently vacant while undergoing major renovation and modernization (project to be completed and building reoccupied in early 2012). The other approximately 41,000 gsf of nonoperational buildings will be excessed and demolished during the strategic planning period, and as appropriate are included in the projects discussed in the preceding project summaries.

LBNL's plan conforms to DOE SC's expectation that the ACI metric for mission-critical facilities at LBNL (approximately 90% of LBNL's capital assets) will be a minimum of 0.980 within the 10-year planning period. LBNL plans to reduce deferred maintenance and achieve this objective with a combination of Deferred Maintenance Reduction (DMR), IGPP, and Line Item Project (LIP) funding and to meet the 0.980 ACI target in FY 2015. A summary of investments and their impact to ACI is provided in Table 6C and Figure 6A, below.

Trends and Metrics

LBNL's annual infrastructure goals are defined in *Contract Performance Evaluation and Measurement Plan* (PEMP) Section 7 — *Sustain Excellence in Operating, Maintaining, and Renewing the Facility and Infrastructure Portfolio to Meet Laboratory Needs*. These goals measure the overall effectiveness and performance of UC in planning for, delivering, and operating LBNL facilities and equipment to ensure that required capabilities are present to meet today's and tomorrow's complex challenges. For FY 2010, UC scored 3.2 for Goal 7, which translates to a letter grade of B+. Noteworthy performance includes preparation of both Utility Infrastructure Fitness-for-Service Evaluation and a Utility Infrastructure Capacity Assessment; successful integration of Mission Readiness into the UniCall institution-wide project identification, prioritization, and funding process; continued successes on the Building 51 and the Bevatron Demolition Project; and successful progress on the ARRA project plan. For FY 2011, CD-0 for the NGLS project has been obtained, and progress has been made on all tasks.

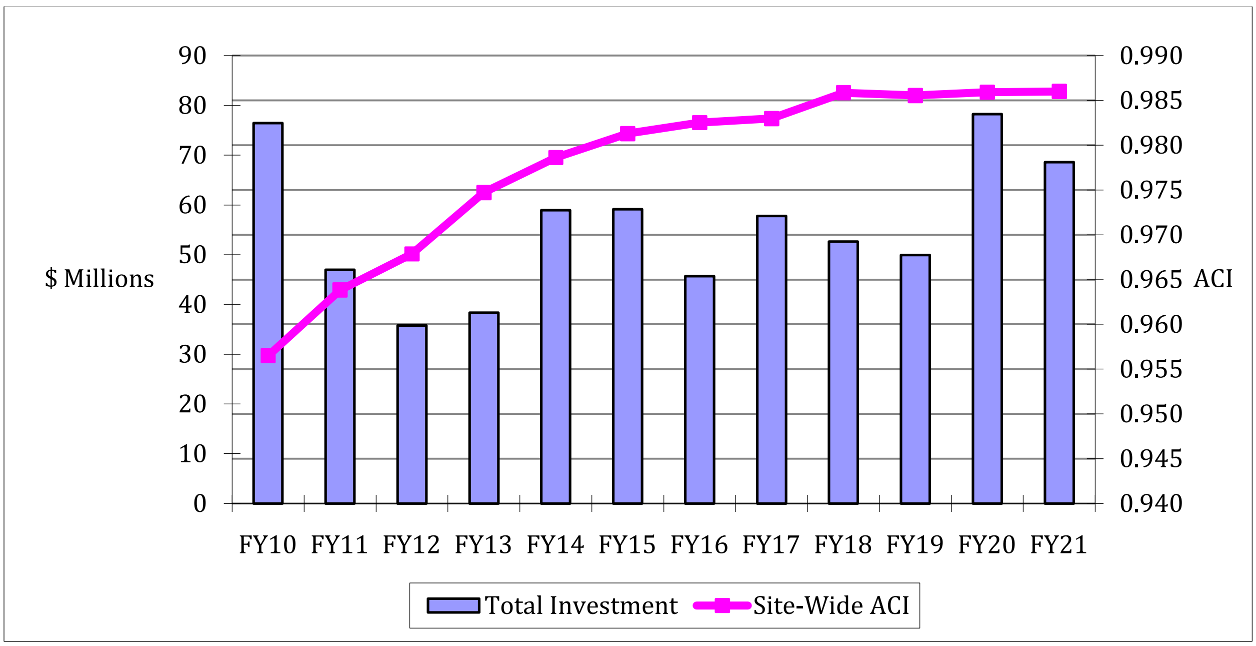
LBNL has implemented the mission-readiness process. A Mission Readiness Peer Review assessed LBNL's implementation of the process in June 2009, and found the program to be effective and appropriate. A summary of support facilities and infrastructure for mission readiness is provided in Tables 6E and 6F, below.

Table 3. Facilities and Infrastructure Investments (FY $M) — Impact to Asset Condition Index

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	18.	18.7	14.7	15.0	15.3	15.7	16.0	16.3	16.6	16.9	17.3	17.6
DMR*	3	3	2.5	2.5	2.6	2.5	0	0	0	0	0	0
Excess Facility Disposition	1.7	1.5	0	0	0	0	0	0	0	0	0	0
IGPP	5.1	5.2	5.5	6	6	6	6	6	6	6	6	6
GPP	0	0	0	0	0	0	0	0	0	0	0	0
Line Items	49.7	20.1	13.0	14.8	35.0	35.0	23.7	35.5	30.0	27.0	55.0	45.0
Total Investment	78.2	48.5	35.7	38.3	58.9	59.2	45.7	57.8	52.6	49.9	78.3	68.6
Estimated RPV	1060	1062	1080	1147	1193	1224	1310	1339	1393	1426	1527	1572
Estimated DM	46.1	38.4	34.7	29	25.5	22.9	22.9	22.8	19.7	20.6	21.5	22
Site-wide ACI	0.957	0.964	0.968	0.975	0.979	0.981	0.983	0.983	0.986	0.986	0.986	0.986

* Does not include DMR resulting from line items, GPP, IGPP, excess facility disposition, or normal maintenance.

Figure 1. Facilities and Infrastructure Investments



Technical Facilities and Infrastructure

Core Capabilities	Time Frame	Mission Ready				Key Buildings	Key Core Capability Objectives	Facilities And Infrastructure Capability Gap	Action Plan	
		N	M	P	C				Laboratory / Contractor	DOE (Program & SLI)
Accelerator Science	Now			■		6, 15, 46, 47, 58/A, 71, 77, 77A, 88, Old Town	High energy, low-emittance beam R&D, including high-repetition-rate photoinjectors, optical manipulation of beams and superconducting technology. Assemble NDCX-II.	Seismic deficiencies; insufficient-quality experimental program space	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• BELLA & NDCX-II construction; • Complete Bevatron deconstruction (FY11); NGLS CD0 has been authorized in FY2011 • Old Town Demolition
	In 5 Years			■		6, 15, 46, 47, 58/A, 71 (incl. BELLA), 77, 77A, 88, Old Town relocation space	Design and demonstration of high-performance, low-emittance beams, including high-repetition-rate photoinjectors, optical manipulation for attosecond photon beams; operate NDCX-II and advanced optical accelerators	Seismic deficiencies; some inadequate space pending seismic upgrade and modernization of select older buildings. User-facility demand outpaces available resources. Limited high-bay space.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure; • Rehabilitate and add sufficient high-bay and high-ceiling space; Old Town staff and program relocations	• Complete NDCX-II & NDCX-II in operation; NGLS construction including user facility; complete BELLA facilities & BELLA in operation; • Complete Old Town Demolition; • Seismic Phs. 3 – General-purpose replacement Lab Bldg. #2
	In 10 Years				■	6, 15, 46, 47, 58/A, 71 (incl. BELLA), 77, 77A, 88, Old Town relocation space, NGLS	Deploy the attosecond high-intensity high-average-power photon beams for the user community, develop highest-energy, lowest-cost accelerators	Some inadequate space pending upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation; • Seismic Phs. 5 - Seismic upgrade of Bldgs. 46 & 58

Technical Facilities and Infrastructure							
Core Capabilities	**Time Frame**	**Mission Ready**	**Key Buildings**	**Key Core Capability Objectives**	**Facilities And Infrastructure Capability Gap**	**Action Plan**	
						Laboratory /	**DOE (Program & SLI)**
Advanced Nuclear Science and Technology	Now		2, 15, 6, 50, 55, 58/A, 64, 70, 70A, 71, 77, 88	Develop detectors for nuclear/security. Develop models for seismic safety of reactors. Understand actinide behavior.	Inadequate space pending seismic upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete Seismic Phs. 1 – Upgrade of Bldg. 50
	In 5 Years		2, 6, 15, 50, 55-replacement, 58/A, 64, 70, 70A, 71, 77, 88	Understand radiation effects on electronics. Perform 3D seismic behavior of reactors. Simulate core flow and dynamics.	Inadequate space pending seismic upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Seismic Phs. 2 - General purpose replacement Lab Bldg. #1
	In 10 Years		2, 6, 15, 50, 55-replacement space, 58/A, 64-replacement space, 70-replacement space, 70A, 71, 77, 88	Deploy advanced models and detectors for materials nuclear safety, including innovative scintillation detection	Some inadequate space pending upgrade / modernization of Bldg. 58 and occupancy of replacement lab buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Seismic Phs. 4 (B70) - Bldg. 70 replacement bldg. • Seismic Phs. 5 - General-purpose replacement Lab Bldg. #3 • Seismic Phs. 5 - Bldg. 58 upgrade
Applied Materials Science and Engineering	Now		6, 15, 67, 72	Develop nanodevices, high-efficiency catalysis and energy conversion, storage and transmission systems	Inadequate space pending seismic upgrade and modernization of select older buildings	• SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS CD0 has been authorized in FY2011 • Old Town Demolition.

Technical Facilities and Infrastructure							
Core Capabilities	**Time Frame**	**Mission Ready**	**Key Buildings**	**Key Core Capability Objectives**	**Facilities And Infrastructure Capability Gap**	**Action Plan**	
						Laboratory /	**DOE (Program & SLI)**
	In 5 Years		6, 15, 67, 72	Develop new energy materials at high efficiency through the study of nano and femtoscale process. Pilot testing of materials and engineered systems. Design integrated and more efficient photovoltaic systems.	Inadequate space pending seismic upgrade and modernization of select older buildings. Limited high-bay space.	• Complete SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure; Rehabilitate and add sufficient high-bay and high-ceiling space	• NGLS construction including user facility; • Complete Old Town Demolition; • Seismic Phs. 2 - general purpose replacement Lab Bldg. #1 • Seismic Phs. 3 - General-purpose replacement Lab Bldg. #2
	In 10 Years		6, 15, 67, 72, NGLS	Utilize attosecond and femtosecond probes to optimize the design of energy capture and storage systems. Deploy and further engineer advanced systems.	Some inadequate space pending seismic upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation; • Seismic Phs. 5 – General-purpose replacement Lab Bldg. #3
Applied Mathematics & Advanced Computer Science, Visualization and Data	Now		50-complex (50C), OSF	Algorithms and systems for next-generation modeling and data; R&D on low-power computing. Modeling and validation for ultrafast science.	Inadequate space pending seismic upgrade and modernization of select older buildings	• CRT, Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS CD0 has been authorized in FY2011 • Complete Seismic Phs. 1 – Upgrade of Bldg. 50
	In 5 Years		50-complex (50C), OSF, CRT	Apply advanced modeling to sustainable-energy systems. Develop software and systems for extreme computing.	NGLS, Some inadequate space pending replacement of 50C and modernization of select older buildings	• Complete CRT, Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS construction including user facility;

Technical Facilities and Infrastructure

Core Capabilities	Time Frame	Mission Ready				Key Buildings	Key Core Capability Objectives	Facilities And Infrastructure Capability Gap	Action Plan: Laboratory /	Action Plan: DOE (Program & SLI)
	In 10 Years				■	50-complex, NGLS, OSF, CRT	Develop and deploy exascale computing, including multimillion processor systems; provide advanced visualization tools; develop low-energy computation systems.	Safe, mission-ready facilities. User facilities to model chemical and materials at the attoscale for low-energy computation systems.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation; • Seismic Phs. 5 - General-purpose replacement Lab Bldg. #3
Biological Systems Science	Now			■		6, 15, 55/A, 56, 64, 67, 70A, 73, 74, 83, 84, Donner Lab, JBEI, JGI, Potter (BWB)	Conduct leading biofuels research, develop biosequestration, achieve multiterabase genome sequencing methods, conduct metagenomics studies of entire biological communities	Inadequate space in both number of on-site laboratory spaces and the capabilities of the older-standard labs, seismically deficient facilities. Need photon user facilities.	• Expand temporary leased space at BWB to defragment additional research programs; maintenance, DMR & IGPP capital renewal of general-purpose infrastructure.	
	In 5 Years			■		55, 56A, 56, 64 & 73-replacement, 6, 15, 67, 74, 83, 84, JBEI, JGI, Potter (BWB)	Develop comparative metagenomics of entire biological communities. Engineer biofuel crops, microbes, and synthetic systems	Inadequate space in both number of on-site laboratory spaces and the capabilities of the older-standard labs, seismically deficient facilities	• Complete Second-Campus; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	
	In 10 Years				■	6, 15, 67, 74, 83, 84, JBEI, JGI, NGLS, Second-Campus	Deploy biofuels and biosequestration, conduct functional nanoscale imaging, and image macromolecules at work	Deploy biofuels and biosequestration, conduct functional nanoscale imaging, and image macromolecules at work	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation;

Technical Facilities and Infrastructure							
Core Capabilities	**Time Frame**	**Mission Ready**	**Key Buildings**	**Key Core Capability Objectives**	**Facilities And Infrastructure Capability Gap**	**Action Plan**	
						Laboratory /	**DOE (Program & SLI)**
Chemical and Molecular Science	Now		2, 6, 15, 62, 70, 70A, 80	Develop sustainable fuels conversion and sequestration systems; understand molecular processes at nano, femto, and attoscales	Inadequate number of laboratory spaces, older-standard labs; Some inadequate space pending seismic replacement	• SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure.	• NGLS CD0 has been authorized in FY2011
	In 5 Years		2, 6, 15, 62, 70-replacement, 70A, 80, SERC	Develop hybrid chemical conversion, artificial photosynthesis, efficient and affordable photovoltaics	Inadequate number of laboratory & office spaces, older-standard labs	• Complete SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure.	• NGLS construction including user facility;
	In 10 Years		2, 6, 15, 62, 70-replacement, 70A, 80, SERC, NGLS	Directly observe how electrons move and control chemical bonds. View electron movies, design highly efficient photosynthetic and chemical conversion systems.	Safe, mission-ready facilities. Need to operate NGLS user facility.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and begin operation; • Seismic Phs. 4 (B70) - Bldg. 70 Replacement Bldg.
Chemical Engineering	Now		2, 6, 15, 62, 67, 70, 70A, 90	Develop advanced chemical systems for sustainable energy conversion & storage. Pilot testing of chemical systems and hybrid systems	Inadequate number of laboratory spaces, older-standard labs; some inadequate space pending seismic replacement	• SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS CD0 has been authorized in FY2011
	In 5 Years		2, 6, 15, 62, 70-replacement, 70A, 80, SERC	Pilot testing of chemical systems and hybrid systems	Inadequate number of laboratory & office spaces, older-standard labs	• Complete SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS construction including user facility; • Complete Pilot-scale Research Facility for Advanced Biofuels

Technical Facilities and Infrastructure							
Core Capabilities	Time Frame	Mission Ready	Key Buildings	Key Core Capability Objectives	Facilities And Infrastructure Capability Gap	Action Plan	
						Laboratory /	DOE (Program & SLI)
	In 10 Years		2, 6, 15, 62, 70-replacement, 70A, 80, SERC, NGLS	Deploy and further engineer advanced chemical systems for DOE missions; provide NGLS molecular engineering capabilities	Safe, mission-ready facilities. Need to operate NGLS user facility.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure.	• Complete NGLS construction and begin operation; • Seismic Phs. 4 (B70) - Bldg. 70 replacement bldg.
Climate Change Science	Now		50-complex, 70, 70A,,	Develop and communicate data, models, research, and transformational solutions to understand the forcing response of the Earth's climate system	Inadequate space pending replacement of seismically deficient older building.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS CD0 has been authorized in FY2011
	In 5 Years		50-complex, 70, 70A, 84	Develop and deploy data, models, research, and transformational solutions to understand and positively influence the forcing and response of the Earth's climate system	Inadequate space pending replacement of seismically deficient older building.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Fund Seismic Phs. 4 SLI LIP; NGLS construction including user facility
	In 10 Years		50-complex, 70-replacement, 70A, 84, CRT, NGLS	Develop, refine, and advance data models, research, and transformational solutions to understand the forcing and response of the Earth's climate system		• Complete CRT: Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation; • Seismic Phs. 4 - General-purpose replacement Lab Bldg. 70

Technical Facilities and Infrastructure

Core Capabilities	Time Frame	Mission Ready	Key Buildings	Key Core Capability Objectives	Facilities And Infrastructure Capability Gap	Action Plan: Laboratory /	Action Plan: DOE (Program & SLI)
Computation-al Science	Now		50-complex, OSF	Develop high-performance computing resources to obtain significant results in many areas of science and engineering. Develop software and model algorithms for transformational solutions in critical DOE missions.	Inadequate space pending seismic upgrade and modernization of select older buildings	• CRT, Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS CD0 has been authorized in FY2011
	In 5 Years		50-complex, OSF, CRT	Develop high-performance computing resources to obtain significant results in many areas of science and engineering. Develop software and model algorithms for transformational solutions in critical DOE missions.	NGLS, Some inadequate space pending upgrade and modernization of select older buildings	• Complete CRT, Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS construction including user facility;

Technical Facilities and Infrastructure										
Core Capabilities	**Time Frame**	**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facilities And Infrastructure Capability Gap**	**Action Plan**	
									Laboratory /	**DOE (Program & SLI)**
	In 10 Years					50-complex, NGLS, OSF, CRT	Develop high-performance computing resources to obtain significant results in many areas of science and engineering. Develop software and model algorithms for transformational solutions in critical DOE missions.	Safe, mission-ready facilities. User facilities to model chemical and materials at the attoscale for low-energy computation systems.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation; • Seismic Phs. 5 - General-purpose replacement Lab Bldg. #3
Condensed Matter Physics and Materials Science	Now					2, 6, 15, 62, 66, 67, 72	Discover and understand novel materials and batteries; develop atto- and femtoscale science	Inadequate number of laboratory and office spaces, older-standard labs. NGLS user capabilities needed.	• SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• NGLS CD0 has been authorized in FY2011 Old Town Demolition
	In 5 Years					2, 6, 15, 62, 66, 67, 72	Nanofabricate and characterize novel energy systems, probes for attoscale and femtoscale materials science, and energy systems physics	Inadequate number of laboratory and office spaces, older-standard labs. User facilities for ultrafast science (NGLS)	• Complete SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure; rehabilitate and add sufficient high-bay and high-ceiling space	• NGLS construction including user facility; • Complete Old Town Demolition; • Seismic Phs. 3 – General-purpose replacement Lab Bldg. #2
	In 10 Years					2, 6, 15, 62, 66, 67, 72, SERC	Fully understand probe, and manipulate materials systems at electron orbital scales for advanced materials; conduct advanced spin physics	Some inadequate space pending occupancy of replacement lab building. Need to operate NGLS.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and start operation; • Seismic Phs. 5 - Seismic upgrade of Bldgs. 46 & 58.

Technical Facilities and Infrastructure							
Core Capabilities	**Time Frame**	**Mission Ready**	**Key Buildings**	**Key Core Capability Objectives**	**Facilities And Infrastructure Capability Gap**	**Action Plan**	
						Laboratory /	**DOE (Program & SLI)**
Environmental Subsurface Science	Now		6, 15, 64, 70, 70A, 90	Research on carbon sequestration, geothermal energy, isotope geochemistry, subsurface transport modeling	Significant seismically low-rated labs & older-standard labs need for computational facilities	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure.	• NGLS CD0 has been authorized in FY2011
	In 5 Years		6, 15, 50-complex, 64, 70, 70A, 90	Pilot testing of enhanced sequestration; development of geothermal, advanced simulation of subsurface processes	Inadequate space pending completion of relocations and new buildings; need for computational resources	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure.	• NGLS construction including user facility
	In 10 Years		6, 15, 50-complex, 64-replacement space, 70-replacement space, 70A	Deployment of advanced sequestration and remediation technologies. Molecular-scale studies of subsurface	Inadequate space pending occupancy of replacement lab building. Need for advanced	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and begin operation; • Seismic Phs. 4 (B70) - Bldg. 70 replacement bldg.
Large-Scale User Facilities/ Advanced Instrumentation	Now		6, 15, 50-complex , 58/A, 62, 67, 71, 72, 77, 77A, 88, ESNET, JGI, JBEI	Develop the technology for ultrafast soft X-ray science; R&D needed on NGLS systems components, including high-repetition-rate photocathodes	Inadequate space pending seismic upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete Bevatron removal; NGLS CD0 has been authorized in FY2011

Technical Facilities and Infrastructure										
Core Capabilities	Time Frame	Mission Ready				Key Buildings	Key Core Capability Objectives	Facilities And Infrastructure Capability Gap	Action Plan	
									Laboratory /	DOE (Program & SLI)
	In 5 Years					6, 15, 50-complex, 58/A, 62, 67, 71, 72, 77, 77A, 88, ESNET, JGI, JBEI, USB	Design the experimental facilities for ultrafast science at the NGLS and begin construction; conduct next-generation high-energy density physics research	Inadequate space pending seismic upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure; rehabilitate and add sufficient high-bay and high-ceiling space	• NGLS construction including user facility
	In 10 Years					6, 15, 50-complex (50C), 58/A, 62, 67, 71, 72, 77, 77A, 88, ESNET, JGI, JBEI, USB, NGLS	Complete and operate NGLS and other facilities for ultrafast science; develop the full array of NGLS beamlines	Some inadequate space pending upgrade / modernization of Bldg. 58 and occupancy of replacement lab building.	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete NGLS construction and begin operation; • Seismic Phs. 5 - General-purpose replacement Lab Bldg. #3 • Seismic Phs. 5 - Bldg. 58 upgrade
Nuclear Physics	Now					50-complex , 70, 70A, 88, ESNET, JGI/JBEI	Develop nuclear physics experiments for FRIB and DUSEL. Conduct nuclear structure studies at the 88-Inch cyclotron.	Seismic deficiencies; insufficient-quality experimental program space	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	•
	In 5 Years					50-complex, 70, 70A, 88	Fabricate and deploy neutrino detectors for FRIB and DUSEL. Conduct isotope structure studies at the 88-Inch Cyclotron.	Seismic deficiencies; some inadequate space pending seismic upgrade and modernization of select older buildings	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Seismic Phs. 4 (B70) - Bldg. 70 Replacement bldg.
	In 10 Years					50-complex, 70-replacement space, 70A, 88	Conduct leading nuclear physics experiments at FRIB, DUSEL, LHC and EIC	Safe, mission-ready facilities	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete Seismic Phs. 4 (B70) - Bldg. 70 Replacement Bldg.

Technical Facilities and Infrastructure							
Core Capabilities	**Time Frame**	**Mission Ready**	**Key Buildings**	**Key Core Capability Objectives**	**Facilities And Infrastructure Capability Gap**	**Action Plan**	
						Laboratory /	**DOE (Program & SLI)**
Particle Physics	Now		50-complex , 70A, 71, 77/A, Old Town	Conduct dark-energy and dark-matter studies and study the properties of neutrinos; develop highest resolution detectors, high-energy beams; operate Boss	Significant seismically low-rated labs & older-standard labs	• CRT, Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• BELLA construction; • Old Town Demolition; • Complete Seismic Phs. 1 – Upgrade of Bldg. 50
	In 5 Years		50-complex, 70A, 71 (incl. BELLA), 77, 77A, CRT, Old Town relocation space	Develop deep-space probes for supernova observation and detectors (e.g. JDEM). Deploy Big Boss. Develop optical accelerators.	Space & equipment to achieve detector, accelerator, and cosmology advances & other missions.	• Complete CRT, Maintenance, DMR & IGPP capital renewal of general-purpose facilities; Old Town staff and program relocations	• Complete BELLA facilities & BELLA in operation; • Complete Old Town Demolition; • Seismic Phs. 3 - replacement lab Bldg. #2
	In 10 Years		50-complex, 70A, 71 (incl. BELLA), 77, 77A, CRT, Old Town relocation space	Operate the JDEM mission. Deploy the highest-energy accelerators. Collaborate on neutrino experiments worldwide.	Safe, mission-ready facilities	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	
Systems Engineering and Integration	Now		25A, 46, 53, 60, 77, 90	Develop integrated systems for energy efficiency, storage sustainable energy conversion. Integrated instrument engineering.	No integrated buildings systems testing facilities; inadequate space; seismic deficiencies	• SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Design User Test-Bed Facility Net-Zero Energy Buildings User Facility in Building 90

Technical Facilities and Infrastructure										
Core Capabilities	Time Frame	Mission Ready				Key Buildings	Key Core Capability Objectives	Facilities And Infrastructure Capability Gap	Action Plan	
									Laboratory /	DOE (Program & SLI)
	In 5 Years					25A, 46, 53, 60, 77, 90, SERC	Modeling and testing of integrated systems for efficiency, conversion and storage, and security; engineering advanced instrumentation of beamlines	Inadequate space pending relocations and completion of new buildings	• Complete SERC; Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Complete User Test-Bed Facility, • Complete Old Town Demolition; • Seismic Phs. 3 – General-purpose replacement Lab Bldg. #2
	In 10 Years					25A, 46, 53, 60, 77, 90, SERC	Deploy and further engineer advanced chemical systems for DOE missions; NGLS beamline engineering	Some inadequate space pending occupancy of replacement lab building	• Maintenance, DMR & IGPP capital renewal of general-purpose infrastructure	• Seismic Phs. 5 - General-purpose replacement Lab Bldg. #3 • Seismic Phs. 5 - Bldg. 46 upgrade

Support Facilities and Infrastructure							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Capability Gap**	**Action Plan**	
	N[a]	**M[b]**	**P[c]**	**C[d]**		**Laboratory**	**DOE SLI**
Work Environment							
Post Office				■	Bldg. 69		
Offices				■	Various locations. Note: Some trailers slated for replacement during term of plan		
Cafeteria			■		Bldg. 54 - Functional but seismic safety upgrade and modernization needed		SLI LIP - Seismic Phs. 3
Recreational/Fitness				■	Bldg. 76 Multipurpose Room		
Child Care	not applicable						
User Accommodations							
Visitor Housing				■	Nonfederal facility completed in 2009		
Visitor Center				■	Bldg. 65		
Site Services							
Library			■		Bldg. 50		
Medical			■		Bldg. 26 - Functional but seismic safety upgrade and modernization needed		SLI LIP - Seismic Phs. 3
Maintenance & Fabrication				■	Bldgs. 77, 77A & 78		
Fire Station			■		Bldgs. 45 & 48 - Functional but seismic safety upgrade and modernization needed		SLI LIP - Seismic Phs. 3
Examination & Testing /Storage	not applicable						
Conference and Collaboration Space							
Auditorium/Theater				■	Bldg. 50		
Conference Rooms				■	Various locations		
Collaboration Space				■	Various locations		
Utilities						Note: Spot repairs are included in annual budget	
Communications				■	None, Radio communication upgrade project initiated in FY10 has been completed.		
Electrical			■		Major issue has been addressed; Transformer Bank 2 in LBNL Substation was replaced and has been commissioned. Some building transformers and related equipment in 1960's era buildings are aging and will be replaced during the term of this Plan.	Replace building transformers and related equipment when building condition surveys find a replacement needs to be scheduled.	

Support Facilities and Infrastructure							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE SLI
Water					The Domestic Water & Natural Gas underground supply piping is over 40 years old. An Infrastructure Fitness-for-Service Evaluation and a Capacity Assessment found the Water & Natural Gas systems in good shape.	The reports indicated that a modern Impressed Current System should be installed on Nat. Gas piping. Funding will be considered in FY12 & 13.	
Gases							
Waste/Sewer Treatment					Portions of the sewer system are over 40 years old. The Sanitary Sewer System Management Plan is being updated.	Funding will be requested to repair the lines if the inspection shows repair is needed.	
Storm Water					Portions of the Storm-water piping systems including hydraugers, above and below ground, are over 40 years old.	Multiyear management and replacement plan is in preparation.	
Compressed Air					Portions of the Compressors and piping systems are over 40 years old. An Infrastructure Fitness-for-Service Evaluation and a Capacity Assessment found the system in good shape.	The reports indicated that a modern Impressed Current System should be installed. Project will be considered for funding in FY12 & 13.	
Steam & Flood Control	not applicable						
Roads & Grounds							
Parking (surfaces and structures)					Engineering survey completed in 2009 identifies opportunities to add parking as required.	Implement new parking as required during the term of this plan.	
Roads & Sid					Pedestrian and vehicular safety improvement opportunities have been identified in a 2009 engineering survey.	Implement corrective actions during the term of this plan.	
Grounds							

N[a] = Not, M[b] = Marginal, P[c] = Partial, C[d] = Capable

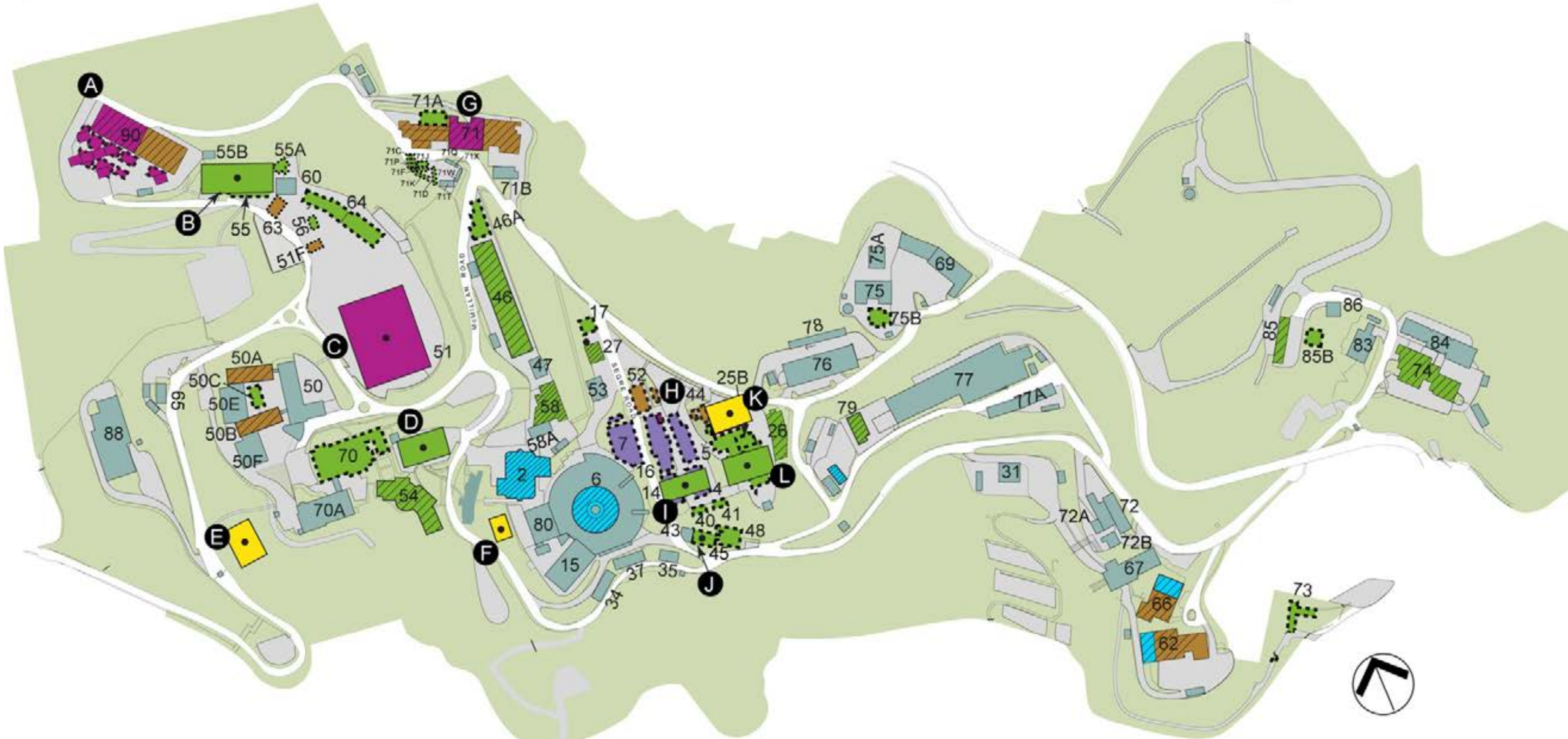
Berkeley Lab FY11-FY21 Projects

Funding

- Contractor
- Operating/IGPP
- Program Const. & Demo
- SC SLI LIP
- SC SLI ARRA GPP (incl. completed projects)
- SC SLI Demo (Old Town – Bldgs. 4, 5, 7, 7C, 14, 16, 16A)

Action

- Upgrade
- New Building
- Demolish



- **A** User Test Bed Facility
- **B** General Purpose Lab Replacement #3
- **C** NGLS
- **D** Bldg. 70 Replacement Lab
- **E** Computing Research Theory Facility (UC)
- **F** STEM Education Facility
- **G** BELLA
- **H** Old Town Demolitions and Restoration
- **I** General Purpose Lab Replacement #2
- **J** Fire House Replacement
- **K** SERC (UC)
- **L** General Purpose Lab Replacement #1

NOTES: All SC Infrastructure Modernization Initiative projects are included. Sitings are illustrative, designs are conceptual and not to scale. Utility projects are not shown.
Advanced Biofuels Process Development Unit (off-site)

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Oak Ridge National Laboratory

Mission and Overview

The mission of Oak Ridge National Laboratory (ORNL) is to deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation. To execute this mission, ORNL integrates and applies distinctive core capabilities that provide it with signature strengths in neutron scattering, advanced materials, high-performance computing (HPC), and nuclear science and engineering. The intended outcome is to produce transformational innovations that will enable a 21st century industrial revolution.

Managed by UT-Battelle, a partnership of the University of Tennessee (UT) and Battelle Memorial Institute, ORNL was established in 1942 to support the Manhattan Project. From an early focus on chemical technology and reactor development, ORNL's research and development (R&D) portfolio broadened to include programs supporting U.S. Department of Energy (DOE) missions in scientific discovery and innovation, clean energy, and nuclear security. Today, as DOE's largest science and energy laboratory, ORNL is engaged in programs and partnerships that leverage major national investments in critical research infrastructure, including the world's foremost resources for neutron sciences, the Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR), and the world's most powerful computing complex. ORNL also manages the U.S. ITER project for DOE. Each year, ORNL hosts thousands of facility users and visiting scientists, many of whom perform work at its 10 user facilities, and supports the development of the next generation of scientific and technical talent.

Current Core Capabilities

Of the 17 core capabilities distributed across DOE's national laboratories, ORNL possesses 15, indicating the exceptional breadth of its scientific and technological foundation. Each is a substantial combination of people, equipment, and facilities, having unique or world-leading components, and is employed in mission delivery for DOE, the National Nuclear Security Administration (NNSA), the U.S. Department of Homeland Security (DHS), and the Laboratory's other customers. ORNL's set of capabilities extends across the continuum from basic to applied research, and the interaction of basic and applied work is itself a signature strength of the Laboratory: in 1967, Alvin Weinberg observed "that applied research done in a basic atmosphere has a sophistication that is hard to

Lab-at-a-Glance

Location: Oak Ridge, Tennessee

Type: Multi-program laboratory

Contractor: UT-Battelle, LLC

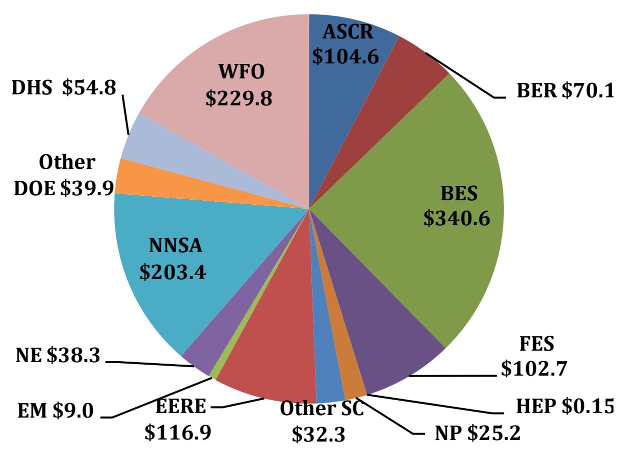
Responsible Field Office: Oak Ridge Office

Web site: http://www.ornl.gov/

Physical Assets:
- 4,470 acres and 252 buildings
- 4.5M GSF in active operational buildings; 206,000 GSF in nonoperational buildings
- Replacement Plant Value: $7B
- Deferred Maintenance: $91.3M
- Asset Condition Index
  - Mission critical: 0.93
  - Mission dependent: 0.93
  - Asset Utilization Index: 0.94

Human Capital:
- 4,702 Full-Time Equivalent (FTE) Employees
- 83 Joint Faculty
- 381 Postdoctoral Researchers
- 490 Undergraduate Students
- 239 Graduate Students
- 2,833 Facility Users
- 1,901 Visiting Scientists

FY 2010 Funding by Source: ***(Cost Data in $M)***



FY 2010 Total Lab Operating Cost (excluding ARRA): $1,367.7
FY 2010 Total DOE/NNSA Costs: $1,083.2
FY 2010 WFO (Non-DOE/DHS) Costs: $229.8
FY 2010 WFO as % Total Lab Operating Costs: 16.8%
FY 2010 Total DHS Costs: $54.8

ARRA Obligated from DOE Sources, FY 2010: $153.0
ARRA Costed from DOE Sources, FY 2010: $145.0

duplicate in a less scientific environment, and that basic research done in an applied atmosphere has a kind of no-nonsense aggressiveness that is hard to duplicate when basic research is done entirely by itself."[2]

Synergies among these capabilities enable ORNL to attack the fundamental research challenges posed by DOE's missions and to carry out the translational research required to accelerate the delivery of solutions to the marketplace, with an emphasis on development, demonstration, and deployment. For example, as one of the world's most comprehensive materials science and technology (S&T) laboratories, ORNL has achieved significant integration of basic and applied research, as demonstrated by its record of accomplishment in building new understanding of the properties of materials, generally with the support of DOE's Office of Science (SC), and applying this understanding to engineer new and improved materials, often with the support of DOE's Offices of Energy Efficiency and Renewable Energy (EERE) and Electricity Delivery and Energy Reliability (OE), other applied energy offices, and global security customers. The new materials developed in this way are effectively transformed into commercial products through technology transfer. For example, EERE, OE, and DOE's Office of Nuclear Energy (NE) have supported ORNL's ability to integrate new materials, electronics, and sensors into engineered systems that achieve energy efficiency through measurement and control of nuclear power systems, transportation systems, and energy delivery in residential and commercial buildings. Another example is extreme-scale computing; ORNL is world leading in the development of advanced computing systems and computational, mathematical, and analysis techniques and in the application of these tools and techniques to advance discovery and meet national needs. These capabilities have attracted substantial investment from other federal agencies, including the National Science Foundation (NSF), the National Atmospheric and Oceanographic Administration (NOAA), and the U.S. Department of Defense (DoD).

As discussed in more detail in Sect. 5, the application of ORNL's core capabilities to the needs of non-DOE sponsors through Work for Others (WFO) and other mechanisms contributes to ensuring the fullest use of the results of DOE's investment in R&D. It also strengthens these capabilities and sustains ORNL's ability to deliver on DOE's missions in scientific discovery and innovation, clean energy, and national security.

1. Nuclear Physics

ORNL's nuclear physics core capability includes extensive theoretical and experimental research, which has been centered on the Holifield Radioactive Ion Beam Facility (HRIBF). While HRIBF will cease operation as a user facility in fiscal year (FY) 2012, internal ORNL experiments will continue as future program directions are established. As a consequence of the decision to cease user operations at HRIBF, ORNL developing a plan to utilize portions of the HRIBF infrastructure that enables a facility for isotope R&D and a reformulated experimental nuclear physics program, leveraging assets at ORNL and other facilities. The nuclear experimental program will also be involved in developing and building experimental detectors for the Facility for Rare Isotope Beams (FRIB). This plan is being reviewed by SC's Nuclear Physics (NP) program.

World-class theory programs in nuclear structure and astrophysics make extensive use of ORNL's computational facilities and extend the scientific impact of ORNL's work in nuclear physics beyond the physical limits of the HRIBF, which provides a unique and world-leading capability to investigate the structure and reactions of both neutron-rich and proton-rich rare isotopes and nuclear astrophysical processes. HRIBF is unique in its ability to deliver beams in the vicinity of the doubly magic radioactive isotopes ^{78}Ni and ^{132}Sn post-accelerated to energies above the Coulomb barrier. These nuclei are relevant to understanding heavy-element production in supernova explosions, fission products associated with the nuclear fuel cycle, and basic nuclear structure.

Staff at ORNL also provide advanced detector systems and related experimental research capabilities and develop new techniques for rare-isotope capability. These detector systems include the Oak Ridge–Rutgers University Barrel Array, which was essential to the confirmation of the doubly magic nature of ^{132}Sn in a 2010 experiment[3] that was described as "a technical tour de force."[4] The High Power Target Laboratory has enhanced an impressive array of tools for advancing the S&T of the isotope separator on-line (ISOL) method of rare isotope beam production. A second injector for radioactive ion beam (RIB) species, designated IRIS2, has improved facility reliability and efficiency; increased the number, intensity, and quality of RIB beams; and increased beam hours on target.

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[2]Alvin M. Weinberg, in *Oak Ridge National Laboratory Annual Report: 1966,* Union Carbide Corp., Oak Ridge, Tennessee, 1967.
[3] K. L. Jones et al., *Nature* 465, 454–457 (2010).
[4] P. Cottle, *Nature* 465, 430–431 (2010).

In addition to the experimental infrastructure at the HRIBF, the unique isotope production and separation capabilities at HFIR and the Radiochemical Engineering Development Center (REDC) that contributed to the discovery of element 117 will be applied to expand international collaborations in superheavy element research, including experiments aimed at the discovery of element 119.

The ORNL nuclear physics program is also home to the Fundamental Neutron Physics Beamline (FNPB) at SNS, which will exploit the special characteristics of a pulsed spallation source to study the detailed nature of the interactions of elementary particles. Of particular interest is the study of fundamental symmetries such as parity and time reversal invariance and the manner in which they are violated in elementary particle interactions. One of the key experiments at the FNPB being led by ORNL is focused on the search for the neutron electric dipole moment (nEDM). This experiment will investigate the nEDM with significantly higher sensitivity than previous experiments and will make precision tests of symmetry principles underlying the Standard Model of particle physics. ORNL also leads another important test of the Standard Model that comes from searches for the very rare neutrinoless double-beta decay mode of nuclei, which is being pursued as part of the MAJORANA DEMONSTRATOR project, a feasibility demonstration for the proposed ton-scale ^{76}Ge Majorana experiment. In addition, ORNL develops electronics and detectors and conducts relativistic heavy ion physics experiments at both Brookhaven National Laboratory and CERN.

This program includes an extensive nuclear theory activity, which makes extensive use of ORNL's computational facilities. A key test of theory describing how quarks respond to the weak force, for which Kobayashi and Maskawa were awarded the 2008 Nobel Prize, comes from experimental study of a handful of nuclei that exhibit "superallowed" beta decays. Relating the results of those very precise measurements to what has become the Standard Model of particle physics requires complicated corrections for the properties of complex nuclei. An international collaboration led by an ORNL scientist has recently performed isospin- and angular-momentum-projected density functional theory calculations to compute these corrections. The calculations represent the state of the art in application of nuclear theory to this problem. The resulting corrections confirm the Nobel-winning prediction to unprecedented accuracy.[5]

ORNL is well positioned to achieve breakthroughs and push the frontiers of discovery in nuclear physics, attacking compelling questions about the nature of the nuclear many-body problem, the fundamental structure of the neutron and the nature of the fundamental forces binding it together, and the origin and stability of the heavy elements. Adding to this excitement is the realization that this nuclear physics capability is well matched to nuclear energy mission goals and national security mission goals in nonproliferation. NP funds work in this area [mission areas SC-22, 23, 28, 29, 30, 31, 32]. NP also supports ORNL work on isotope production and applications, as described in Sect. 3.11.

2. Accelerator Science and Technology

ORNL's core capability in accelerator S&T includes expertise in both the basic physics of high-intensity beams and the supporting technology for production, acceleration, accumulation, and utilization of high-intensity, high-power beams. The SNS accelerator complex, operating at ~1 MW of beam power on target, is the world's most powerful pulsed proton accelerator. SNS is recognized as a world-leading center for the investigation of the dynamics of high-intensity hadron beams and the development of high-power proton targets. ORNL's strengths in computational science (see Sect. 3.10) have been applied to the development of modeling tools that are employed at SNS and other high-intensity accelerator facilities throughout the world; these tools are also being used to design the next generation of spallation neutron sources, high-intensity linear accelerators, and storage rings. The combination of state-of-the-art beam dynamics modeling tools and access to experimental data on collective, halo-formation, and instability effects in high-intensity linear accelerators and rings gives SNS and ORNL a capability that is unique in the world.

ORNL is also a recognized leader in the development of technologies to accelerate, characterize, manipulate, and utilize high-intensity, high-power particle beams in accelerators and storage rings. ORNL's core capability in accelerator S&T includes expertise in ion sources and low-energy beam chopping and manipulation, superconducting radio-frequency (rf) technology, high-power target systems, high-power and low-level rf systems, pulsed-power technology, sophisticated control systems for the manipulation of high-power beams, beam-tuning algorithms and high-level real-time accelerator modeling and analysis, and instrumentation to

[5] W. Satula et al., *Phys. Rev. Lett.* 106, 132502 (2011).

measure properties of high-intensity, high-power beams. Beam instrumentation systems and manipulation techniques developed at ORNL are being incorporated into the next generation of high-power accelerators throughout the world.

The impact of the basic research carried out at ORNL in the fields of high-intensity beam dynamics and technology spans all fields of science enabled by high-power hadron accelerators, including materials science, high-energy physics, nuclear physics, nuclear materials irradiation, and other accelerator-driven systems. This expertise is being applied to the analysis of options for a future neutron source that will expand capabilities for materials science and facilitate isotope production and materials irradiation. In addition, ORNL's distinctive capabilities in rare isotope beam production demonstrate sophistication and diversity in applications of accelerator S&T, providing a unique capability for the production of rare proton-rich and neutron-rich isotopes to explore the limits of nuclear stability and astrophysical processes involved in nucleosynthesis. The SC Basic Energy Sciences (BES) program [mission area SC-9] and NP [mission areas SC-25, 30] are the primary sources of funding for the ongoing accelerator S&T activities.

3. Plasma and Fusion Energy Sciences

ORNL leads the U.S. contributions to ITER, as discussed in Sect. 3.14. In executing this role, ORNL researchers gain and offer insight into the integration of burning plasmas and associated large-scale engineering systems relevant to fusion reactors and contribute to the design of ITER, which is aimed at demonstrating the scientific and technological feasibility of fusion power.

With broad experimental and theoretical expertise in high-temperature plasma science and strong synergies in materials science in extreme environments, computational science, and control theory, ORNL also provides key leadership in several areas of magnetic fusion research, including plasma theory and advanced computation, atomic and plasma boundary physics, plasma heating and fueling systems, and fusion materials science. Through these capabilities, ORNL makes significant contributions to understanding the science of the plasma core, plasma boundary, and plasma–materials interactions and to developing materials and components that can meet the demands of a burning plasma environment and enable fusion research facilities to meet their performance objectives. ORNL's plasma scientists lead experiments on several facilities, including DIII-D and the National Spherical Torus Experiment, to better characterize and control edge-localized instabilities in existing fusion devices and improve predictability for ITER. ORNL is DOE's lead laboratory for ion cyclotron heating and pellet fueling systems and is responsible for providing key enabling technologies for ITER, including the pellet fueling system and rf transmission line components for ITER's plasma heating systems. ORNL scientists make key contributions in the areas of computational materials science and fundamental experiments to provide the understanding needed to support development of advanced alloys and silicon carbide composites. Among the outcomes of the alloy research is high-strength, low-activation steel with superior high-temperature strength due to a fine dispersion of oxide nanoclusters that was recently licensed to Carpenter Technology Corporation for use in the energy and chemical sectors. Building on these core capabilities, ORNL is making substantial discretionary investments in developing the technical basis for the Plasma Materials Test Station (PMTS) to simulate the divertor conditions for ITER and future fusion reactors and serve as a prerequisite facility for a Fusion Nuclear Science Facility (FNSF). ORNL will continue to make critical contributions to develop both plasma-facing and structural materials that can also withstand the extreme radiation environment in future fusion devices by using the unique irradiation capabilities provided by HFIR and potentially SNS.

ORNL's extensive capabilities in plasma theory and simulation are strengthened by the ready availability of the Oak Ridge Leadership Computing Facility (OLCF) and by close and productive partnerships with computational scientists. ORNL fusion researchers make key contributions to the understanding of self-organization in plasmas, transport, and rf heating and current drive and play a significant role in several leading-edge computational activities. SC's Fusion Energy Science (FES) program funds work in this area [mission areas SC-17, 18, 19].

4. Condensed Matter Physics and Materials Science

ORNL is the nation's most comprehensive materials research center, executing a broad range of basic and applied research related to DOE missions. ORNL's research program centers on understanding nanoscale physical, electronic, and chemical phenomena that underpin the discovery of advanced materials, with the goal of enabling new technologies for energy production, storage, and use. This comprehensive program includes state-of-the-art capabilities for the synthesis and characterization of a wide range of materials, including nanophase materials, single crystals, polymers, and structural materials, among others. These synthesis and characterization capabilities are complemented and extended by broad capabilities in theory and modeling at multiple scales, taking advantage of ORNL's computational facilities. ORNL develops advanced instrumentation to provide unprecedented insight into the structure and function of materials at the atomic level, with special emphasis on advanced aberration-corrected electron microscopy and advanced scanning probes, electron and probe microscopies, and neutron scattering techniques. These advances in materials synthesis, characterization and theory span individual research groups and two DOE BES user facilities, the Center for Nanophase Materials Sciences (CNMS) and the Shared Research Equipment (SHaRE) User Facility. One area of emphasis in the ORNL materials program is understanding materials under extremes, including phenomena that limit the ultimate strength of structural materials. Recently, a statistical model was developed to explain the size-dependent stresses needed to initiate plasticity in nanoscale and microscale volumes during nanoindentation.[6] This marks a key step toward understanding and accurately predicting the strength of micrometer-scale structures. In addition, ORNL is home to the Center for Defect Physics, a BES Energy Frontier Research Center (EFRC), which takes advantage of the Laboratory's broad range of characterization and computational tools to understand the fundamental role of defects in materials under extreme conditions—radiation flux and other stresses—that will ultimately allow materials to obtain unprecedented strength and function.

Together, the capabilities of this materials science program facilitate the design of new materials through control of atoms and defects to provide unprecedented functionality and performance under extreme conditions. As a distinctive example, ORNL is known for polymer synthesis via living anionic polymerization, which is the best technique for controlling polymer molecular weight, limiting polydispersity, and synthesizing a wide range of block and graft copolymers, end-functionalized polymers, and complex macromolecular architectures. ORNL creates model polymers that are selectively deuterium labeled and utilizes a wide variety of neutron scattering tools, along with computational tools, to understand the structure and dynamics of these polymers. ORNL's basic materials sciences research focuses on use-inspired research, including materials that are relevant to electrochemical energy storage, superconductivity, thermoelectrics, hydrogen storage and use, photovoltaics, catalysis, and nuclear materials. This work is closely coupled with the Laboratory's applied energy research and the applied materials science and engineering program (see Sect. 3.12). BES is the principal sponsor of work enabled by this core capability [mission areas SC-6, 7, 8, 9, 10].

5. Chemical and Molecular Science

The chemical and molecular science core capability at ORNL is fundamental to DOE's science, energy, national security, and environmental missions. It comprises strengths in the design, precise synthesis, and characterization of the structure and reactivity of organic, inorganic, biological, polymeric, and hybrid materials (especially at the nanoscale), using theory, modeling, and simulation to gain a fundamental understanding of structure–property–function relationships. This research has a particular focus on understanding interfacial molecular processes, which are critical to applications in separations, catalysis, electrical energy storage, geochemistry, corrosion, carbon capture, and many other areas. As an example, a novel method was recently developed to synthesize atomically dispersed vanadyl sites in a cubic silicate building block matrix. Then high-field state-of-the-art ^{17}O nuclear magnetic resonance (NMR) techniques were coupled with ^{17}O labeling to reveal for the first time the coordination environment of isolated vanadyl catalytic sites in silicate supports.[7] Chemistry researchers make extensive use of neutrons from SNS and HFIR, the synthesis and characterization tools at CNMS, and the computational resources of OLCF.

ORNL has also invented and developed new synthesis techniques for bimodal mesoporous carbon composites with desirable electronic and ionic conductivities. These mesoporous carbons are now being studied as effective electrode materials in novel rechargeable lithium batteries and as sorbent materials to capture carbon emissions from combustion flue gas. Major efforts are focused on:

- separations and analytical methods, especially world-leading mass spectrometric methods and advanced chemical imaging modalities;
- characterization, control, and optimization of molecular transformations and interfacial processes in catalysis and geosciences;
- spectroscopy and chemical imaging of interfaces;

[6] J. R. Morris, H. Bei, G. M. Pharr, and E. P. George, *Phys. Rev. Lett.* 106, 165502 (2011).
[7] M.-Y. Lee, J. Jia, R. Mayes, E. W. Hagaman, and C. E. Barnes, *Catal. Today* 160, 153–154 (2011).

- precise synthesis of molecules, supramolecular assemblies, and nanostructured materials with tailored properties; and
- theory and modeling of the structure, dynamics, and energetics of complex functional materials.

A particular strength of the chemical sciences portfolio at ORNL is chemistry at interfaces. The BES-funded EFRC on Fluid Interface Reactions, Structures and Transport (FIRST Center) is focused on developing quantitative and predictive models of molecular-level structure, dynamics, and transport at the fluid–solid interfaces relevant in catalysis and electrochemical energy storage phenomena in batteries and capacitors. As a further example, ORNL's mass spectrometry team has demonstrated for the first time the ability to spatially resolve chemical-specific information by the combined use of a proximal thermal probe and a mass spectrometer.[8] This technique offers a new approach for the rapid, facile analysis of spatially distributed analytes on a surface. Principal funding comes from BES [mission areas SC-6, 7, 8, 10]. Demonstrating the potential of this work to accelerate innovation in DOE mission areas, ORNL chemistry researchers were recently honored with the Council for Chemical Research 2011 Research Collaboration Award for development and implementation of high-level salt waste processing technology. This technology is based on fundamental chemical science developed by ORNL researchers and transitioned, with funding from DOE's Environmental Management Science Program and Office of Environmental Management (EM), to produce a highly selective method for removing radioactive cesium from hazardous waste tanks.

6. Climate Change Science

ORNL addresses the implications of climate change at scales from local to global and leads fundamental studies of climate change impacts on the terrestrial carbon cycle and other biogeochemical cycles and their connections to other natural and human systems. The Laboratory is advancing climate change science through forward-thinking investments in computational infrastructure and methods, active partnerships in coupled climate modeling, and experimental programs focused on biogeochemical cycles and terrestrial ecosystems. These investments are coordinated through ORNL's Climate Change Science Institute, which focuses on integrating scientific projects in modeling, observations, and experimentation; producing transparent and accessible quantitative scientific knowledge to address climate change; and fostering and enhancing collaborations among scientists.

Many of the key questions in climate change science require the development of a new generation of comprehensive climate models known as Earth system models (ESMs), which predict the coupled chemical, biogeochemical, and physical evolution of the climate system. ORNL is leading a multi-laboratory partnership in the development, deployment, and use of ultrahigh-resolution Earth system modeling capabilities. Earth system modeling at ORNL is backed by the Laboratory's core capabilities in computational science, which have enabled the development of exceptional strength in computational climate science. ORNL has a significant role in a multi-laboratory consortium to improve model-based climate prediction for the SC Biological and Environmental Research (BER) program's Climate Science for a Sustainable Energy Future project, which will prepare numerical models for the next generation of high-end computing architectures to better quantify uncertainties in climate predictions.

ORNL is also at the forefront in determining how terrestrial ecosystems respond to changes in temperature, atmospheric carbon dioxide, and precipitation because of its investments in world-class experimental systems and carbon and water cycle observational systems, which feed data to and enable improvements in integrated ESMs. Climate change science at ORNL is supported by advanced networking capabilities and high-profile climate data repositories and services (e.g., the Earth System Grid, the Carbon Dioxide Information Analysis Center, and the Atmospheric Radiation Measurement Archive). ORNL is a leader in the climate change community in the application of advanced cyber technologies to the evaluation of climate change consequences, including decision support tools to deal with ever-increasing data complexity. ORNL's extensive work in energy technologies and their impacts and the strong fundamental science base on which it draws provide insights into mitigation strategies, while the Laboratory's national security engagement yields insights into the impacts of societal adaptation to climate change and the associated national security implications. BER [mission areas SC-12, 14, 15] is the primary sponsor for work enabled by this core capability, which also serves the needs of NNSA [NS-2], the National Aeronautics and Space Administration (NASA) [OF-2], DoD [OF-3], the U.S. Geological Survey (USGS) [OF-4], and NOAA [OF-10]. Notably, a $215M multiyear interagency agreement between DOE and NOAA for the

[8] O. Ovchinnikova, V. Kertesz, and G. J. Van Berkel, *Anal. Chem.* 83, 598–603 (2011).

National Climate-Computing Research Center (NCRC) will bring Gaea, a petascale system dedicated to climate change science, on line at ORNL by the end of 2011.

7. Biological Systems Science

World-renowned ORNL scientists in plant molecular biology and microbiology develop and apply advanced integrated "-omics" capabilities to solve problems in bioenergy, climate change, carbon sequestration, and the health effects of low-dose radiation, supported by BER. The BioEnergy Science Center (BESC) is pioneering systems biology science leading to economical and sustainable production of biomass material and its conversion to biofuel and other products. BESC integrates the efforts of researchers from DOE laboratories, industry, and academia to provide a pipeline from the fundamental "-omics" to feedstock development and pilot-scale demonstrations. ORNL's world-class strengths in proteomics, metabolomics, and protein interactions using mass spectrometry, and in transcriptomics using designed microarrays, are being augmented with the ability to perform genomic resequencing to determine changes in mutant organisms with improved properties. These data-rich experimental efforts interface with leadership bioinformatics expertise in microbial annotation and in construction and interpretation of complex systems biology data in knowledge bases. Application of neutron scattering techniques coupled with biophysics-based computational science modeling is opening new vistas on the enzymatic reactions that break down lignocellulose. ORNL also develops and applies automated tools to perform draft and final genomic annotations for DOE's Joint Genome Institute. In addition, BER supports the Center for Structural Molecular Biology (CSMB) and the small-angle neutron scattering instrument at HFIR. The CSMB takes advantage of specialized facilities for sample deuteration, SNS, and HPC. All of these resources are focused on current projects for BER and on DOE-related R&D for other customers. Research on plant-microbe interactions seeks to understand and predict carbon sequestration in the terrestrial biosphere and ecosystem response to climatic change. Such studies are aided by advanced analytical and imaging capabilities being developed through programs in bioenergy and radiochemistry. Principal funding for this area comes from BER [mission areas SC-11, 14, 15, 16], EERE [ES-3], the National Institutes of Health (NIH) [OF-5], and the Environmental Protection Agency (EPA) [OF-6].

8. Environmental Subsurface Science

Work at ORNL is advancing the fundamental understanding of contaminant transport and transformation in natural environments, enabling the development of solutions to subsurface contamination by uranium and nitrate and to surface contamination by mercury.

ORNL is conducting field-scale studies of coupled biogeochemical processes that are important for predicting and mitigating both uranium and nitrate transport and fate. Field facilities for examining transport, fate, and remediation of uranium and nitrate also accommodate researchers from around the world. HPC has significantly enhanced ORNL's capability to predict contaminant transport, fate, and behavior in subsurface environments.

ORNL is directing one of the world's largest ongoing efforts in mercury research. This program brings together leading experts in microbiology, microbial genetics and biochemistry, computational molecular chemistry, microbial ecology, hydrology, and biogeochemistry. This assembly of mercury researchers and the Science Focus Area (SFA) research agenda is distinctive because of the combined expertise and the critical mass of researchers. Particular emphases include the microbial and molecular details of macromolecules involved in mercury transformations, making use of state-of-the-art scientific tools available at ORNL, such as neutron scattering techniques.

Using combined information from 16S rRNA gene-based analyses, studies of the metabolic potential of microbial communities, and expressed proteins (obtained from metaproteome data), ORNL scientists are able to assess key identities and functions of microbial community operation in determining contaminant fate. Expertise in element cycling in the environment is also relevant to DOE goals for carbon sequestration, providing understanding of carbon behavior as influenced by hydrological and geochemical processes due to warming-induced regional hydrology changes in both vadose and saturated subsurface areas. The program actively uses a wide range of ORNL facilities, including SNS, OLCF, and CNMS. This fully integrated systems approach is leading to new multiprocess, multiscale predictive tools that inform and improve the technical basis for decision-making at contaminated sites throughout the DOE complex. The Oak Ridge Integrated Field Research Challenge and the Mercury SFA are world-class centers for studying the transformation, fate, and transport of contaminants. Funds for this work are provided by BER [mission areas SC-13, 14], EM [EM-1, 2, 3], NNSA [NS-1], DoD [OF-3], and NASA [OF-2].

9. Advanced Computer Science, Visualization, and Data

ORNL's computational capability includes experts in system software, component technologies, architecture-aware algorithms, runtime, fault-tolerant distributed computing, virtualization, computational steering, networking, and distributed data analysis. Tools and software are developed to make ORNL's HPC capability more effective and accessible for scientists and engineers working on problems of national importance. In addition, research is conducted in core technologies for future generations of high-end computing architectures, including experimental computing systems. Using measurement, modeling, and simulation, ORNL investigates these technologies to improve the performance, efficiency, reliability, and usability of extreme-scale architectures and applies the results to develop new algorithms and software systems to effectively exploit the specific benefits of each technology. ORNL is home to two national centers of excellence in HPC architecture and software: the Institute for Advanced Architectures and Algorithms, in partnership with Sandia National Laboratories, and the Extreme Scale Systems Center, both funded by DOE and DoD. All of these R&D activities contribute to accelerating the HPC technology roadmap with a goal of delivering exascale-capable systems later this decade. ORNL develops key capabilities in knowledge discovery and data analytics and applies advanced techniques for visual data understanding to scientific data in order to find visualization methods that are more effective and better integrated with other scientific discovery efforts within DOE. As an example, ORNL's VERDE system (Visualizing Energy Resources Dynamically on Earth) provides real-time geovisualization of electric grid and critical energy sectors. VERDE assists DOE and other federal agencies in coordination and response during major events such as wide-area power outages, national disasters, and other catastrophic events.

When SNS is operating with its full complement of instruments, experiments are expected to generate ~1 terabyte (TB) of data per day. Preparation for SNS operations included efforts devoted to ensuring that users would be able to run experiments, generate datasets, perform data reduction and analysis, visualize results, collaborate with remote users, and archive data for long-term storage in repositories with curation services. Data collected at these facilities are currently reduced from instrumental to physical units using power multiprocessor (typically 32 core) workstations on each of the beamlines. Users then perform sophisticated data analysis offline, after completing their experiments. ORNL plans to extend this core capability to apply the computational processing power needed to provide theoretical interpretation of the experimental data, based on modeling, simulation, and visualization, on the same time scale as the experimental measurements themselves. This marriage of computational and experimental facilities will create a powerful real-time feedback loop between theory and experiment, greatly enhancing the precious experimental beam time and accelerating the process of scientific discovery.

Funding comes from SC's Advanced Scientific Computing Research (ASCR) program [mission area SC-2], BES [mission area SC-9], DHS [mission areas HS-1, 2, 3, 5], and WFO customers such as DoD [OF 3, 7], and EPRI.

10. Computational Science

ORNL is the world's most capable complex for computational science as a result of its outstanding staff, infrastructure, and computers dedicated to a research portfolio that covers the full span of the Laboratory's interests. A distinctive feature of this core capability is the ability to build multidisciplinary teams to execute breakthrough science through scalable algorithms and codes on massively parallel hardware running >10^5 processes consuming petabytes of data. ORNL's Cray Jaguar supercomputer has peak performance of 2.33 petaflops (PF) and delivers sustained petascale performance on a number of scientific applications.

As the flagship system of DOE's Leadership Computing Facility, Jaguar offers prize-winning performance on science applications and world-leading bandwidth to disks and networks. ORNL computational scientists have worked closely with science teams to make effective use of this power, delivering breakthrough science in areas such as high-temperature superconducting materials, chemical catalysis, magnetothermal processing of materials, and the enzymatic reactions that break down lignocellulose. The success of this approach is indicated by the awarding of the 2008, 2009, and 2010 Gordon Bell Prizes for performance on a scientific applications to multi-institutional teams for calculations performed on Jaguar: in 2008 for petascale explorations of high-temperature superconductors, in 2009 for calculating the Curie temperature of magnetic nanoparticles, and in 2010 for numerical simulations of blood flow. A necessary component of ORNL's computational science capability is a healthy HPC ecosystem that provides (1) ubiquitous access to data and workstation-level computing, (2) broad access to midrange cluster and large "capacity computing" supercomputer systems, and (3) appropriate access to capability and leadership computing systems. This ecosystem is supported by multiple sponsors. In particular, NSF has fielded the 1.0 PF (peak) Cray XT5 Kraken at the National Institute for Computational Sciences (NICS), which is managed by a UT-ORNL partnership. Kraken is recognized as the world's most powerful academic supercomputer and the eighth most capable supercomputer in the world. In addition, NOAA and DoD are fielding similar capabilities within the ORNL computational science enterprise, leveraging the expertise and infrastructure supported by DOE to address national needs and attracting talented computational scientists, computer scientists, and applied mathematicians to ORNL's computational science complex.

Ultrascale computing capability for predictive modeling and simulation (M&S) is required by almost all scientific disciplines of interest to DOE, including materials science, chemistry, plasma physics, astrophysics, nuclear physics, biology, climate change impacts, nuclear fission, knowledge discovery, and applied mathematics. ORNL will harness the potential of computational science and engineering for the discovery and development of new materials and processes essential for maintaining leadership in energy technologies. Energy technology program offices have demonstrated interest in developing predictive M&S capabilities for energy systems such as electricity transmission, electrochemical energy storage, solar photovoltaic conversion, and light water reactors (LWRs). ORNL expects that predictive energy systems simulation for nuclear reactors and for energy conversion, storage, and use will increasingly be applied to improving the manufacturability, safety, and performance of these systems.

The confluence of growing mission requirements from SC and NE, NSF, NOAA, and other federal agencies has created a thriving environment for computational science at ORNL. Funding for this work comes from ASCR [mission areas SC-1, 2, 3, 4, 5], other SC programs [mission areas SC-6, 7, 8, 12, 15, 16, 18, 19], and NE and EERE [mission areas ES-2, ES-7]. ORNL also invests discretionary resources in development and application of this core capability.

11. Applied Nuclear Science and Technology

At the beginning of FY 2011, ORNL implemented a new organizational structure combining the Laboratory's extensive nuclear infrastructure (HFIR, REDC, and a variety of radiological laboratories, examination facilities, hot cell facilities, and radioanalytical facilities) with the research programs and personnel who make use of these assets. This action was taken to enable us to align ORNL's existing nuclear S&T programs with recently expanded initiatives in isotope R&D and production; the potential construction of a small modular reactor by the Tennessee Valley Authority (TVA), ORNL's electricity provider; and the Laboratory's role in DOE's new Energy Innovation Hub, the Consortium for Advanced Simulation of Light Water Reactors (CASL). Work in this new organization addresses all aspects of the nuclear fuel cycle, including fuel enrichment processes, the performance of nuclear fuels and materials in extreme environments, chemical processes for fuel reprocessing and recycle, efficient and effective processing of nuclear waste, and advanced waste forms for long-term disposal.

ORNL staff have been leaders in nuclear computational analysis for decades, and the world-class computing facilities at ORNL provide a platform for M&S to advance understanding of the fuel cycle and improve the efficiency and utilization of nuclear systems and associated experimental facilities. These resources are critical assets for CASL, which is addressing the challenge of using M&S to accelerate progress in nuclear reactor design and engineering. Reviving interest in nuclear power in the United States and throughout the world highlights the value of these capabilities to DOE, the Nuclear Regulatory Commission (NRC), and other sponsors.

ORNL uses its unique capabilities to produce and process radioactive isotopes that are distributed for use in medical, industrial, and research applications in support of SC's NP program. For example, ORNL applies capabilities at HFIR and REDC to produce ^{252}Cf, used worldwide for oil exploration, radiographic imaging, and mineral identification, and the alpha-emitting isotope ^{225}Ac, now in clinical trials for cancer treatment by alpha immunotherapy. As home to the Isotope Business Office within the NP-supported National Isotope Development Center (NIDC), ORNL helps to coordinate production and shipment of stable and radioactive isotopes for NP.

ORNL's extensive knowledge of the nuclear fuel cycle, coupled with a secure research capability and expertise in radiation detection and sensor development, enables a world-leading effort in nuclear nonproliferation. Funding in this area comes from several sources, including NE, SC, NNSA, DHS, NASA, and NRC [mission areas ES-2, NS 1, NS-2, OF 1, and OF-9].

12. Applied Materials Science and Engineering

ORNL's applied materials science and engineering programs directly support DOE's missions in clean energy, national security, and industrial competitiveness. These programs target (1) innovations and improvements in materials synthesis, processing, and design; (2) determination and manipulation of critical structure–property relationships; and (3) materials performance and lifetime prediction in application-relevant, often very harsh environments. Current R&D areas span a broad range of applications, including lightweight materials (e.g., carbon fibers and carbon fiber composites, magnesium, and titanium); advanced steels and coatings; energy-efficient and advanced manufacturing; nuclear fuels; high-temperature superconductors; batteries, solar photovoltaics, and long-lived alloys, ceramics, and carbons for service in extreme environments (e.g., high temperature/pressure/stress) and radiation environments. Research in these areas supports major DOE programs for EERE, OE, and NE, as well as DOE's Office of Fossil Energy. Significant funding also comes from the Defense Advanced Research Projects Agency (DARPA) and other WFO customers.

A key strength of ORNL's materials science program is the close coupling of the applied materials science and engineering programs supported by these offices with the fundamental materials program supported by SC's BES program (see Sect. 3.4). Especially notable is the close connection with ORNL's theme of materials under extremes, which is reflected in the Laboratory's applied materials science and engineering programs for specialized treatment of materials for improved performance (thermal, magnetic, flux, etc.) and the development of improved structural and lightweight materials. Other key areas of this program include novel processing techniques for innovative manufacturing, materials joining, surface engineering, mechanical and environmental testing, and physical property determinations. A new Carbon Fiber Technology Facility (CFTF) is being established for the pilot-scale demonstration of new technologies for producing low-cost carbon fiber. For example, the CFTF will enable the evaluation of new fiber precursors, including those from lignin and new synthetic polymers, and fiber treatments.

Capabilities supporting this program also include a wide range of structural and chemical characterization tools and computational M&S capabilities over length scales ranging from atomic to macroscopic. These research programs also access (via peer-reviewed proposals) SC-supported user facilities: at ORNL, including resources in electron microscopy and atom probe tomography (SHaRE), neutron scattering (SNS and HFIR), nanoscience (CNMS), and HPC. In particular, ORNL is emphasizing the integration of experimental capabilities with computational resources for the development of new materials and processes with transformational impacts on energy technologies.

EERE also supports the High Temperature Materials Laboratory (HTML), which provides facilities and staff expertise in microscopy, diffraction, mechanical and physical properties, and other areas in support of external scientists, engineers, and students as part of the EERE Vehicle Technologies Program. Funding from DOE's technology programs, as well as much of the WFO, supports industrial interactions and technology transfer, resulting in considerable impact in materials production and utilization, power production and transmission, energy-efficient vehicles, and spacecraft power systems. Funding comes from EERE and NE [mission areas ES-1, 2, 4, 5, 8], NNSA [NS-1], DHS [HS-9], and DoD and other WFO customers [OF-3].

13. Chemical Engineering

ORNL's core capability in chemical engineering moves knowledge gained from fundamental chemical research results toward applications important to DOE's missions. For example, this capability supports the development of fuel reprocessing techniques for NE and enables radioisotope production, isotope separation, and development of isotope applications for NP. It also contributes to advances in energy efficiency, renewable energy, fossil energy, waste management and environmental remediation, and national security. For example, physical and chemical techniques for carbon capture, with applications for reducing greenhouse gas (GHG) emissions, are being examined using novel adsorbants, including nanostructured materials (see Sect. 3.5). Chemical engineering efforts at ORNL make use of a variety of distinctive resources: radiological laboratories and nuclear facilities, including the REDC; biochemical laboratories for investigating environmental and biofuels technologies; chemistry and materials characterization resources (e.g., HTML, SHaRE, SNS, and CNMS); and specialized combustion and catalytic emission control research facilities at the National Transportation Research Center (NTRC). Importantly, technology development through chemical engineering often builds directly on fundamental research supported by the Office of Science in materials design, synthesis, and processing; chemical separations and catalysis; and neutron scattering, computational science (leveraging the HPC resources of OLCF), and nanoscience (leveraging CNMS). In many cases, ORNL researchers involved in the original discovery science contribute ideas and advice for the further development of processes to accelerate practical application and technology transfer. For example, carbon-based materials, designed with BES support, are being applied to the capture of carbon dioxide from complex gas streams in a project sponsored by the Advanced Research Projects Agency–Energy (ARPA-E). Funding in this area originates from several sources, including NP, NE, EM, and EERE [mission areas ES-1, ES-3].

14. Systems Engineering and Integration

ORNL's core capability in systems engineering and integration is critical to the translation of breakthrough science into robust technologies, systems, and methods that address high-risk, high-complexity, multidisciplinary issues of national importance. The divisions with much of this expertise and some of the applied core capabilities have been combined with ORNL's biological and environmental sciences programs in a new Energy and Environmental Sciences Directorate. ORNL leverages expertise in M&S of engineered systems, spanning physical principles of operation, design and integration of specialized electronics and sensors, and integration into robust and reliable instruments and instrument systems. ORNL has the ability to perform predictive modeling of physical, chemical, and biological systems on massively parallel HPC platforms and to produce high-performance embedded computing systems at the instrument level to perform dedicated functions of measurement and controls. This core capability is playing an increasingly important role in the delivery of solutions to the energy challenge by enabling improvement in the energy efficiency of transportation systems, manufacturing, communications, and buildings.

For example, ORNL is recognized internationally for domain knowledge and expertise in high-power electronic switches and converters, which are critically important to both electric vehicle (EV) and electric grid applications. ORNL has designed, fabricated, and demonstrated a plug-in hybrid electric vehicle (PHEV) traction drive power electronics system that provides significant mobile power generation and vehicle-to-grid support capabilities. In collaboration with Nissan and other vendors, ORNL is developing solar-powered charging infrastructure for EVs, integrating vehicle and electric grid technologies. These efforts are being managed to deliver comprehensive solutions for sustainable electricity and sustainable mobility. ORNL is currently applying programmatic and discretionary R&D investments to build similar expertise in batteries.

This core capability also underpins ORNL efforts to develop and assess advanced nuclear reactor system concepts; to evaluate innovative nuclear fuel cycle system performance attributes; to understand and evaluate strategic energy systems issues, such as national siting strategies for electrical energy generation facilities and nuclear fuel cycle repositories; and to understand national electricity transmission and distribution infrastructure performance. The work draws upon the multidisciplinary subject matter expertise of ORNL, together with a variety of modeling, simulation, and advanced visualization capabilities. ORNL has also used systems engineering principles to conceptualize and initiate design work for space fission power systems.

ORNL has a long history of contributions to the development and integration of energy-efficient technologies in support of DOE's goals for net-zero-energy residential and commercial buildings, more efficient vehicles and engines, materials processes for efficient industry, and electricity delivery. ORNL operates and maintains its own electric grid, which serves as a testbed for innovative electricity delivery technologies. Its Power Delivery Research Center comprises facilities for testing and evaluating transmission technologies, including an advanced conductor test facility, a power electronics test facility, a high-temperature superconducting cable test facility, and a distributed energy communication and controls laboratory.

For EM, ORNL has integrated knowledge of chemistry, materials, and nuclear engineering to conceptualize and demonstrate novel waste processing methods and waste forms. ORNL also integrates advanced instrumentation concepts that include sensor, sampling, and robotic systems for remote characterization of facilities, tanks, and smokestacks in support of the EM deactivation and decommissioning processes throughout the DOE complex. Similarly, ORNL has led nuclear security projects that have conceptualized, developed, and deployed measurement systems for portal monitoring and supported national security missions by developing micro grid and reconfigurable grid technologies and critical infrastructure for control systems security.

ORNL's leadership of the U.S. contributions to ITER for SC also draws on this core capability. The international ITER project provides a transformational opportunity to advance burning plasma science and demonstrate the scientific and technical feasibility of fusion power. This ability to solve problems holistically also underpins the development and deployment of large-scale systems such as SNS, the cold neutron source at HFIR, and the ultrascale computing systems and infrastructure of the OLCF. Funding comes from a number of sources, including EERE, OE, and NE [mission areas ES-2, 4, 5, 6, 7], DHS [HS-1, 2, 3, 4], NRC [OF-1], DoD [OF-3, 7], and the Electric Power Research Institute (EPRI).

15. Large-Scale User Facilities/Advanced Instrumentation

ORNL has a distinguished record in the design, procurement, construction, and operation of major facilities for DOE and in the development of advanced instrumentation for acquisition, management, analysis, and visualization of experimental data. A distinguishing feature of these facilities is innovative instrumentation and world-class research programs that serve to motivate and attract the world's very best user populations.

Table 1. DOE user facilities at ORNL
Building Technologies Research and Integration Center
Center for Nanophase Materials Sciences
Center for Structural Molecular Biology
High Flux Isotope Reactor
High Temperature Materials Laboratory
Holifield Radioactive Ion Beam User Facility
National Transportation Research Center
Oak Ridge Leadership Computing Facility
Shared Research Equipment User Facility
Spallation Neutron Source

The DOE user facilities listed in Table 1 provide unmatched capabilities to ORNL staff and to a growing user community from universities, industry, other national laboratories, and other research institutions throughout the world. Outreach efforts ensure that students and postdoctoral associates are well represented in the user population and receive full access for the conduct of research. These facilities offer a diverse set of tools for experiments across DOE's missions. Instrument development enables effective use of these and other research facilities at ORNL and at other DOE laboratories.

SNS and HFIR together provide the world's foremost instrumentation for studying the structure and dynamics of materials using neutron beams. SNS is now, and will for at least a decade remain, the world's most powerful pulsed spallation neutron source. For neutron scattering experiments that require a steady-state source, HFIR offers thermal and cold neutron beams that are unsurpassed worldwide. Both facilities have achieved stable and reliable operations: SNS is operating at up to 1.1 MW and delivering >4000 hours of neutron production with >90% reliability, and HFIR also operates for 4000 hours annually with reliability close to 100%. To enable effective use of these powerful facilities, ORNL develops unique experimental systems involving detectors, sample environments, data acquisition systems, and optics systems. All new instruments at SNS and HFIR are developed with input from potential users in order to ensure that the scientific needs of the various communities are met. BES funds the design and construction of most instruments; NSF funding has supported the design of one instrument at SNS and the construction of another at HFIR. SNS has also attracted funding from other nations to construct instruments: the Canadian government has funded the construction of an engineering diffractometer, and the German government has funded the construction of a spin echo spectrometer. As is the case for all instruments at SNS and HFIR, 75% of available beam time on these instruments is available through the user program. The neutron instrumentation is complemented by world-class synthesis capabilities—including deuteration capabilities—and materials characterization developed in ORNL's research programs, some of which is available at CNMS and the SHaRE User Facility. Such strong synergy between ORNL's user facilities is a hallmark of ORNL research. For example, CNMS and OLCF have established a strong set of common users as a direct result of an integrated approach to the planning, design, and operation of these facilities.

The HPC resources of the OLCF, including the Cray XT5 Jaguar, are made available through DOE's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program, which OLCF manages in partnership with the Argonne Leadership Computing Facility; through discretionary allocations managed by SC; and through a discretionary allocation managed by the OLCF director. In partnership with UT, ORNL also manages NICS as a user facility for NSF; most NICS resources are allocated through the NSF TeraGrid allocation process.

ORNL staff with experience in measurement science, sensing, signals, communications, robotics, and integrated systems contribute to the development of instruments for detection of rare isotopes, equipment for advanced materials characterization, electron and scanning probe microscopy, mass spectrometry, chemical imaging, and advanced optics for x-ray and neutron imaging and scattering. ORNL also has unique resources for large-scale ecosystem research and has developed advanced tools for monitoring and analysis of environmental contaminants. This core capability is fundamental to ORNL's ability to deliver on its mission assignments for DOE, DHS, and other customers. Work in this area is supported primarily by SC [mission areas SC-9, 12, 13, 16, 20, 30, 34, 35], with contributions from EERE [ES-5, 6, 7], NNSA [NS-1], and DoD [OF-8].

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

ORNL is situated in East Tennessee's Ridge and Valley geologic province, occupying 4,470 acres of DOE's 34,000 acre Oak Ridge Reservation (ORR). ORNL facilities accommodate ~6,200 people on a daily basis, including 4,850 UT-Battelle employees, facility users, subcontractors, and others. Personnel work in 240 operating buildings (4.4M sf) distributed across three distinct campuses and in 24 off-site operating facilities (1.1M sf). About 70 buildings (40 SC, 30 EM) are in shutdown status awaiting demolition. Facility and infrastructure investments approaching $2B over the past decade have modernized significant portions of ORNL and enabled unprecedented accomplishment of world-class science including establishment of the world's foremost center for neutron science; transformative application of advanced computing; and breakthrough nanoscale materials research under extreme conditions.

ORNL operates and maintains a robust utility infrastructure. On-site services include 24/7 laboratory protection with dedicated fire and emergency response personnel, facilities, and equipment; facility maintenance and fabrication; medical facilities; and amenities including a guest house, cafeterias, fitness facilities, and conference centers. The Oak Ridge S&T Park, created through brownfield redevelopment, facilitates DOE's technology transfer mission by creating new opportunities for collaboration between ORNL staff and university and industry researchers housed in S&T Park facilities developed and managed by the private sector. A 20,000 acre portion of the ORR is managed as the Oak Ridge National Environmental Research Park, providing ORNL with an outdoor laboratory for evaluating environmental consequences of energy use and developing strategies to mitigate associated negative effects.

Notable recent or planned real estate lease transactions in FY 2011 and FY 2012 include lease of a building to accommodate research production of next-generation carbon fiber beginning in FY 2012, located on reindustrialized property formerly belonging to the Community Reuse Organization of East Tennessee (CROET).

Table 2. ORNL SC Infrastructure Summary

Replacement plant value ($M)		2,040
Total deferred maintenance ($M)		105.9
Asset Condition Index	Mission critical	0.95
	Mission dependent	0.95
	Not mission dependent	100
Asset Utilization Index	Office	0.93
	Warehouse	0.96
	Laboratory	0.93
	Housing	100
Prior year maintenance ($M)		69.9

Facilities and Infrastructure to Support Laboratory Missions

Although ORNL facilities and infrastructure are currently substantively capable, a set of critical investments is essential to ensure that the Laboratory remains ready to serve the nation in the years ahead. ORNL is pursuing one priority facility investment:

- The SNS next-generation neutron scattering instruments, PUP, and STS project will expand the capability and availability of this world-leading neutron science facility.

Support is also needed for three priority investments that address basic infrastructure needs:

- Support from NE and/or SC is needed to keep ORNL's multiprogram nuclear facilities mission ready. Primarily through discretionary investment, ORNL has significantly reduced its nuclear footprint to support ongoing and future missions. However, unlike other laboratories with significant nuclear infrastructure, ORNL receives no direct programmatic support for operation of these very expensive facilities, though they are used by NE, SC, DOE's Office of Naval Reactors (NR), and others on an incremental cost basis.

- EM must elevate the priority of existing cleanup projects that are not currently receiving adequate support. These projects have significant implications for the Laboratory and include disposition of the ^{233}U inventory, disposition of other legacy materials, decommissioning of excess facilities, and remediation of soil and groundwater.

- SC support is needed for ORNL's next SLI line item project, which has been slipped to FY 2014. This project, the Site Modernization Project, will address needs for sewage treatment, wet chemistry laboratories, and emergency response.

Strategic Site Investments

- **Neutron and Accelerator Science and Technology**

  Three BES-funded projects are in progress and a fourth is proposed to maintain ORNL capability in neutron and accelerator science and technology. When complete, the SNS Instrument Next Generation (SING) and SING-II projects will add 9 next-generation neutron scattering instruments to the SNS instrument suite, bringing the total number of instrumented beam lines to 19 out of the available 24 slots, and the SNS PUP will increase the beam power of this world-leading neutron beam facility. The proposed STS would double the number of SNS beam lines, enabling a much broader scientific program. The Joint Institute for Neutron Sciences (JINS), housed in a facility funded by the State of Tennessee that was brought on line in FY 2011, provides a hub for outreach and education programs aimed at increasing the breadth and impact of research carried out at the ORNL neutron facilities. It is becoming the home base for an extensive visitor program and enabling development of new collaborative research initiatives.

  Multiyear BES maintenance and General Plant Project (GPP) programs will sustain SNS research facilities. Improvements to infrastructure are needed to keep pace with neutron scattering science and user programs as well as Chestnut Ridge and Melton Valley site population growth. The ORNL Guest House on the Chestnut Ridge campus is in operation, and a maintenance facility has been constructed in Melton Valley. Unmet needs on Chestnut Ridge include space for storage, testing, and maintenance of operational equipment; increased data storage and transmission capacity (to 500 TB/year storage and 10 Gbit/s processing); laboratories for activated sample preparation; and parking and site circulation improvements. The Mission Readiness (MR) rating for these core capabilities is Partially Capable now and Marginally Capable in 5 and 10 years, reflecting the additional institutional and programmatic investments (the SNS STS and power upgrade, plus additional laboratory and maintenance support space) required to sustain and advance them.

- **Computational Science**

  Planned HPC opportunities include increasingly powerful petascale systems (20–250 PF over the next 3 to 4 years), leading to an exascale system within a decade. ORNL is forecasting the need to concurrently operate two leadership-class systems while potentially bringing a third system on line without interruption to these systems. In addition, ORNL's WFO collaborations will require similar increases in HPC capabilities. These anticipated systems support the need for additional power, space and cooling capacity. Space needs will be accommodated by allocating space on the second floor of the Computational Sciences Building to unclassified computing and space on the first and second floors of the north wing of the Multiprogram Research Facility to classified computing. Additional power and cooling will be programmed commensurate to the addition of this space and targeted HPC system acquisitions. The MR rating for the Computational Science core capability is Capable now and Capable in 5 and 10 years with the noted improvements in infrastructure.

- **Advanced Computer Science, Visualization, and Data**

  ORNL currently holds the unique infrastructure combination necessary to support and apply its core capability in advanced computer science, visualization, and data, as demonstrated by the selection of a team led by and headquartered at ORNL to operate CASL. ORNL is providing appropriate facilities for the required co-location of nationally and internationally recognized experts in programming and nuclear reactor code maintenance and development and for the scientific visualization that is a key outcome of CASL. Outyear GPP-level investments will be required to sustain performance; the MR rating for this core capability is Capable now and Partially Capable in 5 and 10 years.

- **Condensed Matter Physics and Materials Science; Chemical and Molecular Science**

  The new Chemical and Materials Sciences Building provides 160,000 sf of modern laboratory space that meets today's fire safety, design, and utility requirements, enabling safe and efficient conduct of research and facilitating recruitment and retention of top scientists. Older general chemistry facilities remaining in use, some constructed 50 to 60 years ago, require refurbishment to accommodate modern research. Necessary modifications include provision of flexible (i.e., reconfigurable) work spaces, accommodation of chemical inventory and equipment utility demand, and replacement of essential building systems. Institutional funds will primarily be used to modify and facilitate reuse of existing buildings.

  Central Campus buildings housing materials research are being vacated in preparation for demolition and site remediation. Associated research activities are being relocated into new or renovated East Campus facilities. The Advanced Materials Characterization Laboratory expansion became operational in 2011 and houses some of this country's most advanced microscopes. The MR rating for these core capabilities is Capable now, given the investment in the Chemical and Materials Sciences Building, and Partially Capable in 5 and 10 years due to need for subsequent projects to convert existing laboratory space.

- **Climate Change Science, Biological Systems Science, and Environmental Subsurface Science**

  Recent modernization of ORNL's West Campus has enabled consolidation and co-location of core capabilities in biological and environmental sciences. A new greenhouse complex and storage facility began operation in 2010. The State of Tennessee–funded Joint Institute for Biological Sciences (JIBS) facility provides modern research laboratories, and two DOE-owned research facilities, Building 1504 and portions of Building 1505, have undergone partial reconfiguration to combine several sets of small 1970s-style laboratories into large, open laboratories to enhance research collaboration. The strategy for renovating the remainder of Building 1505, including second and third floor laboratories, is being evaluated. Currently the path forward to meet program needs is implementation of an FY 2014 Site Modernization SLI line item project that includes renovation of Building 1005 to enable relocation of research from Building 1505. Maintenance and repair investments in West Campus office and laboratory buildings have been recognized with Leadership in Energy and Environmental Design (LEED) Existing Building certification. Pedestrian walkways and landscaping are planned to enhance safety and quality of work life. The averaged MR ratings for biological systems science and environmental subsurface science are Capable now and Marginally Capable in 5 years, given the subsequent investment needed to address deteriorating laboratory conditions in Building 1505, complete site circulation improvements, and address reuse of Building 1005. If these investments are made, MR ratings return to Capable within 10 years.

- **Nuclear Physics**

  Programmatically funded investments in the FNPB at SNS and in IRIS2 at HRIBF have upgraded ORNL capabilities for fundamental nuclear physics research. Replacement of the Oak Ridge Isochronous Cyclotron (ORIC) injector with a 70 MeV cyclotron would enable further expansion of these capabilities. A complementary new accelerator and related equipment would enable R&D on production of research isotopes; complementary production of scarce, unique isotopes; enhanced capability to maintain U.S. leadership in RIB science; and university partnerships to support development of next-generation nuclear professionals and provide unique R&D opportunities for academia. With the decision to end operation of HRIBF as a user facility in FY 2012, the future of these capabilities will be determined in part by a review now being conducted by NP. Investments for continued production and processing of stable isotopes and radioisotopes are discussed in conjunction with the applied nuclear S&T core capability. Process control and electrical load monitoring and distribution systems need updating across the nuclear physics facilities. The MR rating for this core capability is Capable now, Marginally Capable in 5 years, and Partially Capable in 10 years.

- **Applied Materials Science and Engineering; Systems Engineering and Integration**

Large high-bay and adjoining low-bay laboratories supplemented with more traditional modular modern laboratories are required to accommodate equipment of the size and complexity needed to spur technology advances for energy generation, storage, and use; improve energy efficiency across transportation, building technologies, industrial technologies, and commercial sectors; enable identification, design, synthesis, and evaluation of key materials to further advances in such areas as energy storage, photovoltaics, and lightweight materials; and advance manufacturing processes and multiple systems integration.

Two ARRA-funded EERE programmatic line items awarded to ORNL in 2009 will facilitate cutting-edge applied research on lightweight materials (Carbon Fiber Technology Facility) and net-zero-energy buildings technologies (Maximum Energy Efficiency Research Laboratory, or MAXLAB). The Carbon Fiber Technology Facility will be housed in a leased building located in a City of Oak Ridge–sponsored industrial park, spurring DOE's Asset Revitalization Initiative and, potentially, regional economic development focused on lightweight material development. Additionally, the National Transportation Research Center and its annex provide much-needed high-bay laboratory space for applied vehicle technology programs.

The average MR rating for these core capabilities is Capable now and Partially Capable at 5 and 10 years, largely driven by the lack of modern high-bay space.

- **Applied Nuclear Science and Technology; Chemical Engineering**

During the past decade, ORNL has undertaken an aggressive strategy, largely funded through discretionary resources, to consolidate its nuclear infrastructure from ten underutilized nonreactor nuclear facilities into four operational facilities. Continued consolidation is planned to reach an end state of three Category 2 nuclear facilities (Buildings 7920, 7930, and 3525). These facilities will be sufficient to support current and known future missions. Consolidation has saved more than $75M over the past 7 years and significantly increased the mission readiness of these facilities. However, maintaining this core capability to meet DOE's nuclear safety expectations is a significant and expensive challenge. Direct support from NE and/or SC is critical to safe and reliable operation of the ORNL hot cell facilities. Without direct support, it is becoming increasingly difficult for ORNL to continue institutional investments to ensure that mission-critical systems and components can continue to operate safely.

Overall efficiency for ORNL's nuclear facility complex is affected by the poor functionality of deteriorating support facilities, especially those in Melton Valley. The FY 2019 Melton Valley Research Operations Support Facility SLI line item project will consolidate office and laboratory space. The FY 2020 Waste Handling Systems SLI line item will provide replacement capability for long-term management of SC radioactive wastes. Programmatic support for stable isotope production and separation at Building 6010 Shield Test Station is proposed. Through the use of programmatic support, ORNL is pursuing the repurposing of a small portion of Building 1005 to accommodate nuclear forensics. The MR rating for this core capability is Partially Capable now and Marginally Capable at 5 and 10 years, largely driven by investments needed to sustain aged nuclear and radiological facilities.

- **Plasma and Fusion Energy Sciences**

Program investments are needed to provide capability to develop integrated simulations and experimental databases for the design of future fusion power systems and to test and demonstrate materials and components under fusion power reactor conditions. Future installation of exascale computing capability can partially address simulation requirements. ORNL has invested discretionary resources to prepare for a PMTS as a precursor to the FNSF, a future programmatic line item proposed to fully address testing needs. Support will also be needed to meet the increasing power needs of fusion R&D. The MR rating for this core capability is Capable now (15 MVA for R&D at Building 7625), Partially Capable at 5 years (15 MVA additional needed for PMTS at Building 7625), and Marginally Capable at 10 years and beyond (300 MVA continuous needed for FNSF at a separate site).

- **Large-Scale User Facilities/Advanced Instrumentation**

ORNL operates the large-scale DOE user facilities listed in Table 3.1 for the benefit of a broad user community and is seeking approval for programmatic upgrades to many of these user facilities. The overall MR rating for this core capability is Partially Capable now and in 5 years and Marginally Capable in 10 years, reflecting the need for periodic investment to keep these facilities at the forefront of scientific research.

- **Laboratory Operations**

ORNL remains reliant on SC SLI line item projects to modernize essential DOE-owned infrastructure that is beyond design life and increasingly failing. ORNL's fire station, constructed in 1943, is well beyond its 30-year design life, is no longer centrally located (increasing emergency response times), and is situated amidst EM cleanup activities on ORNL's Central Campus. The average age of onsite maintenance, fabrication, shipping, and receiving facilities is 47 years with an associated asset condition index of 0.77 (poor) and a deferred maintenance backlog of more than $7M. Several SLI projects are proposed to address these issues. The FY 2014 Site Modernization project will provide replacement, relocation, and consolidation of fire, emergency medical, initial hazardous material (hazmat) event response, and site security operations. The FY 2020 Site Maintenance/Fabrication Facility project will replace and modernize essential site services and manifest associated efficiencies. The Melton Valley Research Operations Support Facility (FY 2019) and Waste Handling System (FY 2020) projects are fundamental investments essential to ongoing safe and reliable operation of ORNL nuclear facilities. If EM ceases to operate existing ORNL nuclear waste facilities prior to the availability of replacement capability in FY 2020, the Laboratory will experience significant risk to ongoing research operations.

ORNL doubled its annual institutional infrastructure capital budget, from $14M in FY 2008 to $30M in FY 2010, in response to infrastructure demands. Institutional GPP (IGPP) investment will decrease substantially in FY 2012 and FY 2013 to help offset rising overhead costs. Near-term planned IGPP/Institutional General Purpose Equipment (IGPE) projects will be directed at strategic site investments. Priorities include site-wide utility system improvements, including electric power distribution, potable water storage and steam plant support facility upgrades, and nuclear footprint consolidation and reliability.

While helping DOE maintain U.S. global leadership in science and engineering, ORNL has a goal of achieving benchmark levels of sustainability on campus by 2020. ORNL has implemented an aggressive sustainability program that is reaping significant benefits in terms of GHG emissions and overall Laboratory efficiency.

- **Maintenance**

At a site level, maintenance investments in facility and infrastructure will be held at industry recommended levels (2–4%). In all cases, assets will be maintained to assure worker safety and protection of the environment. Proactive maintenance (e.g., preventive maintenance) will be done in buildings that have a high confidence of long-term programmatic continuity. For buildings with the potential of shifting programmatic needs, only reactive maintenance (e.g., repair) will be completed until building modifications reconfigure the building for a longer term need. Maintenance will be minimized where possible in buildings approaching or at the end of their programmatic and functional life. The FY 2020 Maintenance and Fabrication SLI line item will consolidate and enable more cost-effective accomplishment of these essential services.

- **Excess Without a Determined Funding Path**

Full ORNL revitalization will not be achieved until legacy facilities and materials, including their liabilities and risks, are removed and sites are readied to accommodate future missions. Legacy facilities include ORNL buildings located at the Y-12 National Security Complex. ORNL has been working to increase EM's support for deactivation and decommissioning of excess and unwanted facilities; disposition of legacy materials/waste; and remediation of residual soil, groundwater, and surface water contamination. Central Campus facilities have been vacated in advance of EM cleanup activities, often requiring institutional upgrade of facilities designated to receive displaced research activities. However, cleanup projects at ORNL have not been a funding priority for EM, and thus progress has been slow. The cleanup activities were jumpstarted in FY 2010 by ARRA investments; however, ORNL is concerned that no baseline funding has been established and the current level of cleanup made possible by the ARRA funding will not be sustained beyond mid-FY 2012. Therefore, it is important for SC to express to EM the importance of EM's cleanup responsibilities at ORNL.

Trends and Metrics

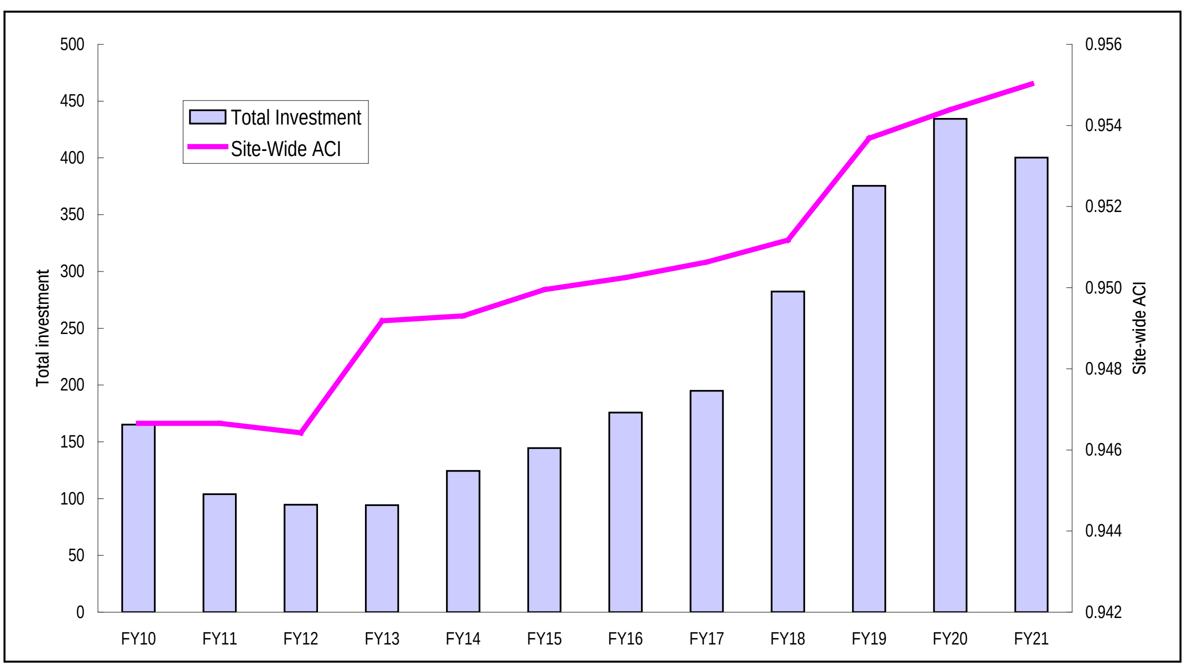
Table 3 summarizes investments in ORNL facilities and infrastructure. The investment strategy leverages SLI, program investments, Laboratory overhead resources including IGPP funding, and maintenance funds. Additionally, private-sector funds totaling ~$140M via alternative financing and Energy Savings Performance Contracts (ESPCs) benefit ORNL's infrastructure. Figure 1 illustrates site-wide Asset Condition Index (ACI) improvement based on planned and proposed investments through 2021.

Funding provided through the American Recovery and Reinvestment Act (ARRA) has been applied to accelerate the availability of the Chemical and Materials Sciences Building; redevelop a portion of CROET property with cutting-edge carbon fiber manufacturing capability; expedite demolition of excess facilities; and enable addition of new, on-site research and support facilities. Electrical and chilled water upgrades were completed to ensure that utility system reliability and capacity could keep pace with the expansion of computational and computing capability.

Table 3. Facilities and infrastructure investments ($M) and impact to Asset Condition Index

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	76.9	72.4	74.1	75.8	77.5	79.3	81.2	83.0	84.9	86.9	88.9	90.9
DMR	9.0	2.0	2.0	0	0	0	0	0	0	0	0	0
Excess facility disposition (overhead)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
IGPP	20.4	25.9	8.0	15.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
GPP	8.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Line items	49.4	0.0	0.0	0.0	13.3	31.7	61.1	78.3	163.9	255.1	312.0	275.9
Total investment	**165.2**	**103.8**	**87.6**	**94.3**	**124.3**	**144.3**	**175.8**	**194.8**	**282.3**	**375.5**	**434.4**	**400.3**
Estimated RPV	1,986.4	1,986.4	1,979.2	2,040.6	2,063.7	2,106.3	2,163.0	2,214.7	2,275.1	2,424.0	2,485.9	2,539.9
Estimated DM	106.0	106.0	106.0	103.7	104.6	105.4	107.6	109.3	111.1	112.3	113.4	114.2
Site-wide ACI	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.96

Figure 1. ORNL Asset Condition Index.



Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
Nuclear Physics	Now				X	Holifield Radioactive Ion Beam Facility (HRIBF) and support buildings in the 6000 Area, Fundamental Neutron Physics Beam (FNPB) line at the SNS, High Performance Computing Facilities in Building 5600	Achieve breakthroughs and push the frontiers of discovery in nuclear physics, attack compelling questions about the nature of the nuclear many-body problem, the origin and stability of the heavy elements, and the fundamental structure of the neutron		Current Lab investment supporting stable isotope production includes legacy material clean out and renovation of HVAC systems in vicinity of Building 6010 Shield Test Station.	Fundamental Neutron Physics Beam line became operational in 2009 (programmatic line item). Injector for Radioactive Ion Species (IRIS)-2 at HRIBF became operational in 2010 (programmatic line item)
	In 5 Years		X					Fundamental nuclear physics research capability (1950s vintage) needs to be modernized to improve safety and reliability. Cyclotron replacement for 40 year old ORIC injector will substantially improve reliability, dramatically reduce operating costs and improve capability to produce broad range of radioisotopes in research quantities. Fire detection systems do not exist within shielded ORIC rooms, potential for significant	Replace single pass heating/ cooling system to reduce Building 6000 water usage. Improve Building 6000 and 6010 HVAC systems.	70MeV cyclotron replacement for ORIC Injector. Complement with new accelerator and related equipment to facilitate small quantity production of radioisotopes. Process control systems and electrical load monitoring and distribution need updating across the nuclear physics facilities. Provide fire detection capability within ORIC shielded rooms.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
								unplanned downtime in the event of fire.		
	In 10 Years			**X**						
Accelerator Science and Technology	Now			**X**		Spallation Neutron Source (SNS), Holifield Radioactive Ion Beam Facility (HRIBF)	Produce pulsed neutrons/steady state neutron fluxes using unique instrumentation and sample environment to provide unprecedented capabilities for understanding the structure and properties of materials, macromolecular and biological systems, and fundamental neutron physics.	At the end of FY 2012, sample environment will need to be relocated because the space currently occupied will be needed to complete a beam line. NScD does not have currently have adequate data storage. As additional instruments are commissioned and users increase, the demand for data storage will continue to increase. Currently, NScD has 125 TB of storage available at Chestnut Ridge. Five hundred TB will be needed in the next year. The SNS and HFIR beam line networks require upgrading to at least 10 Gbit/s. To adequately support NScD's mission, ORNL's networking system (off-campus)		SNS power upgrade CD-1 approval received, construction start targeted in 2013.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
								needs a 10 Gbit/s for users to download data and use ORNL computers for data processing.		
	In 5 Years		X					Additional energy to SNS needed to enable the accelerator to achieve 3 MW. Improvements to Chestnut Ridge infrastructure are needed to keep pace with science and user programs as well as site population growth including: space for storage, testing and maintenance of operational equipment; increased data storage and transmission capacity; laboratories for activated sample preparation; and a warm storage area.	Provide site infrastructure improvements addressing office, parking, general utility, storage, amenity and access needs	SNS Second Target Station has received CD-0 approval; CD-1 in anticipated in FY 2014 with completion in FY 22.
	In 10 Years		X					Increased performance capabilities and new techniques in accelerator technology, neutron scattering	ORNL program development funds used to develop second target station conceptual design and to prototype novel	Construction of the second target station has begun, continuous instrument upgrades, and completion of PUP.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
								instrumentation, and irradiation facilities will be needed to meet science growth.	instrumentation to be deployed at the second target station.	
Plasma and Fusion Energy Sciences	Now				X	Multi-Program High Bay Facility, Building 7625; Power Supply Building, Building 7627; Engineering Technology Facility, Building 5800; High Performance Computing systems, Building 5600; U.S. ITER Project Headquarters	Advance burning plasma science and demonstrate the scientific and technological feasibility of fusion	Diversify and upgrade power supplies and capability to the Plasma Material Interface research.		Complete power supply and associated cooling capacity upgrades for the power delivery facility.
	In 5 Years			X				Lack capability to develop and test integrated simulations needed for design of future fusion power systems.	Leverage use of ORNL computing infrastructure to aid design of fusion power systems.	Expand existing high bay facility to accommodate ITER experimental devices, install Plasma Materials Test Station and co-locate high-voltage and high-power facilities. Sek CD-) approval for Fusion Nuclear Science Facility in 2013.
	In 10 Years		X					Need to establish scientific basis for fusion fuel self-sufficiency, behavior of materials in a fusion environment, tritium breeding, and reliable and efficient power		Construct Fusion Nuclear Science Facility, proposed programmatic line item.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
								extraction under realistic fusion power reactor conditions.		
Condensed Matter Physics and Materials Science	**Now**				**X**	Chemical and Materials Sciences Building, 4100; Buildings 4500N/S; Spallation Neutron Source; High Flux Isotopes Reactor; Center for Nanophase Materials Science (CNMS); Shared Research Equipment Facility (ShaRE)	Understand nanoscale phenomena that underpin the discovery of advanced materials, with the goal of enabling new technologies for energy production, storage and use. Facilitate the design of new materials through control of atoms and defects to provide unprecedented functionality and performance under extreme conditions.	General chemistry facilities are outdated and do not support today's research agenda. Dry room capability not available to support cross-cutting initiatives.	Implement plan and schedule for the Chemical and Materials Sciences Building and complete 4500N/S lab clean out in preparation for these moves. Finalize plans for reuse and renovation of Building 4500N/S. Identify and prepare space for dry room installation.	Complete FY 2008 SLI Modernization of Laboratory Facilities line item (ARRA accelerated funding) to provide needed catalysis and materials synthesis capability.
	In 5 Years			**X**				Existing lab space does not meet the fire safety, utility or design requirements to accommodate forecast research. Dry room capability not available. Additional high sensitivity imaging capability needed to maintain progress in materials synthesis (CNMS).	Modernize 4500N/S laboratory and office space in accordance with backfill plans (IGPP). Identify and prepare space for dry room installation.	CNMS: Add ground floor labs
	In 10 Years			**X**						

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
Chemical and Molecular Science	Now				**X**	Chemical and Materials Sciences Building, 4100; Building 4500N/S; Spallation Neutron Source (SNS); High Flux Isotopes Reactor (HFIR); Center for Nanophase Materials Science (CNMS); Shared Research Equipment Facility (ShaRE)	Combine strengths in the design, precise synthesis, and characterization of the structure and reactivity of materials (especially at the nanoscale) using theory, modeling, and simulation to gain a fundamental understanding of material structure-property-function relationships.	General chemistry facilities are outdated and do not support today's research agenda. Dry room capability not available to support cross-cutting initiatives.	Implement plan and schedule for the Chemical and Materials Sciences Building and complete 4500N/S lab clean out in preparation for these moves. Finalize plans for reuse and renovation of Building 4500N/S. Identify and prepare space for dry room installation.	Complete FY 2008 SLI Modernization of Laboratory Facilities line item (ARRA accelerated funding) to provide needed catalysis and materials synthesis capability.
	In 5 Years			**X**				Existing space does not meet the fire safety, utility or design requirements to accommodate forecast research. Dry room capability not available. Additional high sensitivity imaging capability needed to maintain progress in materials synthesis (CNMS).	Modernize 4500N/S laboratory and office space in accordance with backfill plans (IGPP). Identify and prepare space for dry room installation.	
	In 10 Years			**X**						
Climate Change Science	Now				**X**	ORNL West Campus, 1000 series buildings; Joint Institute for Biological Sciences, Building 1520; Computational	Understand regional to global scale climate change impacts on the terrestrial carbon cycle and other natural and human systems.		Provide site infrastructure improvements to address site lighting, circulation needs	

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
						Sciences Building, Building 5600				
	In 5 Years			X					Provide site infrastructure improvements to address site lighting, circulation needs	
	In 10 Years				X					
Biological Systems Science	Now			X		ORNL West Campus, 1000 series buildings; Joint Institute for Biological Sciences	Develop and apply advanced integrated capabilities to solve worldwide problems in bioenergy, climate change, carbon sequestration, and health effects of low dose radiation	BER's largest laboratory facility, Building 1505, HVAC systems does not possess reliability needed for prolonged operation.		
	In 5 Years		X					BER's largest laboratory facility, Building 1505, HVAC systems does not possess reliability needed for prolonged operation.	Provide building and site infrastructure improvements to address general laboratory improvements as well as site lighting, circulation needs	FY 2012 SLI line item to repurpose Building 1005 (or portions thereof) into flexible, integrative lab space.
	In 10 Years				X					
Environmental Subsurface Science	Now				X	ORNL West Campus, 1000 series buildings; Joint Institute for Biological Sciences, Building 1520; Spallation Neutron Source	Advance understanding of how contaminants influence environmental quality and to develop solutions to contamination problems.	BER's largest laboratory facility, Building 1505, HVAC systems does not possess reliability needed for prolonged operation.		

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
	In 5 Years		X					BER's largest laboratory facility, Building 1505, HVAC systems does not possess reliability needed for prolonged operation.	Provide building and site infrastructure improvements to address general laboratory improvements as well as site lighting, circulation needs	FY 2012 SLI line item to repurpose Building 1005 (or portions thereof) into flexible, integrative lab space.
	In 10 Years				X					
Advanced Computer Science, Visualization, and Data	Now				X	Computational Sciences Building, Building 5600; Engineering Technology Facility, Building 5700	Improve the performance, efficiency, reliability, and usability of extreme-scale architectures and develop new algorithms and software systems to effectively exploit the specific benefits of each technology. Develop key capabilities in knowledge discovery and data analytics and apply advanced techniques for visual data understanding to better integrate effective visualization methods within DOE	Improved measurement, modeling, and simulation tools needed to support next generation HPC capability and solve problems across DOE and WFO research spectrum.	Provide additional visualization capability in Building 5700 and office space via Building 5600 expansion.	
	In 5 Years			X				Improved measurement, modeling, and simulation tools needed to support next generation HPC capability and solve problems across DOE and WFO research spectrum.		Upgrade existing capability as needed to meet future program needs.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
	In 10 Years			X				Improved measurement, modeling, and simulation tools needed to support next generation HPC capability and solve problems across DOE and WFO research spectrum.		Upgrade existing capability as needed to meet future program needs.
Computational Science	Now				X	Joint Institute for Computational Sciences, Building 5100; Computational Sciences Building, Building 5600; Engineering Technology Facility, Building 5700; Multiprogram Research Facility, Building 5300	Build multidisciplinary teams to execute breakthrough science through scalable algorithms and codes on massively parallel hardware running greater that 105 processing threads consuming petabytes of data	Space, power, and cooling required to implement Oak Ridge Leadership Computing Facility-3 (OLCF-3) in 2012 in order to meet multiple near term core capability objectives. Additional office space required to relieve overcrowding and accommodate increased use of HPC resources across ORNL.	Provide for immediate need computing and office space via Building 5600 modification and expansion.	
	In 5 Years		X					Additional space, power and computing needed to implement OLCF-4 (prototype exascale system of several hundred petaflops with expected delivery in the 2015 timeframe) and	Provide infrastructure for MCDC (e.g., road access, concrete pads for electrical equipment, etc.) via IGPP in 2012/2013.	Approval in FY 11 for Multiprogram Computational Data Center (MCDC) as third party financed facility for occupancy in January 2013.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
								expand WFO computing.		
	In 10 Years		X					Additional space, power and computing needed to implement exascale computing in 2018 timeframe.	Provide infrastructure for MCDC (e.g., road access, concrete pads for electrical equipment, etc.) via IGPP in 2012/2013.	Approval in FY 11 for Multiprogram Computational Data Center (MCDC) as third party financed facility for occupancy in January 2013.
Applied Nuclear Science and Technology	Now			X		High Flux Isotopes Reactor (HFIR); Radiochemical Engineering Development Center (REDC); High Rad Materials Examination Facility (Building 3525); (Building 3025E); Nuclear Science and Analytical Chemistry Facility (Buildings 4501, 4505); Building 4500N Wing 1	Produce and process stable and radioactive isotopes that are distributed for use in medical, industrial and research applications. Explore and demonstrate all aspects of the nuclear fuel cycle, including advanced fuel enrichment processes, the performance of nuclear fuels and materials in extreme environments, dynamic chemical processes for fuel reprocessing and recycle, and advanced waste forms for long-term disposal.	ORNL radiological labs execute a vast array of research projects for sponsors including NNSA, DHS, EM, NE as well as internal LDRD projects. These labs are more than 50 years old and renovations will substantially decrease maintenance requirements and improve energy efficiency. The United States does not possess capability to produce stable isotopes.	Refresh rad labs in Bethel Valley. Improve Melton Valley site parking and circulation in response to new buildings and increased user population. Revise planning basis for consolidation and refurbishment of ORNL nuclear and radiological infrastructure. Electrical feeder 294 is the primary feeder for the Melton Valley site. Electrical 13.8Kv feeder 234 for the Melton Valley site is a secondary feeder that has experienced several interruptions in the last year; this feeder needs to be more reliable.	DOE-NE and/or SC direct support for maintaining ORNL's multiprogram nuclear facilities in mission ready status. DOE EM ownership and timely demolition of vacated nuclear and radiological facilities. Program funding for research and development of stable isotope separation technologies. Operation of new Melton Valley Maintenance Facility (ARRA funded) commenced in April 2011.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
	In 5 Years		X					Refreshment and renovation of nuclear and radiological facilities required to execute vast array of research projects. United States does not possess capability to produce stable isotopes.	Continue to refresh rad labs. Upgrade utilities and peripheral systems for radiological facilities in 4500 Area. Utilize institutional capital where appropriate to support implementation of plans to refurbish nuclear and radiological infrastructure. Decisions in 2015 regarding HFIR will dictate future required investments (beryllium reflector, HB-4 beam tube replacement, and possible installation of a second cold neutron source on HB-2). Refurbishment of research support infrastructure needed in Melton Valley. Decisions in 2015 regarding HFIR will dictate future required investments (beryllium reflector,	DOE-NE and/or SC direct support for maintaining ORNL's multiprogram nuclear facilities in mission ready status. DOE EM ownership and timely demolition of vacated nuclear and radiological facilities. Implement stable isotope separation capability at Building 6010 Shield Test Station (proposed programmatic).

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
									HB-4 beam tube replacement, and possible installation of a second cold neutron source on HB-2). Refurbishment of research support infrastructure needed in Melton Valley.	
	In 10 Years		X					Nuclear facility consolidation and refurbishment as well as ability to manage SC mission waste are required to support out year missions. All are long lead items requiring immediate planning and near term action in order to support outyear missions. Existing equipment will not support next generation isotope production processes.	Utilize institutional capital where appropriate to support implementation of plans to refurbish nuclear and radiological infrastructure.	DOE-NE and/or SC direct support for maintaining ORNL's multiprogram nuclear facilities in mission ready status. DOE EM ownership and timely demolition of vacated nuclear and radiological facilities. HFIR HB-2 Second Cold Source and Guide Hall (proposed programmatic line item). FY 2018 SLI for Melton Valley Research Operations Support Facility to consolidate office and lab space. FY 2020 SLI for radioactive waste handling system replacement.
Applied Materials Science and	Now				X	4500 Building Complex including	Apply ORNL's unique materials science and	Combined laboratory/high bay	Refurbish existing labs as available to	DOE EE/RE ARRA line item, Carbon

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		Mission Ready				Key Buildings	Key Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
Engineering						the High Temperature Materials Laboratory; Engineering Technology Facility; Building 5500; Building 3100 series; Oak Ridge Science and Technology Park	engineering resources and facilities to support DOE's applied missions and national needs including solving materials problems that limit the efficiency and reliability of systems for power generation and energy conversion, distribution, and use. Facilitate commercialization of key technologies.	facility space is needed to co-locate and leverage multiple cross-cutting capabilities and thereby accelerate science through the development and demonstration phases into commercial markets to expedite resolution of urgent national and global priorities.	accommodate new equipment (expense, IGPP). Upgrade Building 4508 Exhaust Fans and Housing (IGPP). Finalize 4500N/S backfill plans.	Technology Complex, awarded in FY09, provides capability to manufacture low cost, high quality carbon fiber as well as consolidation of on-site carbon fiber composites research. Sponsor modification of existing facilities to provide essential new laboratory/high bay facilities to enable the translation of science to applied technology and spur national competitiveness.
	In 5 Years			**X**				Combined laboratory/high bay facility space is needed to co-locate and leverage multiple cross-cutting capabilities and thereby accelerate science through the development and demonstration phases into commercial markets to expedite resolution of urgent national and global	Modernize 4500N/S laboratory and office space in accordance with backfill plans (IGPP).	Sponsor modification of existing facilities to provide essential new laboratory/high bay facilities to enable the translation of science to applied technology and spur national competitiveness.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
								priorities.		
	In 10 Years			**X**				Combined laboratory/high bay facility space is needed to co-locate and leverage multiple cross-cutting capabilities and thereby accelerate science through the development and demonstration phases into commercial markets to expedite resolution of urgent national and global priorities.		Sponsor modification of existing facilities to provide essential new laboratory/high bay facilities to enable the translation of science to applied technology and spur national competitiveness.
Chemical Engineering	Now			**X**		Radiochemical Engineering Development Center and other radiological laboratories and nuclear facilities; BioEnergy Sciences Center; Center for Nanophase Materials Science; High Temperature Materials Laboratory; High Performance Computing Buildings; 4500 Building complex	Generate innovative solutions in alternative energy systems, carbon management, energy-intensive industrial processing, nuclear fuel cycle development, and waste and environmental management. Translate solutions into use via technology transfer.	Existing lab space does not meet the fire safety, utility or design requirements to accommodate research including energy storage.	IGPPs for utility and infrastructure improvements.	On time completion of the FY 2008 SLI Modernization of Laboratory Facilities line item (ARRA accelerated funding). DOE-NE and/or SC direct support for maintaining ORNL's multiprogram nuclear facilities in mission ready status.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
	In 5 Years		**X**					Existing lab space does not meet the fire safety, utility or design requirements to accommodate research including energy storage.	IGPPs for utility and infrastructure improvements.	DOE-NE and/or SC direct support for maintaining ORNL's multiprogram nuclear facilities in mission ready status (e.g., REDC hot cell upgrades to replace in cell equipment in support of curium target fabrication and Cf 252 encapsulation operations).
	In 10 Years		**X**					Existing lab space does not meet the fire safety, utility or design requirements to accommodate research including energy storage.	IGPPs for utility and infrastructure improvements.	DOE-NE and/or SC direct support for maintaining ORNL's multiprogram nuclear facilities in mission ready status (e.g., REDC hot cell upgrades to replace in cell equipment in support of curium target fabrication and Cf 252 encapsulation operations).

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
Systems Engineering and Integration	Now				**X**	Engineering Technology Facility, Building 5800; Instrumentation Research Facility, Building 3500; National Transportation Research Center; Multi-Program Research Facility; High Performance Computing Buildings; Oak Ridge Science and Technology Park	Translate breakthrough science into robust technologies and methods that address high-risk, high-complexity, multidisciplinary issues of national importance. Work in this area is focused on meeting the mission needs of DOE and other federal agencies, with an emphasis on delivering systems to meet requirements related to energy security, national security, health, and economic competitiveness.	Capacity to develop and integrate energy-efficient technologies into residential and commercial buildings, materials processes for efficient industry, and electricity delivery are constrained by existing facilities and infrastructure.	NTRC Annex lease	DOE EE/RE ARRA line item, Maximum Energy Efficiency Research Laboratory (MAXLAB) was awarded in FY09 to holistically address the multiple interactions among building systems and components to develop integrated, high performance net-zero energy buildings (NZEBs) while improving other facets (safety, comfort, environmental). Sponsor modification of existing DOE or leased facilities to provide laboratory/high bay facilities to enable the translation of science to applied technology.
	In 5 Years			**X**					IGPPs for utility and infrastructure improvements.	Sponsor modification of existing DOE or leased facilities to provide laboratory/high bay facilities to enable the translation of science to applied

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
										technology.
	In 10 Years			**X**					IGPPs for utility and infrastructure improvements.	Sponsor modification of existing DOE or leased facilities to provide laboratory/high bay facilities to enable the translation of science to applied technology.
Large Scale User Facilities/Advanced Instrumentation	Now			**X**		Building Technologies Research and Integration Center (BTRIC); Center for Nanophase Materials Science (CNMS); High Flux Isotopes Reactor (HFIR); High Temperature Materials Laboratory (HTML); Holifield Radioactive Ion Beam Facility (HRIBF); Center for Structural Molecular Biology; National Institute for Computational Sciences (NICS); National Transportation Research Center (NTRC); Safeguards Laboratory (SL); Shared Research Equipment Facility	Execute world-class research programs to deliver science and innovation. Ensure students and postdoctoral associates are well represented in the user population and receive full access for conduct of research.	ORNL's networking system (off-campus) needs a 10 Gbit/s for users to download data and use ORNL computers for data processing. Many of ORNL's facilities operate 24/7; however, it is difficult for visitors arriving on the weekends or after-hours to obtain the necessary credentials because the Visitor's Center is closed and it is difficult to access the LSS. An off-site location is needed to obtain the necessary credentials to visit or work at ORNL.	Evaluate reuse of HRIBF guest quarters	SNS: Power Upgrade Project

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
						(ShaRE); Spallation Neutron Source (SNS)				
	In 5 Years			**X**					IGPPs for utility and infrastructure improvements.	SNS: Program GPPs CNMS: Add ground floor labs
	In 10 Years		**X**						IGPPs for utility and infrastructure improvements.	SNS: second target station HFIR: HB-2 Second Cold Source and Guide Hall

N[a] = Not Capable; "Deficiencies are preventing achievement of mission despite the use of work arounds; not operable, cannot deliver defined mission demand; requires capital investments in excess of GPP limit to return to mission ready."
M[b] = Marginal; "Deficiencies require major resources to ensure achievement of mission; investments to return to mission ready require capital investments in excess of GPP limits."

P[c] = Partial; "Deficiencies require minor resources to ensure achievement of mission; investments to return to mission ready are within GPP limits (if capital expenditure)".

C[d] = Capable; "No deficiencies that impact mission delivery, operable without work arounds; operating parameters meet current and known future demand".

Pacific Northwest National Laboratory

Mission Statement/Overview

The Pacific Northwest National Laboratory (PNNL) is a U.S. Department of Energy (DOE) Office of Science (SC) laboratory located in Richland, WA with an enduring mission and vision to be recognized worldwide and valued nationally for leadership in accelerating scientific discovery and innovation, and deploying solutions to challenges in energy, national security, and the environment important to DOE and the nation.

To do this, the Laboratory provides distinctive, world-leading science and technology in

- design and scalable synthesis of materials and chemicals
- coupling climate and energy systems for sustainability
- efficient and secure electricity management from generation to end use
- signature discovery and exploitation for threat detection and reduction.

PNNL leadership also extends to two national scientific user facilities: the Environmental Molecular Sciences Laboratory (EMSL), providing integrated experimental and computational resources for discovery and technological innovation; and the Atmospheric Radiation Measurement Climate Research Facility (ACRF).

Established in 1965 with 2200 employees and facilities supporting Hanford Site operations, PNNL focused on expanding nuclear fuel cycle research, developing advanced reactor designs and materials, fabricating and testing novel reactor fuels, and monitoring and protecting human health and the environment. PNNL has since become a leading multidisciplinary national laboratory with a long-standing reputation for advancing scientific frontiers through world-class research and development.

PNNL is operated by Battelle Memorial Institute, a private, non-profit, science and technology enterprise that explores emerging areas of science, develops and commercializes technology, and manages laboratories. Total PNNL cost for FY 2010 was $880M. In addition to SC, principal PNNL customers include DOE's Offices of Energy Efficiency and Renewable Energy (EERE), Environmental Management (EM), Fossil Energy (FE), Electricity Delivery and Energy Reliability (OE), and the National Nuclear Security Administration (NNSA); U.S. Department of Homeland Security (DHS); U.S. Department of Defense (DoD); U.S. Nuclear Regulatory Commission (NRC); and the National Institutes of Health (NIH).

Lab at a Glance

Location: Richland, Washington

Type: Multi-program Laboratory

Contract Operator: Battelle Memorial Institute

Responsible Field Office: Pacific Northwest Site Office (PNSO)

Web site: http://www.pnl.gov/

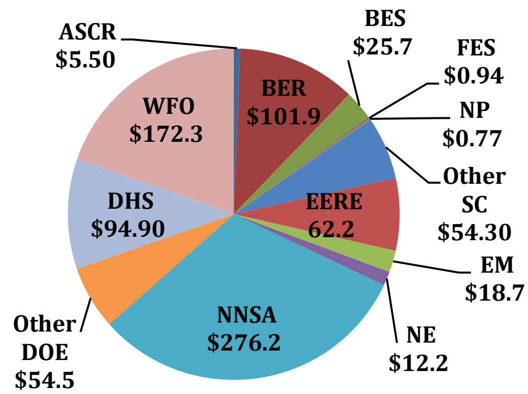
Physical Assets:

- 350acres DOE, 250 acres Battelle, 101 buildings
- 831,249 gross square feet (gsf) of DOE-owned operating buildings.
- Replacement plant value: $428,481,552
- Deferred maintenance: $7,966,000
- Asset Condition Index:
  - Mission critical: 0.993
  - Mission dependent: 0.967
  - Asset Utilization Index: 0.886

Human Capital:

- 4103 Full-Time Equivalent Employees (FTE)
- 1 Joint Faculty
- 200 Postdoctoral Researchers
- 185 Graduate Students
- 232 Undergraduate Students
- 1,894 Facility Users
- 19 Visiting Scientists

FY 2010 Funding by Source (*Costs $M):*



FY 2010 Total Lab Operating Costs (excluding ARRA): $880.0
FY 2010 Total DOE/NNSA Costs: $612.8
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $172.3
FY 2010 WFO as % Total Lab Operating Costs: 18%
FY 2010 Total DHS Costs: $94.9

ARRA Obligated from DOE Sources FY 2010: $85.0
ARRA Costed from DOE Sources FY 2010: $96.0

Current Core Capabilities

PNNL has ten acknowledged core capabilities. Each is a powerful combination of people, equipment, and facilities nurtured through programmatic, institutional, and corporate investments. PNNL makes discretionary investments in these core capabilities and other strategically important areas to respond to emerging and future national needs. Current investments are designed to expand the Laboratory's capabilities in multi-modal imaging, computational science, climate science, microbiology (or genome sciences), and materials science.

Several PNNL core capabilities have matured into world-class research programs. For example, PNNL is widely recognized as a world leader in proteomics, drawing on core capabilities in chemical and molecular sciences and biological systems science. Other capabilities have led to world-class research, development, and technology deployment programs in catalysis, subsurface science, and radiation detection.

One of PNNL's strengths is the ability to bring multiple capabilities to bear on complex scientific and technological challenges. This approach, combined with our focus on accelerating scientific discovery and innovation and deploying solutions, is evident in the core capability descriptions, primary funding sources, and supported missions that follow. See Appendix 2 for the Mission Area key used in the core capability descriptions.

1. Chemical and Molecular Sciences

As a DOE national laboratory, PNNL is a national leader in chemical and molecular sciences. This core capability advances the understanding, prediction, and control of chemical and physical processes in complex, multiphase environments. PNNL has domain expertise in condensed phase and interfacial molecular sciences, catalysis science, computational and theoretical chemistry, geochemistry, separations and analysis, actinide science, self-assembled nanomaterials, and defects in materials.

This capability is the basis for PNNL's computational chemistry software application (NWChem), which is used worldwide to solve large molecular science problems efficiently, using computing resources ranging from high-performance parallel supercomputers to workstation clusters. The Laboratory has made significant contributions in condensed phase and interfacial molecular science and basic catalysis science. PNNL has the largest fundamental research effort within the national laboratory system in these areas, and this success has resulted in the establishment of the Institute of Interfacial Catalysis and the award of an Energy Frontier Research Center in Molecular Electrocatalysis from DOE's Basic Energy Sciences (BES) program. PNNL has also developed Northwest–Infrared, a comprehensive vapor phase spectral library for chemical-sensing applications, and made it available to researchers worldwide. This capability supports 145 staff scientists and engineers (including more than 65 senior researchers) housed in the Physical Sciences Laboratory (PSL), EMSL, and other facilities. This capability contributes to, and benefits from, EMSL's state-of-the-art resources.

The chemical and molecular science capability forms the basis for PNNL's fundamental science programs in condensed phase and interfacial molecular sciences, chemical analysis, computational chemistry, geochemistry, and catalysis science. Applied programs include improved energy technologies, catalysis and reaction engineering, hydrogen storage, biomass conversions, environmental remediation, and carbon capture and sequestration. This capability is funded through programs in SC (BES and Biological and Environmental Research [BER]), EM (environmental remediation), EERE (geothermal; biomass; hydrogen, fuel cells, and infrastructure technology), FE (carbon- and co-sequestration), and the NNSA (nonproliferation). This capability enables PNNL to advance DOE's missions in scientific discovery and innovation (SC 6, 7, 8, 10, 16), energy security (ES 5, 8, 9), environmental management (EM 2, 3), national security (NNSA 2), and homeland security (HS 1, 2, 3, 5, 6).

2. Chemical Engineering

PNNL is recognized internationally for its chemical engineering core capability. This capability applies chemical research and engineering across molecular to engineering-scale problems and demonstrations, translating scientific discovery into innovative processes for advanced energy and environmental systems. PNNL's strength in chemical engineering is derived from its scientific foundations in molecular, biological, nuclear, and material sciences and engineering. An important feature of this capability is its ability to deliver continuous, high-throughput, efficient and cost-effective processing solutions with supporting equipment and controls, often incorporating several advanced individual processes and systems. The Laboratory has domain expertise in applications of catalysis for biomass and fossil fuel conversion; separations and waste immobilization for nuclear waste processing; online sensing of nuclear, chemical, and biological materials; clean hydrocarbon processing and emissions; micro-technology-based chemical engineering and micro-chemical reactor technology; fluid dynamics for complex fluids; electrochemistry; and carbon capture.

In collaboration with Washington State University (WSU), PNNL established the Bioproducts, Sciences, and Engineering Laboratory (BSEL), including state-of-the-art catalytic reactors and bio-processing laboratories to convert biomass into viable products such as biofuels and chemicals. PNNL has more than 105 scientists and engineers (including 30 senior researchers) supporting this capability, along with unique facilities for radiochemical processing and process engineering, including the BSEL, PSL, Radiochemical Processing Laboratory (RPL), and Applied Process Engineering Laboratory (APEL).

The chemical engineering capability forms the basis for PNNL's programs in emission catalysis, hydrogen fuel safety and storage, hydrogen storage and carbon capture, biomass conversion, clean coal technologies, fuel cell development (including solid oxide fuel cells), tactical energy systems, used nuclear fuel and waste processing, and waste forms. It is funded through programs in EERE (geothermal; biomass; hydrogen, fuel cells, and infrastructure technology; and vehicles), FE (clean coal, hydrogen and other clean fuels, and carbon capture), DOE's Office of Nuclear Energy (NE – used fuel treatment), and EM (waste processing). This capability enables PNNL to advance DOE's missions in scientific discovery and innovation (SC 10), energy security (ES 6, 7, 8, 9), environmental management (EM 2, 3), national security (NNSA 2), and homeland security (HS 3, 6, 7, 8, 9).

3. Biological Systems Science

PNNL is recognized internationally for its biological systems sciences capability, including leadership in proteomics, environmental microbiology, fungal biology and biotechnology. PNNL's multiple 'omic technologies are widely used in the broader BER Genomic Science Program. PNNL's domain expertise also includes cell biology and biochemistry, radiation biology, computational biology and bioinformatics, systems toxicology, bioforensics, and biodetection.

The Laboratory has demonstrated international leadership in proteomics and environmental microbiology, designing strategies for biorestoration of sites contaminated with heavy metals and radionuclides, predicting contaminant behavior in the subsurface, and a systems biology approach to microbial and algal systems relevant to DOE missions of bioenergy and climate change. PNNL's expertise in fungal biology has generated an in-depth understanding of the biological processes underlying efficient fungal bioprocesses that produce fuels and other chemicals. Supporting this capability are more than 170 scientists and engineers (including more than 65 senior researchers) housed in the new Biological Sciences Facility, Computational Sciences Facility (CSF), BSEL, Marine Sciences Laboratory, 331 Building, and EMSL. PNNL is also a partner in the Joint Genome Institute, which provides large-scale genome sequencing and analysis for DOE missions.

The biological systems science capability enables PNNL to provide a systems-level understanding of biological systems involved in biomass conversion, radiation biology, biology of oxidative stress and signaling, bioremediation, carbon cycling and terrestrial biosequestration, biogeochemical transformation of environmental contaminants, environmental microbiology, microbial ecology, and bioforensics and biodetection. The capability is funded through programs in SC (BER), EM (waste processing), EERE (biomass), DHS, NIH, and the U.S. Environmental Protection Agency (EPA). This capability advances DOE's missions in scientific discovery and innovation (SC 11, 13, 14, 15, 16), energy security (ES 8, 9), environmental management (EM 2), and homeland security (HS 3, 11).

4. Climate Change Science

PNNL is a national leader in climate change science, with capabilities spanning the full range of disciplines and tools needed to understand and quantify complex interactions among the climate system, energy production and use, and other natural processes and human activities. This core capability includes activities ranging from measurements to process/regional/global models to integrated analyses of climate impacts and response options. PNNL has domain expertise in instrument development; cloud physics; atmospheric aerosol chemistry; cloud-aerosol interactions; atmospheric process modeling; regional climate and Earth system modeling; integrated assessment; and quantitative analyses of emissions, land use changes, and mitigation and adaptation scenarios. These activities are closely linked to PNNL's expertise in related areas—for example, integrated regional Earth system models include coastal, watershed, ecosystem, and agricultural/land use model components; require advanced computing and data management and visualization tools; and are increasingly being coupled to models of energy systems and other human activities to identify regional impacts and evaluate adaptation and mitigation options.

This capability is internationally recognized for improving our basic understanding of the causes and consequences of climate change and for developing the data-driven regional and global modeling frameworks needed to predict changes in climate as well as in related human and environmental systems. More than 130 scientists and engineers support this capability, including those housed in the Atmospheric Measurements Laboratory (AML) and the Marine Sciences Laboratory, those supporting the ACRF, and those at the Joint Global Change Research Institute (JGCRI), a partnership between PNNL and the University of Maryland that focuses on understanding the interactions between climate, natural resources, energy production and use, economic activity, and the environment. PNNL scientists have contributed to every major national and international assessment of climate change, including the Nobel Prize-winning Intergovernmental Panel on Climate Change.

The climate change science capability provides the basis for PNNL's programs in clouds, aerosols, and other atmospheric processes; radiation measurements and observations; integrated assessment of climate and related global changes; and climate change modeling and prediction. It is funded by programs in SC (BER and Advanced Scientific Computing Research [ASCR]), EERE (wind and water power technologies), FE (carbon- and co-sequestration), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA). This capability advances DOE's missions in scientific discovery and innovation (SC 1, 10, 12, 14, 15, 16), energy security (ES 16), and homeland security (HS 7, 9, 11).

5. Environmental Subsurface Science

PNNL is a leader in environmental subsurface science. This core capability focuses on developing and applying the basic understanding of biogeochemical reactions, energy, and mass transfer to the prediction, assessment, mitigation, and design and operation of *in situ* environmental processes. PNNL has domain expertise in molecular-to-field scale biogeochemistry and reactive and multiphase transport modeling; laboratory-to-field scale geohydrology, surface water hydrology, and multiphase flow modeling; ecological assessment, management, and monitoring; human health and environmental risk assessment; and environmental systems technology development and deployment.

PNNL applies an iterative experimental and modeling approach to contaminant fate and transport at DOE sites, demonstrating its leadership at the Integrated Field Research Challenges located within the Hanford Site 300 Area and in Rifle, CO. The Laboratory applies this expertise toward the protection of regional water sources and aquatic ecosystems affected by contaminated soils and groundwater, releases from waste disposal units, climate change mitigation, energy development, water use, and hydropower systems operations. Our expertise in environmental subsurface science has resulted in the Laboratory's emergence as a national leader in mitigating greenhouse gases (GHGs) through geologic sequestration science supporting the Midwest, Southwest, and Big Sky Regional Carbon Sequestration Partnerships, with major roles in the Wallula Carbon Sequestration Demonstration and FutureGen projects. PNNL has more than 205 staff scientists and engineers (including 60 senior researchers) advancing this capability in the MSL, 331, and Sigma 5 facilities, PSL, Research Technology Laboratory (RTL), and EMSL.

The environmental subsurface science capability provides the basis for PNNL's programs in environmental remediation sciences; fate and transport of subsurface contaminants and legacy waste cleanup; GHG co-sequestration and demonstration; environmental impact assessments for nuclear, geothermal, water/ocean, and wind energy; ecological management; and marine science research. This capability is funded through programs in SC (BER), EM (waste processing, groundwater and soil remediation, nuclear materials disposition), FE (carbon- and co-sequestration), EERE (geothermal technologies, wind and water power technologies), and the NRC and U.S. Army Corps of Engineers (USACE). This capability advances DOE's missions in scientific discovery and innovation (SC 11, 12, 13, 16), energy security (ES 2, 3, 4, 5, 9, 16), environmental management (EM 2, 3), national security (NNSA 2), and homeland security (HS 3, 7, 11).

6. Applied Materials Science and Engineering

PNNL is recognized internationally for its capability in applied materials science and engineering, with domain expertise in materials theory, simulation, design, and synthesis; materials structural and chemical modification;

the role of defects in controlling material properties; materials characterization; and materials performance in hostile environments, including the effects of radiation and corrosion. PNNL's strength in this capability is derived from the Laboratory's foundations in chemical, molecular, biological, and subsurface science, and the ability to engineer enabling nano-structured and self-assembled materials, tailored thin films, ceramics, glasses, alloys, composites, and biomolecular materials.

The Laboratory is specifically known for its expertise in radiation effects on materials, solid oxide fuel cells and energy storage materials, solid-state lighting, and organic electronic materials as well as its expertise in developing functionalized nanoporous ceramics for catalytic, sorbent, and sensing applications. PNNL has more than 180 scientists and engineers (including more than 60 senior researchers) who contribute to and use state-of-the-art material characterization instrumentation at EMSL; high- and low-dose radiological facilities, including PSL and the new Physical Sciences Facility (PSF); and laboratories for thin-film material synthesis and deposition, including APEL and RTL.

The applied materials science and engineering capability forms the basis of PNNL's programs in radiation effects in materials; multi-scale behavior of structural materials; design and scalable synthesis of materials and chemicals; fuel cells and energy storage; electric and lightweight vehicle technology; nuclear reactor safety assessment, regulatory criteria, and life extension; and legacy waste forms. It is funded through programs in SC (BES, FES), NE (advanced fuel cycle initiative), EERE (hydrogen storage and fuel cell technology), EM (waste processing), and the NRC. This capability advances DOE's missions in scientific discovery and innovation (SC 6, 7, 8, 10, 16, 19), energy security (ES 2, 11, 13, 14, 15, 16), environmental management (EM 3), national security (NNSA 2), and homeland security (HS 3, 11).

7. Applied Nuclear Science and Technology

PNNL is a national leader in applied nuclear science and technology. The depth and breadth of this capability enables PNNL to play pivotal roles in fundamental scientific, nuclear nonproliferation, and nuclear energy efforts. PNNL has domain expertise in ultra-trace detection and analysis, non-destructive evaluation, dosimetry and health physics, international nuclear intelligence analysis, nuclear material security and interdiction systems, fuel cycle characterization, nuclear fuels production and processing, nuclear safety analysis and risk assessment, nuclear detectors, actinide chemistry, online monitoring techniques, and radiochemical process engineering.

PNNL is internationally recognized for our capability in environmental sampling for nonproliferation and nuclear detonation monitoring missions and best known for leadership in developing new science, tools, and techniques for monitoring and predicting materials and process performance for nuclear power applications, performing nuclear safety and risk assessments that include human health exposure impacts, and identifying trace environmental signatures for monitoring nuclear activities. More than 300 staff scientists and engineers (including 60 senior researchers) support this capability along with uniquely equipped high- and low-dose radiological and ultra-low background counting facilities (PSF), CAT-II radiological chemical processing (RPL), and National Institute of Standards and Technology (NIST) certified calibration (Radiation Calibration Laboratory [RCL]). Additionally, PNNL has outdoor facilities for testing interdiction systems designed for border security as part of the PSF complex.

The applied nuclear science and technology capability forms the basis for PNNL's programs in nuclear nonproliferation, tritium target qualifications, health physics, nuclear fuel cycle research and development, radiation portal monitoring, dosimetry, international nuclear intelligence analysis, and neutrinoless double beta decay. This capability is funded through programs in NNSA (nonproliferation, defense programs), DHS, NE (fuel cycle), EM (waste processing, nuclear materials disposition), NRC, the Intelligence Community, and SC (Nuclear Physics). This capability advances DOE missions of scientific discovery and innovation (SC 23, 26, 29, 30, 31, 32), energy security (ES 2, 16), environmental management (EM 2, 3), national security (NNSA 2), and homeland security (HS 1, 2, 3, 4, 6, 7, 8, 10).

8. Advanced Computer Science, Visualization, and Data

PNNL is recognized internationally in advanced computer science, visualization, and data management. PNNL uses its expertise in computing and mathematics to develop scalable analysis algorithms, high-performance computing tools, data-intensive information systems, and secure computing infrastructures for scientific discovery, predictive modeling, situational awareness, and decision support.

PNNL's unique capabilities and leadership in data-intensive computing applications and architectures is exemplified in three centers. The DoD-funded Center for Adaptive Supercomputing Software-MultiThreaded Architectures conducts research in algorithms, systems software, and programming environments to enable data-intensive applications that do not have spatial or temporal locality and will benefit from novel architectures. Second, PNNL provides international leadership for information analytics through the DHS and Intelligence Community-funded National Visualization and Analytics Center (NVAC), which delivers decision-making and analysis tools to intelligence analysts, national and homeland security officials, and first responders and law enforcement personnel. Third, the Electricity Infrastructure Operations Center (EIOC) merges real-time sensor data with advanced computing, bringing together industry software, real-time grid data, and advanced computation into a functional control room for real-time monitoring and management of the nation's electric grid.

PNNL's strengths in data management and informatics support EMSL and the ACRF. PNNL is a leader in computational chemistry, subsurface transport simulation and modeling & simulation for the power grid. For 10 years, PNNL has led the nation in new cyber security capabilities to detect and analyze DOE networks and electricity infrastructure. Leading the DOE Cooperative Protection Program and the recent Electric Sector Network Program, PNNL is responsible for the research and development of next generation cyber security sensors, standards for secure communication protocols, design of analytic methods and tools, and operational analysis of the integrity and security of cyber networks. Computer science capabilities include data analysis and visualization, performance and power modeling, programming and execution models, and hardware & software multithreading. Computational math capabilities include upscaling, stochastic PDEs and uncertainty quantification. PNNL has more than 375 staff scientists and engineers (including 55 senior researchers) supporting this core capability.

PNNL hosts a variety of high-performance computing resources ranging from special-purpose mid-range machines to EMSL's Chinook, a 163 teraflops, 18,000+ core super-cluster with a 4.5 petabyte data archive. Other PNNL high-end computing resources include a 128-node (16,384 threads) Cray XMT system, 14.3 teraflops IBM system, HP SuperDome, multiple NVidia GP/GPU clusters, and a Netezza TwinFin. With American Recovery and Reinvestment Act (ARRA) funding, PNNL procured new high-performance computing systems to provide long-term data storage and services to support EMSL experimental and computational research; leading-edge GP/GPU systems, solid-state storage, and high-speed interconnect technology supporting computational chemistry programs; and a 20-teraflop Intel Nehalem cluster with over 1 petabyte of storage to advance our understanding of global climate change.

The new CSF supports an integrated Power Wall with a touch surface for scientific and information visualization and 10,000 square feet of raised floor space with a highly energy-efficient geothermal cooling system. PNNL's regional network now provides independent pathways from two locations on the PNNL campus to Seattle and Boise. Through the DOE Energy Sciences Network and the Pacific Northwest Gigapop, resilient high-speed connectivity is supported between geographically diverse collaborators across major research and education networks.

This capability underpins PNNL's programs in data-intensive and high-performance computing, scientific and knowledge discovery frameworks, cyber security, information analytics, computational chemistry, computational biology and bioinformatics, and computational subsurface science. This capability is funded through programs in SC (ASCR, BER, BES), Intelligence and Counterterrorism, OE, NNSA (nuclear nonproliferation), DHS, DoD, Intelligence Community, NIH, the National Science Foundation, and the U.S. Department of the Treasury. This capability advances DOE's missions of scientific discovery and innovation (SC 1, 2, 3, 4, 5, 11, 12, 13, 16, 26), energy security (ES 10), national security (NNSA 2), and homeland security (HS 1, 2, 3, 4, 5, 6, 7, 8, 10, 12).

9. Systems Engineering and Integration

PNNL is a national leader in systems engineering and integration. This core capability focuses on solving complex problems—from concept to deployment—by synthesizing and integrating multiple disciplines and products to develop and implement efficient solutions. The Laboratory interprets complex technical requirements and translates them into integrated assessment and fielded solutions that address economic, social, and engineering considerations. Using a structured approach to understand complex systems throughout their life-cycle, PNNL uses its domain knowledge and experience in engineered systems simulation and modeling; system architecture and design; test, evaluation, and optimization; technology assessment, integration, and deployment; policy assessment and economic evaluation; safeguards and physical security systems; and regulatory analysis, risk assessment, and decision support.

PNNL is known worldwide for field-deploying international nuclear materials safeguards and security and complex radiation detection systems. PNNL utilizes a graded approach to technology development challenges that enables us to deliver solutions in a highly efficient and effective way. PNNL also leads in developing integrated building energy technologies, advancing national power grid reliability and smart grid technology, and conducting large-scale demonstrations of carbon management demonstrations. To support this capability, PNNL has more than 485 staff scientists and engineers (including 63 senior researchers) and key facilities that include the EIOC and Radiation Portal Monitoring Integration Laboratory as part of the PSF complex.

The systems engineering and integration capability is funded through programs in EERE (buildings), EM (waste processing, nuclear materials disposition), OE (infrastructure security and energy restoration), FE (carbon- and co-sequestration), SC (BER), NNSA (nonproliferation), and DHS. This capability advances DOE's missions of scientific discovery and innovation (SC 10, 16, 30), energy security (ES 3, 4, 7, 8, 9, 10, 14, 15, 16), environmental management (EM 2, 3), national security (NNSA 2), and homeland security (HS 1, 2, 3, 5, 6, 9).

10. Large-Scale User Facilities/Advanced Instrumentation

PNNL is recognized internationally for its ability to conceive, design, build, operate, and manage world-class scientific user facilities. This capability focuses on the design and development of transformational research tools and techniques that accelerate scientific discovery and technical solutions. PNNL has demonstrated this ability in the design, construction, and operation of the EMSL, DOE's first user facility to deliver a suite of unique and state-of-the-art instruments that accelerate scientific discovery and innovation to advance DOE's missions. This capability also enables PNNL's contribution to the design and operation of the ACRF.

EMSL boasts an unparalleled collection of state-of-the-art computational and experimental capabilities that is focused around its three science themes of biological interactions and dynamics; subsurface science, geochemistry, and biogeochemistry; and the science of interfacial phenomena to address critical challenges in DOE's environmental and energy mission areas. Advanced instrumentation is integrated with teams of teams collaborating with expert staff to resolve complex scientific problems and include high-performance mass spectroscopy, high-resolution microscopy, high-field magnetic resonance spectroscopy and imaging, and high-performance molecular science computing.

The ACRF is designed to understand the fundamental physics of the interactions between clouds and radiation in the atmosphere and improve the representation of these processes in global climate models. In addition, the G-1 aircraft is an airborne laboratory for atmospheric measurements.

Together, EMSL and ACRF provide unique opportunities to national and international scientific users to conduct world-class research individually and in collaboration with PNNL staff. Nearly 80 personnel are dedicated to designing, building, operating, and managing large-scale user facilities.

The large-scale user facility and advanced instrumentation capability is funded by SC (BER, BES) and NIH (National Center for Research Resources). This capability advances DOE's missions of scientific discovery and innovation (SC 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 24, 26), energy security (ES 8, 9), environmental management (EM 2, 3), national security (NNSA 2), and homeland security (HS 1, 3).

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

PNNL is located in Richland, WA with several offsite locations, including JGCRI, co-located on the University of Maryland campus. The main PNNL campus located at the north end of Richland consists of land owned by DOE, Battelle, and third parties. Utilities infrastructure is owned, operated, and maintained by DOE and the City of Richland. The facility profile comprises 101 buildings, including:

- 25 buildings owned by DOE (831,249 sq ft; average age of 23 years)
- 42 buildings owned by Battelle (404,941 sq ft; average age of 34 years)
- 34 buildings from third-party leases and agreements (1,034,902 sq ft; average age of 24 years).

All PNNL Hanford 300 Area buildings were transferred to the Hanford Site cleanup contractor during the second quarter of FY 2011, with the exception of the RPL (325 Building) and the 331, 318 (RCL), and 350 buildings, which will be retained for PNNL use until approximately 2026, in accordance with the Memorandum of Agreement between SC and EM.

PNNL's planned real estate actions during FY 2011 and FY 2012 consist of one 47,000 gsf lease, six lease renewals (over 10,000 sf each), and various GPP and Institutional General Plant Project (IGPP) facility actions. Site land use is described in the PNNL Master Campus Plan.[9] Table 2 includes the SC buildings and Hanford Site EM buildings totally occupied and maintained by PNNL. Asset Utilization Index values were calculated from Facility Information Management System data validated March 2011.

Table 1. PNNL's DOE-SC Owned and Operated Facilities and Infrastructure Data Summary

Replacement Plant Value		$428M
Total Deferred Maintenance		$8K
Asset Condition Index	Mission Critical	0.983
	Mission Dependent	0.967
	Non-mission Dependent	0.886
Asset Utilization Index	Office	91.50
	Warehouse	100.00
	Laboratory	95.10
	Housing	NA
Prior Year Maintenance (FY 2010)		$8.5M

Facilities and Infrastructure to Support Laboratory Missions

During FY 2010 and FY 2011, PNNL successfully addressed the first of the three main drivers of our facility and infrastructure strategy, with Phase I of the transition out of the Hanford Site 300 Area completed ahead of schedule and within budget. Significant portions of the biological systems, advanced nuclear science and technology, applied material science and engineering, and advanced computer science, visualization and data core capabilities were relocated from pre- and cold war-era buildings to new facilities. The four remaining 300 Area facilities were upgraded to extend their useful life to 2026.

The second major driver of our strategy is the continuing need to modernize the remaining facilities on PNNL's South Core Campus to support the expanding impact of the EMSL user program by increasing access to EMSL capabilities by external users, and support the increasing demand for our applied materials science and engineering, chemical engineering, and chemical and molecular sciences core capabilities that are central to our world-class science in catalysis.

Significant progress was made on this task in FY 2011 with the development and implementation of a detailed 5-year plan for campus modernization. This plan was driven by an analysis of the mission readiness of our core capabilities, particularly in facilities and infrastructure. The results of this analysis are shown in Appendix 3, which details the facilities and infrastructure mission readiness for all of our core capabilities, and Appendix 4, which shows the mission readiness of our support facilities and infrastructure.

While the PNNL facility footprint on the South Core Campus is well maintained and provides safe, secure, and reliable operations to research programs, the space is fully subscribed and facing increasing demands from programs that are strategically important to DOE and the nation. Moreover, this space has not kept pace with the changing face of science in the 21st century. In all buildings, collaboration space has fallen well below industry design standards as conference rooms and other office support space has been used to house staff. In addition, with the exception of EMSL

[9] http://facilities.pnl.gov/resources/fsp/PNNLCampusMasterPlan_0109.pdf

and parts of the newly constructed PSF, PNNL's non-radiological laboratory space was constructed during the mid-1960s and early 1970s and since that time research technology and operations have changed significantly. Original laboratory building designs now encumber research productivity and collaboration.

In some cases, functionality now common to scientific laboratory facilities, such as highly specialized vibrationally, electrically, and magnetically "quiet" laboratories for multi-modal imaging tools and modern synthetic chemistry laboratories, does not exist and cannot be retrofit into existing facilities. This affects our chemical and molecular sciences, chemical engineering and subsurface science core capabilities, as well as the *In Situ* Chemical Imaging and Analysis major initiative. The need for this highly specialized space, along with fume hood intensive synthesis laboratories, is driving our SLI request for the CSIL.

The third major driver of our facility strategy is the need to continue planning for Phase II of the 300 Area transition. With the completion of the Capability Replacement Laboratory (CRL) and 300 Area life extension projects, PNNL has 300,000 gsf of highly specialized radiological and nuclear laboratory space in the Hanford Site 300 Area that PNNL is expected to vacate no later than 2026. Given the magnitude of the challenge to provide modern, replacement laboratories to keep our core capabilities in applied nuclear science and technology, applied materials science and engineering, and subsurface science fully mission ready, pre-CD-0 planning has begun for Phase II of this transition. Given the highly specialized, high-hazard class nature of these laboratories, the Laboratory expects these replacement facilities to be federally funded and sited on federal lands.

In the following section the Laboratory will describe in detail some of the actions PNNL has already taken to address the two remaining drivers of the facility strategy, and outline what the Laboratory needs from DOE in order to keep the core capabilities mission ready, achieve the Laboratory's scientific vision for future, and solve problems in energy, the environment, and national and homeland security critical to DOE and the nation. PNNL's assessment process to identify facility and infrastructure needs and set strategy was first peer reviewed in 2009. At our request, individuals from Ames' and ORNL's research and facility management communities conducted a follow-up review. They concluded our process had matured and contained elements they deemed best practices that may be applicable to the entire family of National Laboratories.

Strategic Site Investments

PNNL is committed to keeping its core capabilities mission ready. The Laboratory has been successful, in part, in responding to the increasing demand for these capabilities by programs of strategic importance to DOE and the nation by aggressively and comprehensively managing our costs. In turn, this has enabled strategic investments to optimize current facilities and provide new, modern laboratory facilities to enable scientific excellence in the 21st century.

- Campus Modernization. Three efforts are essential to PNNL's campus modernization efforts. The first is critically examining our existing facilities and making the investments necessary to increase the efficient and effective use of the laboratory space in high demand. A detailed examination of PNNL's office and laboratory buildings identified the opportunity, with some investment, to increase office utilization by 5% and laboratory utilization by 10%. In the four laboratory buildings with the chemistry, radiochemistry, and radiological laboratories that are in greatest demand—RCL, RPL, PSL, and RTL—a series of PNNL-funded expense, IGPP, and Battelle capital projects are underway that will recover approximately 50 laboratory work stations. PNNL has tripled its annual IGPP budget to support modernization; an increase that would not have been possible without aggressive management of costs (see Section 8.0). Most of these optimization projects primarily benefit the applied material science and engineering, subsurface science, and applied nuclear science and technology core capabilities. The RCL and RPL projects will address a portion of the Transform Situational Awareness through Signature Discovery and Exploitation major initiative resource requirements.

  Using our existing space more efficiently, however, addresses only a small portion of the programmatic demand for specialized laboratory space. A review of ongoing projects did not identify any space that could be reprogrammed to provide this specialized laboratory space without adversely affecting programs of strategic importance to DOE or the nation. Consequently, the second major effort is focused on the acquisition of space to support the expanding impact of the EMSL User Program and provide sufficient swing space to upgrade and modernize our existing laboratory facilities in the South Core Campus. PNNL has identified the Life Sciences Laboratory II (LSL-II) facility, a Battelle-owned facility on the South Core Campus that is available for this purpose. Battelle and DOE are working to define the appropriate mechanism to allow PNNL full use of this facility.

Access to LSL-II immediately provides approximately 10,000 nsf of biology laboratories and hood capacity which reconfigured can accommodate part of the catalysis programs using the chemical and molecular sciences capability that would be relocated from EMSL. As additional LSL-II space is made available in FY 2014 it would also be reconfigured into chemistry and instrumentation laboratories to create the surge space for modernizing the remaining South Campus.

The third and most important major effort is the construction of the CSIL facility to provide the specialized isolation and chemical synthesis space critical to achieving PNNL's scientific vision for the future. This vision requires interdisciplinary and collaborative teams of world-class scientists and engineers working in modern state-of-the-art research facilities specifically designed for science in the 21st century. The CSIL will provide mission-critical space, including:

- Dedicated, modern, electromagnetic force, acoustic-, and vibration-isolated (*i.e.*, quiet space) special purpose laboratories for state-of-the-art imaging and analytical capabilities. This space would provide isolation from noise that can negatively impact the performance of new-generation imaging instruments (*e.g.*, aberration-corrected TEMs; in situ scanning-probe microscopes; other atom or nanometer-scaled probes for tomographic or structural determinations).

- Centralized modern fume-hood-intensive, wet chemistry space for fine molecular chemical synthesis and nano-phase materials synthesis.

- Adaptable, high-ceiling, high-clearance space for large scientific instruments (NMRs, chemical physics) and bench-scale chemical reactors for chemical engineering.

The new construction enables PNNL to accelerate research in catalysis science and emissions engineering by combining research and facility capabilities that focus on making, measuring, observing, and modeling new materials for clean energy production. Many core capabilities will benefit, as will several major initiatives, including Controlling Complex Interactions across Scales to Enable Scalable Synthesis, *In Situ* Chemical Imaging and Analysis, and Subsurface Science for Geological Sequestration of Greenhouse Gases and Environmental Remediation.

The challenge is that the CSIL, originally scheduled for construction starting in 2013 as an SLI line item, has now slipped to 2016. This schedule does not support the mission readiness needs of our core capabilities or the achievement of our scientific vision, and PNNL is working with DOE to address this.

In summary, as a result of our aggressive prioritization of work and optimization of our existing space—enabled by the Laboratory's disciplined cost control efforts—PNNL is fully utilizing its facility functional capabilities. However, the construction of CSIL and access to the LSL-II facility are essential to the continued modernization of the PNNL campus. Without these facilities the gap between facility functionality and the demands of our modern research enterprise will continue to grow.

- <u>300 Area Transition – Phase II</u>. This year, Phase I of PNNL's transition out of the Hanford Site's 300 Area was accomplished with the completion of the CRL and 300 Area facility life extension projects. This leaves 300,000 gsf of highly specialized radiological and nuclear laboratory space in the 300 Area that PNNL is expected to vacate no later than 2026. Given the magnitude of the challenge to provide modern replacement laboratories to keep our core capabilities in applied nuclear science and technology, applied materials science and engineering, and subsurface science fully mission ready, pre-CD-0 planning has begun for Phase II of this transition. Given the highly specialized, high hazard class nature of these laboratories, PNNL expects these replacement facilities to be federally funded and sited on federal lands.

Trends and Metrics

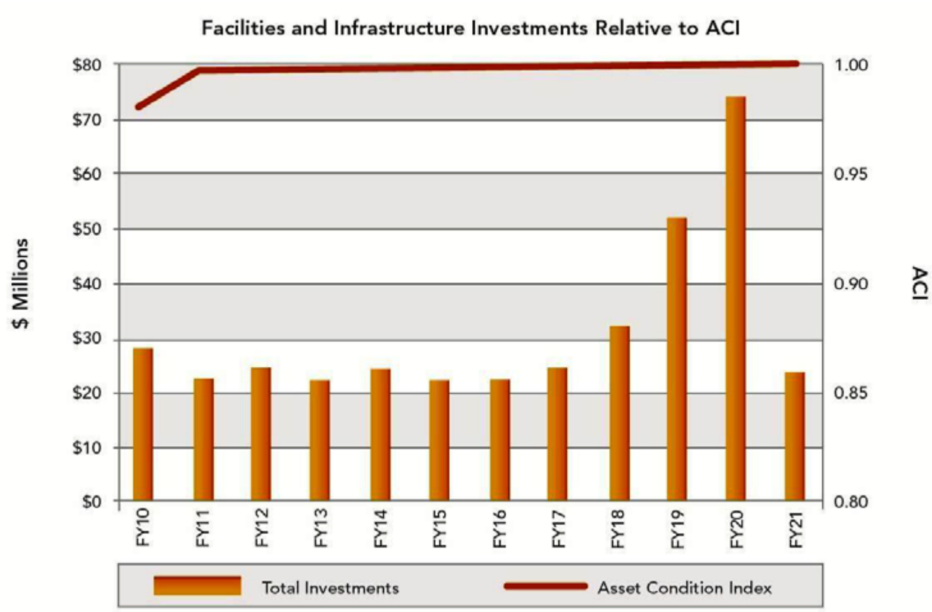
PNNL's Mission Readiness Assessment Process is fully implemented. Within that process, the PNNL facility and infrastructure maintenance program has been cited as a strength in both peer review and DOE maintenance program assessments. Investment planning for this program combines component-based maintenance forecasting with real-time condition inspection and performance data to maintain facilities and infrastructure across their life cycle, minimizing deferred maintenance and operating with a high degree of reliability. The maintenance approach is consistent across the SC, EM, and Battelle-owned buildings PNNL occupies

The CRL project facilities and building life extension investments and planned maintenance and renewal will continue to keep deferred maintenance manageable. From a maintenance perspective, the facility and infrastructure condition is fully able to support PNNL's core capabilities. The asset condition index for PNNL SC owned and operated retained facilities and infrastructure remains at 1.0 (excellent) through the planning period. Planned levels of investment are shown in Table 3 and Figure 2.

Table 2. PNNL's SC Owned and Operated Facilities and Infrastructure Investments ($M) – Impact to Asset Condition Index

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	8.5	7.8	8.6	8.5	9.5	8.7	9.3	9.2	8.2	7.3	9.1	9.0
Deferred Maintenance Reduction	0	0	0	0	0	0	0	0	0	0	0	0
Excess Facility Deposition	0	0	0	0	0	0	0	0	0	0	0	0
IGPP	5.0	13.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
GPP	3.2	2.8	1.5									
Line Item	11.7							1.0	10.0	30.0	50.0	0.5
Total Investment	**28.4**	**23.6**	**25.1**	**23.5**	**24.5**	**23.7**	**24.3**	**25.2**	**33.2**	**52.3**	**74.1**	**24.5**
Estimated Replacement Value	428.5	379.1	388.5	398.3	408.3	418.5	428.9	439.7	450.7	461.9	473.5	485.3
Estimated Deferred Maintenance	8	1.6	1.3	1.2	1	0.8	0.7	0.6	0.5	0.4	0.4	0.3
Asset Condition Index	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 1. PNNL's Facilities and Infrastructure Investments



Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		Mission Ready				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
		N	M	P	C			Laboratory	DOE
Chemical and Molecular Sciences	Now		X			EMSL, PSL	The EMSL large instrumentation and chemical synthesis laboratory space is fully subscribed, chemical and molecular sciences capabilities less aligned to EMSL User Program need to be relocated outside EMSL to address overcrowding. PSL building design cannot support chemical and molecular sciences' need for hood-intensive, chemical synthesis laboratories or vibration and EMF-isolated imaging suites. Dated laboratory layouts and fixed casework limit research productivity and make housing analytical equipment a challenge. Even under these conditions, PSL is fully subscribed hampering renewal. Approximately 18,000 nsf of vacated contiguous space is needed to accommodate the renewal construction work. A completed FY 2010 laboratory optimization study identified several stop-gap actions to help accommodate ongoing work.	Near term, individual optimization projects are underway to increase utilization of existing laboratories. The available on-campus Battelle-owned LSL-II and BIL buildings are being acquired and modified to provide additional hood-intense, chemical synthesis laboratory space. Chemical and molecular sciences catalysis activities will be relocated from EMSL and PSL to LSL-II and BIL. Long term, PSL will be upgraded for energy conversion activities. Projects: Various optimization; LSL-II renovation-multiyear; reconfigure BIL; PSL renovation-multiyear.	Construct 140,000 gsf to provide chemical synthesis and imaging laboratories adjacent to materials and process development efforts. This facility is envisioned configured to bring science and applied core capabilities together to create clean energy sources. Project: CSIL line item.
	In 5 Years		X						
	In 10 Years				X				
Climate Change Science	Now				X	AML, JGCRI, ACRF, MSL	With the continued growth of the JGCRI, it is anticipated that additional leased space will be needed within the next 3 years to mitigate predicted overcrowding. A new hanger is needed for the Atmospheric Radiation Measurement Aerial Facility, including the G-1 aircraft as well as office space to house aircraft personnel. Additional mid-scale computing resources are needed to support regional and global climate and Earthy system modeling activities. Upgrading AML interior	Bids are currently being evaluated for the new aircraft hangar, which needs to be located at an airport with a runway greater than 5,000 feet in length and within 30 miles of main PNNL campus in Richland, WA, with a desired occupancy date of December 2011; Requirements for additional mid-scale computing resources are currently being evaluated.	Design and implement a plan to build a National Atmospheric Laboratory Facility for studying cloud and aerosol processes, a programmatic facility need recognized by DOE's Atmospheric Systems Research program that PNNL is uniquely qualified to fill.
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		Mission Ready				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
		N	M	P	C			Laboratory	DOE
							finishes and securing additional office space for atmospheric sciences & global change personnel in Richland would also be desirable.		
Biological Systems Science	Now				X	BSEL, BSF, EMSL, CSF, MSL	With the exception of off-campus MSL, all facilities are newly constructed or fully functional and are fully subscribed. By agreement with WSU, PNNL's BSEL footprint is limited. Radioactive dispersible material work requires more space.	Project: 331 Building Filter Exhaust; Aquatic laboratory upgrades.	
	In 5 Years				X				
	In 10 Years				X				
Environmental Subsurface Science	Now			X		331, MSL, PSL, Sigma 5, RTL, EMSL	In general existing space meets functional needs, though staff and equipment could be better located to enhance collaboration.	Upgrades to the leased Sigma 5 building will provide material synthesis and scale-up laboratories to meet the near-term need. Projects: Sigma 5 Laboratory Upgrade.	Construct 140,000 gsf to provide materials synthesis and scale-up demonstration laboratories adjacent to fundamental science efforts. This facility is envisioned to bring science and applied core capabilities together to create clean energy sources. Project: CSIL line item.
	In 5 Years			X					
	In 10 Years				X				
Advanced Computer Science, Visualization and Data	Now				X	CSF	Classified and unclassified computer technology and computational staff count and equipment inventory continue to grow out pacing available CSF space and facility/site infrastructure.	EMSL and CSF infrastructure upgrades will allow for full utilization of computational space. Additional classified office and laboratory space is being acquired through building leases. Projects: PNNL/EMSL South Electrical Power Addition; CSF Data Center Infrastructure, Optical Fiber Network Upgrades.	
	In 5 Years			X					
	In 10 Years			X					

Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		**Mission Ready**				**Key Buildings**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N	**M**	**P**	**C**			**Laboratory**	**DOE**
Applied Nuclear Science and Technology	Now			X		318, 325, PSF	The newly constructed PSL and the 300 Area 318 and 325 buildings are fully functional. Additional radiochemistry and sensor development laboratories are required to address anticipated rapid growth in signature science. Additionally a small part of this core capability is located in an off-campus leased office and instrumentation development laboratory facility. Efficiencies and collaborative opportunities can be gained by locating this core capability on the PNNL campus. Note: though replacement of the 325 CAT II facility is outside of the 10-year planning period, the planning for replacement needs to begin.	Various upgrades to 325 Building laboratory configurations and capabilities are needed to fully enable this core capability in the near term. Additional PSF office space will be provided through staff relocations. Longer term, it will be necessary to replace off-campus leased space, 2400 Stevens. Projects: Various 325 laboratory optimization projects; off-load of ISB2 to office PSF overflow.	Provide swing space to renovate on-campus facilities to replace off-campus leased 2400 Stevens Building. Projects: Out year 300 Area Phase II Capability Replacement.
	In 5 Years			X					
	In 10 Years			X					
Applied Material Science and Engineering	Now		X			PSF, RTL, APEL, PSL EMSL	PSF and EMSL are fully functional and fully subscribed. The availability of space and building utility systems has limited the use of PSL and RTL. APEL is a Port of Benton incubator facility remote from the PNNL campus in which PNNL leases a limited amount (amount is limited by written agreement) of materials development and high ceiling process development laboratory and office space. Hood capacity in APEL is limited.	The additional optimization projects will relocate several PSL and RTL research organizations to improve adjacencies. Longer term, it will be necessary to replace off-campus leased APEL space. Projects: Various PSL, RTL, and APEL laboratory optimization projects.	Provide swing space to renovate on-campus facilities to replace off-campus leased APEL. Projects: CSIL line item.
	In 5 Years		X						
	In 10 Years				X				
Chemical Engineering	Now			X		BSEL, PSL, RPL, APEL	BSEL, the relatively new WSU joint-partner facility, is fully functional for its use. APEL is a Port of Benton incubator	The additional optimization projects will relocate several PSL and RTL research organizations to	Complete 140,000 gsf new construction to provide process engineering laboratories and high
	In 5 Years			X					

Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		**Mission Ready**				**Key Buildings**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N	**M**	**P**	**C**			**Laboratory**	**DOE**
	In 10 Years				X		facility remote from the PNNL campus in which PNNL leases a limited amount of chemistry, high ceiling process development, and office space. APEL hood capacity is limited. Chemical engineering activities housed in PSL face the same challenges as others in adequate hood capacity, dated and inflexible laboratory configurations.	improve adjacencies. Longer term, it will be necessary to replace off-campus leased APEL space. Projects: Various laboratory optimization projects.	bay space adjacent to fundamental science effort. This facility is envisioned configured to bring science and applied core capabilities together to create clean energy sources. Project: CSIL line item.
Systems Engineering and Integration	Now			X		PSF, Math	The newly constructed PSF provides replacement laboratories supporting radiation portal monitoring activities. The Math Building which houses systems engineering and integration computational and visualization laboratories may require building utility system upgrades in cooling, and humidity control. Multiple on-campus and off-campus leased facilities house required instrument development laboratories, and classified office and laboratory space. Efficiencies and collaborative opportunities can be gained by locating this core capability on the PNNL campus.	Math Building infrastructure is being upgraded to address cooling and humidity control issues. Lease acquisitions are addressing the need for expanded classified and non-classified office, computational space, and classified instrument development space. Longer term, it will be necessary to replace off-campus leased space, 2400 Stevens. Projects: Math Infrastructure Upgrade.	Expand EIOC to NEIOC; Programmatic NEIOC Line, provide swing space to renovate on-campus facilities to replace off-campus leased 2400 Stevens Project: Programmatic NEIOC, CSIL line item.
	In 5 Years				X				
	In 10 Years				X				

Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		Mission Ready				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
		N	M	P	C			Laboratory	DOE
Large-Scale User Facilities/ Advanced Instrumentation	Now			X		EMSL, ACRF	The EMSL unique large instrumentation and chemical synthesis laboratory space is fully functional and fully subscribed. Estimates are approximately 13,000 nsf of laboratory space is needed to address current overcrowding. Planned expansion in computational capacity will require increased electrical power and cooling, and additional high-end analytical equipment requires vibration- and EMF-isolated laboratories. EMSL user program is also pursuing the ability to work with radiological materials.	Programmatic GPP will provide specialty laboratory space. The on-campus Battelle owned LSL-II building will be acquired and modified to provide additional hood-intense, chemical synthesis laboratory space to support relocation of programs less aligned to the EMSL User Program. Projects: Ultra Sensitive Equipment Capability, Radiological Capability; PNNL/EMSL South Electrical Power Addition; LSL-II and RTL modifications	Continued growth in the EMSL program would drive the need for an EMSL North Laboratory and Office Pod. Project: EMSL North Pod Expansion.
	In 5 Years				X				
	In 10 Years				X				

325 Building	=	**Radiochemical Processing Laboratory**	gsf	=	gross square feet
AML	=	**Atmospheric Measurements Laboratory**	JGCRI	=	Joint Global Change Research Institute
APEL	=	**Applied Process Engineering Laboratory**	LSL-II	=	Life Sciences Laboratory II
ACRF	=	**Atmospheric Radiation Measurement Climate Research Facility**	M	=	marginal
BIL	=	**Battelle Inhalation Laboratory**	MSL	=	Marine Sciences Laboratory
BSEL	=	**Bioproducts, Sciences, and Engineering Laboratory**	N	=	not
BSF	=	**Biological Sciences Facility**	NEIOC	=	National Electricity Infrastructure Operations Center
C	=	**capable**	nsf	=	net square feet
CSF	=	**Computational Sciences Facility**	P	=	partial
CSIL	=	**Chemical Sciences and Imaging Laboratory**	PSF	=	Physical Sciences Facility
DOE	=	**U.S. Department of Energy**	PSL	=	Physical Sciences Laboratory
EIOC	=	**Electricity Infrastructure Operations Center**	RPL	=	Radiochemical Processing Laboratory (325 Building)
EMF	=	**electromagnetic field**	RTL	=	Research Technology Laboratory
EMSL	=	**Environmental Molecular Sciences Laboratory**	TYSP	=	Ten-Year Site Plan
GPP	=	**general plant project**	WSU	=	Washington State University

Support Facilities and Infrastructure							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
	N	M	P	C		Laboratory	DOE

Work Environment			X		Various on-site amenities are inadequate including conferencing and food center, and fitness center. A lack of storage facilities result in not-in-use materials and equipment stored in offices and laboratories.	Laboratory Collaboration Center (cafeteria, visitor center, fitness)	
User Accommodations			X		Various on-site amenities are inadequate, including conferencing and food center, and fitness center.		
Site Services			X		Maintenance and fabrication facilities are in a poor condition and/or location. These facilities are over-subscribed.	Central Operations Building, Central Machine Shop	
Conference and Collaboration Space			X		Amount of co-laboratory space is below industry standards. On-site conferencing space is less than required.	EMSL Conference Room Addition, PSF Conferencing Center	
Utilities			X		A limited amount of compliance-driven upgrades to water system back flow preventors is required. An increase in the reliability of electrical distribution system, and a decrease in energy and water usage are required.	BMI-funded backflow preventor installation; EMSL Electrical Infrastructure Upgrade (city of Richland); leased facility energy upgrades, DOE-owned facility and energy upgrades	
Roads and Grounds			X		General end-of-life issues	Various road and grounds projects (BMI)	
Security Infrastructure			X		Security operations are transferring to PNNL from an outside provider. To meet future needs, a new security operation building is envisioned to house equipment and operations.	Central Security Operations	

NOTE: Current plans address technical facilities and infrastructure ahead of the support facilities.

BMI = Battelle Memorial Institute	M = marginal
C = capable	N = not
DOE = U.S. Department of Energy	P = partial
EMSL = Environmental Molecular Sciences Laboratory	PNNL = Pacific Northwest National Laboratory
	PSF = Physical Sciences Facility

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Princeton Plasma Pbysics Laboratory

Mission and Overview

The Princeton Plasma Physics Laboratory is a collaborative national center for plasma and fusion energy sciences. It is the only Department of Energy laboratory devoted to these areas and it is committed to being the leading U.S. institution investigating the science of magnetic fusion energy.

PPPL has two coupled missions. First, PPPL develops the scientific knowledge to realize fusion energy as a clean, safe, and abundant energy source for all nations. Plasma is a hot, ionized gas that under appropriate conditions of temperature, density, and confinement produces fusion energy. PPPL has been a leader in developing the physics of high temperature plasmas needed for fusion. PPPL will continue to solve plasma physics problems crucial to fusion energy, as well as contribute to solutions of key engineering science challenges associated with the material structure that surrounds the hot plasma. The second mission is to develop plasma science over its broad range of physics challenges and applications. Modern plasma physics began with the advent of the world fusion program, and continues to lead to new discoveries in the nonlinear dynamics of this complex state of matter. The vast applications range from scientific (e.g., plasmas in the cosmos) to technological (e.g., plasma-aided manufacturing).

For over five decades PPPL has been a leader in magnetic confinement experiments and theory. PPPL is a partner in the U.S. Contributions to the ITER Project and leads multi-institutional collaborative work on the National Spherical Torus Experiment. The Laboratory hosts smaller experimental facilities used by multi-institutional research teams and collaborates strongly by sending scientists, engineers and specialized equipment to other fusion research facilities in the U.S. and abroad. To support these activities, the Laboratory maintains nationally leading programs in plasma theory and computation, plasma science and technology, and graduate education.

Current Core Capabilities

The following core scientific and engineering capabilities enable PPPL to make major progress in support of the DOE Office of Fusion Energy Science's mission to develop the knowledge base for fusion energy and high temperature plasmas. These capabilities also provide the scientific training ground for Princeton University's Graduate Program in Plasma Physics, ranked one highest in the nation in plasma physics, providing leaders who will

Lab-at-a-Glance

Location: Princeton, New Jersey

Type: Single-program Laboratory

Contract Operator: Princeton University

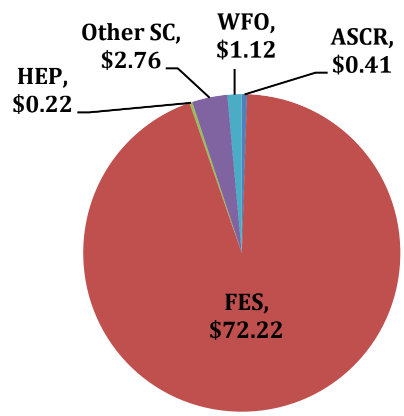
Responsible Field Office: Princeton Site Office

Website: http://www.pppl.gov/

Physical Assets:
- 88.5 acres; 34 buildings
- 754K GSF in Active Operational Buildings
- Replacement Plant Value: $339M
- Deferred Maintenance: $7.3M
- Asset Condition Index:
  - Mission Critical: good
  - Mission Dependent: good
  - Asset Utilization Index: excellent

Human Capital:
- 436 Full Time Equivalent Employees (FTEs)
- 4 Joint Faculty
- 15 Postdoctoral Researchers
- 38 Graduate Students
- 0 Undergraduate Students
- 0 Facility Users
- 250 Visiting Scientists

FY 2010 DOE Funding by Source *(Cost Data in $M)*:



FY 2010 Total Lab Operating Cost (excluding ARRA): $76.7
FY2010 Total DOE/NNSA Funding: $75.6
FY2010WFO (Non-DOE/Non DHS) Funding: $1.1
FY2010WFO as % Total Lab Operating Costs: 1.5%
FY2010 Total DHS Funding: $0

ARRA Obligated From DOE Sources in FY2010: $4.7
ARRA Costed from DOE Sources in FY2010: $7.05

sustain plasma physics and fusion energy science research into the future.

1. Plasma and Fusion Energy Sciences

PPPL has unique and world-leading experimental and theoretical capabilities and facilities to explore the physical processes that take place within the high-temperature, high-pressure plasmas required for fusion energy. Areas of special strength include the National Spherical Torus Experiment (NSTX), the Lithium Tokamak Experiment (LTX), high-resolution techniques to measure plasma properties and processes at a wide range of space and time scales, extremely powerful capabilities for plasma heating and current drive, capabilities for analysis of data from high-temperature plasmas used by experimental teams around the world, expertise in a wide range of magnetic confinement configurations, world-leading basic plasma experimental facilities such as the Magnetic Reconnection Experiment (MRX), and premier analytic theory capabilities that are internationally recognized as a continuing source of seminal ideas and mathematical foundations for plasma physics and fusion energy science.

PPPL has unique and world-leading computational capabilities to study and accelerate progress in understanding the physics of high temperature and burning plasmas (e.g., ITER), including small-scale plasma turbulence and associated plasma transport, nonlinear extended magnetohydrodynamics of larger scale plasma equilibria and motions, and wave-plasma interactions including the heating of the plasma and the fusion-product induced instabilities possibly present in ITER, the international burning plasma experiment. PPPL leads in advanced algorithmic development to enable efficient utilization of DOE-SC's leadership-class computing facilities for fusion research. This is required to validate physics-based predictive models against existing experiments, to apply validated integrated models to help guide the operation of ITER, and to investigate the innovations required for the successful development of fusion energy. PPPL is currently leading a national effort, the Fusion Simulation Program, to define a program for developing an experimentally – validated predictive model of fusion plasmas.

2. Large Scale User Facilities/Advanced Instrumentation

PPPL has unique and world-leading engineering capabilities in the areas of plasma measurement, heating, and current drive system design and construction; safe and environmentally benign facility operation including the use of tritium fuel; and specialized fusion confinement facility design and construction. These engineering strengths together with an enormously capable site for fusion research in the U.S., which include shielded test cells for fusion facilities, high-current power supplies, extensive cryogenic facilities, and a readily-upgradeable modern, high-speed broad-band (10 Gb/s) network together support operation of NSTX, aid the development and testing of components for ITER, and enable collaborations on major national and international fusion research facilities. In partnership with ORNL and Savannah River, PPPL manages the U.S. role in ITER diagnostics and the ITER steady state electric network. A PPPL engineer is on assignment to manage the U.S. role in ITER magnets and one of PPPL's senior scientist is serving as the Deputy Director General and Director of the ITER Administration Department for the international organization. These capabilities provide a flexible, capable location for possible next-step U.S. fusion research facilities.

PPPL is internationally recognized as a pioneer in the development and implementation of fusion plasma diagnostics. It has provided diagnostics as well as the supporting expertise to many fusion programs around the world. Over the years, many new techniques were developed at PPPL, often in collaboration with other U.S. institutions. PPPL's seminal contributions have been particularly strong in techniques to measure in detail the profile of the plasma parameters (density, temperature, current density, and rotation), fluctuation diagnostics to measure the underlying instabilities and turbulence responsible for plasma transport, and measurements of both the confined and lost alpha-particles produced by fusion reactions. PPPL has a long-standing, active collaboration program providing diagnostics to fusion programs around the world (currently JET, JT-60, LHD, C-Mod, DIII-D, EAST, and KSTAR). In partnership with ORNL on the U.S. ITER Project, PPPL manages the U.S. role in ITER diagnostics.

Science Strategy for the Future / Major Activities

PPPL has a dual mission to enable fusion energy for the world and to lead discoveries across the broad frontier of plasma science and technology. There is a rapidly increasing imperative to develop clean, plentiful, and safe fusion energy. PPPL plans to provide solutions to the key physics and engineering challenges of fusion, in collaboration with laboratories worldwide. The understanding of plasma has huge consequences to neighboring sciences (such as understanding the visible cosmos, mostly composed of plasma) and to technological applications (from plasma-aided manufacturing to rocket thrusters).

PPPL focuses on magnetic fusion energy in which the hot fusion plasma is confined magnetically. PPPL is developing the compact, high pressure (relative to magnetic pressure) approach known as the spherical tokamak (ST), through its major collaborative facility, the National Spherical Torus Experiment. The ST is an attractive candidate for a next step fusion nuclear facility in the US and ideal for attacking key problems, including those related to the plasma-material interface and confinement of high (normalized) pressure plasmas. PPPL participates in the design and preparation for ITER – the international fusion experiment, based on the standard tokamak design that will generate 500 MW of fusion power. A lab-wide program is exploring novel solutions to the plasma-material interface problem, such as the use of a liquid wall. PPPL aims to enter the new era of integrated modeling using the most advanced computers to understand the full fusion plasma system, building on a current national planning activity. New 3D designs for fusion systems are under study – with modern computation physicists can devise new, remarkable configurations that confine hot plasmas in steady state with reliability. Looking forward to the frontier of fusion-producing plasmas, PPPL is performing scoping studies of a potential next step in which abundant fusion power and neutrons are produced in an integrated facility. Beyond fusion, PPPL performs research to understand how plasma processes determine the behavior of major astronomical objects, and aims to form a center of excellence in this area, jointly with the Princeton University Department of Astrophysical Sciences. PPPL will enhance its contributions to plasma science and applications generally, building on current programs that range from ion beam research for inertial fusion energy to plasma rocket thrusters. PPPL conducts an expansive education program, including activities for middle and high school students, research activities for undergraduates, research and training experiences for middle and high school teachers, and operation of the Princeton University graduate program in plasma physics.

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

Princeton Plasma Physics Laboratory is located on 88.5 acres within the Princeton University Forrestal Campus. The 1,750-acre campus is punctuated by dense woods, brooks and nearby streams; almost 500 acres remain in their natural state in order to protect and enhance the character of the campus. The Laboratory setting provides an attractive environment to conduct research, appropriately separated from its neighbors. The PPPL Environmental Management System provides a comprehensive approach for controlling PPPL activities in a manner that minimizes negative impacts to the environment.

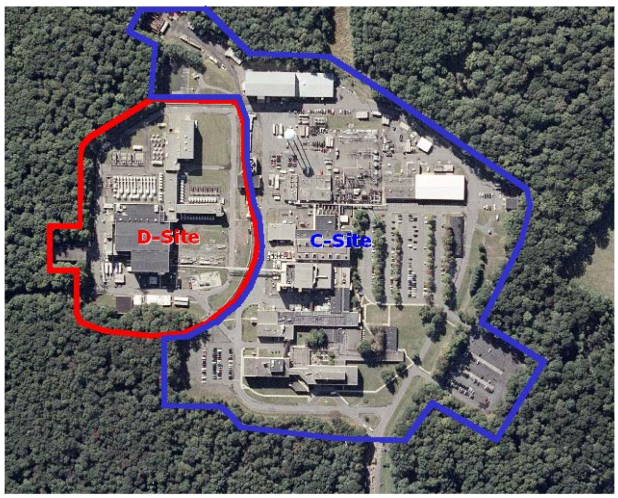
The Laboratory utilizes 754,196 gross square feet of space in 33 Government-owned buildings located on "C" and "D" sites [see Figure 1] and one offsite (pump house). There are currently no leased buildings or facilities and no plans to enter into any lease agreements. The Total Replacement Value (RPV) of all PPPL facilities and infrastructure is ~$498M. Non-Programmatic RPV (used for calculating indices) is ~$339M. The overall Asset Utilization Index (AUI) is .998 ("excellent") and the overall Asset Condition Index (ACI) is .973 ("good"). Funding of facility maintenance, the Maintenance Investment Index (MII), is based on a calculation of 2% of the FY08 Replacement Value. The Laboratory has agreed to contribute an additional $300K of overhead funds through FY11 for accelerated deferred maintenance reduction. The PPPL maintenance budget for FY11 is approximately $6.3M.

Table 1. SC Infrastructure Data Summary

Replacement Plant Value ($M)*		$339
Total Deferred Maintenance ($M)		$7.3
Asset Condition Index	Mission Critical	0.97
	Mission Dependent	0.93
	Non-Mission Dependent	N/A
Asset Utilization Index	Office	100
	Warehouse	100
	Laboratory	100
	Housing / Other	99.3
Prior Year Maintenance ($M)		$6.3

* This is the RPV value used for calculating indices. It excludes category 3000 facilities. Total RPV is $498M.

Figure 1. PPPL C and D Sites



Facilities and Infrastructure to Support Laboratory Missions - Mission Readiness

PPPL has a comprehensive plan that will result in a thoroughly modern facility to support world-class research. It addresses how real property assets will support and implement the objectives of the Department of Energy Strategic Plan, the Energy Policy Act, the American Competitiveness Initiative, and the DOE Office of Science report "Facilities for the Future: A Twenty-Year Outlook." This approach specifically supports the initiatives described in the Science Strategy. Planning is developed in accordance with the Real Property Asset Management Order, DOE 0 430.1B and the DOE-SC objective of integrating land use, facilities and infrastructure acquisition, maintenance, recapitalization, safety and security, and disposition plans into a comprehensive site-wide management plan.

The goal of the PPPL plan is to cost-effectively improve the capacity, maintenance, and operations of the Laboratory in order to provide first class facilities that enable world-leading science and support the science initiatives. The plan is implemented by establishing and following strategic priorities in the conduct of maintenance, facility modifications, closure of unneeded facilities, and construction of new facilities.

While the size of the PPPL site is adequate for current and anticipated future needs, present facilities are marginally adequate and impede rapid progress. In the near term, PPPL staff size will remain relatively unchanged and the number of onsite collaborators is expected to grow modestly if PPPL succeeds in beginning work on the new initiatives and the ITER work under WFO. However, even with a staff of constant size, there is a strong current need to modernize and replace outdated facilities. The focus of the facilities planning must, and has been, on the refurbishment, modernization, and conversion of several existing buildings so that PPPL can provide facilities that are suited to current and planned R&D activities.

In recent years, additional funding has been directed toward reducing maintenance backlogs with substantial success. In addition, the Laboratory has utilized ARRA funds to significantly improve its electrical distribution which directly supports the existing and future project (activities described later). However, this approach does not result in the development of infrastructure that is needed to support the world-leading initiatives of the future and attract scientists and engineers.

Two key Science Laboratory Infrastructure (SLI) projects will allow PPPL to appropriately modernize its facilities to support mission lines. The first project will entail construction of a new Science and Technology Center, rehabilitate and convert the existing Laboratory and C-Site MG Buildings, and demolish other outdated inefficient buildings. This project will begin in FY13 and be completed in FY16. Funding of the SLI beginning in FY13 is necessary to modernize facilities to enable critical science missions and allow PPPL to meet infrastructure goals.

PPPL's SLI Mission aligns with the DOE Strategic Plan, the Office of Fusion Energy Sciences (OFES) four high level goals, and the initiatives described in the Science Strategy section of this document.

PPPL has fully implemented the Mission Readiness Process and successfully completed the Mission Readiness PEER Review. The Laboratory uses the Capitol Asset Management Process (CAMP) developed by DOE to rank both Capital, and Operationally funded improvements. This process ensures that a systematic approach is used in the allocation of funds and execution of projects. Projects are ranked based on their risk and the benefit they provide to the Laboratory Mission. In 2010 PPPL fully implemented the Mission Readiness Process and completed the mandatory review of the implementation. It was noted that PPPL had a fully mature process with several notable best practices including the use of the TRC Committee which ensures complete laboratory representation in Facility project planning.

The "Mission Readiness" Table (Attachment 1) provides a list of PPPL's core capabilities, broken down into major categories of research and development activities, along with the facility and infrastructure plans that will appropriately support those capabilities. This table summarizes a process that assesses building and facility conditions and links the results to the critical business lines and determines the mission readiness of those facilities. The facility improvement plans, which include the two SLI projects mentioned above, are designed to ensure the mission readiness is attained to fully support the core capabilities as needed. Details of the first SLI projects are discussed under the Strategic Site Investments section.

Strategic Site Investments

The scope and priority of the PPPL site investment strategy is consistent with the IFI crosscut budget submission and the Twenty Year Outlook. A site map that depicts the major changes for the strategic investment plans is attached along with a listing of PPPL buildings names (Attachment 2).

The highest priority facilities and infrastructure project is the SLI Project for Construction of Science and Technology Support Infrastructure. This project consists of: construction of a new Science and Technology building; conversion of the Lab Building into modern offices; conversion of the C-Site MG building into a machine shop; and demolition of the Theory Building, Modular Building 6, and a portion of the Administration Building. These objectives will be carefully staged in the most efficient manner so that work disruptions and moves will be minimized.

- <u>Programmatic Justification for the Science and Technology Support Infrastructure</u>. PPPL requires modern facilities to maintain leadership in fusion science and technology and support the science strategy initiatives in the following areas.
  - Fusion materials – Molten metal experiments
  - Laboratory plasma astrophysics – Magnetic reconnection/accretion physics
  - High energy density plasma physics – Heavy ion beams
  - Plasma processing of materials – Nano-phase materials
  - Education – Scientists and engineers

- <u>SLI Projects</u>. The new PPPL Science and Technology Center will be a modern laboratory structure that will house the research devices (current and future) operated by the Plasma Science and Technology Division, which will be relocated from the outdated, crowded, and inefficient 50 year-old Laboratory Building. The building will provide experimental areas as well as research, laboratory, office, classroom and collaboration space. Flexible experimental research bays will be provided with adequate power, ventilation, overhead crane, and necessary amenities to facilitate safe and efficient operation, maintenance, repairs, and modifications to research devices. Researchers, post-doctoral students, and graduate students will be located in offices that have close and safe proximity to their research devices. The building configuration and area layouts are designed to stimulate active collaboration and encourage sharing of ideas among experimentalists working on different devices.

The total estimated cost of the SLI projects (combined CD 0 approved by the Office of Science in FY10) is $53-$59 million. These projects will modernize nearly 20% of the PPPL facility and will reduce maintenance, deferred maintenance and operating costs. The average age of PPPL facilities will be reduced by 8 years, and the deferred maintenance backlog will be reduced by $2.2 million. In addition, the PPPL energy use profile will be reduced by 12%; over 100,000 gsf will be rehabilitated; and ongoing maintenance costs will be reduced by 6% ($280,000/year). The cumulative savings in overhead costs due to the reduction in energy and maintenance costs over a ten-year period is estimated at $5.8 million. The cumulative effect will be to reduce deferred maintenance to meet and exceed DOE-SC goals; resulting in a PPPL ACI of .99.

The projects are being conducted in accordance with the project management requirements of DOE O413.3B, *Program and Project Management for the Acquisition of Capital Assets*, and all appropriate project management requirements. New construction and major renovations will be performed in accordance with LEED Gold certification standards. Major renovations will incorporate the Guiding Principles for high performance sustainable buildings.

In addition to the new building the following actions will be taken:

- The Laboratory Building will be converted from an experimental and shop area to a modernized office and collaboration center. The revitalization of the Laboratory building will result in significant improvements to working conditions and will improve communications among staffs.
- The Theory Building and a portion of the Administration Building will be demolished. This will eliminate nearly $700,000 of deferred maintenance.
- Module 6, an aging modular building will be demolished eliminating $200,000 of deferred maintenance.
- Conversion and refurbishment of the C-Site MG Building into a centrally located main machine shop and fabrication area. Rehabilitation of the MG Building will reduce deferred maintenance by approximately $400,000.

A site map is attached depicting the laboratory at the end of the five-year planning period and identifying new, refurbished, and demolished facilities that will result from SLI Line Item funding (Attachment 2).

The impact of the SLI Projects will be to modernize the Laboratory's facilities and provide the building infrastructure to support the scientific initiatives described above in the Science Strategy. The Department can contribute cost-effectively to basic science by taking advantage of the Laboratory's experienced research and engineering staff and unique infrastructure. Presently, eight experimental projects are housed in a 50-year-old building, with small rooms and low ceilings. The low ceiling prevents the use of a crane to move large experimental components. The rooms' small space prevents the expansion of the existing projects and the start of new larger scale projects. Presently, there are three projects in the Plasma Science and Technology Department that cannot grow because of their limited space and low ceilings: Magnetic Reconnection Experiment, Lithium Tokamak Experiment, and Field Reverse Configuration/Rotating Magnetic Field. The construction of a new Plasma Science and Technology Center will significantly improve the Laboratory's ability to cost effectively meet its mission.

The Total Estimated Cost (TEC) range estimate for the mission need analysis is $53M - $59M and the Total Project Cost range for this project is $53.5M to $59.5M. The expected source of funding is the Science Laboratories Infrastructure Program.

SLI Projects Schedule - Proposed	Requested funding profile
2010 – Approve Mission Need (CD-0) – COMPLETED 2012 – Approve Alternative Selection & Cost Range (CD-1) 2013 – Approve Performance Baseline (CD-2) 2013 – Approve Start of Construction (CD-3) 2016 – Approve Project Completion (CD-4)	FY11 $0.40M FY12 $0.35M FY13 $18.0M FY14 $20.0M FY15 $18.0M FY16 $2.75M

The estimated cost (Other Project Cost) to support programmatic strategic planning, complete conceptual design, and prepare the project documentation to proceed from CD- 0 to CD-1 is $750K.

- American Recovery and Reinvestment Act (ARRA) Electrical Utility Upgrade. Money directed through the ARRA has been designated to upgrade to the Laboratory's 138KV switch gear, transformers, and associated circuit breakers, remove obsolete transformers and equipment that limit planned expansion of the 138kV switchyard and prevent potential environmental problems. In addition this project will provide voltage regulation to the Laboratory's alternate 26kV electrical service, remove and replace obsolete Federal Pacific (FPE) switchgear and breakers with new, state-of-the-art arc-resistant switchgear with vacuum breakers. Completion of this project will result in an upgrade to more than 50% of the Laboratory's Electrical Utility System. Implementation of this project will improve reliability and maintainability of the entire site electrical system thereby improving the research and development performance of the Lab.

Trends and Metrics

PPPL continues to be a world-leading facility for the research of plasma physics, able to meet all of its key core capability objectives. The Laboratory continues progressing toward complete implementation of Mission Readiness and the majority of the components of the program are in place. Using the principles of the Mission Readiness model, PPPL has improved cross-functional communications and identified infrastructure gaps along with improving action plans that will allow the Laboratory to bridge those gap and remain mission capable for the foreseeable future.

The overall condition of PPPL's facilities continues to be good. PPPL has demonstrated an effective management system for planning, delivering, and operating Laboratory facilities and equipment. Maintenance of active conventional facilities with respect to DOE corporate maintenance investment goals was excellent in FY10. In a facility that is over 50 years old, all facility support systems were maintained in an operational state ensuring no impact to experimental operations, while deferred maintenance was slightly reduced, and the maintenance investment index goal was met. Infrastructure system reliability, as measured by a reliability index of 1.0, indicates total system reliability for electrical and building support systems. There were no situations in FY10 that resulted in a building or facility being without critical services (or being unusable) during times that the normal population for those buildings is present. PPPL has also exceeded all energy reduction goals established by Presidential Executive Orders.

PPPL developed and implemented an aggressive construction schedule in FY10. The Infrastructure Recapitalization Program, comprised primarily of GPP work, expedited work to meet the needs of the laboratory mission. Facilities projects were managed efficiently with regard to on time completion, budget performance, and meeting baseline scope requirements. The FY10 GPP expenditure as a percentage of the Replacement Plant Value yielded a Recapitalization Investment Index of 0.99%, which is excellent and met the highest performance rating.

The PPPL deferred maintenance, exclusive of other structures and facilities, backlog decreased from $7.7 million in FY08 to 7.3 million in FY10 for a decrease of $.4 million. Since FY04, when PPPL's deferred maintenance backlog was $12.7 million, the backlog has been reduced by $5.4 million for a 43% reduction. DOE guidance is to reduce the deferred maintenance backlog so that the average ACI for all buildings is above 0.98 by FY15. The current PPPL ACI is 0.98. PPPL funding plans, depicted in the table, show that the Laboratory exceeded the DOE guidance timeline by reaching the 0.98 ACI goal in FY10 and will reach 0.99 in FY15 and sustain that level thereafter. It should be noted that if funding is not provided per the projections in the table, achieving the ACI goals may not be possible or will suffer delays. Most notably, the SLI project scheduled to begin in FY13 is a key component not only to the Laboratory's modernization plans, but also to the plans to reduce deferred maintenance. Without funding for this project, the Laboratory will not be able to contribute the planned additional funding from the resultant energy and maintenance savings, toward increasing GPP funding aimed at reducing deferred maintenance.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
Plasma and Fusion Energy Sciences	Now			X		C22 -LAB BLDG, C23-C SITE THEORY C01-LSB	ITER/Burning plasmas Collaborations: DIII-D, C-Mod, Jet, MAST, EAST, KSTAR, LHD, W7X Prototype ITER remote control room	Obsolete Lab Space, No High Bay Space To support small experiments, Overhead Crane needed for assembly and disassembly		SLI Funding
	In 5 Years				X	C22 -LAB BLDG C23-C SITE THEORY C01-LSB	Theory and Modeling: Fusion Simulation Project computation and simulation projects			
						C22 -LAB BLDG, C23-C SITE THEORY, C01-LSB, C20-ENGINEERING WING, D43-TFTR TEST CELL, C-41 CS Bldg test cell	Strategic Planning for Fusion Initiatives: Next Step Options / potential next generation machines			
	In 10 Years				X	C21-C SITE L WING, C22 -LAB BLDG, C32-C SITE SHOP C40-C SITE RF, C41-C SITE CS BLDG, C42-C SITE COB C50-ESAT, C51-C SITE MG,C90-RESA, C91-CAS, D72-MG P1-OFF SITE C21-C SITE L -WING, C22 -LAB BLDG, C40-C SITE RF	Plasma Science and Technology; Basic Plasma Science liquid walls, magnetic configurations, basic plasma physics, astrophysics, high energy density plasma			

Technical Facilities and Infrastructure (Assumes TYSP Implemented)

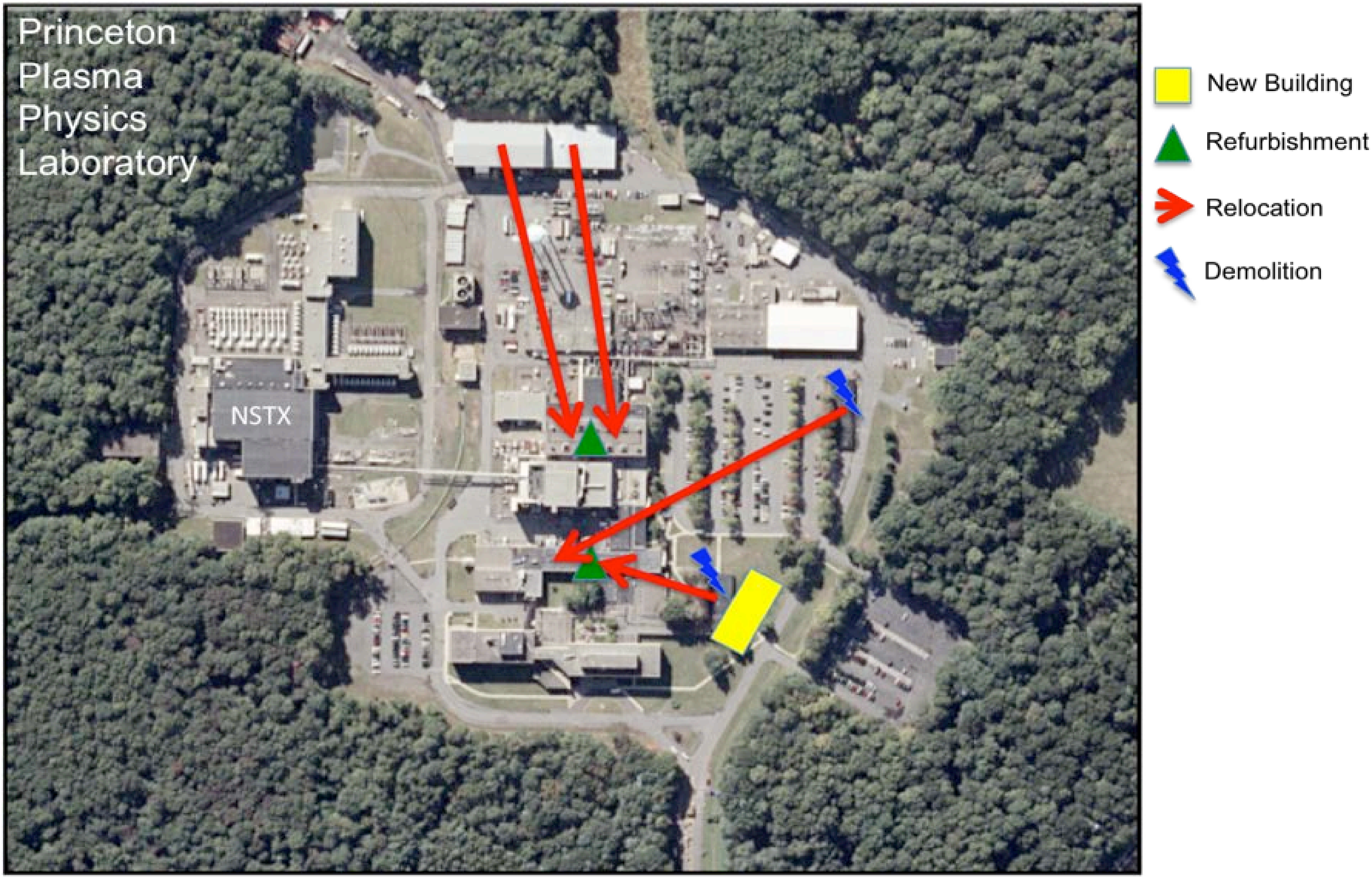
Core Capabilities		Mission Ready				Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N[a]	M[b]	P[c]	C[d]				Laboratory	DOE
Large Scale User Facilities / Advanced Instrumentation	Now			X		C21-C SITE L WING, C22 -LAB BLDG, C32-C SITE SHOP C40-C SITE RF, C41-C SITE CS BLDG, C42-C SITE COB C50-ESAT, C51-C SITE MG, C52-PLT PWR BLDG C60-CSITE COOLING TWR C90-RESA, C91-CAS, D34-LEC D42-EXP.AREA, D-70D Site Pump House (total), D72-MG P1-OFF SITE	Toroidal Confinement Experiments NSTX NSTX upgrades	Obsolete Electrical Utilities are no longer supported by manufacturers and spare parts are not available.	GPP Funding	ARRA Project Funding
	In 5 Years				X					
	In 10 Years				X					

[a]N = Not [b]M = Marginal [c]P = Partial [d]C = Capable

Support Facilities and Infrastructure							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Gap	Action Plan	
	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE
Work Environment							
Post Office				X			
Offices				X			
Cafeteria				X			
Recreational/Fitness				X			
Child Care					N/A		
User Accommodations							
Visitor Housing					N/A		
Visitor Center					N/A		
Site Services							
Library				X			
Medical				X			
Examination & Testing				X			
Maintenance & Fabrication				X			
Fire Station				X			
Storage				X			
Conference and Collaboration Space							
Auditorium/Theater				X			
Conference Rooms				X			
Collaboration Space				X			
Utilities							
Communications				X			
Electrical			X		Equipment is near its end of life and no longer supported by manufacturer.	Assigned to the sites GPP list and work scheduled using ARRA funds.	Additional requirements and upgrades are addressed by the SLI project that will upgrade Critical Utility Infrastructure and will begin in FY17 and be completed in FY19.
Water				X			
Petroleum/Oil				X			
Gases				X			
Waste/Sewage Treatment				X			
Storm Water				X			

Support Facilities and Infrastructure							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Gap	Action Plan	
	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE
Chilled Water			X		Underground Lines at end of life and require replacement.	Assigned to GPP List	
Steam				X			
Flood Control				X			
Road & Grounds							
Parking (surfaces and structures)				X			
Roads & Sidewalks (improved & paved surfaces)				X			
Grounds				X			
[a]N = Not [b]M = Marginal [c]P = Partial [d]C = Capable							

Aerial view of PPPL C- and D- Sites showing areas to undergo major improvements and changes



SLAC National Accelerator Laboratory

Mission and Overview

The SLAC National Accelerator Laboratory is home to some of the world's most cutting-edge technologies, used by researchers to acquire scientific insights pertinent to national and international challenges within the Department of Energy (DOE) mission. SLAC is a multi-program laboratory, involved in leading research in the areas of materials and chemical science, energy, structural biology, and particle physics and astrophysics, among others. SLAC's mission is three-fold: to be an internationally recognized photon science user laboratory; to maintain its leadership position as one of the world's premier accelerator laboratories; and to pursue targeted programs in particle physics and particle astrophysics. SLAC operates two leading x-ray scientific facilities: the Linac Coherent Light Source (LCLS) and the Stanford Synchrotron Radiation Lightsource (SSRL).

The LCLS began operating at SLAC in 2009 and has redefined the frontiers of x-ray science with its ultra-short, ultra-bright pulses of hard x-rays. Over a billion times brighter than any other hard x-ray source, LCLS allows experimenters to probe the structure and dynamics of materials at the atomic scale. Scientists can now see where the atoms are and what they are doing on atomic time scales of femtoseconds. Early experiments ranged from nanocrystal diffraction, demonstrating the technology to study macromolecular structures that do not form crystals large enough to be examined at synchrotron-based sources, to studies of reaction states on surfaces to understand the structural dynamics of catalysis. LCLS works in synergy with SSRL, as well as the many science programs that drive the development of the facilities for the broader user community.

SLAC's particle physics programs have a heavy emphasis on particle astrophysics. SLAC led the development of the primary instrument for the Fermi Gamma-ray Space Telescope (FGST), a joint DOE-NASA mission that launched in 2008. Currently, SLAC runs the Instrument Science and Operations Center for Fermi and is a primary contributor to the science. SLAC anticipates mission need approval (CD-0) in the near future for the Large Synoptic Survey Telescope (LSST), a ground-based telescope that will survey the entire night sky every few nights. LSST will be a joint DOE-National Science Foundation (NSF) project, with SLAC responsible for the camera fabrication.

As a premier accelerator laboratory, SLAC accelerator scientists and engineers design, build and operate leading accelerator facilities such as LCLS and SSRL. In

Lab-at-a-Glance

Location: Menlo Park, California

Type: Multi-program Laboratory

Contractor: Stanford University

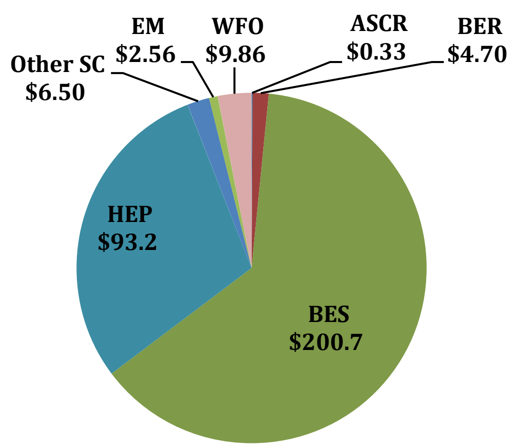
Responsible Site Office: SLAC Site Office

Website: http://www.slac.stanford.edu

Physical Assets:
- 426 acres and 142[#] buildings
- 1.725M GSF in buildings[#]
- Replacement Plant Value: $1.134B
- Deferred Maintenance: $21.4M
- Asset Condition Index:
  - Mission Critical: 0.98
  - Mission Dependent: 0.98
  - Asset Utilization Index: 0.98

Human Capital:
- 1,579 Full Time Equivalent Employees (FTEs)
- 21 Joint Faculty
- 70 Postdoctoral Researchers
- 135 Graduate Students
- 0 Undergraduate Students
- 3,112 Facility Users
- 30 Visiting Scientists

FY 2010 Funding by Source *(Cost Data in $M)*



FY 2010 Total Lab Operating Costs (Excluding ARRA): $317.8
FY 2010 Total DOE Costs: $308.0
FY 2010 WFO (Non-DOE/Non-DHS) Costs: $9.86
FY 2010 WFO as % Total Lab Operating Costs: 3.1%
FY 2010 Total DHS Costs: $0.0

ARRA Obligated from DOE Sources in FY 2010: $6.5
ARRA Costed from DOE Sources in FY 2010: $32.8

addition, accelerator research programs at SLAC are developing new acceleration mechanisms and technologies for the future. To date, six scientists have been awarded the Nobel Prize for work carried out at SLAC. SLAC is operated by Stanford University (Stanford) for DOE's Office of Science (SC).

Current Core Capabilities

1. Accelerator Science and Technology

Accelerator science and technology are vital to the operations and future development of light source and particle physics facilities serving the research missions of the DOE SC and SLAC over the coming decades. SLAC has the intellectual capital in accelerator physics and engineering, research instrumentation, accelerator test facilities and physical infrastructure to enable forefront research and development (R&D) in accelerator science and technology, in particular for electron accelerators. Areas of R&D include: advanced electron guns for high-brightness and high-repetition rate X-ray Free Electron Lasers (XFEL) and energy recovery linacs; beam manipulation and laser-seeding methods for generating higher performance XFEL beams; high-power normal conducting (NC) radio frequency (RF) sources, power distribution, and structures; beam physics in the areas of accelerator optics design, collective effects, feedback and low-level RF systems; linac- and ring-based light source and colliding beam accelerator design; laser- and plasma-wakefield acceleration; and computational techniques for accelerator simulation. With the LCLS, SLAC has the only operational hard XFEL in the world today, and the associated R&D impacts other U.S. and international projects and how they are being designed, constructed and operated.

SLAC applies these capabilities to optimize exploitation of existing facilities in the near-term, to develop the next generation of accelerators in the mid-term, and for long-term frontier research on the next generation of acceleration techniques. In addition SLAC will make its technology and infrastructure increasingly available to outside customers as reflected in the increased Work for Others (WFO) program. Based on SLAC's three mission objectives, the Accelerator Directorate has defined and is pursuing the following five strategic R&D objectives:

- Maintain the world-leading XFEL program with innovation and new concepts.
- Be the world leader in linear accelerator design, with a unique technology base for high-power RF systems, high gradient structures and normal conducting RF linacs.
- Be a world leader in the advanced accelerator R&D program.
- Support the accelerator-based program at SLAC and make major contributions to the Large Hadron Collider (LHC) and future initiatives.
- Have a renowned accelerator education program training future leaders in the field.

The following table illustrates how these objectives relate to the DOE SC mission.

Elements	Major Sources of Funding	Tie to Mission
XFEL R&D	BES, LDRD	SC: 9, 26
RF power/NC structure R&D	HEP, BES, LDRD, WFO	SC: 24, 25, 26
Advanced accelerator R&D	BES, HEP, LDRD	SC: 21, 24, 25, 26
Support of the SLAC accelerator-based programs	BES, HEP, WFO	SC: 9, 24

2. Large-Scale User Facilities and Advanced Instrumentation

SLAC has the intellectual capital, infrastructure, and experience to conceive, design, construct, maintain, and effectively operate large-scale scientific user facilities, delivering discoveries relevant to DOE SC and SLAC missions. SLAC has also developed the tools and means to support large international scientific user communities and collaborations.

SLAC currently hosts two major DOE Basic Energy Science (BES) onsite scientific user facilities: LCLS and SSRL. LCLS is SLAC's newest scientific user facility and achieved the world's first hard x-ray lasing in April 2009. The LCLS user program started in October 2009, much earlier than projected, and by the end of 2010 three of six experimental stations were available to users. By February 2011, the fourth station became operational, and by the end of 2012, all six will be operational. Besides realizing an unparalleled speed of commissioning, LCLS also exceeded expectations in reliability with 96% beam uptime, and capability with extensions over the baseline design in spectral range, pulse length, and increased energy per pulse. Users immediately seized on these capabilities and LCLS today runs much more like a "laser in the lab" where the experimenters vary photon energy, pulse duration, and energy per pulse at times on an hourly basis. In its first 18 months of operation, LCLS has already produced forefront scientific results that have been published in top scientific journals and received widespread attention, not only from the international scientific community, but also through press releases and commentaries that have reached a broader audience.

SSRL provides a complementary source of synchrotron x-rays from its third generation SPEAR3 storage ring and associated beamlines and instrumentation, serving the research needs of more than 1,400 users annually across many areas of science, engineering and technology. Performance of SPEAR3 continues to be enhanced, with high current, higher-frequency top-off injections becoming the new standard operating mode in the spring of 2010. Research at SSRL supports DOE SC and SLAC mission research, including the understanding and development of new materials relevant to energy generation and storage such as fuel cells, solar cells and batteries, and rapid structure determination of large complex biomolecules and targets for Biopharma drug-discovery programs. SSRL's capabilities in chemical speciation and spectromicroscopy contribute fundamental knowledge on the nature of contaminants and waste streams informing and accelerating remediation activities of DOE SC national laboratories.

Associated with LCLS and SSRL are coordinated R&D programs focused on new methodologies and instrumentation, and their scientific applications, to maximize the impact of the light sources on innovation and scientific discovery. Deployment of these new technologies, and the capability of supporting the outside user communities in their applications, is a key element of the successful operation of SLAC's scientific user facilities. The R&D programs also provide for a vital engagement of scientific staff with forefront research problems that strongly couple to SLAC's research programs. Education and training are also integrated elements of the LCLS and SSRL programs. There is extensive use by graduate and post-doctoral students in their research. Training workshops and summer schools are tailored to bring in young scientists from new areas.

In the Particle Physics and Astrophysics (PPA) area, SLAC has a history of successfully delivering large-scale user facilities. SLAC managed the design, development, construction, and operation of the Large Area Telescope (LAT) that was launched in June 2008 on the FGST, a major space observatory that is revolutionizing the understanding of high-energy processes in the universe. The experience gained from these programs is being applied to future facilities that will be located offsite: the wide-field LSST in northern Chile; upgrades to the A Toroidal LHC Apparatus (ATLAS) detector at the LHC; the next generation electron-positron collider for flavor physics; and Lepton Collider R&D for the longer term. SLAC is playing a lead role in the design and development of specific elements on these large international projects.

In support of its large-scale facilities and science programs, SLAC has developed and maintains a number of capabilities in advanced instrumentation and computational tools driven by the needs of existing and future experiments. These capabilities include system design for state-of-the-art, high-bandwidth data acquisition systems, spanning detector front-ends to data storage and distributed access; advanced instrumentation and diagnostics for characterization and control of micron-scale photon beams; and highly automated, robotic-enabled, computer-based instrument control and remote access. Applications include highly integrated x-ray beamlines and instrumentation for photon science experiments enabled by advanced robotics for sample handling and computational resources for automated and optimized data acquisition strategies, data collection and analysis. SLAC has developed leading expertise and capability in managing very large sets of experimental data, and is actively engaged in using this asset to develop strategies for data acquisition and management for LCLS and for future opportunities with LSST and ATLAS.

The following table illustrates how these objectives relate to the DOE SC mission.

Elements	Major Sources of Funding	Tie to Mission
LCLS operation and science/user program	BES	SC: 9
SSRL operation and science/user program	BES	SC: 9
B-Factory/ BaBar Data Analysis, contribution to ATLAS/LHC, Lepton Collider R&D	HEP	SC: 21, 22, 24, 25, 26
FGST instrument operations, LSST instrumentation	HEP	SC: 23, 24, 26
Management of petascale experimental data sets	HEP	SC: 2, 24, 26

3. Condensed Matter Physics and Materials Science

The SLAC Materials Science Division is engaged in multidisciplinary research activities in selected areas of materials sciences, including correlated and superconducting materials, diamondoids, bio-inspired materials, topological insulators, and atomically engineered heterostructures. The research is relevant to BES mission needs and selected grand challenge basic energy science questions in condensed matter and materials physics and nanomaterials science. The mission need consists of the development of future energy technologies, including storage and transmission of electrical energy, improving efficiency of energy conversion processes, and energy production that minimizes CO_2 emissions.

Research programs utilize and help drive forefront technique and methodology developments on SLAC's light sources (LCLS and SSRL) by pushing the state-of-the-art of tools for study and characterization of the electronic and structural properties of new materials on the nanoscale at increasingly high levels of energy, spatial and time resolution. The unique experimental opportunities that are afforded by LCLS allow development of a strong leadership position in the field of ultrafast materials science where processes like ultrafast charge and spin dynamics become accessible for direct study. Two specific themes of near-term focus are ultrafast materials science using LCLS, and advanced spectroscopy, nanobeams and high throughput *in-situ* characterization using SSRL.

Research within the Division is coordinated under the umbrella of a joint Institute between SLAC and Stanford called Stanford Institute for Materials and Energy Science (SIMES) and supports the mission of BES. SIMES provides a link between SLAC and Stanford, where the basic science focus has synergy with initiatives at Stanford that focus on energy technology and policy in sustainable energy such as the Global Climate and Energy Project (GCEP) and the Precourt Institute for Energy (PIE). SIMES is also involved in collaborations with larger consortia focused on DOE mission and grand challenges, including the BES Energy Frontier Research Centers, the Joint Center for Artificial Photosynthesis Hub, and the Bay Area Photovoltaics (PV) Consortium. Further, SIMES engages in outreach activities for energy science education and training, helping to develop a next generation of talent.

The following table illustrates how these objectives relate to the DOE SC mission.

Elements	Major Sources of Funding	Tie to Mission
Research on correlated materials and superconductivity	BES	SC: 7, 8
Synthesis, structure, properties of novel materials	BES	SC: 6
Spin physics	BES	SC: 8
Interfacial and catalysis science	BES	SC: 6, 7, 8

4. Chemical and Molecular Science

The SLAC Chemical Sciences Division is engaged in multidisciplinary research activities in selected areas of chemical and molecular science that involve the interface between ultrafast physics, chemistry, materials, theory and simulations, and x-ray science. R&D in the Division develops capabilities to advance science, especially using the LCLS and in catalytic-related energy science. Research programs in one thrust area unified by ultrafast science focus on attosecond atomic and molecular experiments and theory; femtosecond atomic-scale imaging of physical, chemical, and biological processes using ultrafast x-rays, strong-field laser-matter interactions, materials science; and ultrafast magnetic phenomena. A strong theory program in excited-state dynamics complements the experimental studies. Areas of exploration include understanding how nature utilizes femtosecond time scales for energy conversion from light into other useful forms of energy, exploring the ultimate speed of information transfer and processing in materials, and understanding chemical catalysis by directly using ultrafast and short wavelength coherent radiation to probe the ultrafast processes that initiate and control these phenomena.

A second thrust area in the Division involves a unified theme of research that addresses the fundamental challenges associated with the atomic-scale design of catalysts for chemical transformations of interest for energy conversion and storage. The goal is to combine experimental and theoretical methods to understand the electronic and structural factors determining the catalytic properties of solid surfaces, and to use this insight to design new catalysts. The research focus is on catalysts of importance in energy transformations and storage: catalysts for transformation of syngas (made from biomass or other feed-stocks) to fuels; (photo-) electrocatalysts for fuel production; and electrode processes in new types of batteries. Electronic structure methods and computer codes are being developed to treat surface reactions on solids and nanoparticles with one emphasis being on developing user-friendly theoretical simulations of spectroscopies to interface with experiments at SSRL, LCLS and other synchrotron facilities. The goal is to build up experimental activities in catalyst synthesis, characterization (using SSRL and LCLS) and testing to complement the theoretical developments.

Ultrafast science has synergies both more broadly in the Photon Science Directorate (study of ultrafast processes in catalytic reactions and in dynamic behavior of materials in the Materials Sciences Division) and cross-directorate (using SSRL and LCLS for studies in complementary time domains from milliseconds down to femtoseconds). Research within the Chemical Sciences Division is primarily organized within the framework of two multidisciplinary units: the Photon Ultrafast Laser Science and Engineering (PULSE) Institute for Ultrafast Science, and the Center for Sustainable Energy through Catalysis (SUNCAT). The research is aligned with and supports the mission objectives of BES.

The following table illustrates how these objectives relate to the DOE SC mission.

Elements	Major Sources of Funding	Tie to Mission
Atomic and nanoscale imaging on femtosecond and below timescales	BES	SC: 7, 8
Investigation of ultrafast phenomena	BES, LDRD	SC: 7, 8
Study of dynamics in correlated systems	BES	SC: 7, 8
Properties of matter in extreme environments	BES	SC: 7
Atomic-scale design of catalysis	BES	SC: 6

5. Particle Physics

SLAC has a significant scientific and technical workforce focused on using a unique combination of ground- and space-based experiments to explore the frontiers of particle physics and cosmology. The ATLAS experiment at the LHC will probe the energy frontier at TeV mass scales and beyond, with prospects for discovering supersymmetry and its possible dark matter candidate—the neutralino, new spatial dimensions suggested by quantum gravity theories, or even mini black holes, as the constituents of a new understanding of the Universe. The LSST has been designed to probe the properties of dark energy with high precision, enabling a better understanding of this dominant component of the universe. SLAC is the lead DOE laboratory for construction of the 3.2 gigapixel camera for the project. The Super Cryogenic Dark Matter Search (CDMS) will allow direct searches for relic dark matter candidates at unprecedented levels of sensitivity. Exploring the origins of the matter-antimatter asymmetry of the Universe will extend from ongoing studies with the B-Factory data to new exploration at ATLAS. The now-commissioning Enriched Xenon Observatory (EXO) will provide the first understanding of the nature of the neutrino, and a glimpse at the mass scale for the ephemeral neutrino content of the Universe. The FGST has embarked on a decade-long program of space-based gamma-ray observations, which will transform our understanding of the high-energy universe. SLAC is also a leading contributor to accelerator and detector R&D for future energy frontier Lepton Colliders and upgrades to the LHC. In 2012, SLAC will engage in a Muon generation/Muon Collider program to design subsystems and evaluate feasibilities of these alternatives. SLAC performs this R&D in close collaboration with other laboratories and universities as a partner in major scientific international ventures.

The Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), jointly hosted by SLAC and Stanford's Physics Department, is a central force in the present and future core program in experimental and theoretical particle astrophysics. SLAC has developed capabilities in detector systems design, including silicon detectors, wire chambers and optical sensors, end-to-end electronic systems design and implementation, state-of-the-art systems design for data acquisition and controls, large-scale data management, specialized capabilities for space and low-background applications, and overall project management.

Also supporting SLAC's core experimental capabilities in particle physics are particle and particle astrophysics theory efforts pursuing a broad spectrum of forefront theoretical research across all areas of fundamental physics from inflationary cosmology to computational Quantum Chromodynamics (QCD) to string theory. The SLAC theory effort plays a major role in developing and promoting the future directions of particle physics, such as at the energy frontier physics enabled by the LHC and a possible future linear collider. The combination of expertise in the SLAC and KIPAC theory groups with that of the theory groups in the Stanford Physics Department and

Institute for Theoretical Physics has made the SLAC-Stanford community a leading international center of theoretical physics.

The following table illustrates how these objectives relate to the DOE SC mission.

Elements	Major Sources of Funding	Tie to Mission
Research at energy frontier – ATLAS Collaboration	HEP	SC: 21, 22, 24, 26
Experiments focused on discovery of dark matter energy/dark matter	HEP, NSF, NASA, LDRD	SC: 23, 26
Properties of the neutrino	HEP	SC: 23, 29
Understanding the high-energy universe	HEP, NASA, LDRD	SC: 23, 26
Theory research in particle physics and cosmology	HEP	SC: 21, 22, 23, 27

Science Strategy for the Future/Major Initiatives

SLAC has three objectives that will define and distinguish the Laboratory in the decade to come:

- To be an internationally leading photon science laboratory.
- To be a premier electron accelerator laboratory.
- To have targeted programs in particle physics, particle astrophysics and cosmology.

These objectives build on SLAC's core capabilities described in Section 3.0 and are supported by its future/major initiatives in light sources, accelerator R&D, particle astrophysics, and energy science. The future of SLAC starts with LCLS and the opening of a new frontier of dynamics at the atomic scale. In the near term, SLAC must complete the instruments for LCLS and fully engage the growing user community, enabling them to perform discovery-class science. Because of LCLS's rapid turn-on and excellent early performance of the x-ray laser, upgrades are underway to increase its capacity and capability. However, delivery of outstanding facilities to users is not sufficient for SLAC to achieve its objective as a leading photon science laboratory. SLAC must also drive the science, and so the initiative on energy science and the initiative on particle astrophysics and cosmology are both part of a broader program to grow SLAC's portfolio of performing science.

Key to the future of SLAC is accelerator research that drives SLAC's ability to develop, design, build, operate and utilize large-scale accelerator-based facilities. SLAC accelerator research focuses on advancing operating facilities around the world, as well as contributing to the next generations of High Energy Physics (HEP) and BES accelerators. The accelerator R&D initiative supports all of SLAC's major laboratory-wide objectives and goes beyond, utilizing an increased WFO strategy (see Section 5.0 *Work for Others*) to maintain and eventually further develop SLAC's high-tech infrastructure. Close collaboration with other funding agencies and with industries will enable an increased dissemination of SLAC-developed technology and provide a motivation to develop advanced technology.

SLAC aspires to evolve a new initiative in biosciences and, in the longer term, advanced scientific computing. The development of a SLAC biosciences strategy is currently underway under the stewardship of a Biosciences Taskforce that includes representatives from SLAC and Stanford and outside experts. This effort is expected to culminate in a set of strategic recommendations and areas of focus by Fall of 2011. Informing and underpinning this effort and strategy are core capabilities at SLAC and Stanford. SLAC's light source capabilities and scientific tools (at LCLS and SSRL) together with relevant scientific expertise at Stanford in microbial systems, biocatalysis, computational biology and bioinformatics, provide a strong platform upon which to build a new division. SLAC's co-location with Stanford's Schools of Medicine, Engineering, and Humanities and Sciences provides a unique intellectual environment to attract talent and develop programs. SLAC's goal includes building a biosciences portfolio that is relevant to the BER mission involving the bioenergy, including the FY 2012 focus on "Science for Innovation and Clean Energy" and "biosystems by design". A recent key strategic hire in scientific computing positions the Laboratory to embark upon a development strategy for this area as well. SLAC anticipates that these may become future/major initiatives in future Annual Laboratory Plans.

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

Established in 1962, SLAC is located on 426 acres of Stanford land in Menlo Park, California, adjacent to the Stanford campus. Major onsite facilities and supporting research programs include LCLS, which uses the last one-third of the SLAC linac, and SSRL, which utilizes the SPEAR3 storage ring.

Overall, SLAC has approximately 2M square feet of space in 164 buildings that are a combination of operational and non-operational user facilities, scientific laboratories, and industrial facilities and general-purpose space. With the exception of LCLS, most buildings and infrastructure are approaching 45 to 50 years old and capability gaps exist in some mission critical areas. In order to ensure mission readiness at SLAC, the Laboratory utilizes a portfolio funding approach, including DOE SC Science Laboratory Infrastructure (SLI) funding, American Recovery and Reinvestment Act (ARRA) funding, DOE SC program capital funding (includes GPP), SLAC institutional capital project infrastructure funding, and Stanford investments. Examples of this portfolio approach are:

- SLI funds support the Research Support Building (RSB) project, which has achieved CD-2/3A. This includes the renovation of Buildings 028 and 041 and a new three-story building (Building 052), and demolition of the PEP-II trailer complex. Additionally, the Scientific User Support Building (SUSB), which has achieved CD-0, will greatly enhance SLAC's ability to serve the growing SSRL and LCLS user communities. The Photon Sciences Laboratory Building (PSLB), where CD-0 is being scheduled as this Annual Plan is being written, will provide the modern improved laboratories and staff space required by SLAC's performing sciences programs.

- ARRA funds support several upgrades to SLAC's major infrastructure systems. This includes new Master Substation protective relays, three major electrical substation upgrades, replacement of hot, chilled, and compressed air piping and two air compressors, and two major seismic upgrades to the SPEAR ring at SSRL.

- Program capital and GPP funds support the upgrade of the linac's Fire Alarm system, increase office and laboratory space for the SIMES program, and improvements to offices/labs/utilities for the LCLS Experimental areas. This also includes upgrades to the Data Center electrical infrastructure, reliability improvements in the Campus Cooling tower, and the installation of emergency generators for some mission critical facilities.

- Stanford supports the development of SLAC's site plan, and is providing support for early design studies on the site of the Scientific Research Computing Facility (SRCF) and on identifying utilities requirements.

SLAC's most recent master site plan was revised in 2010 with Stanford and can be found online at: https://www-internal.slac.stanford.edu/do/longrangeplan/slac%20plan%20final.pdf. A table of key infrastructure data for DOE SC facilities is below.

Table 1: SC Infrastructure Data Summary

Replacement Plant Value ($M)		$1,134
Total Deferred Maintenance ($M)		$21.4
Asset Condition Index (1-DM/RPV)	Mission Critical	0.98
	Mission Dependent	0.98
	Non-Mission Dependent	1.00
Asset Utilization Index (Utilized square feet/Occupiable square feet)	Office*	0.96
	Warehouse	0.98
	Laboratory*	0.95
	Housing	NA
Prior Year Maintenance ($M)		$13.4

*The PEP Ring, over 85,000 sq-ft is no longer functioning laboratory space. The PEP Ring-supporting office trailers are scheduled for D&D in 2011. These assets are not included in this table.

Facilities and Infrastructure to Support Laboratory Missions

SLAC has determined the mission requirements for all of its facilities and has performed an assessment of the current condition of the facilities and associated infrastructure required to support the Laboratory's core capabilities. This condition assessment includes input from directorate representatives, the scientific principal investigators and building landlords most familiar with the core capability requirements.

Tables 3 and 4 below describe facility and infrastructure capability gaps, and investments needed to ensure mission readiness to accomplish SLAC's core capabilities and future initiatives. This information has been prepared consistent with the mission readiness approach used throughout the DOE SC national laboratory complex. A mission readiness peer review at SLAC is scheduled for May 2011.

Strategic Site Investments

Several near-term strategic site investments will address the capability gaps identified in the mission readiness assessments and will reduce the deferred maintenance backlog. Refer to Appendix F: *Planned Laboratory Site Map* for pictorial information about SLAC's infrastructure and mission readiness, and facility funding sources.

- **Projects with Funding**
  - SIMES Laboratories and Offices. SLAC has begun the renovation of about 14,750 square feet of existing space in Building 040 for laboratory research and office space for the SIMES Institute. SLAC expects the final phase to complete in February 2012. Funding is through BES.
  - FACET. SLAC will house FACET between Sectors 1 and 20 of the Klystron Gallery. Minor infrastructure construction is required in Sector 19, and some utility modifications are required throughout the Klystron Gallery. Funding is through AIP and GPP (BES and HEP).
  - Substation Replacement Project. Three electrical substations critical to SLAC operations require modernization and seismic stabilization. Two of the substations were installed over 40 years ago and consist of equipment that no longer meets performance specifications. Substation 40S has been replaced and has corrected the partial capability of Building 040 to provide mission readiness. Funding is through ARRA.
  - Infrastructure Modernization. This project will replace infrastructure that is beyond its useful life and represents an operational risk. The main site air compressor requires replacement with an oil free unit, and all of the underground air system piping requires replacement. Site-wide hot and chilled water requires replacement, and the CT101 requires redundant pumps and larger piping to utilize fully the chiller plant capacity. Funding is through ARRA.
  - Seismic Upgrade Infrastructure Modernization. SLAC's proximity to the San Andreas Fault requires enhanced ability to mitigate the impacts of a major earthquake. This project will improve the seismic strength of several important research and infrastructure facilities including SSRL's SPEAR3 enclosure (Building 100) and Building 140. Funding is through ARRA.
  - SLAC Site Security Systems. Phase I of the Site Security Systems Upgrade will include: a license plate reader at the main gate with cameras and indicator lights; a new sliding gate at Alpine Gate with a card reader and cameras; and installation of cameras, card readers, and motion and door-close detectors at Building 050.

    Phase II of the Site Security Systems Upgrade will include: installation of card readers in research areas located at SSRL and LCLS; automated gates at PEP Ring Road, North Research Yard and Sector 30 Gate; and installation of closed-circuit TVs at sensitive areas. Funding is through HSS and Laboratory indirect.
  - LCLS-II. The LCLS-II conventional facilities design takes advantage of the existing infrastructure and recent construction at SLAC and will need some new facilities and infrastructure to be constructed.

The injector tunnel at Sector 10 will require some modifications to bring it to current safety standards and to accommodate the specific requirements of the LCLS-II Injector. The magnets and vacuum chambers for the two pulse compressors will need distribution systems for power and water. A new beam transport segment will require some modifications to the existing facilities, including an extension of the recently completed Beam Transport Hall head house to the beginning of a new Undulator Hall tunnel. This tunnel will traverse under an existing hill and terminate at a new experimental hall. An Electron Beam Dump and Front End Enclosure will be constructed between the end of the undulator magnet devices and the new experimental hall. The experimental (lowest) floor of the experimental hall will provide sufficient space for up to four experiments and the associated control cabins. Laser rooms and electrical/mechanical rooms will be located on a second floor above the experimental floor. An auxiliary utility plant is necessary to augment the existing LCLS-I Central Utility Plant. Funding is through BES.

- **Projects with Funding to be Proposed**

  - LSST. SLAC will assemble and test key components of the LSST in Building 033, SLAC clean room, requiring modifications to the existing floor plan to accommodate a class 10,000 clean room, and a ceiling adjustment to accommodate the LSST camera assembly fixture. The clean room upgrade requires significant modifications to the existing HVAC and electrical and fire alarm systems. Funding is proposed through HEP.

  - Scientific User Facilities. Building 120 and Building 131 will require 1,500 square feet of additional modernized SSRL user facilities. Two new alcoves will be needed for future experiments. Funding is proposed through BES.

  - Power Distribution to Mission Critical Equipment. In order to maximize availability and reliability of critical LCLS support systems and infrastructure, the aging K Substations in the Klystron Gallery require replacement. SLAC will evaluate the protective relay system in the Master Substation and replace as necessary. Funding is proposed through BES.

- **Investments Funded or Proposed to be Funded by SLI**

  Building upon nearly 50 years of successful research in high-energy physics and basic energy sciences, SLAC is now expanding the frontier of ultrafast nanoscience with the LCLS, the world's first x-ray laser and new areas of energy-related basic science. To ensure that the excellent research conducted by SLAC scientific staff and users is supported by modern, mission-ready facilities, SLAC is upgrading its central campus infrastructure and is proposing future upgrades. These new facilities are consistent with SLAC's Long Range Development Plan and support SLAC's scientific research by interconnecting multi-program research, improving visitor facilities, and upgrading the general-purpose infrastructure to support the SLAC mission.

  - Research Support Building (RSB) and Infrastructure Modernization Initiative. As part of the SLI Modernization proposal, the RSB and Infrastructure Modernization project achieved the CD-2/3A milestone in December 2010. This project will construct approximately 64,000 square feet of modern office building to house accelerator science and technology staff currently dispersed throughout the site in aging trailers and other decentralized, inefficient locations. The RSB will meet LEED® Gold certification and the guiding principles in Executive Order 13423 for high performance and sustainable buildings.

    This project also modernizes space (68,000 square feet) in two major buildings located in the campus area, Building 028 (Warehouse and User Offices), and Building 041 (Administration and Engineering). The modernization will bring the buildings into compliance with current building codes and the American Disabilities Act.

    SLAC will demolish approximately 20,000 square feet consisting of a modular building and sub-standard trailers, approximately 45 years of age. This demolition will provide part of the footprint for the new building. These actions, accompanied by the renovation of two associated buildings, will reduce SLAC's Deferred Maintenance (DM) by approximately $8M. Funding is through SLI.

- <u>Future Initiative - Science and User Support Building (SUSB)</u>. With the resounding success of the LCLS, SLAC is enjoying a major influx of visitors and users to its campus. SLAC expects this trend to continue with LCLS-II offering a broader capability for experiments and multiplexed beamlines. The proposed SUSB, located on a hilltop at the entrance to the Laboratory, will be the first stop for all visitors and users to SLAC. This structure will bring together many of the Laboratory's visitor, user, and administrative services building on the "One Lab" concept to enhance productivity and collaboration. This building will also serve as the major architectural icon of the SLAC campus, synonymous with the Laboratory's cutting-edge discoveries and exceptional user research program. The SUSB will:

  - Be a LEED® Gold certified, LEED® Platinum preferred building that is a national showcase for energy efficiency through sustainable high-performance design.
  - Bring researchers, users, and visitors from across the Laboratory together in one facility.
  - House a centrally located administration hub to concentrate SLAC support personnel for all SLAC scientific users.
  - Offer members of the public the chance to experience SLAC science in a progressive visitor's center.
  - Offer a fitting location for presentations of SLAC research in a state-of-the-art auditorium and conference spaces.

  The four-story, 60,000–70,000 square foot SUSB is estimated at $65M total projected cost. It will replace the aging structures that currently hold Panofsky Auditorium and the cafeteria, both built in 1962—the same year SLAC was founded. The SUSB achieved its CD-0 milestone in September 2010.

- <u>Future Initiative - Photon Science Laboratory Building (PSLB)</u>. Growth in SLAC's photon science research program is outpacing the Laboratory's existing laboratory space. As a key element in SLAC's strategic plan to leverage the Laboratory's existing capabilities, the proposed PSLB will dissolve this limitation, allowing SLAC to exploit fully its scientific capability.

  In alignment with the mission objectives of the offices of BES and BER, as well as potential future stakeholders including Fusion Energy Sciences and Advanced Scientific Computing Research, the PSLB is proposed with the following scientific goals:

  - Create a hub of discovery and innovation with a focus on energy conversion and storage, heterogeneous catalysis, and photo-electrochemical processes.
  - House an innovative research cluster built around theory, modeling and simulation, co-locating preeminent theorists in condensed matter, chemical and excited state dynamics, and chemical and interfacial science.
  - House contemporary laboratory space facilities for the synthesis of new materials and characterization tools.
  - Complement and leverage investments by Stanford in energy and sustainability facilities and programs including the PIE/GCEP, nanoscience and nanotechnology (including a DOE Energy Frontier Research Center), and other "use-inspired" research.

  The three-story, 55,000-square-foot PSLB is estimated at $55M and will be located between the new SUSB and SLAC's preexisting Central Lab Building (Building 040), which holds the current PULSE/SIMES research centers. After completion of the new building, the Central Lab Building will provide additional office space to house resources.

  SLAC identified this project in its FY 2009 Annual Laboratory Plan as a strategic site investment. Currently, the project has no funding source, but is proposed to be funded by SLI.

Facilities Renewal Plan

In an effort to plan effectively for future needs, SLAC's Facilities Division will develop a set of laboratory facility and infrastructure plans to describe the campus infrastructure standards, the existing conditions of each infrastructure system, future demands and needs, and implementation priorities for the physical infrastructure elements. It will include individual plans, and integrate and coordinate various systems, such as the utility systems (sanitary sewer, electrical, domestic water, etc.), circulation system (roads, pedestrian paths and emergency routes), security system, parking lots and outdoor elements like signs, furniture and lighting.

These plans will tie to SLAC's Long Range Development Plan to develop the facilities renewal plan, which is used as an integral element of the mission readiness model and forms the basis for consideration of DM reduction when prioritizing infrastructure investments. This Plan will guide the strategy for future facilities capital renewal and infrastructure upgrades. The goal is to ensure mission readiness, reduce the current DM, and minimize future DM.

Excess Facility Needs

The BaBar Disassembly and Disposal (D&D) program began in FY 2009 and has a scope of work spanning 51 months. There are five parts to this project: program management; engineering and tooling refurbishment; peripherals disassembly; core detector disassembly; and subsystem disassembly (only if no reuse). Some items of the detector have potential reuse at SuperB in Italy, such as the EMC barrel, DIRC bars and structure, superconducting solenoid, flux return steel, and the EMC end cap structure. On the instruction of the DOE's Office of High Energy Physics, SLAC will negotiate with the Italian Institute for Nuclear Physics on this transfer. Some of the detector items are located in accelerator housing subjecting them to beamline radiation, and therefore these materials may be subject to the DOE Metals Suspension Directive. SLAC will catalog, survey for activation, and either store in a manner that preserves assets for potential future use, or dispose these materials in accordance with recently approved protocols. Funding is through HEP.

There are many disassembled beam components stored around site that may be subject to the current DOE policy regarding the Secretarial mandates on the suspension and moratorium on material disposition. The DOE SC conducted a review of SLAC's property and material clearance processes in December 2009, and reviewed the status of excess concrete shield blocks in the Boneyard and metals from the PEP-II accelerator and PEP-II detector. The DOE SC found that SLAC complies with the applicable occupational, public and environmental radiation protection regulations, and DOE Orders and Secretarial mandates. The DOE SC determined that the concrete shield blocks (including reinforcing bars) are not subject to metal suspension. In accordance with commitments made in SLAC's letter to the DOE dated September 30, 2010 (regarding the Multi-year Strategy for Disposition of Concrete Shield Blocks and BaBar Detector and PEP-II Metals), protocols have been developed and 87 large blocks have been moved offsite. Funding is through HEP.

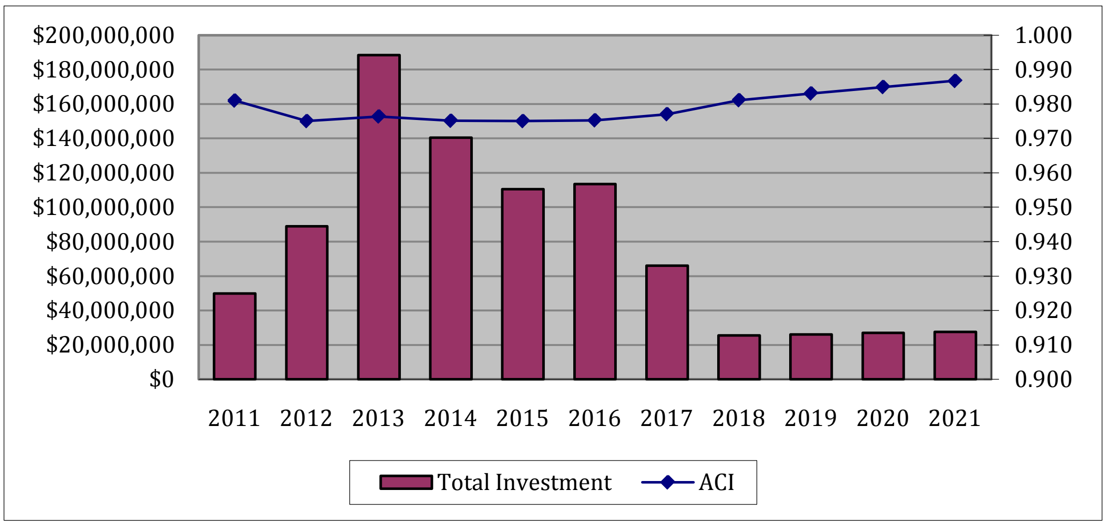
Trends and Metrics

SLAC's mission readiness process guides the Laboratory's infrastructure investment strategy. The process has served us well in the past year enabling us to quickly identify mission critical projects to propose for ARRA funding. The Facilities Department is continuing to implement best practices for all aspects of project management, operations and maintenance. These efforts will lead to a sustained mission readiness condition through effective use of available resources. The capability gaps identified in Table 3 were used to project the funding needs indicated below in Table 5 and its supporting chart, Figure 1. Table 5 includes all assets, and reflects the addition of the LCLS building—an additional 141,000 square feet—which increased the values for replacement plant value (RPV) in all years.

Table 2: Facilities and Infrastructure Investments (BA in $M)

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	13.4	13.4	13.8	14.2	14.6	15.1	15.5	16.0	16.5	17.0	17.5	18.0
DMR												
Excess Facility Disposition	0.0	0.0	0.0	0.0	0.4	4.1	0.0	0.0	0.0	0.0	0.5	0.5
IGPP	2.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
GPP	4.4	3.0	5.8	6.9	3.9	3.3	3.4	5.0	5.0	5.0	5.0	5.0
Line Items	29.0	29.5	65.3	163.3	117.5	84.0	90.5	41.0	0.0	0.0	0.0	0.0
Total Investment	**48.9**	**49.9**	**88.9**	**188.4**	**140.4**	**110.4**	**113.4**	**66.0**	**25.5**	**26.0**	**27.0**	**27.5**
Estimated RPV		1,178.4	1,213.8	1,250.2	1,327.0	1,430.8	1,473.8	1,518.0	1,713.5	1,764.9	1,817.9	1,872.4
Estimated DM		22.4	30.3	29.6	33.0	35.7	36.5	34.9	32.4	29.9	27.4	24.9
Site Wide ACI		0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99

Figure 1. Facilities and Infrastructure Investments



Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
Accelerator Science and Technology	Now			X		Building 002	FACET	FACET requires modifications to existing utility support systems.	Modify and upgrade existing utilities (electrical and mechanical) and stair in Sector 19 for FACET. Funded from AIP and GPP (BES and HEP).	
	In 5 years			X		Building 002	LCLS-II	Aging electrical and mechanical infrastructure to support LCLS-II program in Sectors 10-19.	Replace K-subs and VVS sectors 10-19. To be funded by BES.	
				X		Building 010	LCLS-II	Water intrusion on the tunnel ceiling.	Waterproof ceiling. To be funded by IGPP.	
				X		Building 002	LCLS-II	Sectors 1-10 requires remediation of water intrusion and wave-guide deterioration. Replace K-Subs and VVS in sectors 10 to 19 to support LCLS-II.	Execute the remediation. To be funded by BES.	
				X		Building 002	LCLS-II	Aging electrical and mechanical infrastructure to support LCLS-II program in Sectors 10-19.	Replace K-Subs, VVS and Heat Exchangers at Sectors 10-19. To be funded by BES.	
	In 10 Years			X		Building 002	LCLS-I	Aging electrical and mechanical infrastructure to support LCLS –I program in Sectors 20-30.	Replace K-Subs, VVS and Heat Exchangers at Sectors 20-30. To be funded by BES.	

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
					X	LCLS Buildings: 910, 911, 912, 913 920, 921, 930, 940, 950, 950A, 960, 999	LCLS	No capability gaps forecasted in 10 years.		
	Now			X		SSRL Buildings: 100	SSRL	Requires seismic upgrades.		Funded by ARRA.
				X		LCLS-II Building 002	LCLS-II	Sector 10 vault not up to code.	Bring Sector 10 vault up to code. Funded by BES.	
				X		LCLS Building 999	LCLS	Space upgrade and modifications on the Mezzanine of FEH.	Funded by BES.	
				X		LCLS Building 999	LCLS	Modifications to FEH to house MEC instrument.		Modify FEH to house MEC instrument. Funded by ARRA Fusion Science.
Large-Scale User Facilities and Advanced Instrumentation	In 5 Years			X		LCLS Building 950	LCLS	Labs require modification to support developing user program.	Modify labs to support user program. To be funded by BES.	
				X		LCLS Building 751	LCLS	User space is required in close proximity to NEH and FEH.	Remodel first floor space to support LCLS experiments. To be funded by BES.	
				X		LCLS-II	LCLS-II	A new tunnel is required to house the hard and soft undulators. A new experiment hall is needed to accommodate four experiment stations.		Build a new tunnel to house the hard and soft undulators. Build Experimental Hall-II. Dismantle and remove Trailer 211. Modify existing facilities at Sector 10 to accommodate

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
								A dedicated independent electron source is needed.		new injector. Build a laser room at sector 10. To be funded by BES.
				X		SSRL Buildings 120 and 131	SSRL	Requires additional modernized user facilities. Four additional beamlines are needed for future experiments.		Build an additional 1,500 GSF and modernize existing space. Build two new alcoves. To be funded by BES.
				X		Building 131	SSRL	Cooling tower line needs to be upgraded from 4" to 6" to provide additional cooling.	Upgrade of cooling tower line. To be funded by BES.	
	In 10 Years			X		Buildings: 600, 620, 621, 680	PEP-X	Requires expansion of existing buildings, and construction of new buildings to house equipment and staff for PEP-X. Requires demolition and disposal of existing equipment in PEP tunnels.		Fund upgrades, expansions, construction, demolition and disposal of buildings. Funding to be requested from DOE.
Condensed Matter Physics and Materials Science	Now			X		Building 040	SIMES	Requires increased office and lab space area for existing SIMES program. Program is partially and temporarily housed in Building 040 and the Stanford campus.	Funded by BES.	
	In 5 Years			X		New Facility	Photon Science	Expand and modernize facility to		New PSLB. Funding to be requested as next SLI.

Technical Facilities and Infrastructure (Assumes TYSP Implemented)										
Core Capabilities		**Mission Ready**				**Key Buildings**	**Key Core Capability Objectives**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N[a]	**M[b]**	**P[c]**	**C[d]**				**Laboratory**	**DOE**
								meet the future needs of Photon Science.		
	In 10 Years			X		New Facility	Photon Science	Expand and modernize facility to meet the future needs of Photon Science.	Building II, PSLB. Funding to be requested from Stanford.	
Chemical and Molecular Science	In 5 Years			X		New Facility	Photon Science	Expand and modernize facilities to meet the future needs of Photon Science.		New PSLB. Funding to be requested as next SLI.
	In 10 Years			X		New Facility	Photon Science	Expand and modernize facilities to meet the future needs of Photon Science.	Building II, PSLB. Funding to be requested from Stanford.	
Particle Physics	Now				X	Buildings 033, 048, 051, 084	All PPA	Currently, there is no capability gap.		
	In 5 Years			X		Building 033	LSST	Building modifications required to upgrade the clean room to class 10K. For LSST Project.	Funded by HEP.	
	In 10 Years				X	Buildings 033, 048, 051, 084	All PPA	No capability gap forecasted in 10 years.		
Mission	Now			X		Master Substation Building 016	Supports all core capability objectives	Master Substation protective relays are obsolete, non-functional, or have not been tested and calibrated. An electrical fault could damage property and prevent lab operation for an extended period.	Phase II Master Substation protective relays upgrade. Funded by IGPP.	Test and document protective relay system. Replace obsolete or non-functioning components. Funded by ARRA.
N[a] = Not, M[b] = Marginal, P[c] = Partial, C[d] = Capable										

Support Facilities and Infrastructure (Assumes TYSP Implemented)							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE
Work Environment							
Offices			X		Lack of infrastructure needed to integrate the accelerator physics community across SLAC.	Fund the dismantlement and removal of trailers that are not included in the footprint of the SLI funded RSB (Building 052). Funded by Laboratory indirect.	New RSB (Building 052) and modernization of Buildings 028 and 041. Funded by SLI. (CD-2/3A achieved.)
			X		Office space is needed to house the PULSE and SIMES institutes. Additional conference space is also required in near proximity.	Renovate space in Building 040 for PULSE and SIMES. Funded by BES. Fund the remodeling of space into general-purpose training center in Building 040. Funded by IGPP.	
Cafeteria			X		Cafeteria expansion and modernization is needed to support a growing user community.		A proposed new SUSB will include an expanded and modernized cafeteria. Funding to be requested as next SLI. (CD-0 achieved.)
User Accommodations							
Stanford Guest House			X		Expansion to support a growing short-term visitor community.	Negotiate funding with Stanford.	
Visitor Center			X		An adequate visitor center to enhance community outreach programs.		A proposed new SUSB will include a visitor center. Funding to be requested as next SLI. (CD-0 achieved.)
Site Services							
Computing			X		Electrical and chilled water systems in Building 050 data center lack capacity for high-density computing hardware facilities.	Increase electrical and cooling capacity to Building 050. Funded by IGPP. Partner with Stanford on new SRCF Data Center.	
			X		Existing systems lack fiber optics needed to support the computational needs of future experiments.	Develop plan to systematically replace underground communication lines. Funded by IGPP.	
			X		Existing Sun Modular Data Center will reach end-of-life in 2014.	Partner with Stanford on new SRCF Data Center.	

Support Facilities and Infrastructure (Assumes TYSP Implemented)							
Real Property Capability	**Mission Ready Current**				**Facility and Infrastructure Capability Gap**	**Action Plan**	
	N[a]	**M[b]**	**P[c]**	**C[d]**		**Laboratory**	**DOE**
Communications		X			Central phone switch is unreliable and outdated technology.	Replace phone switch and upgrade support mechanism. To be funded by IGPP.	
Storage		X			Radioactive materials are currently stored in an unsheltered structure.	Develop coordinated storage requirement needs and a plan to meet those needs. To be funded by IGPP.	
Conference and Collaboration Space							
Auditorium		X			Current auditorium lacks sufficient audiovisual capability		A proposed new SUSB will include an expanded and modernized auditorium. Funding to be requested as next SLI. (CD-0 achieved.)
Conference Rooms			X		Insufficient conference room capacity exists for both SLAC staff and visitors.		A proposed new SUSB will include a reconfigurable conference facility. Funding to be requested as next SLI. (CD-0 achieved.) The new RSB (Building 52) will include additional conference room capacity. Funded by SLI. (CD-2/3A achieved.)
Collaboration Space			X		Insufficient infrastructure exists to facilitate increased communications and cross-functional activities.		The new RSB (Building 052) and the remodel of Building 028 will improve communications and cross-functional activities in these buildings and surrounding areas. Funded by SLI. (CD-2/3A achieved.) A new SUSB will be proposed to increase communications and cross-functional activities. Funded by SLI. (CD-0 achieved.)
Roads and Grounds							
Pathways			X		No pedestrian pathway from Gate 17 to the Near Experimental Hall, which forces users to walk on the side of the road that includes a blind corner.	Build a recreational pathway from Gate 17 to the Near Experimental Hall B950 to facilitate walking and biking. Funded by IGPP.	

Support Facilities and Infrastructure (Assumes TYSP Implemented)							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE
Hillside Erosion			X		Soil erosion on hillsides creates a potential hazard to personnel and property.	Create a comprehensive plan to stabilize eroding hillsides. Funded by Laboratory indirect.	
Utilities							
High Voltage Power Distribution		X			Master Substation protective relays are obsolete, non-functional or have not been tested and calibrated. An electrical fault could damage property and prevent Laboratory operation for an extended period.		Test and document protective relay system. Replace obsolete or non-functioning components. Funded by ARRA.
Medium Voltage Power Distribution			X		Site electrical system protection is not fully coordinated and designed in an integrated manner. Short circuits and faults on the system could create life-safety and property damage hazards due to lack of documentation and incorrect design.	Perform a site-wide 12kV relay coordination, short circuit, and arc flash study. This is required by NFPA and OSHA, and reduces risk to personnel and property. Funded by Laboratory indirect.	
Site Electrical System			X		Electrical documentation is either nonexistent inaccurate and does not meet OSHA and NFPA requirements.	Field-verify as-built drawings and document existing electrical systems. Establish configuration management processes to ensure that documentation is kept current. Funded by Laboratory indirect.	
Low Voltage Distribution			X		Many switchboards, transformers, Motor Control Centers & panel boards are old and obsolete. Age of equipment increases risk of a failure interrupting operations to mission critical equipment, damaging property & injuring people.	Replace old and obsolete electrical equipment with new equipment in critical areas in Klystron Gallery. Funded by BES.	
Fire Alarm System			X		Obsolete fire alarm panels in Buildings 081, 104, 137, 140, 750, and 233 create nuisance alarms and increase the risk of fire damage to property.	Replace obsolete fire alarm panels in Buildings 081, 104, 137, 140, 750, and 233. Funded by Laboratory indirect.	
Compressed Air			X		Existing compressed air system has multiple underground leaks and the		Replacement of air compressors will be complete in FY 2011.

Support Facilities and Infrastructure (Assumes TYSP Implemented)							
Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
	N[a]	M[b]	P[c]	C[d]		Laboratory	DOE
					compressors have exceeded useful life.		Funded by ARRA.
Low Conductivity Water Distribution System			X		Pumps and control valves on pump pad 1802 are obsolete and need to be replaced.	Replace pumps and control valves on pump pad 1802. Funded by Laboratory indirect.	
Cooling Tower Water Distribution System			X		Underground cooling tower water piping from CT1201 and CT1202 to VVS is aging. Periodic leaks cause operational interruptions.	Replace underground cooling tower water piping from CT1201 and CT1202 to VVS. Funded by IGPP.	
			X		CT1701 underground piping components and valves are beyond their life expectancy.	Replace all underground valves and metal components. Funded by IGPP.	
			X		CT 1201, CT1202, and CT1701 all aboveground piping and supports need replaced or recoated.	CT1201, CT1202, and CT1701 all aboveground piping and supports to be inspected and replaced or recoated as needed. Funded by IGPP.	
			X		CT101 does not have redundant pumping capability.	Provide a back up pumps for redundancy. Funded by IGPP.	
Security Infrastructure							
Site Access Control			X		Limited security surveillance or control systems to effectively and efficiently monitor and control access and, when necessary, provide forensic information.	Some of initial funding was through Laboratory indirect.	The Office of Health, Safety, and Security (HSS) and SC has provided funding for hardware and installation for Phase I. Funding for Phase II (internal gates and hazardous material storage) is being budgeted, but cannot be funded until FY 2011 and FY 2012 DOE budgets are finalized.
N[a] = Not, M[b] = Marginal, P[c] = Partial, C[d] = Capable							

SLAC Planned Laboratory Site Map

BES=Basic Energy Science; SLI=Science Laboratory Infrastructure; TPS=Third Party Source (e.g. Stanford University)

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Thomas Jefferson National Accelerator Facility

Mission and Overview

The Thomas Jefferson National Accelerator Facility (TJNAF), located in Newport News, Virginia, is a laboratory operated by Jefferson Science Associates, LLC for the Department of Energy's (DOE) Office of Science (SC). The primary mission of the laboratory is to utilize its unique Continuous Electron-Beam Accelerator Facility (CEBAF) to explore the fundamental nature of confined states of quarks and gluons, including the nucleons that comprise the mass of the visible universe. TJNAF also is a world-leader in the further development of the superconducting radio-frequency (SRF) technology utilized for CEBAF. This technology is the basis for an increasing array of applications at TJNAF, other DOE labs, and in the international scientific community. At TJNAF, the advancement of SRF technology has enabled the 12 GeV upgrade project to double the energy of CEBAF which is presently underway. In addition, it facilitated the development of TJNAF's Free Electron Laser (FEL) and Energy Recovery Linac (ERL), key technologies for future state-of–the–art light sources. TJNAF's present core capabilities are: experimental, theoretical and computational Nuclear Physics; Accelerator Science; Applied Nuclear Science and Technology; and Large Scale User Facilities/Advanced Instrumentation.

TJNAF has an international user community of 1,356 researchers whose work has resulted in scientific data from 172 experiments to date, 289 Physics Letters and Physical Review Letters publications and 889 publications in other refereed journals at the end of FY 2010. Collectively, there have been over 30,000 citations for work done at Jefferson Lab.

Research at TJNAF and CEBAF also contributes to thesis research material for about one-third of all U.S. Ph.D.s awarded annually in Nuclear Physics (25 in FY 2010; 419 to date, 204 more in progress). The Lab's outstanding science education programs for K-12 students, undergraduates and teachers build critical knowledge and skills in the physical sciences that are needed to solve many of the nation's future challenges.

Core Capabilities

The following core capabilities distinguish TJNAF and provide a basis for effective teaming and partnering with other DOE laboratories, universities, and private sector partners in pursuit of the laboratory mission. These distinguishing core capabilities provide a window into the mission focus and unique contributions and

Lab-at-a-Glance

Location: Newport News, Virginia

Type: Single-Program Laboratory

Contract Operator: Jefferson Science Associates, LLC (JSA)

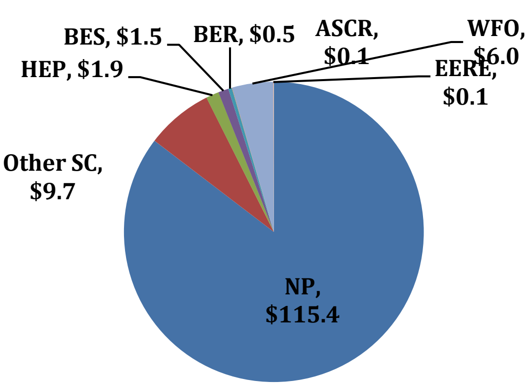
Responsible Site Office: Thomas Jefferson Site Office

Website: http://www.jlab.org

Physical Assets:
- 169 acres and 79 buildings and trailers
- 703,582 GSF in buildings and trailers
- Replacement Plant Value (RPV): $316.9M
- Deferred Maintenance: $15.6M
- Asset Condition Index (ACI):
  - Mission Critical 0.96
  - Mission Dependent 0.84
  - Asset Utilization Index: 0.97

Human Capital:
- 763 Full Time Equivalent Employees (FTEs)
- 23 Joint Faculty
- 25 Postdoctoral Researchers
- 14 Undergraduate Students
- 30 Graduate Students
- 1,356 Facility Users
- 1,188 Visiting Scientists

FY 2010 Funding by Source: ***(Cost Data in $M)***



FY 2010 Total Lab Operating Costs (excluding ARRA): $135.1
FY 2010 Total DOE Costs: $129.1
FY 2010 WFO (Non-DOE/Non-DHS): $6.0
FY 2010 WFO as % Total Lab Operating Costs: 4.4%
FY 2010 DHS Costs: $0.0

ARRA Obligated from DOE Sources in FY 2010: $0.0
ARRA Costed from DOE Sources in FY 2010: $43.5

strengths of TJNAF and its role within the Office of Science laboratory complex. Descriptions of these contributions and strengths of TJNAF and its role within the Office of Science laboratory complex. Descriptions of these facilities can be found at the website noted in the Lab-at-a-Glance section of this Plan. Each of the laboratory's core capabilities involves a substantial combination of facilities and/or teams of people and/or equipment, has a unique and/or world-leading component, and serves DOE/DHS missions and national needs. Specifically, TJNAF's four major core capabilities meeting these criteria are described below in detail:

1. Nuclear Physics

- Experimental Nuclear Physics

  TJNAF is unique in the world as a user facility for studies of the quark structure of matter using continuous beams of high-energy, polarized electrons. Its detector and data acquisition capabilities, when coupled with the high-energy electron beams, provide the highest luminosity (10^{39}/eN/cm^2/s) capability in the world. TJNAF supports one of the largest nuclear physics user communities in the world. The scientific program aims for excellence and pre-eminence in a number of key areas of nuclear physics. These include:

  - the structure of hadrons – especially the nucleon's charge and magnetization distributions including the separation in individual quark contributions, the exploration of the degrees-of-freedom governing baryon excitation, the momentum and spin distributions of valence quarks, and the experimental and theoretical tools necessary to carry out a program of nucleon tomography;

  - the structure of nuclei – including that due to the short-range component of the nucleon-nucleon interaction, the neutron radius of ^{208}Pb, and the underlying quark-gluon structure of the nucleus; and

  - Tests of fundamental symmetries in nuclear and particle physics, such as the determination of the weak charges of the proton and the electron, tests of the predictions of the Standard Model and the search for its possible extensions.

- Theoretical & Computational Nuclear Physics

  The program aims to provide comprehensive theoretical effort and leadership across nuclear physics. Support for the experimental program ranges from phenomenological analyses of the nucleon-nucleon interaction, and precise low-energy studies of the Standard Model, to the structure of the nucleon and its excitations, and explorations of the internal landscape of hadrons in terms of momentum, spin and spatial distributions. This internal dynamics is investigated in parallel studies using the methods of both lattice and perturbative QCD, and through the EBAC (Excited Baryon Analysis Center) project exploiting the development of appropriate state-of –the-art theoretical tools and technology.

  The synthesis of the latest technology with innovative theoretical tools is particularly notable in the area of High Performance Computing in lattice QCD, which focuses on hadronic and nuclear physics. The development and provision of novel software tools (Chroma) and science-optimized hardware (within the national lattice QCD program) have allowed the calculation of observables of direct relevance to the TJNAF experimental program from the spectroscopy of baryons and mesons, including exotics, to form factors and generalized parton distributions. When combined with the power and speed of the dedicated Graphical Processing Unit infrastructure, results of unprecedented precision for the hadron spectrum have been produced, as well as the first computations of hadronic scattering amplitudes, with more results to come. TJNAF's Jozef Dudek (joint appointment with Old Dominion University) received the DOE SC Early Career prize for his research on subatomic particle structure using lattice QCD in May of 2011. Half the Theory Center members are also engaged in phenomenological studies of the physics to be accessed at a future Electron Ion Collider and are contributing to the "white paper" on the physics case. In all aspects, the Theory Center works closely with the experimental community, whether in extracting the properties of nucleon excited states from hadro and photoproduction data, or in studies to constrain generalized parton distribution functions from the full kinematic range of results that TJNAF will produce.

The Nuclear Physics Core Capability serves DOE Scientific Discovery and Innovation (SC) mission numbers 2, 4, 22, 24, 26, 27, 28, 30, 33, 34, and 35.

2. Accelerator Science

The focus of TJNAF's Accelerator Science is on superconducting, high current, continuous wave, multi-pass linear accelerators (linacs), including energy recovering linacs. Past achievements and future plans are based on the lab's expertise in three fields, namely, SRF niobium-based accelerating technology, liquid helium refrigeration, and high current, low emittance electron injectors. This expertise, complemented by a talented group of accelerator scientists, supports the five TJNAF Accelerator Science priorities: the 12 GeV CEBAF Upgrade, continued 6 GeV operation, positioning TJNAF for a future beyond 12 GeV, a world-class light source based on a Free Electron Laser (FEL) and Energy Recovering Linac (ERL), and graduate and undergraduate education. Pavel Evtushenko was awarded a DOE SC Early Career prize for his research at TJNAF's FEL to develop high dynamic range diagnostics for linear particle accelerators in May, 2011. The prestigious APS Robert R. Wilson prize for Achievement in the Physics of Particle Accelerators was awarded to TJNAF's accelerator physicist, Yaroslav Derbenev for 2011.

With CEBAF, TJNAF has more integrated operating experience of superconducting linacs (>35%) than any other institution in the world. TJNAF SRF facilities have processed more multi-cell superconducting cavities of multiple types and designs, to consistently higher performance levels than any other facility in the world. TJNAF electron sources and injectors have produced continuous wave electron beams with currents of 170 μA and 89% polarization and unpolarized beams of 9 mA. TJNAF cryogenics staff has received numerous awards for improving the efficiency of cryogenic plants at NASA and at other DOE facilities, notably at Relativistic Heavy Ion Collider of Brookhaven National Laboratory (BNL). Our patented cryogenic operating cycles have been licensed to a commercial vendor for all of their existing and future plants. TJNAF technical infrastructure and staff position us uniquely to design and apply advances in SRF, FEL and injectors, at TJNAF, at other DOE laboratories and at laboratories around the world.

All Office of Science projects requiring SRF expertise are currently under discussion to determine how TJNAF can support these efforts. The SRF Institute at TJNAF can be a cost-effective R&D partner because of its experience and facilities. Past partnerships include jointly funded R&D and digital RF conductivity with the Facility for Rare Isotope Beams' (FRIB) predecessor, Rare Isotope Accelerator (RIA), high efficiency cryogenics jointly funded by NASA, high-current cavities funded by ONR, high-voltage electron guns funded by International Linear Collider (ILC), and crab cavities funded by the Advanced Photon Source (APS). Office of Nuclear Physics projects for which partnerships are envisioned are FRIB and all versions of an electron ion collider (EIC). Support for other Office of Science projects would include the Spallation Neutron Source (SNS) Power Upgrade Project (PUP), Project X at Fermilab, APS Upgrade at Argonne National Lab (ANL), and International Linear Collider (ILC).

The Accelerator Science Core Capability serves DOE Scientific Discovery and Innovation mission numbers 25, 26, and 30.

3. Applied Nuclear Science and Technology

- Free Electron Laser

  The development of key technologies in accelerator, photon, and detector science at TJNAF established a key skill base enabling the development of other advanced instruments and research tools, namely the Free Electron Laser Facility. Originally commissioned in 1995, it is currently the most powerful Free Electron Laser in the world. Producing up to 14 kW of CW average power in the near infrared regime, the coherent pulses of light have been used for research on such varied topics as the development of a treatment for adult acne, energy loss in semiconductors due to interstitial hydrogen, terahertz imaging for homeland security purposes, and a search for dark matter. The primary funding source for the Infrared (IR) FEL has been the ONR in support of its program to develop a high average power laser for shipboard defense against cruise missiles. That program has now entered a new phase with technology transfer to industry happening as the applications move from the laboratory to the field. TJNAF continues to be involved through Work for Others.

  During the last year under separate $12M United States Air Force (AF) funding a new ultraviolet (UV) FEL system has provided 20 microjoule pulses of 300 nm light at 4.7 MHz repetition rates again in 120 fs pulse trains. The harmonics of that UV FEL at 10 to 13 eV provide fully coherent beams with higher average brightness by a factor of 100 than any 3rd generation storage ring and have the added capability to provide ultra-short pulses to address systems dynamically. The use of narrow-line laser photons in many cases eliminates the requirement for a monochromator giving further advantage over relatively broadband synchrotron sources. The TJNAF UV FEL leads the world in its capability. TJNAF has transported the VUV beam and measured its power in the laboratory in preparation for some demonstration experiments planned for summer 2011. Such experiments are intended to demonstrate the usefulness of such a machine and its potential for science relevant to Basic Energy Sciences (BES) programs. Specific activities are directed at temporally resolved studies of combustion dynamics in diesel engines performed by researchers from Sandia National Laboratory, studies of long-lived trace isotopes using atomic trap trace analysis (ATTA) for dating ancient groundwater by PI from ANL and work on angular resolved photoemission studies (ARPES) by a group from Brookhaven National Laboratory.

This program has operated synergistically with the Nuclear Physics activities at TJNAF, benefitting from core capabilities such as SRF accelerators (developing high gradient modules partially under BES funding and providing valuable experience in high average current DC injector guns (extending voltage standoff from 320 kV to 500 kV), rf control systems (developing a new digital control system), and beam diagnostics (studying effects which degrade beam brightness such as CSR). It also developed a new technology deemed critical for one of the two major branches of next generation light sources for DOE: the ERL. In the ERL, the electron beam is re-cycled back through the accelerator out of phase with the accelerating field so the beam's energy is extracted back into RF power. This power, which would otherwise be lost, can represent 90% of the input to a high power linear accelerator. This development is an enabling technology for next generation machines which will produce ultra-short pulses of X-rays for studies into materials as outlined in "Directing Matter and Energy: Five Challenges for Science and the Imagination, a report from the DOE Basic Energy Sciences Advisory Committee". TJNAF was the pioneer in developing this technology and its FEL remains the highest power system extant. A number of other laboratories are adopting this technology and NSF is considering the development at Cornell of a very high power system based on such experience. ERL technology is likely to become an important contribution to sustainability initiatives at DOE labs.

- Experimental Nuclear Physics

  TJNAF is home to and developer of state-of-the-art radiation detection, data analysis and imaging techniques, fast electronics and data-acquisition, and data storage capabilities. These capabilities are crucial to the state-of-the-art and anticipated experimental nuclear physics program, and underpin the bio-medical applications described below. Scientists and engineers have also developed advanced radiation shielding solutions as part of the lab's 12 GeV program, including recently-invented and cost-effective hydrogen and boron-enhanced products, particularly well suited for absorbing neutrons.

- Radiation Detection and 2D and 3D Imaging in Nuclear, Biomedical and other applications

  The Jefferson Lab Radiation Detector and Imaging Group develops, constructs and tests a variety of novel high performance (high resolution and high sensitivity) 2D and 3D single photon, emission computed tomography (SPECT), positron emission tomography (PET), and optical and x-ray computed tomography (CT) imaging systems. These imaging systems are used for a broad variety of applications including: studies of biological function in plants and small animals; motion tracking and imaging, medical preclinical and clinical applications; and the potential for non-destructive evaluation and homeland security applications. Silicon photomultipliers were explored at Jefferson Lab for nuclear physics detector systems because of their immunity to magnetic fields and have potential for highly compact photosensors for biomedical applications.

The Applied Nuclear Science and Technology Core Capability serves DOE Scientific Discovery and Innovation mission numbers 9, 14, 26, and 30.

4. Large Scale User Facilities/Advanced Instrumentation

- Experimental Nuclear Physics

  TJNAF is the world's leading user facility for studies of the quark structure of matter using continuous beams of high-energy, polarized electrons. The Continuous Electron Beam Accelerator is housed in a 7/8 mile racetrack and can deliver precise electron beams with energies up to 6 GeV to three experimental End

Stations or Halls simultaneously. Hall A houses two high-resolution magnetic spectrometers of some 100 feet length and a plethora of auxiliary detector systems. Hall B is the home of the CEBAF large-acceptance spectrometer with multiple detector systems and some 40,000 readout channels. Hall C boasts an 80 feet long high-momentum magnetic spectrometer and houses many unique large-installation experiments. Maintenance, operations and improvements of the accelerator beam enclosure and beam quality, and the cavernous experimental Halls and the multiple devices in them, are conducted by the Jefferson Lab staff, to facilitate user experiments.

The expertise developed in building and operating CEBAF has led to the design of an upgrade that will double the energy (to 12 GeV) and provide a unique facility for nuclear physics research that will ensure continued world leadership in this field for several decades. This upgrade will add one new experimental facility, Hall D, dedicated to the operation of a hermetic large-acceptance detector for photon-beam experiments. The upgrade will add a new magnetic spectrometer in Hall C, and convert the Hall B apparatus to allow for the higher-energy and higher luminosity operations. Unique opportunities exist in Hall A with a proposed large-acceptance magnetic spectrometer and possible dedicated apparatus for one-of-a-kind experiments.

Jefferson Lab staff has gained the unique ability to conceive and design large accelerator facilities, building upon 6-GeV CEBAF operations and augmented with the ongoing 12-GeV Upgrade. In partnership with BNL and scientists and engineers world-wide, TJNAF scientists and engineers are thus leading the conceptual design of a powerful electron-ion collider that many believe will be needed to advance the field beyond the 12 GeV Upgrade.

- Accelerator Science

TJNAF has developed state-of-the-art instrumentation for R&D, design, fabrication, chemical processing, and testing of superconducting RF cavities. This complete concept-to-delivery capability is unique in the world. In addition, TJNAF has extensive expertise in high current photoemission sources, especially polarized sources. This broad suite of hardware capabilities is complemented by world-class expertise in accelerator design and modeling. (It should be noted that Jefferson Lab accelerator physicist Yaroslav Derbenev received the 2011 APS Robert R. Wilson prize Achievement in the Physics of Particle Accelerators.) All of these capabilities are essential to the development, deployment, commissioning and operation of the CEBAF 12 GeV upgrade project. The addition of TJNAF's Technology and Engineering Development Facility (TEDF), currently under construction, will provide 100,000 additional square feet that will enhance and collocate all SRF operations elements and will provide additional experimental assembly space. It will also provide configurable space that can be adapted to work on different kinds of srf cavities as TJNAF's portfolio of projects expands.

In addition, this expertise can be available to other projects within the Office of Science, and also around the world. For example, the extensive experience of TJNAF in the design and construction of high current ERLs, in combination with the world leading capabilities in accelerator science and superconducting radiofrequency techniques, mean that TJNAF is making a major contribution to the design and construction of future large scale user facilities in BES, especially 4th generation light sources.

The Large-Scale User Facilities/Advanced Instrumentation Core Capability serves DOE's Scientific Discovery and Innovation mission numbers 24, 26 and 30.

Science Strategy for the Future/Major Initiatives

Science in the 21st Century is making enormous advances on several fronts in physics, chemistry, biology and other subjects through the research capabilities provided by advanced accelerator facilities and their operation as international user facilities. TJNAF possesses key capabilities and competencies in accelerator science and in the application of the modern accelerator technologies. This core competence is dominated by the employment of superconducting radio frequency techniques in multiple pass linear accelerators, energy recovery linear accelerators and free electron lasers. Continued development of these capabilities is one of the major initiatives integral to this strategic plan. Based on the studies made under the auspices of both the Nuclear Science Advisory Committee (NSAC) and the Basic Energy Sciences Advisory Committee (BESAC), TJNAF has identified areas in nuclear physics and in photon science where it can directly provide world leading user facilities meeting the identified needs of the research community. In addition it has identified collaborative roles that it can play in the provision of facilities elsewhere associated with the Office of Science (Basic Energy Sciences, High Energy Physics and Nuclear Physics) and other agencies.

The nuclear physics program being pursued by more than 1,300 staff and users is currently dominated by a series of key experiments using the Continuous Electron Beam Accelerator Facility operating at energies up to 6 GeV. Among the incisive measurements underway is a measurement of the weak charge of the proton. The motivation and interpretation of these experimental studies is underpinned by theoretical studies using state-of-the-art calculational techniques in QCD both on the lattice and in the continuum, as well as precision photon-Z boson radiative corrections to experiments like Qweak. A major goal of the laboratory is to execute the 12 GeV Upgrade Project. This project, which was identified as the highest priority for the field of Nuclear Physics by the 2007 NSAC Long Range Plan, is currently under construction and will be commissioned in 2013-2015. This will allow a unique 3D map of the valence quarks and extend the earlier studies to comprehensively describe the valence quark momentum and spin distributions in nucleons and nuclei. New opportunities to discover heretofore unobserved hadron states predicted by quantum chromodynamics will be opened. Measurements of the weak couplings of elementary particles are accessible through measurements of parity violating asymmetries. Lepton scattering has proven and continues to be a powerful tool in the elucidation of the structure of the world, and a future electron-ion collider with high luminosity could provide the opportunity to explore hadronic structure in a region dominated by the quark-antiquark sea and by gluons.

The existing free electron laser facilities at TJNAF employ a single pass electron linear accelerator followed by combinations of undulator and optical cavities. Energy recovery occurs on a second (out of phase) passage down the linac. The existing facility is set up to operate in the infrared or the ultra-violet regime. A design has been developed to install the capability to accelerate to 300 MeV in one pass and using two passes of acceleration and two passes of deceleration, to generate a continuous wave, coherent, short pulse photon beam with energies up to 100 eV and beyond in the soft X-ray region. There is no comparable facility currently available in the world.

Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

TJNAF is located on a 169 acre federal reservation. North of the DOE-owned land is an eight acre parcel referred to as the Virginia Associated Research Campus (VARC) which is owned by the Commonwealth of Virginia and leased to SURA which, in turn, sub-leases this property for $1 dollar per year to DOE for use in support of the Lab. SURA owns 37 acres, adjacent to the TJNAF site, where it operates a 42-room Residence Facility at no cost to DOE.

TJNAF consists of 60 DOE owned buildings (684,832 SF), two state leased buildings (37,643 SF), and 15 real property trailers (18,750 SF) totaling 741,225 (SF), plus roads and utilities. Additionally, the Lab leases office and lab space (44,280 SF) from the City of Newport News located in the Applied Research Center (ARC), which was constructed by the City of Newport News and adjacent to the TJNAF campus. In addition to these facilities, TJNAF has 72 shipping containers (22,080 SF) used for storage and 19,030 SF of off-site leased storage space. There were no real estate actions in FY 2010 or planned for FY 2011 involving leases of more than 10,000 SF. At the close of FY 2010, ~820 employees were employed and occupying site facilities. Each day, TJNAF hosts on average, ~100 users from the United States and around the world.

The Lab currently has a shortage of technical and office space. The Test Lab has the largest amount of deferred maintenance of any Lab building. Accelerator Site electrical distribution and cooling towers have reached the end of their service life. Communications, computing air conditioning and power, and the Cryogenics Test Facility serving the Test Lab have reached their capacity and need to be expanded to meet the Lab's mission.

A current copy of the Land Use Plan can be can be found on the TJNAF Facilities Management website. Table 1 reflects an Asset Condition Index as of 1 October 2010 that meets the current goal established by DOE SC for Mission Critical Facilities. Mission Dependent Facilities are below the established goal due to aging real property trailers. Through GPP and SLI investments, TJNAF will achieve the SC goal for Mission Dependent Facilities by FY 2015. The site wide

Asset Utilization Index is ~ 100% and has been since construction of the Lab. In most areas space is not adequate to accommodate an efficient work environment.

Table 1. SC Infrastructure Data Summary

Total Replacement Plant Value ($)		$316,910,947		
Total Deferred Maintenance ($)		$15,556,758		
Site-Wide ACI (B, S, T)		0.951		
			# Assets (B, S, T)	GSF (B, T)
Asset Condition Index (B, S, T)	Mission Critical	0.961	54	633,977
	Mission Dependent	0.844	41	69,605
	Not Mission Dependent	0.000	0	0
			# Assets (B, T)	GSF (B, T)
Asset Utilization Index (B, T)	Office	100	19	171,122
	Warehouse	92.06	10	45,315
	Laboratory	100	35	452,079
	Hospital	0	0	0
	Housing	0	0	0

B = Buildings; S = Structures; T = Trailers

Facilities and Infrastructure to Support Laboratory Missions

The completion of the 12 GeV Upgrade, scheduled for FY 2015, adds a fourth experimental hall along with upgrades to existing halls and will provide TJNAF users with state-of-the-art facilities necessary to advance science in support of DOE SC goals. Additionally, completion of the Technology and Engineering Development Facility (TEDF), scheduled for FY 2013, will provide a first rate facility for the advancement of research and development in superconducting radio frequency (SRF) technology. While the support facilities and infrastructure are not mission-ready today, the completion of the TEDF, the Utilities Infrastructure Modernization SLI project and the Research and User Support Facility would enable TJNAF to meet its current modernization goals by 2017.

TJNAF assesses the condition of its facilities on a four year cycle using a software package called "VFA Facility" that is offered by Vanderweil Facility Advisors (VFA). Overall, the condition of the facility infrastructure is good. There are, however, shortages in office technical and experimental assembly work space. Currently over 18,750 square feet of temporary trailers are used to provide both office and technical space. GPP and SLI funded projects have been identified in the Lab's Ten Year Facilities Plan to correct these shortages and eliminate temporary trailers. The Experimental Staging Facility, General Purpose Building Expansion, 4 KW End Station Refrigerator Building, installation of a new 22 MVA substation, and replacement of the Test Lab Cooling Towers completed in 2010 provided some of the needed critical infrastructure. Completion of the 12 GeV and TEDF projects will provide an additional 154,000 SF of technical and experimental space. In addition to space provided by these two projects, the Ten Year Facilities Plan identifies 102,000 SF of additional needed technical, office, or support space.

A Mission Readiness Peer Review of TJNAF was held in September 2010 with a very favorable outcome. The review did not report any findings and identified three opportunities for improvement. The Mission Readiness assessment of technical and support facilities and infrastructure is summarized in Enclosure 2. TJNAF is seeking DOE support for two SLI line item projects; the Utilities Infrastructure Modernization Project and the Research and User Support Facility currently in the SLI funding profile for 2013. Completion of these projects will upgrade critical site support utilities and allow consolidation of staff currently in leased space, provide additional conference space and bring the buildings up to desired sustainability and aesthetic standards.

Strategic Site Investments.

- **12 GeV Conventional Facilities (Line Item)** Conventional facilities required for construction, pre-operation, and some operations of CEBAF at 12 GeV are included as part of the 12 GeV CEBAF Upgrade project. The conventional construction includes 36,400 SF of new space including an extension to the tunnel, a fourth experimental hall, and upgrades to Halls A, B and C.

- **Technology & Engineering Development Facility (SLI) (CD-3B)** The project renovates the current Test Lab (about 95,000 square feet), removes over 10,000 SF of inadequate and obsolete work space in and adjacent to the Test Lab, and removes 12,000 SF of dilapidated trailers that do not meet current commercial standards. The project includes construction of a new building and a building addition which will add over 117,000 SF of needed workspace for critical technical support functions, including mechanical and electrical engineering, cryogenics engineering and fabrication, and environment, safety, and health. The project has been submitted as two Leadership in Energy and Environmental Design (LEED) projects (Technology and Engineering Development Building and Test Lab Addition/Rehab) with the design goal of achieving, LEED Gold (second highest designation). Energy savings from the Test Lab Renovation are estimated at 762,570 kWh/yr of electricity and 7,437 therms of natural gas for a total of utility cost savings of $52,000/year.

- **Utilities Infrastructure Modernization Project (SLI) (CD-1)** This project replaces or upgrades the following utility systems:

    - Electrical Distribution: Replace accelerator site primary and secondary electric feeders and provide an alternate power feed capable of restarting the Central Helium Liquifier (CHL).

    - Process Cooling: Replace/upgrade 20 to 40 year old site cooling towers serving the Accelerator Site Low Conductivity Water (LCW) systems and provide additional computer center cooling and uninterruptable power.

    - Cryogenics: Upgrade Cryogenics Test Facility adjacent to the Test Lab (TEDF) to fully support SRF and FEL R&D and experimental hall operations.

    - Communications: Replace 20 to 40 year old underground communications and data cabling and equipment.

    - This project initially programmed for FY 2011-13 funding has been delayed. The Lab has requested FY 2013 funding for this critical project.

- **Research and User Support Facility (SLI)** This project funds the modernization of, and additions to, the CEBAF Center, which is the hub of the Lab. Construction includes two additional wings (95,000 SF) and the rehabilitation of 67,300 SF of space in the building. The project alleviates overcrowding of personnel, relocates staff and users currently occupying leased space, accommodates planned staff growth needed for the additional 12 GeV experimental hall and reduces leased space in the Applied Research Center and in commercial storage warehouses. The project will be designed and constructed to meet LEED Gold standards and reduce energy consumption of the existing building by 30%.

Maintenance Strategy

TJNAF utilizes small business subcontractors to perform the majority of facility maintenance tasks. Maintenance investment will continue at a level to maintain the facilities mission ready. The Lab has developed SLI or GPP projects to significantly reduce deferred maintenance. It is estimated the TEDF and UIM projects will eliminate over 70% of the Lab's deferred maintenance associated primarily with the rehabilitation of the Test Lab and elimination of temporary trailers. The Lab has a trailer disposal plan to replace trailers with permanent building space.

Excess Facility/Material/Environmental

TJNAF does not have any excess facilities or environmental issues. The Lab is in the process of recycling 130 concrete blocks from the Test Lab Building from when it was operated as the NASA Space Radiation Effects Laboratory (1964 to 1984). DOE recently determined that these blocks are not subject to the moratorium on the release of radioactive material. The plan is to recycle these blocks during FY 2011. The Lab has an active metal recycling program with more than 80,000 pounds recycled during the first half of FY 2011.

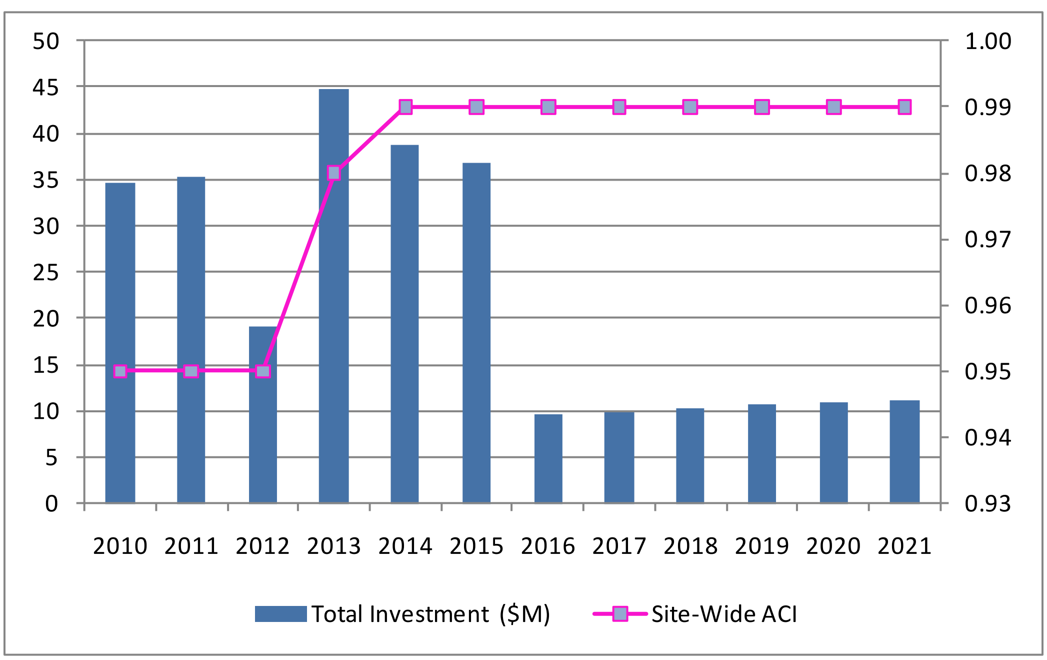
Trends and Metrics

Table 2 shows the Lab's planned infrastructure investment and the positive impact on the Asset Condition Index (ACI) and level of deferred maintenance (DM). Figure 1 depicts site wide ACI and infrastructure investments. Planned projects would allow the Lab to reach and sustain a DOE performance rating of "Excellent" by FY 2013. TJNAF facilities are expected to be mission ready upon completion of the projects identified in the Ten Year Site Plan.

Table 2. Facilities and Infrastructure Investments (BA in $M)

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	4.9	4.2	4.7	5.2	5.7	6.0	6.6	6.8	7.0	7.3	7.5	7.7
Deferred Maintenance (DM) Reduction												
Excess Facility Disposition (overhead)	-	-	-	-	-	-	-	-	-	-	-	-
IGPP	-	-	-	-	-	-	-	-	-	-	-	-
GPP	2	2.5	2.2	4.6	3.1	3.1	3.1	3.1	3.2	3.3	3.4	3.5
Line Items	27.7	28.5	12.3	35.0	30.0	27.6	0	0	0	0	0	0
Total Investment	34.6	35.2	19.2	44.8	38.8	36.7	9.7	9.9	10.2	10.6	10.9	11.2
Estimated Replacement Plant Value (RPV)	316.6	327.8	339.6	378.6	411.3	433.2	479.1	493.5	512.3	527.7	543.5	559.8
Estimated DM	15.6	16	16.5	8.1	5	5.1	4.5	4.6	4.7	4.9	5	5.2
Site-Wide Asset Condition Index (ACI)	0.95	0.95	0.95	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

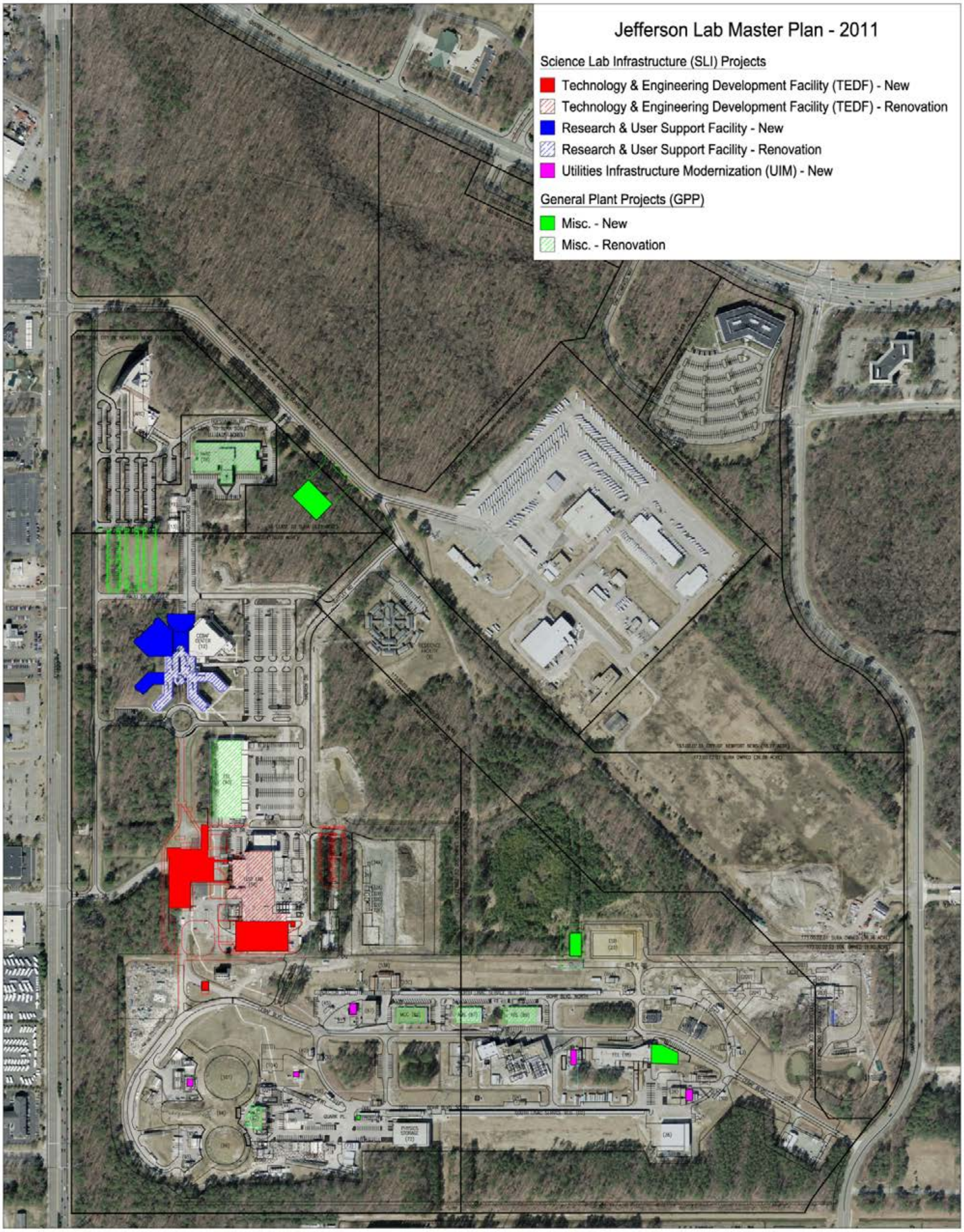
Figure 1. Facilities and Infrastructure Investments



Technical Facilities and Infrastructure (Assumes TYSP Implemented)									
Core Capabilities		**Mission Ready**				**Key Buildings**	**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N	**M**	**P**	**C**			**Laboratory**	**DOE**
Nuclear Physics	Now			X		• Central Helium Liquefier • South Access Bldg • North Access Bldg • Test Lab • Counting House • Experimental Equipment Laboratory (EEL) • End Station Refrigerator • Accelerator Tunnel	• Inadequate: Technical & Experimental Assembly Space • Inadequate Service Bdgs. • Deferred Maintenance • Building Code Deficiencies	• Counting House Sustain. Improvements (FY12) • Service Bldg 68 Addition (FY12) • Hall B Fire Sprinkler (FY12) • Cooling North & South LINAC (FY12) • Relocate Shipping & Receiving from EEL (FY15-17) • Experimental Equipment Laboratory Rehab (FY 16-19)	• 12 GeV Conventional Facilities (LI) FY 08-12 • Technology & Eng. Development Facility (SLI) FY 09-12
	In 5 Years				X				
	In 10 Years				X				
Accelerator Science	Now			X		• Test Lab • Cryogenics Test Facility	• Inadequate Work Space • Aging Facilities • Inadequate Utility Capacity	• Injector & Cryomodule Test Facility (FY 13)	• Technology & Eng. Development Facility (SLI) FY 09-12 • Utilities Infrastructure Modernization -Expand CTF (SLI) FY 13-14
	In 5 Years				X				
	In 10 Years				X				
Applied Nuclear Science & Technology	Now			X		• Free Electron Laser • Experimental Equipment Laboratory (EEL) • NN Applied Research Center	• Inadequate Technical Space • Assembly • Staging • Inadequate South Site LCW	• Experimental Equipment Laboratory Rehab (FY 16-19) • South Site LCW Plant (FY11) • FEL Offices (FY18-21)	
	In 5 Years				X				
	In 10 Years				X				
Large Scale User Facilities - Advanced Instrumentation	Now			X		• Experimental Halls • Experimental Equipment Laboratory (EEL) • CEBAF Center	• Inadequate experimental halls for planned program • Inadequate experimental support and work space • Inadequate work space for scientists & users		• 12 GeV Conventional Facilities (LI) FY 08-12 • Technology & Eng. Development Facility (SLI) FY09-12 • Researcher and User Support Facility (SLI) FY16-18
	In 5 Years			X					
	In 10 Years				X				
N = Not, M = Marginal, P = Partial, C = Capable						S= Stimulus GPP, LI=Line Item, SLI= Science Lab Infrastructure, UIM=Utilities Infrastructure Modernization			

Support Facilities and Infrastructure (Assumes TYSP Implemented)								
Real Property Capability		**Mission Ready**				**Facility and Infrastructure Capability Gap**	**Action Plan**	
		N	**M**	**P**	**C**		**Laboratory**	**DOE**
Work Environment	Now			X		• Insufficient Offices • CEBAF Center Bldg systems at end of service life • No recreational/fitness facilities • Cafeteria undersized	• FEL Offices (FY18-21) • Sustainability Improvements Technical Support Bldgs (FY13-14)	• TEDF (SLI) FY09-12 • Researcher and User Support Facility (SLI) FY16-18
	In 5 Years			X				
	In 10 Years				X			
User Accommodations	Now			X		• Minimum User and visitor areas		• Researcher and User Support Facility (SLI) FY16-18
	In 5 Years				X			
	In 10 Years				X			
Site Services	Now			X		• Poor location of RADCON Calibration Facility • Limited Computer Center Cooling • Unconsolidated of Facility Storage • Inadequate Site Laydown Area	• RADCON Calibration Facility (FY13) • Cooling for LQCD Data Center FY12) • Relocate Shipping & Receiving (FY15-17)	• UIM(SLI) FY 13-14
	In 5 Years			X				
	In 10 Years				X			
Conference and Collaboration Space	Now			X		• Insufficient conference/collaboration space • Auditorium too small		• Researcher and User Support Facility (SLI) FY16-18
	In 5 Years				X			
	In 10 Years				X			
Utilities	Now			X		• Aging electrical distribution • Aging Cooling water systems • Complete fire protection loop • Aging/inadequate comms/data • Insufficient cryogenics • Aging Access Control System • Sustainability	• MCC Sustainability Improvements (FY13) • VARC Sustainability Improvements (FY13) • Upgrade Access Control System (Security - FY11) Fire Prot Loop (FY-14)	• UIM(SLI) FY 13-14 • Water Reuse (TBD) FY14
	In 5 Years				X			
	In 10 Years				X			
Roads & Grounds	**Now**			X		• Inefficient Site Lighting and coverage • Stormwater Mgmt Shortfalls • Roadway surface improvements • Parking Shortage	• Misc Lighting Projects (FY11-15) • Storm water (FY15) • Misc Paving (FY14-15) • Parking Improvements (FY15)	
	In 5 Years				X			
	In 10 Years				X			
N = Not, M = Marginal, P = Partial, C = Capable						S= Stimulus GPP, LI=Line Item, SLI= Science Lab Infrastructure, UIM=Utilities Infrastructure Modernization		

TJNAF Lab Site Map – Planned Infrastructure Projects



Appendix A. Distribution of Core Capabilities across the SC Laboratories

SC has identified seventeen categories of core capabilities that comprise the scientific and technological foundation of its national laboratories. SC uses three criteria to define core capabilities. They must:

- Encompass a substantial combination of facilities and/or teams of people and/or equipment;
- Have a unique and/or world-leading component; and
- Be relevant to a discussion of DOE/NNSA/DHS missions.

Definitions of the core capability categories are provided in Appendix B, and Figure 1 shows the distribution of the core capabilities across the ten SC laboratories.

Figure 1. Distribution of Core Capabilities Across the SC Laboratories

Categories of Core Capabilities	AMES	ANL	BNL	FNAL	LBNL	ORNL	PNNL	PPPL	SLAC	TJNAF
Particle Physics		✓	✓	✓	✓				✓	
Nuclear Physics		✓	✓		✓	✓				✓
Accelerator Science		✓	✓	✓	✓	✓			✓	✓
Plasma and Fusion Energy Sciences						✓		✓		
Condensed Matter Physics and Materials Science	✓	✓	✓		✓	✓			✓	
Chemical and Molecular Science	✓	✓	✓		✓	✓	✓		✓	
Climate Change Science			✓		✓	✓	✓			
Biological Systems Science			✓		✓	✓	✓			
Environmental Subsurface Science					✓	✓	✓			
Applied Mathematics		✓			✓					
Advanced Computer Science, Visualization, and Data		✓			✓	✓	✓			
Computational Science					✓	✓				
Applied Nuclear Science and Technology		✓	✓		✓	✓	✓			✓
Applied Materials Science and Engineering	✓	✓	✓		✓	✓	✓			
Chemical Engineering		✓	✓		✓	✓	✓			
Systems Engineering and Integration		✓	✓		✓	✓	✓			
Large Scale User Facilities/Advanced Instrumentation		✓	✓	✓	✓	✓	✓	✓	✓	✓

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Appendix B: SC Core Capability Category Definitions

1. *Particle Physics*: The ability to carry out experimental and theoretical research to provide new insights and advance our knowledge on the nature of matter and energy, and the basic nature of space and time itself. This includes the design, operation and analysis of experiments to discover the elementary constituents of matter and energy and probe the interactions between them and the development of models and theories to understand their properties and behaviors.
2. *Nuclear Physics*: The ability to carry out experimental and theoretical research to provide new insights and advance our knowledge on the nature of matter and energy. This includes the design, operation and analysis of experiments to establish the basic properties of hadrons, atomic nuclei, and other particles, and the development of models and theories to understand these properties and behaviors in terms of the fundamental forces of nature.
3. *Accelerator Science and Technology*: The ability to conduct experimental, computational, and theoretical research on the physics of particle beams and to develop technologies to accelerate, characterize, and manipulate particle beams in accelerators and storage rings. The research seeks to achieve fundamental understanding beyond current accelerator and detector science and technologies to develop new concepts and systems for the design of advanced scientific user facilities.
4. *Plasma and Fusion Energy Sciences*: The ability to conduct world-leading plasma research that can range from low-temperature to high temperature/high pressure plasmas. This ability can be in operation of the state-of-the-art experimental fusion facilities to carry out world-leading research on the fundamental physics of plasmas, in theory and computations, which is critical to the full understanding of the plasma phenomena being studied or to enable technologies that allow experiments to reach and in many cases exceed their performance goals.
5. *Condensed Matter Physics and Materials Science*: The ability to conduct experimental, theoretical, and computational research to fundamentally understand condensed matter physics and materials sciences that provide a basis for the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and utilization. Areas of research include experimental and theoretical condensed matter physics, x-ray and neutron scattering, electron and scanning probe microscopies, ultrafast materials science, physical and mechanical behavior of materials, radiation effects in materials, materials chemistry, and bimolecular materials.
6. *Chemical and Molecular Science*: The ability to conduct experimental, theoretical, and computational research to fundamentally understand chemical change and energy flow in molecular systems that provide a basis for the development of new processes for the generation, storage, and use of energy and for mitigation of the environmental impacts of energy use. Areas of research include atomic, molecular and optical sciences; gas-phase chemical physics; condensed phase and interfacial molecular science; solar photochemistry; photosynthetic systems; physical biosciences; catalysis science; separations and analytical science; actinide chemistry; and geosciences.
7. *Climate Change Science*: The ability to address critical scientific questions on the causes, impacts, and predictability of climate change via the integration of laboratory-specific research facilities, instrumentation and/or leadership-class computational systems, and individuals with expertise in climate change research and related disciplines. This unique combination of tools and people is the foundation for research of scale and breadth unmatched by other facilities, world-wide, for example, on (1) atmospheric-process research and modeling, including clouds, aerosols, and the terrestrial carbon cycle; (2) climate change modeling at global to regional scales; (3) research on the effects of climate change on ecosystems; and (4) integrated analyses of climate change, from causes to impacts, including impacts on energy production, use, and other human systems.
8. *Biological Systems Science*: The ability to address critical scientific questions in understanding complex biological systems via the integration of laboratory-specific research facilities, instrumentation and/or leadership-class computational systems, and individuals with expertise in biological systems research and related disciplines to advance DOE missions in energy, climate, and the environment. This unique combination of tools and people is the foundation for research of scale and breadth unmatched by other facilities world-wide, for example, on research that employs systems biology and computational modeling approaches enabled by genome sequencing of microbes, plants, and biological communities relevant to (1) bioenergy production, (2) environmental contaminants processing, and (3) global carbon cycling and biosequestration and (4) fundamental research on

radiochemistry tracers and the effects of low dose radiation exposure to the interactions between biological systems and the environment.

9. *Environmental Subsurface Science*: The ability to understand, predict and mitigate the impacts of environmental contamination from past nuclear weapons production and provide a scientific basis for the long-term stewardship of nuclear waste disposal via the integration of laboratory-specific research facilities, instrumentation and/or leadership-class computational systems, and multidisciplinary teams of individuals with expertise in environmental subsurface science and related disciplines. This unique combination of tools and expertise is the foundation for research of scale and integration unmatched by other environmental subsurface science activities world-wide, for example, on (1) linking research across scales from the molecular to field scale, (2) integration of advanced computer models into the research and (3) multidisciplinary, iterative experimentation to understand and predict contaminant transport in complex subsurface environments.

10. *Applied Mathematics*: The ability to support basic research in the development of the mathematical models, computational algorithms and analytical techniques needed to enable science and engineering-based solutions of national problems in energy, the environment and national security, often through the application of high-performance computing. Laboratory Core Competencies in this area would involve a critical mass of world-leading researchers with recognized expertise and publications in such areas as linear algebra and nonlinear solvers, discretization and meshing, multi-scale mathematics, optimization, modeling of complex systems, and analysis methods (e.g., analysis of large-scale data, uncertainty quantification, and error analysis).

11. *Advanced Computer Science, Visualization, and Data*: The ability to have a widely-recognized role in advances in all applications in computational science and engineering. A core competency in these areas would involve a large pool of nationally and internationally recognized experts in areas such as programming languages, high-performance computing tools, peta- to exa-scale scientific data management and scientific visualization, distributed computing infrastructure, programming models for novel computer architectures, and automatic tuning for improving code performance, with unique and/or world-leading components in one or more of these areas. A core competency would also require access to (note: these resources do not need to be co-located) a high end computational facility with the resources to test and develop new tools, libraries, languages, etc. In addition, linkages to application teams in computational science and/or engineering of interest to the Department of Energy and/or the Department of Homeland Security would be beneficial to promptly address needs and requirements of those teams.

12. *Computational Science*: The ability to connect applied mathematics and computer science with research in scientific disciplines (e.g., biological sciences, chemistry, materials, physics, etc.). A core competency in this area would involve a large pool of nationally and internationally recognized experts in applied mathematics, computer science and in scientific domains with a proven record of effectively and efficiently utilizing high performance computing resources to obtain significant results in areas of science and/or engineering of interest to the Department of Energy and/or the Department of Homeland Security. The individual strengths in applied mathematics, computer science and in scientific domains in concert with the strength of the synergy between them is the critical element of this core competency.

13. *Applied Nuclear Science and Technology*: The ability to use a broad range of facilities, instrumentation, equipment and, often, interdisciplinary teams that apply the knowledge, data, methods, and techniques of nuclear physics, nuclear chemistry, and related accelerator physics to missions of the Departments of Energy and Homeland Security. The elements of this capability are often brought together in unique combinations with those of other disciplines to address high priority needs such as new and improved energy sources and systems; radioisotope production and advanced instrumentation for nuclear medicine; development of methods and systems to assure nonproliferation and combat terrorism; and environmental studies, monitoring, and remediation.

14. *Applied Materials Science & Engineering*: The ability to conduct theoretical, experimental, and computational research to fundamentally understand the science of materials with focus on the design, synthesis, prediction and measurement of structure/property relationships, the role of defects in controlling properties, and the performance of materials in hostile environments. The strong linkages with molecular science, engineering, and environmental science provides a basis for the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and utilization. Areas of research include nanoscale phenomena, x-ray and neutron scattering, electron and scanning probe microscopies, ultrafast materials science, physical and mechanical behavior of materials, radiation effects in materials, materials chemistry, and bimolecular materials.

15. *Chemical Engineering*: The ability to conduct applied chemical research that spans multiple scales from the molecular to macroscopic and from picoseconds, to years. Chemical engineering translates scientific discovery into transformational solutions for advanced energy systems and other U.S. needs related to environment, security, and national competitiveness. The strong linkages between molecular, biological, and materials sciences, engineering science, and separations, catalysis and other chemical conversions provide a basis for the development of chemical processes that improve the efficiency, economy, competitiveness, environmental acceptability, and safety in energy generation, conversion, and utilization. A core capability in chemical engineering would underpin R&D in various areas such as nanomanufacturing, process intensification, biomass utilization, radiochemical processing, high-efficiency clean combustion, and would generate innovative solutions in alternative energy systems, carbon management, energy-intensive industrial processing, nuclear fuel cycle development, and waste and environmental management.

16. *Systems Engineering and Integration*: The ability to solve problems holistically from the concept and design phase to ultimate deliverable and completion phase, by synthesizing multiple disciplines, and to develop and implement optimal solutions. The ability to develop solutions that address issues of national energy and environmental security. Areas of application of this capability include development of programs in energy supply, storage and efficiency; and deployment of novel solutions to materials and sensor problems in fields of interest to the Department of Energy and/or the Department of Homeland Security.

17. *Large-Scale User Facilities/Advanced Instrumentation*: The ability to conceive, design, construct and operate leading-edge specialty research user facilities. This includes the ability to manage effectively construction of $100 million or greater one-of-a-kind scientific facilities, and to host hundreds to thousands of U.S. and international users in addition to carrying out world-class research at the facility itself. The ability to conceive, design, build, operate and use first-in-class technical instruments intended for a particular research purpose, often requiring the material expertise of multiple scientific disciplines. Instrumentation that can be created by a small number of individuals or that would sit on a laboratory bench-top is not considered part of this core capability.

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Appendix C: List of Funding Sources

DOE Office of Science

- Advanced Scientific Computing Research
- Basic Energy Sciences
- Biological and Environmental Research
- Fusion Energy Sciences
- High Energy Physics
- Nuclear Physics

DOE Energy Programs

- Biomass Program
- Buildings Technologies
- Electricity Delivery and Energy Reliability
- Federal Energy Management
- Fossil Energy
- Geothermal Technologies
- Hydrogen, Fuel Cells and Infrastructure Technologies
- Industrial Technologies
- Nuclear Energy
- Solar Energy Technology
- Wind and Water Power Technologies
- Weatherization and Intergovernmental

DOE Environmental Research

- Environmental Management

National Nuclear Security Administration

- Defense Programs
- Nuclear Nonproliferation
- Naval Reactors
- Emergency Operations
- Infrastructure & Environment
- Defense Nuclear Security

Department of Homeland Security

- Borders & Maritime Security
- Chemical & Biological Security
- Command, Control & Interoperability
- Explosives
- Human Factors
- Infrastructure & Geophysical

Work for Others

- (Specify)

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Appendix D: List of DOE/NNSA/DHS Missions

Scientific Discovery and Innovation (SC)

1. Develop mathematical descriptions, models, methods, and algorithms to enable scientists to accurately describe and understand the behavior of the earth's climate, living cells, and other complex systems involving processes that span vastly different time and/or length scales to advance DOE missions in energy and environment
2. Develop the underlying understanding and software to enable scientists to make effective use of computers at extreme scales—many thousands of multi-core processors with complicated interconnections; and to transform extreme scale data from experiments and simulations into scientific insight
3. Advance key areas of computational science and discovery that advance the missions of the Office of Science through partnerships within the Office of Science, R&D integration efforts with the Department's applied programs, and interagency collaborations. For example, ASCR's new applied mathematics research efforts in optimization and risk assessment in complex systems has been identified as important to the research efforts in the Office of Electricity Delivery and Reliability (OE), Office of Nuclear Energy (NE) and other applied energy programs, and critical to cyber security research in other federal agencies
4. Deliver the forefront computational and networking capabilities that enable researchers to extend the frontiers of science
5. Develop networking and collaboration tools and facilities that enable scientists worldwide to work together and share extreme scale scientific resources
6. Discover and design new materials and molecular assemblies with novel structures, functions, and properties, and to create a new paradigm for the deterministic design of materials through achievement of atom-by-atom and molecule-by-molecule control
7. Conceptualize, calculate, and predict processes underlying physical and chemical transformations, tackling challenging real-world systems – for example, materials with many atomic constituents, with complex architectures, or that contain defects; systems that exhibit correlated emergent behavior; systems that are far from equilibrium; and chemistry in complex heterogeneous environments such as those occurring in combustion or the subsurface
8. Probe, understand, and control the interactions of phonons, photons, electrons, and ions with matter to direct and control energy flow in materials and chemical systems
9. Conceive, plan, design, construct, and operate scientific user facilities to probe the most fundamental electronic and atomic properties of materials at extreme limits of time, space, and energy resolution through x-ray, neutron, and electron beam scattering and through coherent x-ray scattering. Properties of anticipated new x-ray sources include the ability to reach to the frontier of ultrafast timescales of electron motion around an atom, the spatial scale of the atomic bond, and the energy scale of the bond that holds electrons in correlated motion with near neighbors
10. Foster integration of the basic research conducted in the program with research in NNSA and the DOE technology programs, the latter particularly in areas addressed during the studies of the past six years, e.g., in areas such as solar energy conversion, electrical energy storage and transmission, solid state lighting and other aspects of energy efficiency, geological sequestration, catalysis, and materials in extreme energy environments
11. Obtain new molecular-level insight into the functioning and regulation of plants, microbes, and biological communities to provide the science base for cost-effective production of next generation biofuels as a major secure national energy resource
12. Understand the relationships between climate change and Earth's ecosystems, develop and assess options for carbon sequestration, and provide science to underpin a fully predictive understanding of the complex Earth system and the potential impacts of climate change on ecosystems
13. Understand the molecular behavior of contaminants in subsurface environments, enabling prediction of their fate and transport in support of long term environmental stewardship and development of new, science-based remediation strategies
14. Make fundamental discoveries at the interface of biology and physics by developing and using new, enabling technologies and resources for DOE's needs in climate, bioenergy, and subsurface science

15. Foster integration of research by leveraging DOE computational capabilities across BER programs and promoting coordination of bioenergy, climate and environmental research across DOE's applied technology programs and other agencies such as the Department of Agriculture, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration
16. Operate scientific user facilities that provide high-throughput genomic sequencing and analysis; provide experimental and computational resources for the environmental molecular sciences; and resolve critical uncertainties about the role of clouds and aerosols in the prediction of climatic process
17. Advance fundamental low temperature plasma science and high-energy-density plasma science and to coordinate these programs with those of other agencies and the National Nuclear Security Administration
18. Understand the highly non-linear behavior of high-temperature, magnetically confined plasmas and ultimately to learn how to create, confine, and control a burning plasma
19. Develop the fundamental understanding to fabricate materials that can withstand the material-plasma interface and to develop other enabling technologies needed for a sustainable fusion energy source
20. Operate scientific user facilities that maintain world-leading research programs in high-temperature, magnetically confined plasmas, and to participate in the design and construction of ITER, the world's first facility for studying a burning plasma
21. Understand the properties and interactions of the elementary particles and fundamental forces of nature from studies at the highest energies available with particle accelerators
22. Understand the fundamental symmetries that govern the interactions of elementary particles from studies of rare or very subtle processes, requiring high intensity particle beams, and/or high precision, ultra-sensitive detectors.
23. Obtain new insight and new information about elementary particles and fundamental forces from observations of naturally occurring processes -- those which do not require particle accelerators
24. Conceive, plan, design, construct, and operate forefront scientific user facilities to advance the mission of the program and deliver significant results.
25. Steward a national accelerator science program with a strategy that is drawn from an inclusive perspective of the field; involves stakeholders in industry, medicine and other branches of science; aims to maintain core competencies and a trained workforce in this field; and meets the science needs of the SC community
26. Foster integration of the research with the work of other organizations in DOE, in other agencies and in other nations to optimize the use of the resources available in achieving scientific goals
27. Understand how quarks and gluons assemble into the various forms of matter and to search for yet undiscovered forms of matter
28. Understand how protons and neutrons combine to form atomic nuclei and how these nuclei have emerged during the 13.7 billion years since the origin of the cosmos
29. Understand the fundamental properties of the neutron and develop a better understanding of the neutrino, the nearly undetectable fundamental particle produced by the weak interaction that was first indirectly observed in nuclear beta decay
30. Conceive, plan, design, construct, and operate national scientific user facilities to make important discoveries in order to advance the understanding of nuclear matter. To develop new detector and accelerator technologies that will advance NP mission priorities
31. Provide stewardship of isotope production and technologies to advance important applications, research and tools for the nation
32. Foster integration of the research with the work of other organizations in DOE, such as in next generation nuclear reactors and nuclear forensics, and in other agencies and nations to optimize the use of the resources available in achieving scientific goals
33. Increase opportunities for under-represented students and faculty to participate in STEM energy and environment education and careers leveraging the unique opportunities at DOE national laboratories
34. Contribute to the development of STEM K-12 educators through experiential-based programs.

35. Provide mentored research experiences to undergraduate students and faculty through participation in the DOE research enterprise

Energy Security (ES)

1. Supply - Solar
2. Supply - Nuclear
3. Supply - Hydro
4. Supply - Wind
5. Supply - Geothermal
6. Supply - Natural gas
7. Supply - Coal
8. Supply - Bioenergy/Biofuels
9. Supply - Carbon capture and storage
10. Distribution - Electric Grid
11. Distribution - Hydrogen and Gas Infrastructure
12. Distribution - Liquid Fuels
13. Use - Industrial Technologies (including efficiency and conservation)
14. Use - Advanced Building Systems (including efficiency and conservation)
15. Use - Vehicle Technologies (including efficiency and conservation)
16. Energy Systems Assessment/Optimization

Environmental Management (EM)

1. Facility D&D
2. Groundwater and Soil Remediation
3. Waste Processing

National Security (NNSA)

1. Stockpile Stewardship and Nuclear Weapons Infrastructure
2. Nonproliferation
3. Nuclear Propulsion

Homeland Security (HS)

1. Border Security
2. Cargo Security
3. Chemical/Biological Defense
4. Cyber Security
5. Transportation Security
6. Counter-IED
7. Incident Management
8. Information Sharing

9. Infrastructure Protection
10. Interoperability
11. Maritime Security
12. Human Factors

Other Federal Agencies (OF)

1. Nuclear Regulatory Commission (NRC). The NRC mission is to regulate the nation's civilian use of by-product, source, and special nuclear materials to ensure adequate protection of public health and safety, to promote the common defense and security, and to protect the environment.
2. National Aeronautics and Space Administration (NASA), Science Directorate, Terrestrial Ecology Research Program. NASA's Terrestrial Ecology Research Program addresses Earth's carbon cycle and ecosystems using space-based observations. This program supports studies on land-based ecosystems, changes in their structure and functioning, and their roles in supporting human life and maintaining planet Earth.
3. Department of Defense (DOD). The DOD mission to develop advanced technologies for various defense scenarios flows through organizations, including the Strategic Environmental Research and Development Program, the Joint Forces Command, the Joint Warfare Analysis Center, U.S. Strategic Command, Special Operations Command, Naval Sea Systems Command, the Environ-mental Security Technology Certification Program, and the U.S. Army. These organizations often require nonmilitary expertise in sensor technology, transportation logistics, advanced materials, advanced computing and data analytics technology, and other areas to fulfill their missions.
4. National Biological Information Infrastructure (NBII) Program. The NBII program is managed by the Biological Informatics Office of the U.S. Geological Survey (USGS), a bureau of the U.S. Department of Interior. The USGS mission is to provide reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life. The NBII provides increased access to data and information on the nation's biological resources.
5. National Institutes of Health (NIH), Bioinformatics and Molecular Analysis Section (BIMAS). The NIH mission is science in pursuit of fundamental knowledge about the nature and behavior of living systems and application of that knowledge to extend healthy life and reduce the burdens of illness and disability. The mission of BIMAS is to provide guidance, support, and resources to scientists throughout NIH in the genomic and genetic analysis fields of bioinformatics.
6. Environmental Protection Agency (EPA). The EPA mission is to protect human health and the environment. Research is conducted on ways to prevent pollution, protect human health, and reduce risk, with the aim of improving the quality of air, water, soil, and use of resources.
7. Defense Advanced Research Projects Agency (DARPA). As the central R&D organization of DoD, DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming national security by sponsoring revolutionary, high-payoff research bridging the gap between fundamental discoveries and their military use.
8. Defense Threat Reduction Agency (DTRA). The DTRA mission is to safeguard America and its allies from weapons of mass destruction (chemical, biological, radiological, nuclear, and high explosives) by providing capabilities to reduce, eliminate, and counter the threat, and mitigate its effects.
9. NASA, Science Directorate, Exploration Technology Development Program. This program develops capabilities and supporting research and technology to enable sustained human and robotic exploration to ensure the health and performance of crews during long-duration space exploration.
10. National Oceanic and Atmospheric Administration (NOAA). NOAA's climate mission is to understand climate variability and change to enhance society's ability to plan and respond to climate change.