SLAC National Accelerator Laboratory
Annual Laboratory Plan
2015
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Approval
This SLAC Annual Laboratory Plan for 2015 has been reviewed and approved by:

Electronically approved
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SLAC National Accelerator Laboratory

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About the cover image: Scientists at the Department of Energy’s SLAC National Accelerator Laboratory and Stanford University have discovered a potential way to make graphene – a single layer of carbon atoms with great promise for future electronics – superconducting, a state in which it would carry electricity with 100 percent efficiency. Adding calcium atoms (orange spheres) between graphene planes (blue honeycomb) creates a superconducting material called CaC6. Now a study at SLAC has shown for the first time that graphene is a key player in this superconductivity: Electrons scatter back and forth between the graphene and calcium layers, interact with natural vibrations in the material’s atomic structure and pair up to conduct electricity without resistance. [Image credit: Greg Stewart/SLAC]
Table of Contents

1.0 Mission and Overview .......................................................... 4
2.0 Lab-at-a-Glance ................................................................. 4
3.0 Current Core Capabilities .................................................. 5
   Large-Scale User Facilities and Advanced Instrumentation .... 5
   Condensed Matter Physics and Materials Science .......... 6
   Chemical and Molecular Science ................................... 7
   Accelerator Science and Technology ......................... 8
   Particle Physics .............................................................. 9
4.0 Science Strategy for the Future/Major Initiatives ............. 10
   Overview and Context ...................................................... 10
   Innovating and Operating Premiere Accelerator-based Facilities 10
      LCLS ........................................................................ 10
      SSRL Enhancements .................................................. 12
      FACET-II ................................................................ 13
      Ultrafast Electron Diffraction / Microscopy ................ 13
   Identifying and Pursuing New Science Enabled by Our Facilities and Defining Their Future Direction 14
      Ultrafast Science ......................................................... 14
      Catalysts .................................................................. 15
      Biosciences ............................................................... 16
      High Energy Density Science .................................... 16
      Major Upgrades to the ATLAS Detector at the Large Hadron Collider 17
   Performing Use-Inspired and Translational Research in Energy 17
      Defining and Pursuing a Frontier Program in Cosmology 18
   Core Competencies and Supporting Technology R&D .... 19
      Advanced RF Accelerator Technology ....................... 19
      Instrumentation Development for Light Sources and Particle Physics 19
   Laser Development ....................................................... 20
5.0 Strategic Partnership Projects ......................................... 22
   Baseline SPP Program .................................................... 22
   SPP Strategy for the Future ........................................... 23
6.0 Infrastructure / Mission Readiness .................................. 25
   Overview of Site Facilities and Infrastructure ................... 25
   Campus Strategy .......................................................... 26
   Site Sustainability Plan Summary [Internal] ................. 35
7.0 Human Resources ............................................................ 37
   Recent History ............................................................ 37
   Future Challenges and Actions ....................................... 38
8.0 Cost of Doing Business ..................................................... 40
   Overhead Budget Process ............................................ 40
   Metrics .................................................................... 40
   Major Cost Drivers .................................................... 41
   Decisions and Trade-offs ............................................. 42
Appendix 1: Annual Strategic Partnership Projects Report ........ 44
Appendix 2: Proposed Line Item Investments .................... 45
Acronyms ................................................................. 46

Tables and Figures

Table 1. Strategic Partnership Projects Funding ................. 23
Table 2. Current Condition and Utilization Summary .......... 25
Table 3. Core Capability Infrastructure Gaps ................. 28
Table 5. Planned Investments ........................................... 34
Table 6. Three-year Staffing Profile ..................................... 37
Table 7. Laboratory Overhead Trends ............................. 40

Figure 1. SLAC Campus Vision, 5-10 years ...................... 26
Figure 2. Electricity Usage and Cost Projections ............ 36
1.0 Mission and Overview

SLAC National Accelerator Laboratory pursues transformative research on some of the most important scientific questions and technology challenges within the mission of the Department of Energy (DOE) using unique cutting-edge accelerator facilities and world-leading light sources. Founded in 1962 with a two-mile linear accelerator used for revolutionary high-energy physics experiments, SLAC has evolved into a multi-program laboratory whose mission leverages its intellectual capital, unique relationship with Stanford University, and location within Silicon Valley to:

- Innovate, develop and operate world-leading accelerators, light sources and scientific tools;
- Deliver transformative chemical, materials and biological science enabled by our unique facilities and defining their direction;
- Perform use-inspired and translational research in energy; and
- Define and pursue a frontier program in cosmology.

SLAC draws more than 4,000 researchers from around the world to use its facilities and participate in laboratory-hosted science programs each year. The Laboratory operates two leading X-ray scientific user facilities—the Linac Coherent Light Source (LCLS) and the Stanford Synchrotron Radiation Lightsource (SSRL)—as well as the Facility for Advanced Accelerator Experimental Tests (FACET), a unique research and development (R&D) facility opened in 2012 for research on next-generation accelerator concepts. SLAC also runs the Instrument Science and Operations Center for the Fermi Gamma-ray Space Telescope (FGST), a joint DOE-NASA mission that launched in 2008, and is leading the construction and operation of the Large Synoptic Survey Telescope (LSST).

Since LCLS began operations in 2009, it has redefined the frontiers of X-ray science as an unprecedented source of ultrashort, ultrabright pulses of coherent X-rays. The recent demonstration of hard and soft X-ray self-seeding and other advanced techniques has further enhanced the unique capabilities of this facility. Breakthrough scientific results achieved at the LCLS have garnered worldwide attention, and prompted construction of similar facilities around the world. Work has begun on an upgrade, LCLS-II, which will provide a much higher repetition rate, increasing the number of experiments run each year, and an expanded range of X-ray wavelengths, adding important new capabilities to keep the U.S. in an internationally leading position.

SLAC is operated by Stanford University (Stanford) for DOE’s Office of Science (DOE-SC). To date, six scientists have been awarded the Nobel Prize for work carried out at SLAC.

2.0 Lab-at-a-Glance

Location: Menlo Park, CA
Type: Multi-program Laboratory
Contractor: Stanford University
Responsible Site Office: SLAC Site Office
Website: www.slac.stanford.edu

Physical Assets:
- 426 acres, 147 buildings and 39 trailers
- 1.606M GSF in buildings
- Replacement Plant Value: $1.442B
- 2,662 GSF in 2 Excess Facilities
- 654 GSF in 1 Leased Trailer

Human Capital:
- 1,422 Full Time Equivalent Employees (FTEs)
- 52 Joint Faculty
- 110 Postdoctoral Researchers
- 0 Undergraduate Students
- 120 Graduate Students
- 2,913 Facility Users*
- 24 Visiting Scientists

FY 2014 Funding by Source: (Cost Data in $M):

- BES, 224.0
- HEP, 82.6
- PES, 4.0
- SLL, 49.8
- Other SC, 3.4
- BER, 4.6
- EEER, 2.0
- NNSA, 1.3
- Other DOE, 0.7
- WFO, 12.3

FY 2014 Lab Operating Costs (excluding Recovery Act): $383.6
FY 2014 DOE/NNSA Costs: $384.6
FY 2014 WFO (Non-DOE/Non-DHS) Costs: $12.3
FY 2014 WFO as % Total Lab Operating Costs: 3.2%
FY 2014 DHS Costs: N/A
Recovery Act Costed from DOE Sources in FY2014: $1.0

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* GSF and building count relates only to DOE-owned active, operational buildings per FIMS.
* Facility Users as reported to DOE from the user facilities LCLS, SSRL, FACET and test facilities ASTA, ESTB, NLCTA. Excludes SLAC employees.
3.0 Current Core Capabilities

The Office of Science has identified five core capabilities at SLAC, which reflect the Laboratory’s scientific and technical excellence: Large-Scale User Facilities and Advanced Instrumentation; Condensed Matter Physics and Materials Science; Chemical and Molecular Science; Accelerator Science and Technology; and Particle Physics.

Large-Scale User Facilities and Advanced Instrumentation

SLAC has the intellectual capital, infrastructure and experience to innovate, develop, design, construct, maintain and effectively operate large-scale scientific user facilities, delivering breakthrough discoveries that are relevant to the DOE-SC and SLAC missions. SLAC currently operates three DOE-SC user facilities—LCLS, SSRL and FACET—as well the FGST.

Linac Coherent Light Source: SLAC’s LCLS is the world’s first and most powerful X-ray free-electron laser (FEL) operating in the hard X-ray spectral range. LCLS provides highly focused beams to approximately 600 scientists annually (with over 1,300 user visits), enabling frontier science into the fundamental processes of chemistry, materials, energy and life sciences and technology. In the past 12 months, using the LCLS’s six instruments and experimental stations, scientists have made many important advances. These include the first observations of the atomic structure of a room-temperature material as it entered a state resembling superconductivity; the dynamics of liquid helium nanodroplets, revealing the presence of quantized vortices; major advances in the field of coherent diffractive imaging, with the first ever 3-D reconstruction of a live virus from LCLS; the first time-resolved data from a serial femtosecond crystallography experiment; and new observations of reaction intermediates in the oxidation of carbon monoxide on a catalytic ruthenium surface.

These experiments utilize the facility’s groundbreaking X-ray beam, which offers a photon energy range from 280 electronvolts (eV) to 11.2 kiloelectronvolts (keV), with pulse energy up to 6 millijoules (mJ). The pulse length is typically 50 femtoseconds (fs) and can be varied from about 5 to more than 300 fs, while the maximum repetition rate of the LCLS is 120 Hertz (Hz). Self-seeding modes are now available in both soft X-ray and hard X-ray spectral regimes (0.5-1.0 and 4.5-9.5 keV), benefitting experiments that require narrow bandwidth. The new soft-x-ray capability was featured on the front cover of Physical Review Letters. The peak power achieved was over an order of magnitude higher than previous approaches.

LCLS has recently utilized a new “two-color” mode of operation that should have significant impact in fields such as protein crystallography and materials science. This allows LCLS to deliver two bursts of X-rays with independent spectral and temporal tunability within femtoseconds, coupled to a recently developed timing device to measure the temporal overlap.

The first of a new family of detectors developed at SLAC was recently fielded at LCLS, continuing the tradition of driving the state of the art in this field based on synergies gained from multiple programs. Known as ePixi100, this detector demonstrated the ability to operate under a wide range of conditions – from a high number of photons per frame, usually achieved in SAXS geometry, down to a few photons per frame.

LCLS has been extremely reliable, providing more than 4,500 hours of user operation in FY14 with 94% uptime. Recent work has further improved the stability of the source, with energy jitter of 0.05% (at 1 keV) and 0.025% (at 8 keV) now possible.

Stanford Synchrotron Radiation Lightsource: Building on many of the same core competencies that support LCLS, SSRL provides synchrotron X-rays from its third-generation storage ring (SPEAR3) and associated beamlines and instrumentation, serving the research needs of more than 1,600 unique users annually across many areas of science, engineering and technology. SPEAR3 performance continues to be excellent, providing 98.4% uptime in FY14 at high-current (500 milliamp) operation, with top-off injections every five minutes as the standard operating mode, along with the ability to run in the low-α mode allowing for picosecond (ps) time-resolved experiments.

Research at SSRL supports DOE-SC and SLAC mission research, including condensed matter physics, energy-related materials research, catalysis, sustainable energy, life sciences and biopharma drug-discovery programs. SSRL is also involved in larger DOE and other initiatives including the Joint Center for Artificial Photosynthesis (JCAP), the Joint Center for Energy Storage (JCESR) and Energy Frontier Research Centers (EFRCs). To improve its support of these programs, ongoing R&D is aimed at further reducing the SPEAR3 emittance to 6 nanometer-radians and improving time-resolved capabilities to keep SPEAR3 competitive with other third-generation sources. Ongoing beamline construction projects include advanced spectroscopy capabilities for energy-related materials and catalysis with a
focus on time-resolved science; a calibration beamline to support DOE mission needs; and a micro-beam facility for macromolecular crystallography, which is also coupled to the structural biology R&D and user program at LCLS. Future beamlines include an X-ray scattering beamline for energy sciences with a focus on interfaces and time-resolved science.

The different properties of X-ray beams at LCLS and SSRL allow the design of complementary types of experiments from femtoseconds to days. In addition, to maximize the impact of the light sources on innovation and scientific discovery, LCLS and SSRL coordinate R&D programs focused on new methodologies and instrumentation. SSRL offers an R&D test bed for new instrumentation and techniques prior to deployment on LCLS, allowing more optimal use of limited LCLS beamtime.

**Facility for Advanced Accelerator Experimental Tests:** With the aid of powerful electron and positron beams from a section of SLAC’s 2-mile-long linear accelerator, FACET, which opened to scientists in 2012, is exploring how to harness plasmas and specialized materials to boost particles quickly to gigaelectronvolt (GeV) energies over an approximately 1-meter distance. Recently, plasma acceleration of positrons was proven, a key step to future collider development. The goal is to shrink particle accelerators for use in high-energy physics research as well as for other applications across DOE-SC, in medicine and in industry. Scientists are also using FACET to study magnetic properties in materials, with applications in data storage; high-energy sources of terahertz radiation, with applications in materials science and chemical imaging; and diagnostics for future accelerators. In FY14, FACET, combined with the Laboratory’s other test facilities—the Next Linear Collider Test Accelerator (NLCTA), the Accelerator Structure Test Area (ASTA) and the End Station Test Beam (ESTB)—supported 43 experiments for 401 users from SLAC, Stanford and other institutions. In FY15, FACET alone is expected to support 15 experiments with a total of 144 users.

**Particle Physics and Astrophysics facilities and instruments:** SLAC plays an important role in major particle physics and astrophysics (PPA) projects. The Laboratory led the design, development, construction and operation of the state-of-the-art Fermi Large Area Telescope (LAT), which 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 this program is now being applied to future facilities that will be located offsite: the wide-field Large Synoptic Survey Telescope (LSST) in northern Chile; upgrades to the A Toroidal LHC Apparatus (ATLAS) detector at the Large Hadron Collider; two next-generation experiments for direct detection of relic dark matter – Super Cryogenic Dark Matter Search (SuperCDMS) and LUX-ZEPELIN (LZ); development of next-generation experiments for precision cosmology with Cosmic Microwave Background (CMB) studies; and development of the future national neutrino program with the Long-Baseline Neutrino Experiment (LBNE) at Fermi National Accelerator Laboratory. SLAC is playing a lead role in designing and developing important elements of each of 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 high-bandwidth **data acquisition systems**, extending all the way from **custom sensors** and **application-specific integrated circuits** for detectors, to storage and distributed access for 100-petabyte-class data sets; 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 in photon science experiments, ultralow background experiments for direct dark matter detection, and space-qualified electronic systems, as well as computational resources for automated and optimized data acquisition strategies, data collection and data analysis. SLAC has significant expertise and capability in managing **very large sets of experimental data**, and is actively developing strategies for data acquisition and management for LCLS and for future opportunities with LSST and ATLAS.

Basic Energy Sciences (DOE-BES) and High Energy Physics (DOE-HEP) are the major sources of funding for this core capability at SLAC. Other sources include Biological and Environmental Research (DOE-BER), Fusion Energy Sciences (DOE-FES), and Strategic Partnership Projects (SPP) from the National Institutes of Health (NIH). SLAC’s efforts support the DOE-SC mission in scientific discovery and innovation (SC 2, 10, 21, 22, 23, 24, 26).

**Condensed Matter Physics and Materials Science**

Materials, chemistry and energy sciences are central to many of today’s most critical technical challenges. Condensed matter physics and materials science research at SLAC address DOE-BES mission needs and selected Grand Challenge energy science questions. The Laboratory focuses on selected areas of materials science, including correlated and superconducting materials, diamondoids, bio-inspired materials, topological insulators, atomically engineered heterostructures and chalcogenides. SLAC also applies this research toward the development of future energy
technologies, including methods for storing energy, more efficient energy conversion and carbon-free energy production.

SLAC uses and helps drive the development of forefront materials science techniques and methodologies at LCLS and SSRL. Recent work has demonstrated the ability of spectroscopy to illuminate fundamental electron, spin, orbital and lattice dynamics on natural time and length scales. For example, unique laser-based capabilities allow ultrafast photoemission studies to investigate single particle dynamics, resolved according to the electron's energy, momentum and spin in the time domain, where processes such as ultrafast charge and spin dynamics become accessible for direct observation. Coupling these efforts with \textit{in situ} materials synthesis and characterization at SSRL, and with advanced theoretical simulation, provides synergistic advancement on all fronts. Adding to the capacity already in place at LCLS's soft X-ray end station has enabled pump-probe resonant inelastic soft X-ray scattering to study the time evolution of coupled order parameters. Other recent efforts in ultrafast materials science allow study of the physics of coupled orders in nickelates, cuprates, manganites and other correlated materials, charge density wave collective modes, and magnetization dynamics in magnetic films and interfaces, important for next-generation electronic devices.

SLAC’s materials science research is coordinated under a joint institute between SLAC and Stanford called the Stanford Institute for Materials and Energy Sciences (SIMES). Through SIMES, SLAC provides a strong coupling to energy technology and policy initiatives at Stanford, such as the Global Climate and Energy Project (GCEP) and the Precourt Institute for Energy (PIE). SIMES is also involved in larger DOE initiatives including JCESR, the Bay Area Photovoltaic Consortium (BAPVC) and EFRCs. In addition, SIMES is dedicated to outreach activities for energy science education and training, helping to develop the next generation of talent.

\textit{Funding for this core capability comes from DOE-BES, with support from other DOE offices such as the Office of Energy Efficiency and Renewable Energy (EERE) and internal Laboratory Directed Research and Development (LDRD) investments, and serves the DOE-SC mission in scientific discovery and innovation (SC 7, 8, 9).}

\section*{Chemical and Molecular Science}

SLAC’s efforts in chemical and molecular science explore selected areas at the interface between ultrafast physics, chemistry, materials, X-ray science and theory and simulation. Ultrafast science has synergies across SLAC and enables technology for many different areas of the Laboratory.

Research programs in ultrafast chemical science focus on several areas that lie at the science frontier and are also of particular relevance to the Laboratory’s mission. Experiments permit access to dynamics occurring down to the attosecond and few-femtosecond time scales using laboratory sources and capabilities, including high harmonics and time-resolved ultraviolet and soft X-ray spectroscopy. These methods are currently being applied to study non-Born-Oppenheimer dynamics, strong-field laser-molecule interactions, solution phase dynamics, non-periodic X-ray imaging, nonlinear X-ray optics, and, most recently, time-resolved studies of reduced dimensional systems. The experimental efforts are coupled to a strong theory program supported by advanced computational capabilities.

Another major research area addresses the fundamental challenges associated with the atomic-scale design of catalysts. The overall aim of the SLAC catalysis program is to develop understanding of surface phenomena and catalysis to the point where science-based design strategies for new catalysts can be developed. Major challenges where new catalysts are essential include artificial photosynthesis, chemical fuels, energy storage and sustainable chemical processes. The theoretical description of surface reactivity and heterogeneous catalysis, electrocatalysis and photocatalysis has been developed over the last five years at SLAC in association with Stanford.

By combining theoretical research with complementary experimental activity in catalyst synthesis, characterization, and testing, SLAC can make great headway toward realizing the full potential of the catalysis initiative. Experimental activity has now been established, and the plan is to expand it significantly, while exploiting the unique possibilities provided by SSRL and LCLS. The theoretical activities have also paved the way for new “materials genome” approaches to catalyst discovery that call for new infrastructure in terms of computing strategies and the development of databases.

The research efforts in chemical science are closely coupled to aligned departments and institutes at Stanford, specifically through the Stanford PULSE Institute and the SUNCAT Center for Interface Science and Catalysis, providing a broad foundation for the research and an essential educational role in addition to supporting the DOE-BES mission objectives.
Funding for this core capability comes from DOE-BES, with support from internal LDRD investments, and serves the DOE-SC mission in scientific discovery and innovation (SC 7, 8, 9).

Accelerator Science and Technology

The future development of light source and particle physics facilities serving the research missions of DOE-SC and SLAC relies on a continuing advancement of accelerator science and associated technology. SLAC has a strong core competency in accelerator physics and technology, and major thrusts in accelerator R&D include the development of forefront light sources and novel compact acceleration schemes. SLAC also continues to play a significant role in the design of future colliders, both linear and circular. These endeavors support SLAC’s strategic goal of maintaining world leadership in accelerator design for X-ray FELs, storage ring light sources, high-energy physics applications and various industrial, medical and security-related applications. At the same time, in conjunction with Stanford, SLAC maintains a renowned accelerator education program, training future leaders in the field.

With the LCLS, SLAC has the most advanced operational hard X-ray FEL in the world today, and the associated R&D impacts how international projects are being designed, constructed and operated. The demonstrations of both hard and soft X-ray self-seeding at SLAC have paved the way for self-seeding operations now being adopted by major XFEL facilities around the world. The development of two-color FEL beams generated by two individual electron bunches is enabling new methods to study ultrafast processes in biology, materials, chemistry and other fields.

The LCLS-II upgrade project employs high repetition rate superconducting accelerator technology, leveraging core capabilities of other U.S. laboratories through a large-scale collaboration. The facility will increase both capability and capacity of a broad X-ray FEL-based program, serving both hard- and soft-X-ray users. In contrast to the pulsed superconducting European XFEL, LCLS-II will operate in a 1-megahertz (MHz), continuous-wave mode. This opens the door for new X-ray science. Full exploitation of these possibilities will require developments in accelerator physics simulation tools, beam instrumentation and accelerator control technology. Advanced FEL techniques are being pursued for future applications, such as precision synchronization among X-ray, laser and RF systems; circularly polarized undulators; and for manipulating bandwidth and duration of pulses to enable new capabilities in spectroscopy and dynamics.

SLAC has a long history of developing and delivering new technologies for compact and high-gradient accelerators. Over the last decade, we have systematically and successfully investigated the limits on RF breakdown phenomena in high-vacuum metallic accelerating structures. Significant advances have been made in our understanding of RF breakdown phenomena to the point where gradients as high as 175 MV/m – about twice the previous state-of-the-art for normal conducting and six times for superconducting structures – appear to be achievable, through choosing the right materials and geometry for the accelerator structure. Further gains can also be obtained by cooling these structures to cryogenic temperatures and initial experiments indicate that a gradient of about 300 MV/m at X-band frequencies is ultimately possible.

Now the Laboratory has embarked on a new program that uses RF structures in a novel way, extending beyond the traditional 11.4-gigahertz (GHz) X-band regime to terahertz (THz) frequencies. This is accompanied by a development effort for the next generation of compact and highly efficient RF-to-THz power sources. These programs are relevant for SLAC's ongoing research program, including SPP activities. SLAC maintains a core capability in RF power source technology among the Office of Science laboratories and U.S. industry.

SLAC has an internationally unique role in developing more novel accelerating methods, including beam-driven plasma wakefield acceleration (PWFA), dielectric wakefield acceleration, and laser-driven dielectric acceleration (DLA). These technologies hold the promise of reaching accelerating gradients of GeV per meter (in the case of DLA and beam-driven dielectric acceleration) to tens of GeV per meter (in the case of beam-driven PWFA), which would revolutionize the world of compact accelerators used for medicine, industry, light sources and teraelectronvolt (TeV)-scale linear colliders. FACET, a user facility operated by DOE-HEP, is the centerpiece of this program. FACET-II, the proposed follow-on facility, would expand the wide range of high-energy electron beam experiments that are unique at SLAC and timely for accelerator science needs over the next 5-10 years.

The SLAC accelerator test facilities, including the low-energy ASTA bunker, the medium-energy NLCTA, and the higher-energy ESTB, support not only new-generation acceleration development, but also a wide range of experiments in materials science, THz generation, Compton-scattered photon sources, photocathode R&D, FEL seeding, high energy physics accelerator component and detector development, and general accelerator R&D. Recently, a new initiative has been launched to develop an Ultrafast Electron Diffraction and Ultrafast Electron Microscopy (UED/UEM) facility. The UED/UEM initiative leverages SLAC’s accelerator core competencies to provide
the most advanced ultrafast and nano-diffraction facility in the world, complementary to the X-ray FELs. As with the novel RF technology program, these programs are relevant for both SLAC’s increasing SPP activities (Section 5.0) and the nascent DOE-HEP Accelerator Stewardship program.

Funding for this core capability comes from DOE-BES and DOE-HEP, with support from SPP customers and internal LDRD investments. The core capability supports the DOE-SC mission in scientific discovery and innovation (SC 10, 21, 24, 25, 26).

Particle Physics

SLAC’s scientific and technical workforce provides leading contributions to a unique combination of underground-, surface- and space-based experiments to explore the frontiers of particle physics and cosmology. The primary science drivers for cosmic frontier research are identification of the new physics of dark matter, testing the nature of dark surface-and space-based experiments to explore the frontiers of particle physics and cosmology. The primary science scales and beyond, with prospects for elucidating the properties of the Higgs boson and discovering supersymmetry. SLAC and Stanford supported research with the BICEP2 experiment, which, in a joint analysis with the Planck observatory, has provided the most stringent limits on B-modes from gravitational waves in the early universe. The BICEP team is deploying BICEP3 at the South Pole this winter, a new instrument with a two-fold improvement in sensitivity and 10-fold improvement in survey capability over its predecessor. The ultimate experiment in this field, CMB-S4, will build on this and other pathfinder experiments to provide definitive measurements of the universe’s first light with a broad science scope that includes neutrino mass, CMB lensing and cluster cosmology.

In addition to focusing on inflation and the early universe, the SLAC particle physics program also plays an important role in studies of dark matter and dark energy. SLAC is the lead DOE laboratory for constructing the 3.2 gigapixel camera for the LSST, which will probe the properties of dark energy with high precision, enabling a better understanding of this dominant component of the universe.

Meanwhile, the FGST is seven years into a decade-long program of space-based gamma-ray observations, which are transforming our understanding of the high-energy universe. Recently, FGST revealed the origins of some cosmic rays and may even have detected hints of the nature of dark matter. SLAC was the lead laboratory for construction and integration of the LAT and plays an important role supporting instrument operations. R&D for the next generation Cherenkov Telescope Array, an advanced, ground-based observatory of ultrahigh-energy gamma rays, is also underway.

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The SuperCDMS will allow direct searches for relic dark matter candidates at unprecedented levels of sensitivity at low Weakly Interacting Massive Particle (WIMP) masses, while the complementary LZ liquid xenon experiment will provide the world’s best WIMP sensitivity at higher masses. Both have been selected as next-generation direct dark matter search experiments, with SLAC playing a designated lead role in the SuperCDMS SNOLAB project. SLAC has optimized the design and production of large germanium sensors for SuperCDMS and is establishing cryogenic test facilities and Time Projection Chamber system test capabilities for noble liquid systems for LZ.

SLAC is also involved in several energy frontier endeavors. The ATLAS experiment at the LHC is exploring TeV mass scales and beyond, with prospects for elucidating the properties of the Higgs boson and discovering supersymmetry. SLAC plays a significant role in the recently upgraded pixel tracking system, data acquisition and trigger systems, simulations and operations of ATLAS as well as in upgrade R&D. SLAC is also a leading contributor to detector R&D for the International Linear Collider. At the intensity frontier, SLAC has played a leading role in the design and construction of the Enriched Xenon Observatory (EXO) and is growing its engagement in the Long-Baseline Neutrino Experiment (LBNE), which will also allow exploration of the mass hierarchy for neutrinos and eventually allow the search for charge-parity violation.

Since its inception in 2002, the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) has become a world-leading center for particle astrophysics and cosmology. The particle physics theory effort pursues a broad spectrum of forefront theoretical research across all areas of fundamental physics, from inflationary cosmology to computational Quantum Chromodynamics (QCD) to string theory.

Funding for this core capability comes from DOE-HEP, as well as SPP (NSF and NASA) and internal LDRD investments. SLAC’s efforts serve the DOE-SC mission in scientific discovery and innovation (SC 21, 22, 23, 24, 26, 29).
4.0 Science Strategy for the Future/Major Initiatives

Overview and Context
In September 2014, SLAC completed the development of an institutional strategic plan informed by DOE's Strategic Plan, following a year-long process of engaging stakeholders and considering mission priorities. This plan was informed by the 2008 BES Grand Challenges report and the work leading to the 2015 BES Transformational Opportunities report in the case of materials and chemical sciences, and by the Particle Physics Project Planning Panel (P5) report for HEP. The strategic directions incorporated into the plan rest on four pillars: innovating and operating premiere accelerator-based facilities; identifying and pursuing new science enabled by our facilities and defining their future direction; performing use-inspired and translational research in energy; and defining and pursuing a frontier program in cosmology. A set of core competencies in accelerator technology, instrumentation, X-ray science and technology and optical laser systems underpins these strategic directions. On the basis of the SLAC strategic plan, we have developed and articulated a set of future major initiatives within each of the main thrusts.

Foremost among these major initiatives is a newly defined LCLS-II X-ray laser upgrade, utilizing a continuous-wave superconducting linear accelerator. LCLS-II's capabilities will dramatically expand the FEL capabilities at SLAC and keep the U.S. at the forefront of X-ray science. To take full advantage of this new capability, SLAC has updated its strategies in ultrafast science for materials and chemistry, as well as new programs in catalysis, biology and high energy density plasmas. There are also significant advances required in the Laboratory's core technologies needed for detectors, lasers, X-ray physics, and computing/data management to match the light source capabilities. Continued work in accelerator science will help to not only refine and enhance the capabilities of LCLS-II, but add complementary facilities for UED/UEM and define pathways for compact and high-energy accelerators for future colliders and light sources, including through the proposed FACET-II facility. The new scientific capabilities and discoveries will naturally lead to improved pathways toward solving the energy challenges of tomorrow, and SLAC is refining a strategy to help connect this knowledge to practical solutions through expanded synthesis, characterization and prototyping capabilities. SLAC has also prioritized the cosmic frontier within its high-energy physics program, with leading roles in the recent discovery of the first definitive proof of cosmic inflation, and in many next-generation dark matter and dark energy experiments including the LSST.

Innovating and Operating Premiere Accelerator-based Facilities

LCLS

Vision. The startup and ongoing highly successful operation of LCLS at SLAC has transformed the field of X-ray science. The LCLS-II upgrade project, by providing a second very-high-repetition-rate X-ray source, will expand this X-ray capability in new and pioneering ways while also dramatically increasing the volume of experiments that can be addressed. Our vision is to continue to aggressively build on SLAC's position as the world-leading center for FEL science through the combination of the foremost capabilities of LCLS and LCLS-II and a science-driven development strategy founded on unique accelerator, laser, optics and instrumentation experience, capability and further development.

It is clear that the rest of the world is now responding to the success of the LCLS with well-developed projects to replicate or advance the capabilities presently offered at SLAC. Recognizing this, SLAC and DOE are pursuing a vigorous and well-coordinated series of developments to keep the U.S. facility in a preeminent state. LCLS-II will provide a new, superconducting accelerator in the first kilometer of the linac tunnel, able to deliver X-rays from 0.2 to 5 keV at up to 1 million pulses per second (compared to the current operation at 120 pulses per second). The project will also extend the range of X-ray energies that can be produced from the existing accelerator (from an upper limit of ~11.2 keV currently to ~25 keV in the future), providing capabilities unmatched anywhere in the world.

LCLS-II will be a transformative tool for energy science, qualitatively changing the way that x-ray imaging, scattering, and spectroscopy can be used to study how natural and artificial systems function. It will enable new ways to capture rare chemical events, characterize fluctuating heterogeneous complexes, and reveal quantum phenomena in matter – using nonlinear, multidimensional, and coherent x-ray techniques that are possible only with advanced x-ray laser technology. This facility will provide access to the “tender x-ray” regime (2 to 5 keV) that is largely inaccessible today, and will use the latest seeding technologies to provide fully coherent X-rays (at the spatial diffraction limit and at the temporal transform limit) in a uniformly spaced series of pulses with programmable repetition rate and rapidly tunable photon energies. The extension of capabilities in the hard X-ray regime will enable laser-excited structural
dynamics, serial femtosecond crystallography using multi-wavelength anomalous dispersion phasing, the study of gas-phase photochemistry, and high-resolution structural studies of matter under extreme conditions.

The BES Grand Challenges and Transformative Opportunities reports guide planning for LCLS-II and the further development of LCLS. In the first crucial step towards developing a coherent strategy linking transformative science opportunities to research and development requirements, six strategic science directions emerged from a series of LCLS-II community planning workshops this spring: the fundamental dynamics of energy and charge; catalysis and photocatalysis; emergent phenomena in quantum materials; nanoscale material dynamics, heterogeneity and fluctuations; matter in extreme environments; and revealing biological function on natural length and time scales.

In the near term, SLAC will continue to operate LCLS as a flagship facility, pursuing the following high-level strategy to ensure continued international leadership:

a. Improving LCLS performance in areas such as wave-front quality, energy stability and bandwidth control via seeding.

b. Delivering increased capacity to users via upgrades to X-ray Correlation Spectroscopy (laser pump and pink beam functionality); configured modes of operation in appropriate areas (such as matter in extreme conditions); and multiple chambers in Coherent X-ray Imaging.

c. Introducing new capabilities. One example is a dedicated end station for Macromolecular Femtosecond Crystallography (MFX), working with SSRL and the newly created Bioscience Division. Another is the development of higher-capability optical lasers in conjunction with the MEC hutch, to increase the range of states accessible for fusion science and fundamental plasma physics studies.

d. Improving operational effectiveness and efficiency via adoption of facility-wide and SLAC-wide solutions where appropriate, as well as delivery of a targeted "mission readiness" program.

Another key part of this program is the science-driven development of strategically important technologies and techniques for exploitation on LCLS and LCLS-II, with priorities established through community consultations:

a. Optics: Critical improvements to harness high average power; provide access to the tender X-ray regime; and the develop solutions for high spectroscopic resolution with unsurpassed time resolution.

b. Source: Development of a suite of multi-pulse options (in time, space and spectrum); exquisite synchronization (<10 fs) and source stability; time/bandwidth tradeoffs for spectroscopy and dynamics; and ultra-short pulses with high coherent bandwidth.

c. Detectors: Development of high-repetition-rate detectors and data acquisition (DAQ) infrastructure, consistent with the move to higher photon energies, the high-repetition-rate X-ray source and ultra-low noise environments.

d. Scientific computing: Development of real-time data analysis; large-scale data management; and advanced algorithms to enable wider community access and maximally exploit this new resource.

e. Instrument development: Optimization of the LCLS end-stations, including advanced laser systems driven through a series of strategic improvements linked to near-term and longer-term constraints in the available experimental halls.

Over the longer term, we foresee many options for substantial future development of the LCLS X-ray laser facility at SLAC, exploiting the LCLS-II upgrade as a robust platform for sustained growth that ultimately can drive up to 8 or 10 undulators at a time. Refinement of these options will be informed by ongoing experiments at LCLS, development of science programs for LCLS-II, and experience gained from other FEL facilities around the world. These options have also been considered in the process of updating SLAC’s long-term site master plan.

a. Use of the existing "End Station A" and/or "End Station B" facilities and infrastructure. The LCLS beam can be diverted into these areas and optimized for "soft" X-ray science (<1 keV), allowing the existing LCLS experimental halls to be devoted to the harder X-ray regime.

b. Building a long undulator tunnel that extends to the North of the current facility, coupled to an upgrade of the LCLS-II linac, would provide a capability to reach very high X-ray energies (~50-100 keV), for studying the properties of bulk materials and new regimes of extreme material science.

c. Installing "superconducting undulator" technology, currently in development in partnership with other DOE national laboratories. If successful, this technology would allow very high peak powers (>1 TW), as well as extending the spectral range at high repetition rate.

d. More generally, the performance of the LCLS-II accelerator will allow greatly extended capacity for the current areas of capability with additional undulators and experimental facilities.

**Required Resources.** The total project cost for LCLS-II is due to be baselined for CD-2 later this year, following the independent cost review undertaken as part of the CD-1 approval process. Alongside this, the development of the...
instruments and technologies required to appropriately maintain world leadership is a critical part of the operations budget of LCLS, with many new and significant areas of expense emerging over the next 5-7 years to ensure smooth transition to operations of LCLS-II. Prioritization of this budget is underway as part of developing the LCLS-II strategic plan, alongside scrutiny of the operating budget for the facility. SLAC will also invest in core competencies in optics, lasers and offline laboratories that support these developments.

**SSRL Enhancements**

**Vision.** SSRL and its evolution are an integral part of our vision for aggressively building on SLAC's position as a world-leading center for X-ray facilities. In the mid-term this strategy is built upon continuing to develop and operate state-of-the-art instrumentation and tools to explore the structure and function of matter across a wide range of length and time scales. SSRL offers a broad array of well-established and innovative X-ray instruments and methodologies to a broad community of users, some significant fraction of whom exploit both SSRL and LCLS. In the longer term, SSRL is pursuing accelerator concepts and opportunities that, if proven feasible, will provide performance distinct from the multi-bend achromat designs being pursued by the other U.S. synchrotron facilities, and would provide a globally unique capability at SSRL.

As part of its mid-term strategy, SSRL will target key scientific areas of strategic growth for the Laboratory: (1) time-resolved capabilities that complement those found at LCLS and that further the SLAC ultrafast science strategy, (2) instrumentation for X-ray characterization of use-inspired energy materials under realistic in situ and in operando conditions, and (3) micro-focus X-ray beams for protein crystallography developed in tandem with complementary capability at LCLS. By emphasizing common scientific opportunities, SSRL and LCLS can both directly benefit from the X-ray optics and detector developments needed for LCLS-II. For instance, reducing the footprint of high-resolution soft X-ray spectrometers and the solid angle of soft X-ray detectors would be transformative for chemical, biological and quantum materials research at SSRL. In addition, SSRL is building a metrology beamline and expanding the instrumentation of an existing beamline to accommodate the experimental needs of displaced National Synchrotron Light Source (NSLS) users.

These developments directly support the DOE strategic plan, coupling to and helping drive scientific innovation on new battery and solar cell materials, photosynthesis and catalysis, and strengthening partnerships with Stanford and industry. SSRL will also address DOE-BER mission needs through the BER science focus area on subsurface biogeochemistry, an emerging program in ammonia oxidizing enzymes central to the nitrogen-cycle, and the synchrotron structural biology program. The new capabilities will further align this program with the science directions of LCLS (especially time-resolved imaging, chemical spectroscopy, surface catalysis and nanocrystallography), the SLAC-specific parts of the U.S. energy initiatives and the larger U.S. light source strategy. The synergistic SSRL and LCLS strategy couples the spatial and temporal regimes and helps optimize the limited availability of LCLS beam time to the collective benefit of the scientific user community.

As a third-generation synchrotron light source, SPEAR3 has been operating for more than a decade, refining and substantially improving the beam capability and creating an array of forefront beamlines and instrumentation. However, the NSLS-II will be built out over the remainder of the decade and upgrades for other U.S. synchrotron facilities will presumably be initiated, with the result that the existing SPEAR3 platform will eventually be overtaken by these more capable facilities. Recognizing this outcome, our strategy is to take advantage of the combination of the X-ray and accelerator design capabilities at SLAC and physical accelerator assets on the SLAC site to create a potentially unique opportunity that further strengthens the coupling between SSRL and LCLS. In particular, injection from the LCLS-II superconducting linac into the SPEAR3 ring is being explored in order to provide a new source of exquisite X-ray beams simultaneously delivered to multiple experiments at existing SPEAR3 beamlines. Linac injection provides a novel means of generating picosecond pulses with a high level of transverse coherence. Such beams would enable the development of novel methods for characterizing transient phenomena in heterogeneous materials, reaction bottlenecks in catalysis, charge carrier traps in photovoltaics, thermal energy traps in nano-structured materials and nucleation of emergent behavior in quantum materials.

**Required Resources.** The new metrology beamline is funded by the National Nuclear Security Administration (NNSA), while the new advanced spectroscopy beamline is funded through DOE-BES, in part through JCAP. A significant fraction of the macromolecular crystallography beamline is funded by Stanford and other non-federal sources. Upgrades related to optimized short pulse operation and very low emittance are being explored as R&D projects, as well as the longer-term option of LCLS-II injection into SPEAR3. While the core team needed to implement the SSRL upgrades exists, increased technical strength is also required in some specific areas.
**FACET-II**

**Vision.** FACET-II will enable accelerator science vital to the future of advanced acceleration techniques for DOE-HEP, ultrahigh brightness beams for DOE-BES and novel radiation sources for a wide variety of applications. It will be the only facility worldwide capable of providing high-energy electron and positron beams for a broad array of accelerator R&D applications. By offering a wide range of single pulse charge and emittance, electrons and positrons, single and double bunches, tailored current profiles and energy up to 10 GeV, FACET-II provides unparalleled experimental capabilities. In addition, FACET laser systems provide multi-terawatt peak powers with state-of-the-art synchronization approaching 10 fs.

A primary goal of FACET-II is to utilize gradients 1,000 times higher than current technology in a meter-scale prototype plasma accelerator. The existence of such ultrahigh gradients also makes it possible to trap particles and produce a beam with 1,000 times the brightness currently achievable. The combination of uniquely high-energy, high-density beams and the short pulse, high-power FACET laser enables the generation of very high flux photon beams of interest for nuclear physics, gamma-gamma colliders and many other applications.

The current FACET research program for Plasma Wakefield Acceleration (PWFA) has made significant strides over the past year. PWFA studies with positrons have demonstrated a new acceleration regime offering promising results for coherent positron acceleration capability critical to future colliders. FACET-II would allow these proof-of-principle experiments to be extended into a complete demonstration of a single plasma acceleration module for both electrons and positrons, allowing exploration of emittance and energy preservation, efficiency optimization for the accelerated beam, and a host of issues related to plasma properties in a high-repetition-rate environment.

**Implementation and required resources.** In FY16, the first kilometer of the present SLAC linac will be removed to allow eventual installation of the superconducting LCLS-II linac in the same tunnel. FACET-II will reutilize injector components provided by DOE-BES and the existing middle kilometer of the SLAC linac, along with an enhanced final focus design for flexible electron and positron beam delivery to the experimental area. The project is configured to be implemented in a series of phased steps in close coordination with the LCLS-II construction schedule. Construction costs for FACET-II are estimated at $50M over the five-year period required for completing the full project.

**Ultrafast Electron Diffraction / Microscopy**

**Vision.** SLAC is pursuing the development of a world-leading UED/UEM facility as a key part of its ultrafast science strategy. Since UED and UEM are techniques for studying nuclear geometries on the same temporal and spatial scales as the LCLS probes electronic structures, the combination of these co-located facilities would provide unprecedented capabilities in ultrafast science. Development of nano-UED and microscopy would allow complementary measurements of charge/spin dynamics on the same samples measured at LCLS using soft X-ray holography or scattering. With nanoscale focusing, UED/UEM also complements LCLS’s hard X-ray capabilities by enabling game-changing access to energy transfer processes at the nanoscale. The ability to couple the UED/UEM measurements with linac-based intense THz and X-ray FEL pump pulses could further expand the scientific opportunities.

The DOE-BES sponsored workshop “Future of Electron Scattering and Diffraction” identified ultrafast imaging and diffraction as the new frontier of electron microscopy, and recommended UED and UEM facilities as a major instrumentation development. The electron probe has a large scattering cross section, especially suitable for studying dilute samples and conducting real-space imaging. The proposed SLAC UED/UEM facility is being developed in three stages: (a) ultrafast electron diffraction, with kilohertz operation and 100-fs temporal resolution; (b) nano-UED, with electron beam focus to 10-nm spot size with 100-fs temporal resolution; and (c) ultrafast full-field electron microscopy, capable of single-shot imaging with spatial resolution of 10 nm and temporal resolution of 10 ps.

Over the past year, the first UED stage has been established with available SLAC infrastructure and hardware and a combination of DOE-BES and internal funding. Initial scientific results from UED scattering are already demonstrating the promise of such a facility. SLAC has also acquired a superconducting RF gun from the University of Wisconsin as the basis for the UEM development. Further stages of the SLAC UED/UEM facility will take advantage of the recent developments in high-brightness ultrafast electron sources, high-field magnets and electron detection.

**Required Resources.** SLAC will propose funding from the DOE-BES mid-scale ultrafast instrumentation initiative in FY16 to upgrade ASTA UED to provide better temporal resolution and higher repetition rate. Modest additional funding in FY16 would allow design studies to address the electron beam source optimization and UEM design.
Identifying and Pursuing New Science Enabled by Our Facilities and Defining Their Future Direction

**Ultrasound Science**

**Vision.** The 2008 BES Grand Challenges and 2015 BES Transformational Opportunities reports make a compelling case for the forefront research opportunities that can be realized through advances in ultrasound science. Progress in the field has been enabled by dramatic improvements in lasers, notably the advent of the unique capabilities of the LCLS free-electron laser for ultrasound pulse generation in the X-ray spectral range, with further major improvements to be provided by the high repetition rate of the LCLS-II facility. As a result, SLAC has long identified ultrasound science as a strategic research direction. In our vision, further growth in this program is vital for the timely scientific exploitation of the FEL program, the evolution of challenging experiments at the LCLS and LCLS-II, and ultimately the direction of our future light source facilities.

There are three key elements to our ultrasound strategy: enhancing the Laboratory's ultrasound science program; expanding the capabilities of LCLS and utilizing the new capabilities of LCLS-II; and strengthening the theory and modeling coupling to LCLS science.

**Build internal programs and collaborations aimed at addressing BES grand challenge science problems.** The nature of electron correlation is a key question in photon science. In materials, this is connected to the origins of high temperature superconductivity and the dynamic properties of ferroelectric and magnetic materials. In molecules, electrons and their correlations generate the time-dependent forces that make and break bonds. While these two areas are described separately, there are many connections between them:

a. Materials Science (MS): Using spin, charge, orbital and lattice excitations as fingerprints for this collective behavior, the Materials Science Division endeavors to construct a complete “genomic map” of low-lying excitations that define the physical properties of materials. Among the tools are high-resolution time-domain spectroscopy and scattering experiments at SSRL and LCLS represented by the Resonant Inelastic X-ray Scattering (tr-RIXS) and Angle-Resolved PhotoEmission Spectroscopy (tr-ARPES) techniques.

b. Chemical Science (CS): The electron-nucleus interplay gives rise to chemical change that is best revealed using tools that can resolve the natural femtosecond time scale and Ångström length scale of the chemical bond. Thus, LCLS and LCLS-II are ideal for investigating chemical reactivity. This motivates SLAC’s ultrasound CS strategic plan, “Towards predictive understanding of chemical change,” with its focus on several research themes: the attosecond and high-field frontier; imaging molecular structure and dynamics, controlling charge separation and excited state processes, and following the dynamics of catalytic reactions at surfaces and interfaces in real time.

**Drive the high-priority science agenda for directed discovery at LCLS and LCLS-II.** Several high-priority research directions, under development for a number of years, extend current capabilities and develop new ones uniquely coupled to LCLS and LCLS-II. The importance and priority of these directions has been recently reiterated as part of the LCLS-II strategic planning exercise this spring:

a. Develop capabilities in time-resolved science to take advantage of LCLS-II’s high repetition rate. One example is the development of time-domain methods for resonant inelastic (Raman) scattering at LCLS. Ultrafast X-ray studies with high momentum and energy resolution will play a critical role in addressing the emergence of collective behavior in correlated systems and understanding how to exercise control of the properties and the resulting novel quantum phases and states. These methods, which combine RIXS and diffraction in the time domain, can lead to new insights into grand challenge problems. This capability is currently being implemented in LCLS, and will be well positioned to take advantage of the higher repetition rate LCLS-II source for improved spectral resolution.

The ultrafast CS strategy will similarly require the development of stimulated and spontaneous Raman methods that will be critical for observing electron dynamics with atomic specificity, and will greatly benefit from the higher repetition rate of LCLS-II. These experimental efforts must be strongly coupled to the advancement of theory and simulation to enable the transition from experimental characterization toward meaningful prediction. The ultrafast CS strategy will leverage SLAC’s core competency in laser science to develop novel ultrafast extreme ultraviolet sources for investigating the electron dynamics that control bonding in molecules.

b. Develop avenues of research to derive finer-tuned “pumps” to drive matter in different ways. The goal of this effort is better control of material and molecular systems driven far from equilibrium to create states of matter not realized by other means. Specialized pump sources have been developed through advances in strong field
science over the past decade. For example, SLAC scientists have carried out initial THz pump experiments using both current LCLS and tabletop probes. New sources of attosecond pulses have been commissioned and used for investigations of molecules in non-equilibrium quantum coherent states. Since LCLS-II will create a high-repetition-rate soft X-ray source, work requiring this frequency range and stability will be emphasized.

Additionally, future experiments that add pulsed magnetic field capabilities at LCLS will complement neutron scattering techniques available elsewhere. The time structure and ultrabright LCLS beams provide a unique capability to perform high magnetic field experiments that cannot be done with neutrons. The high magnetic field requirements on the femtosecond timescale may be satisfied in completely new ways.

c. Develop ultrafast electron diffraction research. As noted earlier, SLAC is establishing a facility in ultrafast relativistic electron diffraction. Electron scattering is particularly useful for gas phase or dilute targets, and also for low-dimensional materials or surfaces. Temporal resolution in the femtosecond range will make this a useful probe for ultrafast chemical and materials science.

**Provide strong theory coupling to LCLS and non-equilibrium measurements.** Addressing the grand scientific challenges that require the structure and dynamics of matter to be imaged and understood at the atomic level necessitates a strong theoretical backbone to interpret results and to chart new areas of investigation. By forming a powerful theoretical framework, SLAC has the chance to guide progress and forge successful outcomes to many experiments. This would also be the foundation for seeking to build a larger community beyond SLAC devoted to understanding the theory of non-equilibrium phenomena underlying many of the activities at LCLS, with the goal of revealing new signatures for time-dependent phenomena.

**Required Resources.** A key part of the strategy is the ability of SLAC and Stanford to attract scientific talent with leadership capabilities to expand the research portfolio as well as to cultivate a new generation of young researchers. Critical laboratory space to grow experimental programs will be provided in the next few years by the construction of the Photon Science Laboratory Building (PSLB). A combination of SLAC, Stanford and DOE resources will allow us to equip the PSLB and attract the high-quality talent needed to drive these ambitions.

**Catalysis**

**Vision.** The goal of catalysis research at SLAC is to develop an understanding of chemical transformations at catalyst surfaces. SLAC presently distinguishes itself with a unique theoretical effort in this area. However, the coupling of theory and experiment is critical to developing science-based design strategies for catalysts. New catalysts and processes are needed to solve major challenges related to sustainable energy and chemical production. Thus, we intend to develop a matching experimental program that couples to our X-ray facilities and other capabilities, and enjoys synergies with the ultrafast, biosciences and applied programs.

The experimental catalysis program under development will have three essential components:

a. **Synthesis:** New wet chemical methods, nano-structuring, atomic-layer deposition and physical vapor deposition methods for model systems

b. **Characterization:** Single-crystal model systems and high surface area catalysts developed together with SSRL and involving *in situ* characterization, as well as new SLAC methods for characterizing the surface intermediates

c. **Testing:** Measurements of kinetic activity as well as selectivity, and provision of feedback to reactivity theory.

A recent example is a new electrocatalysis program focused primarily on CO₂ reduction, where there are presently no efficient catalysts and a paradigm shift in our understanding of electrochemical processes is needed to make progress.

One foundation of the catalysis program is the theoretical simulation and screening of millions of different materials, compositions and structures. This presents an enormous computational challenge, while requiring specific infrastructure to store and share electronic structure simulations of relevant materials and processes. The benefit of a data warehouse will be to ensure reproducible quality while providing the possibility for systematically comparing simulations and establishing benchmarks to improve electronic structure theory, and to enable direct comparison of different methodologies. It will also be a natural platform for enabling materials search algorithms, statistical analysis to determine descriptors, data mining tools and machine learning algorithms.

**Required Resources.** As in the case for ultrafast science, SLAC and Stanford intend to attract scientific talent with leadership capabilities to expand the research portfolio as well as to cultivate a new generation of young researchers. Expanded synthesis and characterization laboratories will be located in the new PSLB. SLAC is supporting a common computing hardware facility for its scientific computing needs that is located in the Stanford Research Computing...
Facility (SRCF). Together with similar hardware investments by Stanford and seamless common operations, this facility provides very important support for simulation programs across the Laboratory's science mission.

**Biosciences**

**Vision.** Our vision is to develop a new strategic direction for biosciences research at SLAC by establishing interdisciplinary biosciences programs that, through close coupling to SLAC's unique facilities, will achieve high scientific impact in the areas of structural biology, biogeochemistry and biomedical sciences. Experimental efforts will leverage LCLS and SSRL X-ray facilities and R&D programs, future capabilities with LCLS-II and ultrafast electron diffraction, as well as a planned high-resolution cryo-electron microscopy facility.

New biosciences research programs are focused on targeted elements of BER science mission areas. Currently the most advanced research initiative focuses on the nitrogen (N) cycle, where we will be identifying novel N-cycling enzymes directly from metagenomes from terrestrial field sites and investigating cell surface structure and enzyme function of ammonia oxidizing archaea (AOA). With initial funding from the DOE-BER’s Mesoscale Program, a new beamline, MFX, is being developed at LCLS for studying complex biological systems with radiation sensitivity as is found in AOA enzymes. Strong synergy exists between the MFX instrument and the micro-focus crystallography Beam Line 12-1 at SSRL for studying challenging large-scale complexes and developing instrumentation relevant to both SSRL and LCLS. Computational biology will connect modalities with different spatiotemporal scales and help in the understanding of hierarchical biological systems.

The most challenging problems at the frontiers of bioscience require techniques that interrogate multiple length and time scales. SLAC seeks to build, in stages, a complete suite of facilities and scientific expertise for studying structures and dynamics ranging from single particles to cells. The initial effort is focused on establishing a cryo-electron microscopy (cryoEM) facility for single-particle studies and subcellular and cellular tomographic analyses in collaboration with Stanford. The new cryoEM tomogram and single particle analysis capabilities will be critical to connecting high-resolution structural knowledge with understanding of AOA's global biogeochemical processes. Many of the computational techniques used in cryoEM analysis are also relevant to single particle imaging at LCLS.

**Required Resources.** The SLAC biosciences program will build on existing facilities and expertise within LCLS, SSRL's Structural Molecular Biology (SMB) program, the Science Directorate and SLAC accelerator programs. In addition we intend to strengthen ties with Stanford and other partners through the creation of the newly created Biosciences Division. Future expansion for the biosciences programs will be housed in the planned PSLB, including a high-end cryo-electron microscope. Funding for this facility is being sought in collaboration with Stanford.

**High Energy Density Science**

**Vision.** The combination of the unique properties of the LCLS X-ray beam and next-generation high-power lasers incorporated into the Matter in Extreme Conditions (MEC) instrument will position SLAC to be a world-leading center for high energy density (HED) science. The scientific opportunity this enables will be very broad; from high-pressure condensed matter to hot dense plasmas; exploration of new frontiers of laboratory astrophysics; investigation of fusion-relevant plasmas using wholly new methods; and study of high-pressure materials science relevant to Earth and planetary physics.

Early results from the MEC instrument have established high-precision X-ray probes of transient warm dense matter states using the LCLS X-ray beam. For this purpose, we have developed and utilized record peak brightness X-ray beams that enable spectrally resolved X-ray scattering measurements and dynamic X-ray diffraction from states of matter approaching 5 Mbar. The first experiments have provided accurate equation-of-state data and characterized the dynamic structure factor needed for the successful modeling of laboratory fusion experiments, and have impacted the planetary and material science communities.

In the immediate term, the laser capability at MEC will be enhanced by upgrading the existing 30 TW laser system to 200 TW. This will maintain an internationally leading position for the next 1-2 years, with the ability, for example, to obtain critically important data on the temperature equilibration of electrons and ions in hydrogen and deuterium under fusion-relevant conditions. Other studies will open up the ability to produce MeV-proton radiation sources, as well as very-high-energy X-rays from a “betatron” laser plasma source. These complementary techniques will offer a unique suite of tools to understand the fundamental processes for radiation production and interaction with matter.

However, the funded plans at SACLA (Japan) and European XFEL (Germany) will eventually overtake our capability. To maintain a world-leading experimental program in MEC science at SLAC, higher-power lasers will be needed to reach new regimes, such as radiation pressure acceleration or collisionless shocks. This will also allow us to achieve states of matter at the higher pressure needed to discover new phase transitions and material phases. Finally, it will
allow us to study ion/neutron stopping power and material response effects critical to fusion science. A facility design study is underway to lay out the options for possible future laser capability enhancements. In parallel, our experimental and theoretical effort is preparing novel target and diagnostic capabilities to fully exploit the science opportunities enabled by LCLS and high-power lasers at MEC.

An essential new component of this program is the recent addition of a theory effort in high energy density physics. This will lead to better design of LCLS experiments by providing the physics simulations for comparisons with experimental results and the injection of new ideas for discoveries at the new physics frontier. The theory group will study all areas of matter in extreme conditions and has already begun investigating collisionless shock phenomena and shock wave ion beam acceleration physics.

**Required Resources.** Future expansion for the high energy density science facilities will require upgrades to higher energy and higher power (e.g. petawatt-class) laser drivers at LCLS. In addition, we intend to continue attracting scientific talent supported by a combination of SLAC and DOE resources in order to expand research expertise in theory and simulations. A new HED Science Division has been established to develop all areas of this field.

**Major Upgrades to the ATLAS Detector at the Large Hadron Collider**

**Vision.** The Large Hadron Collider (LHC) at CERN accelerates protons to the highest energies, with the collisions being recorded in complex detectors assembled by large international teams. The LHC forms a core piece of the U.S. particle physics program and SLAC envisions a significant role in the ATLAS detector Phase-2 upgrades. These upgrades were identified by P5 as the highest-priority project for the U.S. HEP program and are essential to exploit the physics opportunities at the high-luminosity LHC, planned for operations from the 2020s into the 2030s. The physics program of these upgrades is compelling and comprehensive with essential precision measurements of the Higgs boson properties, exploration for new particles and material properties, experimental results and the injection of new ideas for discoveries at the new physics frontier. The theory group will study all areas of matter in extreme conditions and has already begun investigating collisionless shock phenomena and shock wave ion beam acceleration physics.

SLAC has invaluable expertise essential to the success of the Phase-2 upgrades. SLAC capabilities are world leading in analysis tool developments on pileup mitigation, jet substructure and jet tagging, in particular $b$-quark tagging, all of which are essential for performing physics in the high-luminosity environment. With its outstanding instrumentation capability, SLAC is well positioned to assume a major role in the construction of the silicon inner tracker – the most important of the detector subsystems requiring upgrade – with substantial experience in several key areas including the 3-D pixels, CMOS pixel and strip detector development and testing, data transmission and readout, and module and stave assembly site. Other critical components of the upgrade are the trigger and data acquisition systems. SLAC’s reconfigurable cluster element, developed by the Technology and Innovation Directorate (TID), is a strong candidate for the inner tracker readout, and SLAC’s expertise in trigger development will be vital to the success of the physics program.

**Required Resources.** SLAC assumes project funding at the level of $20M over the next 8 years for the Phase-2 upgrades. Some initial R&D to explore technical options will be supported by SLAC funding. The primary resource required is the existing core group of physicists and engineers with technical expertise matching the program requirements.

**Performing Use-Inspired and Translational Research in Energy**

**Vision.** An important part of SLAC’s strategy is to leverage the knowledge gained through our scientific facilities and research programs to perform use-inspired R&D in support of the important societal challenges regarding energy generation, use and efficiency described in the DOE strategic plan. By developing a deep scientific understanding of the materials and chemistry of emerging energy technologies, SLAC and Stanford are well positioned to drive the development and translation of these technologies into early prototypes and system concepts as well as connect with industrial partners to transfer the technology.

The first example of this strategy has been in the area of energy storage technology where, as noted earlier, SLAC is a partner in JCESR, the energy storage hub, and has been developing new materials that show promise for higher energy densities and lower costs for both vehicle and grid batteries. Through work at SSRL, we have developed a program for battery imaging using transmission X-ray microscopy that allows in situ and in operando imaging of battery materials to evaluate the chemical states of electrode materials during operation, which can help in developing battery materials and understanding failure mechanisms. This has led to a program supported by the Vehicle Technology Program at EERE to further develop this capability, as well as pending support from the Advanced Research Projects Agency-Energy (ARPA-E) to work with some of their industrial projects on battery management systems. To better facilitate this industrial interaction, SLAC has been a leader in a new collaborative initiative, CalCharge, which provides technology acceleration through easier access and partnerships between companies and...
national labs such as SLAC and Lawrence Berkeley National Laboratory (LBNL). This continuum, from fundamental materials research through characterization analysis and industrial interaction, provides a unique integrated capability and facilitates faster development cycles.

In the future we envision building in an analogous way on our materials and chemistry foundation in catalysts and solar materials to grow the experimental and use-inspired programs in these additional areas as well. As part of the development of multi-lab consortium teams to tackle “big ideas,” SLAC is participating in the Grid Modernization and SubTER programs, as well as in the development of new programs in Materials Manufacturing and the Water Energy Nexus. For example, in connection with Grid Modernization, SLAC, in partnership with Stanford, is developing a smart grid capability prototyping new distribution grid software, measurement and control systems.

**Required Resources**, Expanded synthesis, testing and non-X-ray characterization techniques will be housed in the future PSLB. SLAC intends to improve and expand multiple *in situ* X-ray characterization techniques at SSRL. These programs will be supported by new DOE program growth, SLAC, Stanford and industry partners.

**Defining and Pursuing a Frontier Program in Cosmology**

**Vision**, It has become clear over the past 20 years that many of the most fundamental questions in particle physics and cosmology can only be answered with new instruments underground, on remote mountain-tops or in space that use the universe as a laboratory to explore the interplay between physics and cosmology. SLAC envisions a comprehensive experimental and theoretical program to explore the nature of dark matter, dark energy and cosmic inflation, taking advantage of the synergy in the underlying science, the common technologies and capabilities required for experiments in this area, and the strength of its scientific and technical leadership. Based on an excellent record of scientific and technical accomplishment, SLAC is continuing to play a lead role in the development, construction and ultimately the scientific exploitation of cosmic frontier facilities.

**The measurement of properties of dark energy.** The dark energy that appears to be driving the accelerated expansion of the universe poses fundamental challenges to our understanding of quantum field theory and/or gravity. The detailed properties of dark energy can be constrained via a variety of methods, all relying on deep optical and infrared surveys of major fractions of the sky. The LSST project will provide a definitive wide-field, ultradeep galactic survey for precision measurement of dark energy properties. SLAC is leading the development of the project’s 3.2-gigapixel digital camera system and houses a vibrant dark energy research community at KIPAC. As the host laboratory, SLAC is working closely with the LSST Dark Energy Science Collaboration (DESC) to achieve its important goals of measuring dark energy with high precision. Likewise, SLAC is developing an operations plan together with the Association of Universities for Research in Astronomy and the LSST Corporation for the LSST facility. The combination of close ties to the LSST camera and data management projects, the planned operations support for DESC and LSST, and a strategic investment in dark energy research will make SLAC a powerful center for this science in the 2020s.

**The search for dark matter through direct detection techniques.** Extensive evidence exists that dark matter dominates the matter density of the universe. Various theories predict a small but non-zero cross-section for dark matter interaction with ordinary matter. Detection could be accomplished by fielding large (ton-scale) experiments in mines deep underground, where backgrounds associated with cosmic ray particles can be adequately shielded. The detection of relic dark matter at an underground experiment would provide a crucial complement to efforts to create dark matter particles directly at the Large Hadron Collider and at future energy frontier accelerator facilities. SLAC is leading the development of the recently approved SuperCDMS project at SNOLAB in Canada, a joint DOE/National Science Foundation (NSF) project that would deploy 100-400 kilograms of cryogenic germanium sensors. SLAC is also growing a substantial effort on the noble liquid xenon experiment LZ as the other approved second-generation dark matter search experiment. The two experiments together will provide complementary improvement on the current mass and cross-section sensitivity by several orders of magnitude. These experiments also complement SLAC’s ongoing leading role in the FGST, which is providing the strongest limits from indirect detection searches.

**The measurement of properties of the CMB.** The CMB carries the imprint of cosmology and forces from the inflationary period of the Big Bang, which defined the large-scale structures of the present-day universe. SLAC scientists made key contributions to the 2014 BICEP2 discovery of $B$-mode polarization in the microwave sky. Such observations are expected to constrain the nature of cosmic inflation—the rapid expansion of the infant universe in its first $10^{-36}$ seconds. Over the next 10 years, SLAC plans to remain an important part of the BICEP collaboration as it deploys BICEP3; play a leading role in future CMB experiments; and help make P5’s CMB-S4 experiment a reality. These future experiments will also constrain neutrino masses and number density. These roles couple SLAC’s extensive instrumentation capability with the problem of developing efficient, low-cost, mass-producible microwave detectors required for large-scale CMB experiments.
**Required Resources.** SLAC’s plan assumes project funding for LSST, SuperCDMS at SNOLAB and LZ at Homestake over the next five years. We anticipate a CMB-S4 project will be developed for consideration later in the decade. R&D in advance of these projects is already supported by DOE-HEP and in some cases by SLAC LDRD funds. The primary resource required at SLAC is a largely existing core group of technically capable physicists and engineers with experience in the construction and operation of large experiments in remote environments. Modest personnel additions or redirections in areas such as sensor fabrication, cryogenic and low-background engineering, and project management will be required. SLAC also intends to strategically invest in developing a strong core scientific team to exploit the dark energy and dark matter science expected from the next round of experiments.

**Core Competencies and Supporting Technology R&D**

One of the primary motivations for the recent establishment of the TID at SLAC was recognition of the need to identify and sustain unique core technology capabilities required to support the long-term vision for the SLAC and DOE mission. Initially, TID has been established by consolidating core RF technology and instrumentation capabilities. This list of capabilities may expand in the future to include advanced optics, laser R&D and scientific computing as the underpinning for the science program. SLAC intends to support TID infrastructure needs as part of providing a sustainable business model, while also focusing on developing alternative applications for these technologies outside our traditional DOE sources in order to broaden the funding base.

**Advanced RF Accelerator Technology**

**Vision.** SLAC intends to develop next-generation accelerating systems and power sources that will dramatically increase acceleration gradients and correspondingly shrink the length and cost, thereby opening new doors in many areas of science and applications. Over the last decade, SLAC has extended the limits on RF breakdown phenomena in high vacuum metallic accelerating structures. However, the capability of the RF power sources has not kept pace with this development, and for high-energy, compact or high efficiency accelerator applications, the standard RF approaches are no longer feasible. SLAC seeks to establish a new paradigm for RF sources and acceleration that dramatically changes the cost/capability curve of RF acceleration and opens up a much broader applications space for these technologies for both accelerator systems and standalone RF systems.

The success of this vision requires moving forward simultaneously on three fronts: novel high-gradient accelerator structures with topologies and materials optimized for high efficiency and low cost of manufacturing; advanced power sources from RF through THz frequencies; and the optimization of complete systems from the wall plug through the particle beam, including RF energy recovery. Our science and technology thrust has two parts. The first is directed at improving both the individual components and the overall system efficiencies and cost for systems operating under 20 GHz, where real progress has languished for several decades. The second is extending our frequency reach to close the four-order-of-magnitude gap between RF and optical frequencies, where no practical sources or structures exist. This effort represents a unique new research area that has been largely ignored in the development of advanced, compact high-gradient accelerators despite being motivated by scaling laws for breakdown strength with frequency.

Our proposed RF and THz power source program is built on three pillars: 1) an R&D program with the goal of producing revolutionary source concepts with new levels of power and frequency performance, efficiency and economic feasibility; 2) hardware implementation of these concepts in a spiral development cycle where successively higher performance goals are demonstrated; and 3) parallel development of applications in concert with other government agencies and the commercial sector as sources achieve increasing frequency and power performance. We see a wide range of emerging applications in high-resolution radar, remote sensing, high-bandwidth communications, compact accelerators and other areas that provide a path for long-term sustainability and potential funding sources beyond DOE for the program on a timescale of several decades.

**Required Resources.** The DOE-HEP Accelerator Stewardship program will offer opportunities for funding in more applied areas outside HEP, such as accelerators for medicine, energy or national security. Funding through the Stanford Medical School and other agencies outside of DOE may be possible. SLAC is also investing LDRD funds to explore the development of compact, high-average-power THz sources. Some additions to the scientific staff will be required to enhance the breadth of the source development effort. Flexible and cost-effective experimental test facilities are required to support R&D and testing of advanced structures.

**Instrumentation Development for Light Sources and Particle Physics**

**Vision.** Instrument development plays a critical role in SLAC’s science, from particle physics to light sources. The instrumentation effort is characterized by an integrated capability all the way from sensors to DAQ and software with an overarching systems design emphasis. SLAC benefits from high-quality staff, strong connections to the Stanford
Several high-priority upcoming programmatic science opportunities will depend critically on our core competency in instrumentation. The LCLS-II strategic planning exercise underway at the moment defines challenging requirements for instrumentation R&D, such as high frame rate, improved dynamic range, increased array scale, improved spectral resolution and high-efficiency spectroscopy, in order to meet demands for high-repetition-rate, ultralow-noise detectors and DAQ infrastructure. Radiation-hard silicon tracking systems for high-multiplicity environments and sophisticated high-performance DAQ systems will be required for the ATLAS upgrade for the high-luminosity LHC. Highly integrated large-scale focal planes will be required for CMB Stage IV experiments. Beyond these programmatic opportunities, we see potential interest from the neurosciences community in high-density integrated instrumentation and from the astronomy community in building on our experience with the LSST camera project. In order for SLAC to support these opportunities, we must continue to invest in infrastructure for the instrumentation core competency, including the development of a clean room facility for sensor fabrication and detector integration. Such a flagship facility would be the foundation for development of detectors for LCLS-II and the CMB Stage IV.

**Required Resources.** SLAC has a well-developed core scientific, engineering and technical staff in instrumentation and we envision only modest additions in new areas of development. The fabrication and integration clean room is anticipated to be jointly funded by SLAC and Stanford with operations supported by funding from facility users.

**Laser Development**

**Vision.** There is a great opportunity for SLAC to evolve to be the U.S. home for an important area of high-power laser technology. The U.S. DOE/NNSA has strong capabilities in high-energy and high-peak-power lasers, which SLAC can complement with its strength in the area of ultrafast, high-average-power laser systems, coupled to exquisite synchronization and pulse tailoring capabilities. Flowing from the scientific opportunities identified for LCLS-II, and building on the use of optical laser systems in the majority of present-day LCLS experiments, SLAC has a strategic need to drive advances in the state of the art for high-power lasers. This includes the need for a kW-class average power system for pump-probe studies on LCLS-II (representing a step of 5-10 times above the state of the art, currently in development at SLAC); petawatt (PW)-class peak-power lasers for next-generation studies of relativistic plasma physics and extreme materials science; and high-repetition-rate, highly tailored pulse sculpting to provide the capability to map an entire phase space of material properties by carefully matching the X-ray and optical laser systems.

Installation of high-power laser systems is currently a priority for SACLA and the European XFEL, with funded plans that stretch far beyond the capabilities in place at LCLS. However, the experience gained at LCLS in fielding experiments that combine X-ray and optical lasers, coupled to the world-class laser team in place at SLAC, and partnerships with other DOE laboratories such as Lawrence Livermore National Laboratory (LLNL) and LBNL, provides a clear pathway for us to maintain and extend our leadership by informed decisions on the most effective strategic investments.

**Required Resources.** Development of high-average-power pump-probe systems and high-repetition-rate drivers for extreme materials science are multi-million-dollar investments that would represent a major component of the LCLS operations/development budget. The initial steps in this strategy are currently being funded, and require new laser laboratory space as well as R&D resources. Incorporation of high-energy laser systems or high-peak-power (PW-class) lasers would require funding for dedicated new projects. These opportunities could arise as part of the strategy to position SLAC as a world-leading facility for high-energy density science, by combining the properties of the LCLS X-ray source with next-generation optical laser systems.

**Scientific Computing and Data Management**

**Vision.** SLAC will expand its existing core capabilities in scientific computing to achieve a paradigm shift in the exploitation of the large data sets anticipated from LCLS-II and LSST. SLAC has existing world-leading capabilities in real-time data acquisition, database technology and many areas of computational simulation. The addition of a capability in forefront algorithm development and computer science with a focus on exascale software systems will position SLAC to play a lead role in facilitating scientific exploitation of our facilities. SLAC is well situated to exploit synergies with NERSC at LBNL, significant computing expertise at LLNL and the powerful capability of Stanford faculty in many relevant areas, as well as links to leading Silicon Valley companies.
The dramatic improvements in capabilities planned for LCLS-II create significant computational challenges for data acquisition systems, storage systems and data processing and management. One of the main challenges will be to provide real-time feedback to experiments concerning the quality of data and the efficiency of the experimental setup, which could result in a major improvement in efficiency and effectiveness of LCLS experiments. Common software tools and data algorithm development will also be critical.

A comparable challenge for the Cosmic Frontier program will be the LSST data set, which will consist of an enormous 100-200 petabyte public archive. In addition, computing capabilities and software management will be essential to enable dark energy science from the LSST-DESC collaboration. Ongoing development of the advanced database technology being deployed for LSST will provide support for a broad range of future, extremely large database applications in DOE-HEP and DOE-BES. Advanced algorithm development for image processing and image correlation studies will continue to benefit from close ties to Stanford. An extensive program of cosmology simulations will be needed to exploit LSST data, with further R&D required on adaptive mesh and other numerical techniques.

The ability to simulate molecular processes and chemical reactions, at a time scale and spatial resolution that match the experimental capabilities of SLAC’s light sources, are an important aspect of both planning and analyzing experiments that will be greatly expanded with the proposed Theory Institute for Materials and Energy Science (TIMES) and the HED Science initiatives. The development of advanced theories, numerical methods/algorithms and associated modeling simulations are also encompassed in these efforts.

**Required Resources.** SLAC is developing a strategic plan to optimize the exploitation of the unprecedented data made available by the LCLS-II and LSST. We anticipate establishing a centralized core team of outstanding software professionals, building initially on existing capabilities augmented by strategic hires through internal SLAC funds to expand into exascale computer science areas in collaboration with Stanford faculty.
5.0 Strategic Partnership Projects

Baseline SPP Program

SLAC has a focused SPP strategy that is well aligned with its strategic plan, and enables the Laboratory to enhance support for essential core competencies and its science and technology base. SPP also enables hiring and retention of staff, development of new advanced research facilities, development of new methodologies and software, engagement of outside scientific talent, the addition of new instrumentation and collaboration and technology transfer with industry.

SPP places minimal strain on the scientific and technical talent pool; none of the projects expected over the next several years will be large enough to have a significant impact on the workforce if cancelled. On the contrary, SPP enables SLAC to retain talent that would otherwise be lost because of reductions in some DOE base programs and to enhance the viability of core competencies. No discretionary funds are used to support SPP-specific infrastructure and there is no significant subcontracting outside the Laboratory.

**Bioscience and Structural Molecular Biology Programs:** SLAC’s SMB R&D and user support aligns with SLAC’s core capabilities and light source initiatives. The SMB program supports development, operation and user access for about nine dedicated and shared beamlines and associated instrumentation/techniques, enabling application to forefront problems in structural biology by about 800 unique users at SSRL per year – about 10% of whom also use LCLS. SPP funding from the NIH’s National Institute of General Medical Sciences (NIGMS) is managed in close partnership with funding from DOE-BER. NIGMS has provided partial funding for the construction of an LCLS MFX station for developing dedicated capabilities to utilize the “diffact before destroy” concept. The MFX station, located in the LCLS Far Experimental Hall (FEH), will offer increased capacity, provide an in-air sample environment for a number of sample delivery methods and allow for time-resolved studies. In addition to NIH funding, SLAC continues a Defense Advanced Research Projects Agency (DARPA)-funded program on X-ray optics, which can lead to enhancement of beamline instruments as well as broader applications.

**Accelerator and High Energy Physics Programs:** Over the last two years SLAC has been very successful in implementing strategic partnerships to foster and develop its mission. This has been particularly the case for some of the most visible construction projects within the Office of Science, where SLAC has been very successful in setting up national collaborations among DOE-SC laboratories and the NSF. Often SLAC was able to bring international collaborators into the partnership as well. Of particularly note is the LCLS-II project where, without the successful management of a partnership among five national laboratories, Cornell University, an NSF laboratory and contributions from France (SACLAY, ORSAY), Germany (DESY) and Switzerland (CERN), the unprecedented pace of transition from concept (CD-0) to construction (CD-3b, CD-2) would not have been possible. For LSST a collaboration of national laboratories, universities and international partners (IN2P3 Laboratories in France) was established and now is very successfully executing the construction of the LSST camera as part of the NSF-led LSST facility project. Super CDMS, a project presently preparing for CD-1 is similar: a DOE/NSF partnership involving two DOE Laboratories and a combination of NSF- and DOE-supported university groups. In all these examples, national and international resources and partners are efficiently providing existing core competencies, rather than having the project spend time and money to reproduce them locally.

SLAC is the host laboratory for the FGST, a major international HEP collaboration that involves an operating common fund with contributions from all participating international agencies. There are ongoing collaborations with the KEK laboratory in Japan, funded under a collaborative science and technology agreement in high-energy physics which funds high-gradient research and research directed towards future high-luminosity and high-energy electron accelerators, both of which are synergistic with the DOE-funded accelerator research program. SLAC also fabricates X-band klystrons, RF photoinjector guns, and other high-power RF components on an SPP basis for Argonne National Laboratory, Brookhaven National Laboratory, LLNL, CERN, Paul Scherrer Institute and other U.S. and international laboratories. Via SPP agreements, SLAC also gives U.S. industry access to high-power test facilities for testing klystrons that have been built by industry for its customers. The klystrons are a SLAC design that has been transitioned to industry for commercial production, although industry at this time does not have the high-power test infrastructure. This work aligns well with and helps sustain DOE’s high-power RF core capability at SLAC.
Table 1. Strategic Partnership Projects Funding (BA in $M)\textsuperscript{1}

<table>
<thead>
<tr>
<th>Sponsors</th>
<th>FY 2014 Actual Funding Received\textsuperscript{2}</th>
<th>FY 2015 Estimated Funding Level</th>
<th>FY 2016 Request</th>
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<tbody>
<tr>
<td>DOD</td>
<td>1.3</td>
<td>1.0</td>
<td>3.0</td>
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<tr>
<td>NRC</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>DHHS/NIH</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>All Other Federal Work</td>
<td>-</td>
<td>-</td>
<td>1.5</td>
</tr>
<tr>
<td>Non-Federal Work</td>
<td>13.2</td>
<td>13.5</td>
<td>14.9</td>
</tr>
<tr>
<td>Total SPP\textsuperscript{3}</td>
<td>16.5</td>
<td>16.5</td>
<td>21.9</td>
</tr>
<tr>
<td>Lab Operating\textsuperscript{4}</td>
<td>324</td>
<td>333</td>
<td>319</td>
</tr>
<tr>
<td>SPP as % of Lab Operating</td>
<td>5%</td>
<td>5%</td>
<td>7%</td>
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<tr>
<td>DHS</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SPP + DHS as % of Lab Operating</td>
<td>5%</td>
<td>5%</td>
<td>7%</td>
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<tr>
<td>Agreement to Commercialize Technology (if applicable\textsuperscript{5})</td>
<td>0%</td>
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</table>

\textsuperscript{1} Numbers are for planning purposes only.
\textsuperscript{2} Includes funding received as part of the ARRA.
\textsuperscript{3} Does not include DHS funding when computing the Total SPP funding level.
\textsuperscript{4} Funding programs and others sent to the lab to perform R&D, etc. including capital equipment and GPP, but excluding construction.

SPP Strategy for the Future

SLAC’s SPP strategy is to expand its program consistent with the DOE-SC and SLAC missions. The Laboratory’s goal is to increase the SPP portfolio from the current ~5% of the FY15 Laboratory budget to ~8% by the end of the decade (approximately $30M). This level of funding will balance primary mission execution with sustaining critical capabilities and infrastructure, particularly in accelerator and high-power RF core capabilities, detectors, sensors and instrumentation, and lasers.

SLAC also aims to more effectively transition successful technologies to U.S. industry for commercial applications and help them remain at the cutting edge. The newly-created TID is developing an aggressive SPP program in the near term to help achieve this goal, to enhance the core competencies on which the SLAC core programs depend and to develop a broader sponsor base across federal agencies to further serve the nation's interest. It has added staff to support and manage these growth efforts. Current areas being developed by TID and other organizations at SLAC are outlined below.

Targeted areas of SPP growth in FY15 and beyond:

**Industrial Applications of Light Sources:** Opportunities exist for support of industrial R&D at SLAC’s light sources, especially SSRL and in the future LCLS. A strong base already exists in using SSRL for drug discovery, and there is significant potential for expansion through innovative NIH-funded programs for the development of pipelines, as well as emergent interest from NIH in using LCLS for translational drug discovery research. Strong interest in the use of SSRL for energy-related technologies by industrial partners working on batteries, photovoltaics and catalysts has also been demonstrated, as has the first (non-proprietary) use of LCLS by an industrial research team (from Rolls Royce). SLAC’s strong connection to Stanford offers potential synergy with several initiatives at Stanford that focus on sustainable energy technology.

**Materials and Chemical Sciences:** SLAC’s SSRL-based programs in materials science, chemistry and catalysis are formulating a scientific and instrumentation strategy to enable development of new facilities and techniques. Interest in enhancing high-throughput materials testing and data analysis has developed and will be pursued with both DOE and SPP funding.

**Biosciences:** The development of Bioscience Division research programs rests on strategies addressing the needs of DOE-BER and NIH missions. Funding for new initiatives and instrumentation are pursued together with LCLS, SSRL, Stanford and external collaborators, and target federal and private SPP funding mechanisms.

**Accelerator and RF Technology and Applications:** SLAC will broaden and strengthen its core capabilities in accelerator and high-power RF science and technology by applying them to a wide range of new applications,
including new projects with DARPA, Department of Homeland Security (DHS) and the Office of Naval Research (ONR). U.S. industry has initiated discussions regarding advanced technology development that SLAC could undertake in the areas of medicine, terahertz sources and detection of nuclear material and contraband. In addition, the success of LCLS has led to several opportunities in support of FEL projects worldwide. SLAC is beginning a new DARPA program to develop a novel approach for achieving revolutionary increases in neutron source intensity and reductions in device size, weight and power for in-the-field neutron radiography and analytical techniques.

**Applications of Detectors, Instrumentation and Computing:** SLAC’s core competencies in sensors; instrumentation; data acquisition and controls; electronics and electronics systems; space-based, low-background and systems engineering; data management; simulation; and analysis frameworks, will likewise find beneficial applications to new problems. With a broader foundation of related activities, SLAC will be in a better position to sustain core capabilities and retain the best talent. SPP opportunities include NSF, NASA and NIH as well as industry. Strong capabilities in superconducting sensors and amplifiers impact a broad range of activities in X-ray spectroscopy, quantum-limited signal processing and sensitive THz and mm-wave detection for materials, biology, forensics, cosmology and astrophysics applications. SPP opportunities include NSF, NASA, NIH, the Justice Department, NNSA, DARPA and partners in industry and the private sector.

SLAC is providing accelerator controls and instrumentation, such as beam position monitor systems and controls electronics and software to Pohang Accelerator Lab (PAL) in Korea via an SPP agreement and to the European Spallation Source (ESS) through a CRADA. In the ESS case, the technology developed will directly benefit the LCLS-II project.
6.0 Infrastructure / Mission Readiness

Overview of Site Facilities and Infrastructure

SLAC’s 426-acre campus sits within a larger tract of land owned by Stanford University in unincorporated San Mateo County. The campus accommodates 152 buildings (147 of which are DOE-owned) and over 40 parking lots with 1,900 spaces. Stanford leases the land to DOE and all SLAC facilities, with the exception of the Stanford Guest House, Starbucks, Arrillaga Recreation Center, Stanford Research Computing Facility, and KIPAC, are owned by DOE. Major utility systems include electricity, chilled and hot water, domestic water, sewer, storm drain, and gas. Power is provided by a DOE-owned 230 kV tap line that runs from the public utility 230 kV circuit to the SLAC Master Substation, a distance of about 7.5 miles. The SLAC site includes many tunnels and other unique experimental facilities, the largest of which are the 2-mile-long Klystron Gallery and the tunnel that houses the linear accelerator underneath it.

SLAC’s site master plan, entitled the SLAC National Accelerator Long Range Development Plan, is located at [https://www-internal.slac.stanford.edu/do/longrangeplan/slac%20plan%20final.pdf](https://www-internal.slac.stanford.edu/do/longrangeplan/slac%20plan%20final.pdf). SLAC is updating its site master plan to guide the coordinated use and development of all campus areas. The plan provides a conceptual roadmap toward achieving a collaborative, safe, sustainable and inspiring work environment. It shows where buildings are needed based upon existing and planned programmatic needs, and also illustrates where new programs that are not yet known could be placed in the future.

Over the last several years, key investments totaling $228M for current and recently completed projects have been funded by SLAC, Stanford, and DOE-SC. Important SLAC investments over the last 10 years include Institutional General Plant Projects (IGPP) and General Plant Projects (GPP). Key Stanford investments include KIPAC, SRCF, Arrillaga Recreation Center, Stanford Guest House, and Starbucks. The DOE Science Laboratory Infrastructure (SLI) investments provided line item construction funding for projects including the Research Support Building (RSB) 052, Administration and Engineering (A&E) Building 041, Operations Support Building 028, Science User Support Building (SUSB) 053, and the future Photon Science Laboratory Building (PSLB) 057.

With the oldest facility 52 year old, the newest 2 years old and the average trailer and building 31.7 years old, the SLAC site poses a challenge for the reliability and maintenance of utility infrastructure. In FY14, the Laboratory Operations Board (LOB) initiated a condition and utilization effort in order to understand infrastructure needs across the DOE national laboratory complex. Table 2 summarizes the general condition and utilization of non-mission-unique assets per this assessment (SLAC will complete its assessment of mission-unique facilities in FY15).

SLAC is also undertaking an assessment as part of the LOB’s initiative on excess facilities to determine those that are no longer operating or needed for the mission and those planned to become excess facilities over the next decade in order to understand the extent of excess facilities across the complex. Two facilities have already been declared excess, per Table 2 below, and more are expected in the near future. Information about SLAC’s plan for these excess facilities is discussed in the Campus Strategy section below.

<table>
<thead>
<tr>
<th>Table 2. Current Condition and Utilization Summary</th>
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<td>Quantity</td>
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<tr>
<td>4</td>
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<tr>
<td>Excess Facilities (per FIMS excess indicator)</td>
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<td>Excess Space</td>
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</table>

**Campus Strategy**

**Overview**

As SLAC embarks on its multi-disciplinary mission in the coming decades, it is challenged to revitalize its aging facilities and infrastructure to meet current and emerging needs, while ensuring effective and efficient management and stewardship of its DOE assets. SLAC’s program expansion requires a substantially different support and operational mode, further challenging the reliability and operability of the existing infrastructure.

SLAC has established a campus strategy and layout that best supports the current and expected future mission initiatives and science and technology competencies. The current primary drivers of our infrastructure planning are upgrading LCLS and SSRL capabilities and capacity, modernizing the existing campus (electrical and cooling distribution reliability, mechanical infrastructure and building repairs and upgrades) and creating modern, collaborative spaces to enable our growing research areas. The conceptual locations of projected investments and their funding sources are identified in Figure 1 below. By 2020, SLAC expects likely new construction of 275,000 gross square feet in eight new buildings with an expected campus occupancy increase. This plan includes:

- New buildings to support facility users visitors, new research and closer collaboration.
- Upgrades to increase general site access to 46% (from 17% today) to encourage cross-discipline collaboration and multi-modal access. Only the accelerator and research yard will be restricted.
- Renewal of the central core of the campus through enhancements to the streetscape, open space and pedestrian networks.
- Improvements in the reliability of electrical power distribution and cooling water systems to increase efficiency and minimize long-term operating costs in support of the mission.
- Plans for Stanford University land return Phase I (12.5 acres), which would result in road realignment, site utility relocation and a reduction of parking space.

**Figure 1. SLAC Campus Vision, 5-10 years**
To meet SLAC's future objectives and make the campus vision possible, infrastructure and systems must be replaced or renewed. In order to maximize scarce resources, the Laboratory has completed a risk-based prioritization that addresses the identified inadequate and substandard gaps and supports SLAC's core capabilities and major initiatives now and over the next decade (summarized in Table 3). SLAC's overall approach is to identify and revitalize the most critical infrastructure first, prioritized by their risk to safety and mission-critical programs. Our current focus is on the reliability of electrical and cooling distribution systems that have been assessed as inadequate or substandard. Remaining needs are prioritized as funding and timing allows or put in run-to-failure mode, where decisions are then made regarding the viability of retaining spare parts and/or contingency funds for unexpected failures.

SLAC's maintenance and repair spending is less than the 2% guideline. Implementing a funding level per the 2% of Replacement Plant Value (RPV) guide would not be practical, since there are high-RPV assets that do not require 2% levels, such as non-operational tunnels, and facilities with limited future use. SLAC uses its mission readiness approach to evaluate current and future needs and plan maintenance and repairs accordingly. For some assets, major repairs will not be conducted because the assets are scheduled for replacement in a few years. SLAC balances its proposals for IGPP projects to reduce SLAC's deferred maintenance against overall laboratory support needs during its budget process. The deferred maintenance trend is expected to remain flat or improve when the planned investments identified in Table 4 below are made. As SLAC continues to refine maintenance and repair processes and identify critical needs, the Laboratory will fund prioritized projects to mitigate those risks.

SLAC's infrastructure priorities including maintenance and repair will be addressed using multiple funding sources, including SLI funding, GPP funding primarily from DOE-BES and DOE-HEP, IGPP funding and Lab-level overhead to fund general infrastructure needs and maintenance. A summary of SLAC's planned investment needs is shown in Table 4.

**Multi-program support gaps**

With the success of the LCLS, SLAC is experiencing an increase in visitors and users to the campus, and expects this trend to continue with LCLS-II. The SLI-funded **Science and User Support Building**, scheduled for completion in late 2015, replaces 50-year-old buildings, including the old auditorium, visitor center and cafeteria. This new building is located at SLAC's entrance, serving as SLAC's front door, and will bring together many of SLAC's administrative functions that support science facility users, visitors and the Laboratory. It will also house an updated auditorium, cafeteria and conference center providing much-needed collaborative space. Once SUSB is complete, the section vacated in B040 can be repurposed into office and laboratory space to meet immediate needs of our growing science programs and initiatives.

The **security infrastructure upgrade** project is also continuing. An important goal of the project is to make a larger percentage of the site open to general access, supporting SLAC's goals of encouraging collaboration across disciplines in part by improving ease of movement and connectivity around the campus. This involves securing excess storage items onsite, moving security fences and automating gates, while securing individual buildings outside the secure perimeter. In 2015, 17% of campus is open to general site access. The goal is to increase access to 46%, including most of the east campus except the research yard. Once complete, the site will be generally open, accessible and secure. Phase I and II security upgrade accomplishments to date include installation of an access control system, construction of Alpine Gate with 24/7 access and automation of Gate 17 (SSRL) and Sector 30 (Accelerator). Funding permitting, work in the next five years will include the removal of Gate 17 and the Sector 30 Gate, the installation of four new gates (SSRL north and south research yards and two new accelerator gates), and the addition of radiation portal monitors at both Sand Hill and Alpine Gates. The ability to successfully grow the campus depends largely on the completion of this project, and therefore funding the entirety of the project is important.

**Conventional infrastructure gaps**

The **electrical distribution system** affects all activities at SLAC, and much maintenance and repair is needed to improve safety and reliability for current operations. For example, replacement or upgrades are needed for multiple Klystron Gallery electrical items (e.g. 12.47kV cables, 480V Motor Control Centers, battery banks) and other electrical distribution components throughout the site. In addition, the 12.47kV substations with Federal Pacific Electric load-break switches and breakers need to be renovated and power factor correction equipment is needed at the master substation to replace a failed synchronous generator. SLAC is planning investments in these as shown in Table 5.

The linac K substations, which are part of the medium voltage electrical system, have significant code and safety deficiencies and operational limitations and are not capable of meeting current and planned mission needs. These substations and related components must be replaced in order to provide operator safety and to ensure system
reliability. Much of the existing electrical distribution equipment is the original equipment installed 50 years ago. Some of the older equipment is not safe to operate and periodically fails, affecting operation of laboratory programs. SLAC plans to replace 12kV distribution feeders that have failed or that have been evaluated to have a high probability of failure, and replace various 480 vac motor control centers, distribution panels and panel boards that are difficult to maintain and indicate high potential for failure, replace multiple cables, purchase electrical panel spares, and upgrade substations and maintain electrical breakers.

The underground pipes for the storm water and sanitary sewer systems are also in need of significant repairs due to pipe breaks and misalignment due to age. Incremental investments are being made each year using IGPP funds to address the most critical issues first.

Upgrades are proposed using GPP funds for control and monitoring systems associated with all infrastructure utilities. Installing modern technology allows for better decision-making based on data as a part of the reliability centered maintenance program.

Like the conventional facilities infrastructure, SLAC’s computing infrastructure is also aging. Servers, cables, switches and other computing infrastructure need to be replaced to support future science and operations. SLAC also places a high priority on cyber security initiatives to protect the data and intellectual assets entrusted to us, and is executing a prioritization plan that also leverages Stanford resources.

**Accelerator mission readiness**

In the past, SLAC has run its accelerator systems to failure; however, we now operate under a new approach where systems with the highest mission need and highest return on investment are being upgraded in a systematic manner. In early 2014, an external review of our accelerator mission readiness approach assessed the method’s effectiveness and return. An accelerator mission readiness program was initiated in FY14, and the initial funding of $5M included projects such as a linac Personnel Protection System upgrade; linac RF modulator upgrades; Beam Switchyard (BSY) pumping; machine tooling; and cryogenic nitrogen tank upgrades. A systematic, comprehensive plan for the next eight years has been developed, which when implemented is expected to assure SLAC’s accelerator mission readiness for decades to come. The associated savings (ROI) are incorporated into the future operations budgets of the associated facilities and allow for a cost-efficient transition to operations.

A similar assessment and process will be completed in 2016 for conventional infrastructure, with its savings serving a large science infrastructure at an approximately flat cost.
## Table 3. Core Capability Infrastructure Gaps

<table>
<thead>
<tr>
<th>Core Capability</th>
<th>Timeframe</th>
<th>Gap</th>
<th>Risk</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large Scale User Facilities/Advanced Instrumentation</strong></td>
<td>Today</td>
<td>Site preparation for LCLS-II is needed including D&amp;D, and cooling tower and electrical reliability needs to be improved to adequately support current and future operations at LCLS and SSRL.</td>
<td>Sectors 0-10 need to be cleared to make way for the LCLS-II upgrade. The CT-1200 and 1201 systems, which support the linac, suffer from weak piping infrastructure, and more importantly, while there is a stand-by pump associated with this system there is no associated stand-by cooling tower cell. Cooling tower maintenance shutdowns or failures would prevent normal operation of accelerator operations. CT1701 supports multiple programs and is a single point of failure. Without these investments, SLAC will not be able to meet LCLS-II construction schedule (resulting in increased costs) or meet major mission objectives. Without investments to address aging cooling tower infrastructure that serves these facilities, SLAC’s ability to perform its mission and necessary upgrades will be severely impacted. There are also risks of lost experimental time due to equipment failure, domestic water usage, and leakage of chemical fluids into the ground.</td>
<td>In FY16, D&amp;D will commence on sectors 0-10 of the linac to prepare for LCLS-II. Modifications to the CT-1201 cooling tower system are now underway to support the upgrades to the linac for LCLS-II. The replacement of CT-1701 is being requested from IGPP funds. The replacement of CT-1200 will be proposed, also from IGPP funds.</td>
</tr>
<tr>
<td><strong>Future</strong></td>
<td></td>
<td>An upgrade to LCLS is required to meet future scientific needs and remain internationally competitive.</td>
<td>Without investments in LCLS-II, SLAC would be unable to meet research goals for users and associated scientific objectives.</td>
<td>LCLS-II will expand the scientific capabilities of the LCLS facility with higher repetition rates and increased photon energy. It will create a new superconducting linac capable of producing higher-intensity electron pulses, and include two new variable-gap undulators that will replace the existing LCLS device. The LCLS instruments will undergo modifications and enhancements to operate with the enhanced beam properties delivered by the LCLS-II project. The project will also include a 10,000SF Cryogenic Building to be built on the west side of the campus near Sector 4. Estimated completion in 2019, with approximately two years of float to 2021.</td>
</tr>
<tr>
<td>Wet lab facilities are required to support LCLS and SSRL user programs.</td>
<td></td>
<td>An inability to support user needs will hinder ability to perform needed research and achieve mission objectives.</td>
<td>The Sample Preparation Laboratories will provide wet lab facilities for SSRL and LCLS user programs. The labs will support final-stage sample preparations and straight-forward laboratory manipulations in biology, chemistry, materials science and the geosciences. SSRL will house two BioChemMat-focused Laboratories (BCM1 &amp; 2) and one geoscience-focused laboratory. LCLS will house one laboratory supporting these disciplines in a more refined...</td>
<td>...</td>
</tr>
<tr>
<td>Core Capability</td>
<td>Timeframe</td>
<td>Gap</td>
<td>Risk</td>
<td>Strategy</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Cleanroom facilities needed to support R&amp;D in detectors, sensors and other devices.</td>
<td>Inability to perform needed R&amp;D and meet mission objectives, and achieve goals associated with core capability.</td>
<td>An assessment of cleanroom needs and options is being conducted to provide facilities for detectors, sensors and other devices. Device fabrication will require low-vibration space and extensive support facilities such as chemical and gas storage. There is potential for reuse of existing buildings (e.g. B033 and B026) to address these gaps, and funding would likely be sought from IGPP.</td>
</tr>
<tr>
<td>Chemical and Molecular Science and Condensed Matter Physics and Materials Science</td>
<td>Today</td>
<td>Increased space and modern laboratory facilities to meet program growth needs in the photon sciences and applied energy initiatives.</td>
<td>Lack of modern laboratory facilities and additional office space will result in our inability to perform needed research and achieve goals associated with core capabilities.</td>
<td>While PSLB is constructed, SLAC plans to renovate B040 when occupants have relocated to SUSB (late 2015) to provide additional office and laboratory space as needed (IGPP).</td>
</tr>
<tr>
<td></td>
<td>Future</td>
<td>Increased space and modern laboratory facilities to meet program growth needs in the photon sciences and applied energy initiatives.</td>
<td>Lack of modern laboratory facilities and additional office space will result in our inability to perform needed research and achieve goals associated with core capabilities.</td>
<td>PSLB (approved for construction in April 2015) will provide around 60,000 square feet of assignable lab and office space that includes wet labs, dry labs, characterization facilities and a small cleanroom. The building will collocate complementary programs to increase collaboration across disciplines. Estimated completion is 2018 (Stanford donor and SLI). See Appendix 1 for Line Item Investment details.</td>
</tr>
<tr>
<td>Accelerator Science</td>
<td>Future</td>
<td>Flexible state-of-the-art experimental test facilities that are agile and cost effective are needed to support R&amp;D for novel accelerator structures, diverse particle species, and radiation sources.</td>
<td>Inability to perform needed R&amp;D and meet mission objectives and achieve goals associated with strengthening foundational core capability.</td>
<td>SLAC is exploring options to develop a flexible experimental facility that leverages existing technical infrastructure. While primarily providing a testbed for SLAC R&amp;D, the facility will be available to Stanford University, industry and other federal agencies through Strategic Partnership Programs and the Accelerator Stewardship Program.</td>
</tr>
<tr>
<td>Particle Physics</td>
<td>Today</td>
<td>Adequate clean room facilities required for preparation of LSST.</td>
<td>Without an investment in cleanroom facilities, SLAC will be unable to meet LSST objectives.</td>
<td>Renovation of B620 at the IR-2 Hall to create a new 2,400 square foot Class 1000 clean room to support the LSST project (GPP-HEP). Expected completion in 2015.</td>
</tr>
<tr>
<td></td>
<td>Future</td>
<td>Space will be needed to support the LSST dark energy science program expansion.</td>
<td>Inability to meet user needs and meet objectives related to future initiatives and core capabilities.</td>
<td>Minor renovations are being considered to B048 to modernize and accommodate program needs.</td>
</tr>
</tbody>
</table>
Plan for Excess Assets and Materials

While none of SLAC’s currently identified excess assets has been assessed as presenting a risk to the public or the environment, or pose a safety risk to employees and visitors at the Laboratory, their continued presence onsite does present a modest burden to mission accomplishment due to their collective annual cost of operation and maintenance. More important is the fact that they occupy valuable land that can be redeveloped (e.g. for parking to offset the Stanford land take-back, office/laboratory space to support future research, and research facility expansion).

The bulk of excess assets onsite are made up of temporary structures (e.g. trailers) that are no longer a sustainable solution for housing people or laboratories, and old scientific structures (e.g. collider arcs, beam dumps and substations) that are no longer serving the SLAC and DOE missions and are not part of the future vision for the laboratory. Because there are no safety, health or significant financial risks associated with the existing suite of excess materials, where it is not cost-effective to remove an item, SLAC instead looks for reuse potential and is also developing a process for minimal maintenance on non-utilized buildings designated as “cold and dark” to lower annual carrying costs.

SLAC’s current inventory of excess assets is summarized in the following categories:

**Trailers:** As shown in Table 2 earlier, SLAC has two facilities currently declared as excess that are awaiting demolition: the B292 Test Laboratory Microwave Lab and B231 Test Laboratory trailers. These two represent 2,662 square feet and around $16,000 in annual carrying costs. The estimated cost of removing these is $105K.

In addition, SLAC has approximately 40 other trailers that are either shut down (pending D&D or disposal) and slated for removal, or are operational and being used for storage or operational and still functioning as office and laboratory space but have the potential to become excess in the next decade. The trailers are of varying ages (ranging from 1966 to 1995) and are located throughout the site, totaling approximately 50,988 square feet. The collective annual operational costs are around $272,500, as many are occupied, and annual maintenance is around $87,500. However, once a trailer is closed, its annual costs drop to less than $1,000 per year.

SLAC has made removing the trailers and other smaller temporary structures a priority for a variety of reasons: cost-effectiveness (removal costs are moderate and maintenance costs are eliminated); need for developable land to support campus growth; and aesthetics. SLAC has therefore developed a Trailer Demolition Plan, phased over the next seven years and aligned with known planning timeframes to address removal of these temporary structures (see Figure 2).

*Figure 2. Proposed Trailer Demolition Plan*
Buildings: SLAC has currently identified a small number of buildings and interaction region (IR) halls as excess assets. Most of the structures are not in use and do not cost SLAC more than $1,000 each per year. However, some of those buildings contain working electrical systems that would need to be re-routed prior to any demolition, which is costly. If adequate funding becomes available, then SLAC would rework the electrical systems and these buildings could then become candidates for demolition.

Since removing the IR halls would be too costly, as they would require a thorough hazard review and are deeply embedded in the land, SLAC’s preference is to repurpose them. The halls’ high bay structure and proximity to the research facilities makes them good candidates for clean rooms; IR-2 has already been repurposed as a clean room space to support the LSST camera construction.

Other Structures and Facilities: After previous scientific facilities ended operations (e.g. PEP, SLC and BaBar), much of the related mission and ancillary infrastructure has remained in place, including two collider arcs (tunnels), beam dumps and substations. The collider arcs are in shutdown pending D&D mode, and are awaiting a decision from EM on funding and D&D\(^1\). The preliminary cost estimate ranged from $70M to $150M; since the collider arcs are not accessible to the majority of staff and therefore pose no safety or health risk, and there are negligible annual carrying costs, the vacant space is being used to store old programmatic equipment until funds are available for their D&D.

The PEP rings and old beam dumps will remain in place until they are deactivated, and a number of the excess substations (e.g. those that supported PEP operations) will likely be candidates for removal in the next decade.

Excess Accelerator Materials: There are large amounts of excess accelerator material at many locations around SLAC. The presence of these materials is in part a result of the DOE metal moratorium and metal suspension policy that began in 2000. With laboratory space and real estate now at a premium, and the development of programs enabling responsible management and recycling of accelerator materials, SLAC has put a long-term plan into action to address this issue. Additionally, programs are in place to reduce the radioactive waste inventory at SLAC. A combination of these long-term plans for waste and recycling and a disciplined and consistent approach will eventually result in the clearance of all materials by the projected date of 2025.

In order to make progress in addressing the moratorium policy, a target site was needed and the SLAC B-factory was chosen. In preparation for completion of the B-factory mission (PEP-II accelerator and BaBar detector), and in collaboration with peer accelerator laboratories from DOE-SC, NNSA and CERN, SLAC developed a Material Release Program which addresses all of the key elements outlined in the metals moratorium memorandum. This program was approved in 2011, and shortly after the metals recycling began at SLAC.

Since FY11, the SLAC Accelerator Material Clearance Program has focused on recycling metals inside both PEP-II and BaBar, and materials stored outdoors. These efforts have yielded 3,000 tons as of April, 2015, and $1.4M in recycling revenue. In addition, SLAC has led the development of a DOE Technical Standard that will enable all DOE sites to perform similar recycling operations.

The work expected to occur between FY15 and FY18 will focus on the equipment removal project from linac Sectors 0–10 and the BSY that is needed to facilitate LCLS-II installation work. This will prepare SLAC for the construction of LCLS-II. During the long-range period of FY15–FY25, this program plans to recycle materials included in the more than 10,000 tons of legacy accelerator equipment that no longer support the SLAC mission.

In addition to the materials that can be recycled, SLAC has large quantities of radioactive waste onsite that no longer serve the Laboratory mission. In the past 10 years, SLAC has disposed of 1,470 cubic yards of radioactive and mixed wastes and 422 excess radioactive sealed sources, and has made disposal of legacy wastes a long-term priority. The work slated to occur between FY15 and FY18 will focus primarily on the disposal of the waste from linac Sectors 0–10 and the BSY, and complete disposal of the remaining 300 radioactive sealed sources. Over the next decade, SLAC will continue the efforts to reduce the 3,367 cubic yards of legacy radioactive waste.

The impact and benefits of the recycling and disposal operations are numerous. They include protection of the environment, reduction of the DOE footprint at contractor sites and reduction of DOE future liabilities, cleaner and safer areas, and new spaces into which SLAC can expand its science mission.

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\(^1\) In 2009, EM agreed to accept the collider tunnels for demolition, under a memorandum entitled “Environmental Management Transfer Decisions for Office of Science Excess Facilities and Materials”.

SLAC Annual Laboratory Plan  Submitted 1 May 2015
With the decommissioning of the first kilometer of the SLAC linac and klystron gallery to make room for the newly constructed LCLS-II, radioactive as well as non-radioactive waste will be disposed. A project has therefore been put in place to manage the waste stream from LCLS-II construction efficiently and, using SLAC’s approved Accelerator Material Clearance Program, direct as much non-radioactive material as possible to recycling immediately.
Table 4. Planned Investments ($K)

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</thead>
<tbody>
<tr>
<td>GPP Investments Pragrammatic (LCLS Ops, SPEAR 10s, roof replacements)</td>
<td>51,850</td>
<td>-</td>
<td>3,200</td>
<td>2,600</td>
<td>12,500</td>
<td>12,500</td>
<td>2,500</td>
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<td>3,500</td>
<td>3,500</td>
<td>3,000</td>
<td>2,750</td>
<td>GPP(BES)</td>
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<tr>
<td>Lab-wide Infrastructure Investments, Accelerator (50-10 D&amp;D, MMF upgrades,</td>
<td>29,170</td>
<td>-</td>
<td>950</td>
<td>5,910</td>
<td>5,210</td>
<td>8,650</td>
<td>8,450</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Indirect OPE/IGPP</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>stairway and fire alarm upgrades)</td>
<td></td>
<td></td>
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<tr>
<td>Cooling Towers 1200, 1201, and 1202 (Repairs/Replacement)</td>
<td>20,055</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6,500</td>
<td>5,000</td>
<td>6,000</td>
<td>1,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>GPP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K Substations (Replacement)</td>
<td>9,800</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>GPP (SLI)</td>
<td>1</td>
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<tr>
<td>Ramsy Relocation</td>
<td>3,150</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,575</td>
<td>1,575</td>
<td>OPE/IGPP</td>
<td>All</td>
</tr>
<tr>
<td>Lab/Office Upgrades (Emerging Science, new cleanrooms, IR2 LZ Hut,</td>
<td>36,222</td>
<td>2,322</td>
<td>6,448</td>
<td>2,548</td>
<td>798</td>
<td>140</td>
<td>2,321</td>
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<td>4,245</td>
<td>3,700</td>
<td>3,500</td>
<td>3,500</td>
<td>4,300</td>
<td>IGPP</td>
<td>2</td>
</tr>
<tr>
<td>petawatt study, B040 lab and B026 upgrades)</td>
<td></td>
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</tr>
<tr>
<td>Photon Science Laboratory Building</td>
<td>55,000</td>
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<td>10,000</td>
<td>25,000</td>
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<td>LIC (SLI)</td>
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<tr>
<td>LSST Clean Room</td>
<td>1,150</td>
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<td>-</td>
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<td>GPP(NEP)</td>
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<tr>
<td>Science and User Support Building</td>
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<td>25,482</td>
<td>11,920</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>LIC (SLI)</td>
<td>All</td>
</tr>
<tr>
<td>12 KV Electrical (Ksubs, VVs, Cables and Protective Relays)</td>
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<td>59</td>
<td>1,288</td>
<td>4,700</td>
<td>2,700</td>
<td>12,600</td>
<td>11,210</td>
<td>6,300</td>
<td>2,700</td>
<td>2,380</td>
<td>3,500</td>
<td>2,300</td>
<td>1,200</td>
<td>Direct OPE/GPP</td>
<td>All</td>
</tr>
<tr>
<td>230 KV Electrical (installation of new substation at tower 1)</td>
<td>7,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,500</td>
<td>3,500</td>
<td>-</td>
<td>-</td>
<td>Direct OPE/GPP</td>
<td>GPP</td>
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<tr>
<td>480 Electrical Distribution</td>
<td>12,585</td>
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<td>-</td>
<td>277</td>
<td>1,400</td>
<td>1,789</td>
<td>1,567</td>
<td>1,742</td>
<td>610</td>
<td>1,500</td>
<td>1,200</td>
<td>1,900</td>
<td>600</td>
<td>IGPP</td>
<td>All</td>
</tr>
<tr>
<td>Cooling Distribution System (Replace piping, pumps, and heat exchangers; upgrade HVAC)</td>
<td>12,775</td>
<td>53</td>
<td>1,020</td>
<td>1,000</td>
<td>2,250</td>
<td>2,932</td>
<td>1,920</td>
<td>2,350</td>
<td>1,000</td>
<td>250</td>
<td>-</td>
<td>-</td>
<td>Direct OPE/GPP</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Cooling Tower 1701 (pump upgrade, cell replacement, heat exchangers)</td>
<td>11,650</td>
<td>-</td>
<td>250</td>
<td>1,500</td>
<td>4,000</td>
<td>2,000</td>
<td>3,900</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>IGPP</td>
<td>All</td>
</tr>
<tr>
<td>Site Utilities (Storm Drains, Sanitary Sewer, Roads, Domestic Water, Natural Gas, water revitalization)</td>
<td>24,566</td>
<td>383</td>
<td>200</td>
<td>187</td>
<td>564</td>
<td>2,190</td>
<td>2,580</td>
<td>4,058</td>
<td>2,585</td>
<td>4,125</td>
<td>2,475</td>
<td>2,175</td>
<td>3,045</td>
<td>Indirect OPE/IGPP</td>
<td>All</td>
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<tr>
<td>Infrastructure Maintenance and Repairs</td>
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<td>10,743</td>
<td>12,106</td>
<td>12,824</td>
<td>13,804</td>
<td>14,570</td>
<td>14,825</td>
<td>15,167</td>
<td>15,257</td>
<td>15,593</td>
<td>15,688</td>
<td>16,067</td>
<td>16,167</td>
<td>Indirect OPE</td>
<td>All</td>
</tr>
<tr>
<td>Site Computing &amp; Cyber Safety (8050 upgrades, cyber security improvements, server upgrades)</td>
<td>18,789</td>
<td>3,654</td>
<td>1,015</td>
<td>535</td>
<td>1,140</td>
<td>875</td>
<td>975</td>
<td>4,085</td>
<td>1,775</td>
<td>1,185</td>
<td>1,670</td>
<td>1,505</td>
<td>975</td>
<td>Indirect OPE</td>
<td>All</td>
</tr>
<tr>
<td>Site Access (reduce restricted areas)</td>
<td>6,900</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,200</td>
<td>3,700</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>GPP</td>
<td></td>
</tr>
<tr>
<td>D&amp;D (legacy sealed source disposal, concrete blocks, metal recycling)</td>
<td>10,514</td>
<td>204</td>
<td>350</td>
<td>450</td>
<td>550</td>
<td>450</td>
<td>650</td>
<td>850</td>
<td>660</td>
<td>1,450</td>
<td>2,450</td>
<td>1,450</td>
<td>1,000</td>
<td>Indirect OPE</td>
<td>All</td>
</tr>
<tr>
<td>Trailer Demo (remove vacated trailers)</td>
<td>4,210</td>
<td>-</td>
<td>50</td>
<td>105</td>
<td>200</td>
<td>660</td>
<td>1,000</td>
<td>300</td>
<td>500</td>
<td>1,395</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Indirect OPE</td>
<td>All</td>
</tr>
<tr>
<td>Maintenance and Repair</td>
<td>196,106</td>
<td>11,060</td>
<td>13,336</td>
<td>13,851</td>
<td>14,554</td>
<td>15,831</td>
<td>16,995</td>
<td>17,617</td>
<td>18,202</td>
<td>18,243</td>
<td>18,613</td>
<td>18,892</td>
<td>18,912</td>
<td>Indirect OPE</td>
<td>All</td>
</tr>
<tr>
<td>Deferred Maintenance Trend</td>
<td>27,500</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>28,000</td>
<td>Indirect OPE</td>
<td>All</td>
</tr>
</tbody>
</table>
**Site Sustainability Plan Summary [Internal]**

SLAC approaches sustainability on two general fronts: **integrated sustainable infrastructure improvements** and **behavioral changes**. SLAC has strategically invested $5.9M of SLI in the last few years and $2.7M of infrastructure indirect funds on energy/water projects since FY10, in an effort to reduce energy consumption and greenhouse gases (GHG) emissions.

In FY12 and FY13, SLAC renovated and built 85,900 square feet of LEED® Gold certified office spaces, B028 and B052 respectively. In FY14, a 6,600-square-foot SIMES laboratory in B040 achieved LEED® Gold certification. A fresh sustainability approach to office behavior has been implemented in these new buildings, leaving behind inefficient and non-sustainable practices.

SLAC is in the process of an infrastructure modernization program that will replace energy-inefficient trailers and buildings with LEED® Gold certified buildings. SLAC is in the process of certifying new buildings—B028, B041, B052, B053 and B901—to meet DOE High Performance Sustainable Buildings (HPSB) requirements.

Waste diversion successes in FY14 include a municipal solid waste diversion rate of 84% and a construction waste diversion rate of 98%, well in excess of the DOE goal of 50%.

By promoting positive behavioral change through engineered and administrative improvements, SLAC has accomplished the following:

- Provided 16 Level 1 and four Level 2 electric vehicle charging stations to promote staff use of electric vehicles for commuting.
- Installed low-flow aerators in faucets, and instituted site-wide communication outreach on drought awareness. Potable water consumption in buildings dropped by 37%, a reduction of 2 million gallons compared to last year.
- Halted automatic irrigation of campus lawns and shrubs while still watering the campus trees, which saved over 7 million gallons compared to the same period last year.
- Completed lawn replacement with drought-resistant landscaping, which received a $10,000 rebate from the City of Menlo Park. This was a prototype for expanding water-conserving lawn replacements.
- Replaced 80 aged office printing devices with 11 new networked multi-function devices.
- Expanding SLAC’s Zero-Waste program with recycling and composting. One-third of SLAC’s full-time employees and a large portion of the facility user community are now participating in the program.
- Organized a sustainability pledge campaign on printing awareness. SLAC’s continuing three-year sustainability awareness effort on paper waste has resulted in reducing the quantity of paper purchased by 50% over this period.

SLAC anticipates meeting most sustainability goals; however, there are some goals that the Laboratory will not meet. Specifically, SLAC had a goal of nine HPSBs, but will only achieve compliance with five; and SLAC cannot meet the fleet annual fuel consumption goals due to a lack of a local E85 fuel supplier. SLAC had proposed $2M in FY15 to meet the sustainability goals. While the intended projects were not fully funded due to other laboratory funding priorities; approximately $300K was approved to implement needed infrastructure revitalization projects to support the Laboratory’s sustainability operations. Examples of completed and future infrastructure improvements that have a positive sustainability effect include utility piping, cooling and heating equipment, pumping and control systems, and more efficient transformers in electrical substations. Looking ahead, SLAC has applied for a funding award from the Sustainability Performance Office for three projects in FY16: conversion of B048 to a HSPB, a detailed site energy audit and upgrading landscaping for water savings. The total for these three projects is approximately $830K above our projected annual $50K investment, as reflected in Table 5.

As a result of mission growth, SLAC anticipates increased High Energy Mission Specific Facilities-related energy and water usage, with an associated increase in GHG. The planned purchase of renewable energy credits (RECs) will offset the expected increase in GHG emissions and assist SLAC in achieving the GHG goals. In FY14, SLAC purchased RECs to offset 17% of electricity GHG generation at a cost of $22K. In FY20, the goal requirement is to offset a minimum of 20% GHG through RECs.

SLAC will continue to integrate and balance sustainability improvements with needed infrastructure upgrades and revitalization to support the mission of the Laboratory.
Table 5. Sustainability Project Funding

<table>
<thead>
<tr>
<th>Category</th>
<th>FY14 Actual</th>
<th>FY15 Planned</th>
<th>FY16 Projected</th>
<th>FY17 Projected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability Projects</td>
<td>50</td>
<td>50</td>
<td>880</td>
<td>50</td>
</tr>
<tr>
<td>ESPC/UESC Contract Payments</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Renewable Energy Credits (REC) Costs</td>
<td>22</td>
<td>27</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>All other</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>77</td>
<td>910</td>
<td>85</td>
</tr>
</tbody>
</table>

Figure 3. Electricity Usage and Cost Projections
7.0 Human Resources

Recent History

To increase alignment with the Laboratory’s mission and scientific strategies and to ensure critical operations services, SLAC undertook a multi-year workforce evaluation and restructuring that resulted in a net decrease of 166 staff, or 8.8% from FY12 to FY14 (see Table 4 below). Total turnover increased in FY14 to 14.8% from 11.5% in FY13, driven in large part by layoffs, which accounted for 48% of all terminations. Voluntary turnover remained consistent at 7.5%. Adjusted for layoffs, the total turnover was 6.7%, with voluntary at 4.9%. The majority of this workforce restructuring was completed in FY14. Consistent with the Laboratory's strategy to expand and diversify its portfolio of research and scientific practice, the number of scientific staff has increased and several highly renowned scientific leaders have been hired. Strategically planned reductions in force set up SLAC in FY15 to hire the workforce now needed to face future challenges coming with the construction of its new major science facilities.

Table 6. Three-year Staffing Profile (FTEs)

<table>
<thead>
<tr>
<th>Functional Area</th>
<th>FY2012</th>
<th>FY2013</th>
<th>FY2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientists</td>
<td>268</td>
<td>305</td>
<td>308</td>
</tr>
<tr>
<td>Engineers</td>
<td>449</td>
<td>416</td>
<td>401</td>
</tr>
<tr>
<td>Post Docs</td>
<td>90</td>
<td>92</td>
<td>110</td>
</tr>
<tr>
<td>Research Support</td>
<td>217</td>
<td>179</td>
<td>162</td>
</tr>
<tr>
<td>Graduate Students</td>
<td>125</td>
<td>121</td>
<td>120</td>
</tr>
<tr>
<td>Undergraduate Students</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Operations/Administrative Support</td>
<td>720</td>
<td>653</td>
<td>602</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,869</strong></td>
<td><strong>1,766</strong></td>
<td><strong>1,703</strong></td>
</tr>
</tbody>
</table>

After a year-long international search for new directors of SSRL and LCLS, Kelly Gaffney, a SLAC faculty member and a member of the Stanford/SLAC joint PULSE Institute, was promoted to the role of SSRL director, and Michael Dunne, formerly the director for Laser Fusion Energy at LLNL, accepted the position of LCLS director.

In early 2015, SLAC underwent an organizational restructuring to better align its workforce with the strategic plan. This allows the Laboratory to place greater emphasis on scientific areas that are crucial to SLAC’s future; promote interaction and interdisciplinary research opportunities among the scientific divisions; and capitalize on our unique set of core competencies and enable us to pursue new opportunities to grow the Laboratory.

The new Science Directorate is comprised of Chemical Sciences, led by Tony Heinz who comes from Columbia University; Elementary Particle Physics, led by JoAnne Hewett, professor of physics and department head of theoretical particle physics at SLAC; Particle Astrophysics and Cosmology, led by Tom Abel, acting director of KIPAC; Biosciences, led by Soichi Wakatsuki, professor of photon science at SLAC and of structural biology at the Stanford School of Medicine; High Energy Density Science, led by Siegfried Glenzer, a SLAC distinguished scientist; and Materials Science, led by Tom Devereaux, who served as the associate laboratory director (ALD) for the former Photon Science Directorate and has successfully grown the photon science portfolio over the last few years. An Applied Program, led by Mark Hartney, was also created within this directorate and works with the other science divisions to help translate fundamental discoveries into practical applications; it also collaborates with our user facilities to do the same with their unique capabilities.

The newly created Technology and Innovation Directorate focuses on SLAC’s well-developed core competencies in advanced instrumentation and RF technology that support the Laboratory’s science mission broadly. Pulling these teams together has two clear benefits: It consolidates some of our areas of core expertise that have previously resided in different parts of SLAC, and it allows us to better develop these capabilities and leverage them for our user facilities and science programs. Michael Fazio is currently serving as the acting ALD for TID.

As the physical landscape of SLAC is expected to change significantly over the next several years, meeting the demand will require improved coordination of and emphasis on efficient and effective project and facilities management. Two of the Laboratory's key leadership gaps in this regard have been filled. Russell Thackston, the new Facilities and Operations director, held a similar position at UC San Diego and is now providing leadership for campus planning, conventional operations and maintenance, systems engineering, and building management here. Brian Sherin, former deputy ESH director, was promoted to ESH director leading SLAC's ESH initiatives.
Future Challenges and Actions

SLAC’s ongoing challenge is to hire, develop and retain best-in-class scientific and technical talent as well as enhance the Laboratory’s leadership capacity in order to accomplish its strategic science objectives and advance its core capabilities. SLAC is currently in the process of identifying its needed long-term skill capabilities, some of which are outlined below. Many science, technology, engineering and mathematics (STEM) job groups, comprised of highly specialized scientists and engineers, are recruited from a small and very competitive domestic and international pool. The Laboratory also faces challenges associated with the current market conditions, which include having some of the highest housing costs in the country. To address these challenges, SLAC has enhanced its internal recruitment capabilities and targeted critical skill sourcing, and added housing assistance programs and enhanced project-based financial incentives. SLAC is also focusing its recruitment communication to highlight its unique mission; the long-term value of working as part of the SLAC, Stanford and DOE communities; and the benefits of living in the Bay Area, particularly for out-of-state and international candidates.

Technical expertise for LCLS-II. This project remains the most important focus for SLAC, as well as for the Office of Science, and SLAC has assembled a high-performing project team led by John Galayda. The LCLS-II project is working with other laboratories in the complex, most notably the Argonne, Fermi, Lawrence Berkeley and Thomas Jefferson national laboratories, as well as Cornell University, to support the construction of new technology at SLAC. To ensure long-term project success, there is a need for managers, engineers and scientists in cryogenics technology. To acquire this scarce skill set, SLAC is using temporary assignments at other DOE and international labs.

Scientific expertise for LCLS facility operations and development. The emergence of multiple X-ray FEL facilities around the world over the next few years (European XFEL, Swiss-FEL, PAL, in addition to SACLA) means there will be an inevitable migration of some LCLS staff to these facilities and their associated university groups. Such movement can be a positive development as long as there is focused attention on creating a dynamic pipeline of staff for LCLS and attractive career development options at SLAC. The LCLS management team is actively working on these issues. The new Science Directorate at SLAC also provides an opportunity to enhance the research options for LCLS staff.

Leadership for Accelerator directorate. Attracting and selecting a new ALD with the requisite combination of internationally recognized achievement and organizational leadership is a priority for the Laboratory. A search committee has been established and has identified strong candidates. In addition, maintaining the requisite intellectual and technical capacity in accelerator research and development, engineering and technical support is critical to maintaining our core capability and realizing future accelerator initiatives. In the immediate future, SLAC is recruiting leadership for the Accelerator Research Division and the Accelerator Technology Research Department. While the former is still in search mode, a strong candidate has been identified for the latter.

Key science and applied energy initiatives. To build expertise in its basic sciences and applied programs, SLAC will continue to cultivate young researchers within the Laboratory and work with Stanford to identify and attract talent with leadership capabilities to expand the relevant research portfolios, particularly in biosciences, high energy density science and ultrafast science.

To support and strengthen the cosmology programs, SLAC needs a core team of technically capable physicists and engineers for the construction and operation of large experiments in remote environments. To address this, SLAC will continue to recruit new and reassign existing staff in key areas, such as sensor fabrication, cryogenic and low-background engineering, electronic systems and project management. SLAC will also invest in developing a core team for dark energy and dark matter science.

Critical operations. SLAC has recently identified and implemented a methodical workforce and talent planning process. The workforce plan will focus on needed critical skills and hires in the short term (next year) and longer term (2-5 years). The focus here will be on needs, gaps, and plans to close those gaps. The talent plan will focus on the backfills and longer-term (high potential) development of key leadership positions (leadership track), as well as focus on our vital scientific and engineering talent (technical track). For this first year, all employees named in these plans will have individual development plans put in place.

Leadership Development. SLAC has refocused its efforts on developing leadership competency, including more attention to managers nominated to Stanford leadership and management programs to ensure appropriate nominees in need of skill building, and with an eye to women and diverse participants. One internally developed leadership program already in place focuses on strategic planning, customer relationships and business acumen. A second program concentrates on building leadership capabilities around workforce engagement and development practices.
A third program is in development that will give attention to "leadership intelligence," building on research into neuroscience and emotional intelligence principles.

**Diversity considerations.** Despite ongoing efforts, SLAC has made minimal progress on increasing demographics of historically under-represented groups in various job categories across the Laboratory. As a result, SLAC has embraced a new diversity and inclusion strategy that positions the practice within the larger picture of engagement; one of creating an inclusive culture in which each member of the workforce has a voice that is valued and respected and that contributes to the lab's success. There is a three-point focus of this strategy: 1) address cultural biases and define culture-changing practices that create an environment that allows all employees to feel welcome, and to thrive; 2) build a talent pipeline leveraging internal advocates, employee resource groups and relationships with key universities and professional societies; 3) focused development and sponsorship of internal diverse talent. Leadership is committed to this program and is collectively accountable for its success.

SLAC will measure progress against its Diversity & Inclusion efforts along the lines of this three-point strategy, and in terms of near and longer-term progress as such:

<table>
<thead>
<tr>
<th>Near Term Measures</th>
<th>Long Term Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Culture</strong></td>
<td></td>
</tr>
<tr>
<td>• Educate Senior Management Team, and then line managers on inherent bias</td>
<td>• Greater awareness of inherent bias and practices in place to mitigate its influence</td>
</tr>
<tr>
<td>• Involve Employee Advocates in selection and on-boarding process</td>
<td>• Vibrant internal advocacy (individuals and employee resource groups)</td>
</tr>
<tr>
<td>• Engage Employee Resource Groups for key constituencies</td>
<td>• Increased numbers of under-represented groups</td>
</tr>
<tr>
<td>• Create a Diversity &amp; Inclusion Council to advise Senior Management</td>
<td>• Increased retention rates</td>
</tr>
<tr>
<td>• Greater awareness of inherent bias and practices in place to mitigate its influence</td>
<td>• Cultural measures of inclusion including influence, communication openness, strength of relationships, and development received for diverse populations</td>
</tr>
<tr>
<td><strong>Pipeline</strong></td>
<td></td>
</tr>
<tr>
<td>• Cultivate relationships and create partnerships with key universities and professional societies</td>
<td>• Quality partnerships with targeted universities and professional organizations</td>
</tr>
<tr>
<td>• Qualified Diversity representation on candidate slates</td>
<td>• Increased numbers of qualified Diversity representation on each candidate slate</td>
</tr>
<tr>
<td>• Employee Advocates and Employee Resource Groups identifying potential candidates</td>
<td>• Improved numbers of hired candidates and members of management</td>
</tr>
<tr>
<td><strong>Development</strong></td>
<td></td>
</tr>
<tr>
<td>• Identify women and under-represented minorities in talent planning process</td>
<td>• Increased numbers of women and underrepresented candidates in talent planning</td>
</tr>
<tr>
<td>• Create sponsorship for identified candidates</td>
<td>• Increased promotion rates</td>
</tr>
<tr>
<td>• Ensure appropriate representation in Stanford Leadership and Management Academies</td>
<td>• Equitable representation in Stanford Leadership and Management Academies</td>
</tr>
</tbody>
</table>
8.0 Cost of Doing Business

Overhead Budget Process

For the development of the FY15 lab-wide spending plan, SLAC continued its formal institutional budget formulation process based on a best practice adopted by other multi-program national laboratories. The process is jointly stewarded by the chief financial officer and the deputy laboratory director and provides a framework for improved institutional budget performance measurement. The guidance covers the budget formulation process, assumptions, timeline and templates for SLAC’s mission support (General and Administrative, Common Site Support, Procurement, Institutional Capital Projects and LDRD), Program Support, and service center (shops, professional centers or recharge) budgets.

The Institutional Change Control Board (ICCB) was established to ensure that SLAC’s institutional planning and budget execution processes are managed in a strategic, integrated and transparent manner, and that recommendations are made to SLAC’s Senior Management Team with a balanced, cross-cutting and institutional perspective that supports the Laboratory’s mission. Membership of the ICCB includes both research and business representation from each SLAC directorate. The primary objectives of the ICCB are to: 1) review and make recommendations on cost model, including indirect cost pools and budgets; 2) review and make recommendations in program planning and budget execution; 3) recommend priorities for institutional investments, providing alignment with SLAC’s strategic goals; and 4) review performance and all division baseline change proposals. Final decision-making authority resides with the laboratory director and the senior management team.

SLAC’s LDRD portfolio is managed by the director of strategic planning. LDRD proposal prioritization is informed by an internal/external review committee and finalized by the senior management team. Proposals are evaluated in a formal manner that considers the quality of the proposed science, likelihood of success and future funding opportunities, associated risk and other relevant factors. Funds are limited and the process is highly competitive, helping to ensure that approved LDRD projects are valuable initiatives that promote new research directions and seed innovative science programs.

Metrics

Table 7. Laboratory Overhead Trends (Cost Data in $K)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Direct FTE Ratio Staff (Excludes Temporary Employees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numerator: Direct FTEs, for permanent staff which represent time charged to client funded work, including capital but excluding LDRD</td>
<td>1,150</td>
<td>1,109</td>
<td>982</td>
<td>1,007</td>
<td>1,007</td>
</tr>
<tr>
<td>Supplemental Data: Indirect FTEs for permanent staff (all non-direct FTEs, to include LDRD and organizational burden)</td>
<td>533</td>
<td>487</td>
<td>440</td>
<td>418</td>
<td>418</td>
</tr>
<tr>
<td>Denominator: Total FTEs (subtotal of direct and indirect FTEs)</td>
<td>1,684</td>
<td>1,596</td>
<td>1,422</td>
<td>1,425</td>
<td>1,425</td>
</tr>
<tr>
<td>Direct FTE Ratio (%): Direct FTEs/Total FTEs</td>
<td>68%</td>
<td>69%</td>
<td>69%</td>
<td>71%</td>
<td>71%</td>
</tr>
<tr>
<td>1b. Direct Ratio – Total (Includes Temporary Employees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numerator: Same as preceding metric + Limited Term Employees (LTE), Post Doc, and Staff Augmentation Direct FTEs</td>
<td>1,165</td>
<td>1,114</td>
<td>1,047</td>
<td>1,073</td>
<td>1,073</td>
</tr>
<tr>
<td>Supplemental Data: Indirect FTEs for total staff (includes LDRD and organizational burden) including Temporary Employees (LTE, Post Doc, Staff Augmentation)</td>
<td>544</td>
<td>492</td>
<td>450</td>
<td>427</td>
<td>427</td>
</tr>
<tr>
<td>Denominator: Total FTEs (subtotal of direct and indirect FTEs)</td>
<td>1,710</td>
<td>1,605</td>
<td>1,497</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>Direct FTE Ratio (%): Total Direct FTEs / Total FTEs</td>
<td>68%</td>
<td>69%</td>
<td>70%</td>
<td>72%</td>
<td>72%</td>
</tr>
<tr>
<td>2a. Total Overhead/Total Lab Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numerator: Total overhead cost, which includes institutional overhead, LDRD and organizational burdens to the extent this overhead is allocated to client funded work</td>
<td>$110,654</td>
<td>$107,458</td>
<td>$108,240</td>
<td>$114,079</td>
<td>$114,079</td>
</tr>
<tr>
<td>Denominator: Total lab cost includes all cost charged to client funded work (operating and capital). Includes subcontracts and procurements and line item construction costs.</td>
<td>FY 2012</td>
<td>FY 2013</td>
<td>FY 2014</td>
<td>FY 2015 Est.</td>
<td>FY 2016 Est.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>$369,995</td>
<td>$358,384</td>
<td>$389,200</td>
<td>$411,358</td>
<td>$411,358</td>
<td></td>
</tr>
</tbody>
</table>

Total Overhead/Total Lab Cost (%): 30.0% 30.0% 27.8% 27.7% 27.7%

2b. Total Overhead/Total Lab Operating Cost

<table>
<thead>
<tr>
<th>Numerator: Same as preceding metric.</th>
<th>$110,654</th>
<th>$107,458</th>
<th>$108,240</th>
<th>$114,079</th>
<th>$114,079</th>
</tr>
</thead>
</table>

Denominator: Same as preceding metric, but exclude line item construction costs.

<table>
<thead>
<tr>
<th>$345,574</th>
<th>$337,722</th>
<th>$320,705</th>
<th>$301,843</th>
<th>$301,843</th>
</tr>
</thead>
</table>

Total Overhead/Total Lab Operating Cost (%): 32.0% 31.8% 33.8% 37.8% 37.8%

2c. Total Overhead/Total Internal Lab Operating Cost

<table>
<thead>
<tr>
<th>Numerator: Same as preceding metric.</th>
<th>$110,654</th>
<th>$107,458</th>
<th>$108,240</th>
<th>$114,079</th>
<th>$114,079</th>
</tr>
</thead>
</table>

Denominator: Same as preceding metric, but exclude subcontracts and procurements charged to client funded work.

<table>
<thead>
<tr>
<th>$242,768</th>
<th>$238,563</th>
<th>$230,705</th>
<th>$217,867</th>
<th>$217,867</th>
</tr>
</thead>
</table>

Total Overhead/Total Internal Lab Operating Cost (%): 45.6% 45.0% 41.6% 47.2% 47.2%

3. Fringe Rate

<table>
<thead>
<tr>
<th>Numerator: Total cost of employee benefits (including statutory benefits), not including paid absences.</th>
<th>$51,052</th>
<th>$48,957</th>
<th>$47,867</th>
<th>$49,289</th>
<th>$51,847</th>
</tr>
</thead>
</table>

Denominator: Total base salary cost.

<table>
<thead>
<tr>
<th>$171,642</th>
<th>$168,432</th>
<th>$165,831</th>
<th>$161,074</th>
<th>$166,711</th>
</tr>
</thead>
</table>

Fringe Rate (%): 30.4% 29.5% 29.2% 30.6% 31.1%

4. Labor Multiplier on a DOE Operating Funded Project

<table>
<thead>
<tr>
<th>Base Salary of $100K: Includes leave/absence costs</th>
<th>$100 K</th>
<th>$100 K</th>
<th>$100 K</th>
<th>$100 K</th>
</tr>
</thead>
</table>

Fully Burdened Salary Cost

<table>
<thead>
<tr>
<th>$218</th>
<th>$217</th>
<th>$220</th>
<th>$222</th>
</tr>
</thead>
</table>

Labor Multiplier: Divide fully burdened salary cost by $100.0K

<table>
<thead>
<tr>
<th>2.2</th>
<th>2.2</th>
<th>2.2</th>
<th>2.2</th>
</tr>
</thead>
</table>

5a. Fully Burdened Person Year – Staff (Excludes Temporary Employees)

|---|---|---|---|---|

Denominator: Staff Direct FTEs (as reported in Metric 1a)

<table>
<thead>
<tr>
<th>1,150</th>
<th>1,109</th>
<th>982</th>
<th>1,007</th>
</tr>
</thead>
</table>

Fully Burdened Person Year ($K) Staff Direct

<table>
<thead>
<tr>
<th>$211</th>
<th>$218</th>
<th>$242</th>
<th>$228</th>
</tr>
</thead>
</table>

5b. Fully Burdened Person Year – Total (Includes Temporary Employees)

<table>
<thead>
<tr>
<th>Numerator: Same as preceding metrics</th>
<th>$242,594</th>
<th>$241,724</th>
<th>$237,171</th>
<th>$230,105</th>
</tr>
</thead>
</table>

Denominator: Total Direct FTEs (as reported in Metric 1b)

<table>
<thead>
<tr>
<th>1,710</th>
<th>1,605</th>
<th>1,497</th>
<th>1,500</th>
</tr>
</thead>
</table>

Fully Burdened Person Year ($K) Total Direct

<table>
<thead>
<tr>
<th>142</th>
<th>151</th>
<th>158</th>
<th>153</th>
</tr>
</thead>
</table>

1. An FTE is calculated as actual hours charged divided by the expected hours to be charged by a normal employee during a year. Direct FTEs reported in metric 1a should agree with Budget Officers’ Conference Metrics Section 2 “Regular Staff” plus “Bargaining Unit”.

2. "Client funded work” refers to “direct charges”/“direct funded work”.

3. Metric 1b includes LTE, Past Doc, and Staff Aug. Direct FTEs and should agree with Budget Officers’ Metrics Section 2 “Subtotal-Direct FTEs”.

4. "Organizational burden” refers to an overhead pool that accumulates the cost of managing and operating an organization or group of organizations and is usually allocated on a rate established specifically for recovering the cost of the organization and/or grouping. It includes space charges.

5. The $100K base salary is multiplied by the fringe benefit (excluding leave), overhead (using an average for all scientific divisions), G&A, LDRD, IGPP/IGPE, fee, and etc, rates based on SLAC’s burdening methodology for a DOE operating funded project. Does not include composite rates, such as special rates for large construction projects. Uses final indirect rates for FY12, FY13, and FY14, current forward pricing rates for FY15, and does not provide a projection for FY16.

6. From annual Institutional Cost Report submission to DOE, Exhibit 1 – Original Cost.

* FYs 2012-2014 data reflects actual costs. FY15 and FY16 are estimates (adjusted for escalation using a factor that is appropriate to SLAC).

** Major Cost Drivers**

SLAC’s major cost drivers fall into the following primary categories:

**Infrastructure Mission Readiness:** As mentioned in Section 6, with the increasing age of facilities on site and the ambitious scientific agenda that they need to support, SLAC must invest in revitalizing the existing facilities and infrastructure to meet current and emerging needs. The cost of maintenance naturally increases as the systems age, and once the systems are replaced that cost decreases and the savings can be reinvested to renew infrastructure. SLAC’s approach is to identify and revitalize the most critical infrastructure first, and currently our immediate priorities are addressing electrical and cooling distribution reliability risks.

SLAC Annual Laboratory Plan Submitted 1 May 2015 Page 41 of 47
The SLI program has been, and remains, critical to ensure both laboratory and conventional infrastructure in support of DOE-SC programs at SLAC. In addition to the new buildings, SLI funding is used to help address the renewal of these critical underlying utilities and infrastructure systems, which are a high priority given that many such systems are aging and past their useful life.

SLAC’s IT infrastructure is also aging, including the data center and networking throughout the site, and critical needs are prioritized and balanced against other laboratory projects during each budget cycle. To help address our data center needs, the Stanford Research Computing Facility, located at the SLAC site, now affords a modern data center facility with the ability to accommodate future SLAC scientific computing growth. This facility provides a power usage efficiency rating for data centers that meets or exceeds the DOE’s minimum requirement of 1.4. SLAC has entered into an intra-university agreement with Stanford for the period July 1, 2014 to September 30, 2018, to allow SLAC to rent space for servers and equipment.

**Necessary Modern Business Systems:** SLAC has made significant progress strengthening financial controls, and this continues to be a high priority. SLAC completed its Enterprise Resource Planning upgrade with the implementation of the PeopleSoft 9.2 Finance and Supply Chain Management system, effective for FY15. It integrates with the PeopleSoft 9.2 Human Capital Management system that was implemented earlier in FY14, and with other SLAC, Stanford or DOE systems. SLAC has now initiated a Business System Architecture Project to understand and map existing business systems, identify redundancies and create a roadmap to the future state. This project will help SLAC reduce the use of manual spreadsheets and shadow systems throughout the Laboratory. In addition, SLAC continues to address outdated web content and examine existing content management platforms to more efficiently manage electronic resources. SLAC also continues to mature its contractor assurance systems, strengthening internal oversight and better defining critical processes. SLAC is improving the planning, management and performance assessment of the Laboratory to reduce the need for external assessment and oversight, which is expected to result in reduced associated costs.

**Workforce Mission Readiness:** SLAC has made it a priority to ensure a high caliber of talent to underpin its mission and mission support activities. As mentioned in Section 7.0, SLAC’s location poses particular challenges to attracting critical skills because of the high cost of housing. To address this, SLAC continues to explore alternative housing support options with DOE and Stanford. In addition to the current and future workforce needs described in Section 7.0, leadership development and training programs are underway, and management continues to make progress with succession planning to identify and develop future leaders.

**Revolutionary Contract Experiment:** The Secretary of Energy has approved a novel contracting experiment between Stanford and DOE. This experiment will attempt to develop a new M&O contract between Stanford and DOE that is based mainly on Stanford operating policies and procedures, with much of the oversight of SLAC being performed by cognizant state and local agencies. Where state or local standards do not exist, e.g., licensing of accelerators, DOE or national standards will be used. The ultimate goal of this experiment is to determine if a new M&O contract model can be developed to deliver more R&D per dollar spent at SLAC and to improve the working environment for SLAC researchers without degrading operational performance.

**Decisions and Trade-offs**

SLAC has substantial challenges in bringing its infrastructure, institutional information and procedures, and human capital into a state of mission readiness for current and future scientific programs. Through its annual planning process, the Laboratory develops its portfolio of actions—the Laboratory Agenda—that aligns with SLAC’s strategic objectives, identified high-risk areas, and safety and compliance requirements. This planning process is also informed by frequent interaction with the SLAC Site Office and the SLAC Board of Overseers, and by the priorities identified and feedback provided annually through the DOE Performance Evaluation and Management Plan process. Reflecting its commitment to carry out the SLAC mission safely, effectively, and efficiently, SLAC management decided to focus discretionary resources on the following major priorities in FY15:

- Complete site infrastructure projects that are critical to the LCLS-II project.
- Complete the upgrade of institutional business systems to improve financial controls, business tools and reporting capabilities to the SLAC community.
- Continue to improve the cyber security program to reduce risk.
- Build infrastructure for additional laboratories and clean room space.
- Upgrade the Magnetic Measurement Facility to accommodate future growth and maintain our core competency.
- Increase our strategic investments in LDRD from $4.6M to $7.5M.
- Strengthen laboratory leadership and communications training and succession planning.
Appendix 1: Annual Strategic Partnership Projects Report

The funding level for non-DOE funded work requested for FY16 is approximately $22M at SLAC.

Federal

SLAC receives funding for its National Institutes of Health (NIH) activities either directly or through Stanford grants and subcontracts. NIH-funded programs include ongoing support for the Structural Molecular Biology program (an effort jointly coordinated with DOE-BER) and the final year of the Joint Center for Structural Genomics, both at SSRL. NIH has also provided partial support for developing new instrumentation in the area of nanocrystallography using LCLS, and further opportunities will be explored as part of the bioscience strategy.

SLAC has been funded by the Department of Defense (DoD) through the Defense Advanced Research Projects Agency (DARPA) to develop innovative X-ray optics and a new project on compact neutron sources. SLAC has also proposed to DoD projects for producing, controlling and manipulating radiation in the terahertz regime, a relatively unexploited portion of the RF spectrum with applications that include coherent terahertz processing and imaging, ultrawide-bandwidth and ultrahigh-capacity communications, and high-resolution radar imaging.

The National Science Foundation (NSF) is a partner with DOE on the LSST, and provides SPP funding to SLAC for data management systems.

Non-Federal

SLAC’s non-federally sponsored SPP programs cover the Japanese participation, through KEK, at SLAC under the U.S./Japan agreement in HEP research. Japanese involvement includes support of the FGST and various accelerator R&D programs related to the International Linear Collider.

As a leading lab in RF R&D, SLAC provides klystrons and RF components to many international and U.S. laboratories. With its unique high-power test facilities, SLAC has an SPP agreement in place with CPI Inc. to test high-power X-band klystrons that CPI Inc. is under contract to deliver to CERN.

SLAC partners with biopharma companies to develop new instrumentation and capabilities for synchrotron-based structural biology and to accelerate development of new pharmaceuticals. These developments also directly enhance capabilities that strengthen SSRL’s role as a national user facility.

SLAC is collaborating with a number of industrial partners through the Small Business Innovation Research (SBIR) program, developing novel photocathodes for high-brightness photoinjector guns and for improved linac electron beam dynamics for improved FEL performance.

SLAC also receives contributions from international collaborations, private foundations and Stanford in a number of other areas that support our strategic plan and core competencies.
## Proposed Line Item Investment Summary

<table>
<thead>
<tr>
<th>Site Office</th>
<th>SSO (SLAC Site Office)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name (Acronym)</td>
<td>Photon Science Laboratory Building (PSLB)</td>
</tr>
<tr>
<td>Total Estimated Cost Low End</td>
<td>$47,500K (w/o OPC): $55,000K (With OPC)</td>
</tr>
<tr>
<td>Total Estimated Cost High End</td>
<td>$49,500K (W/O OPC): $57,000K (With OPC)</td>
</tr>
<tr>
<td>Projected Scope Elements</td>
<td>Construction of the Photon Science Laboratory Building to provide a centralized modern laboratory and/or office space with the necessary performance capabilities and accommodate growth in the existing photon science program. This structure will include 50,000 gross square feet (gsf) of modern laboratory and office space.</td>
</tr>
<tr>
<td>Support of DOE Strategic Goals</td>
<td>Goal 2: The Science and Engineering Enterprise-Extend our knowledge of the natural world; deliver new technologies to advance our mission; and prioritize scientific facilities to ensure optimal benefit from federal facilities. Goal 4: Management and Operation Excellence-Improve contract and project management</td>
</tr>
<tr>
<td>Capability Gap</td>
<td>Construction of additional modern laboratory facilities is needed to maintain our nation’s global position in the forefront of science and technology by providing a centralized modern laboratory space with the necessary performance capabilities in which to grow the existing photon science program.</td>
</tr>
<tr>
<td>Alignment with Lab Core Capabilities</td>
<td>The laboratory facility that this project will deliver, leveraging the capabilities of two of the country’s world-class light sources, Linac Coherent Light Source (LCLS) and Stanford Synchrotron Radiation Light Source, as well as the Stanford PULSE and SIMES institutes, will enable expansion of the photon science program at SLAC.</td>
</tr>
<tr>
<td>Mission Readiness</td>
<td>The growth in SLAC’s photon science research program is outpacing its existing laboratory space. This investment will support SLAC’s multidisciplinary scientific initiatives related to chemical, materials and biological sciences and energy research. This building will house 15,000 square feet of state-of-the-art laboratory facilities and approximately 100 scientists and engineers.</td>
</tr>
<tr>
<td>Impact if Not Funded</td>
<td>Without this investment, SLAC will be unable to expand its photon science program. This failure to provide modern facilities suitable for collocated and coordinated functionality limits SLAC’s ability to successfully address and deliver on its long-term strategic mission.</td>
</tr>
</tbody>
</table>
## Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALD</td>
<td>Associate Laboratory Director</td>
</tr>
<tr>
<td>AOA</td>
<td>Ammonia oxidizing archaea</td>
</tr>
<tr>
<td>ARPA-E</td>
<td>Advanced Research Projects Agency – Energy</td>
</tr>
<tr>
<td>ARPES</td>
<td>Angle-resolved Photoemission Spectroscopy</td>
</tr>
<tr>
<td>ARRA</td>
<td>American Recovery and Reinvestment Act</td>
</tr>
<tr>
<td>ASTA</td>
<td>Accelerator Structure Test Area</td>
</tr>
<tr>
<td>ATLAS</td>
<td>A Toroidal LHC Apparatus</td>
</tr>
<tr>
<td>BAPVC</td>
<td>Bay Area Photovoltaic Consortium</td>
</tr>
<tr>
<td>BER</td>
<td>Biological &amp; Environmental Research</td>
</tr>
<tr>
<td>BES</td>
<td>Basic Energy Sciences</td>
</tr>
<tr>
<td>BSY</td>
<td>Beam switch yard</td>
</tr>
<tr>
<td>CD</td>
<td>Critical Decision</td>
</tr>
<tr>
<td>CDMS</td>
<td>Cryogenic Dark Matter Search</td>
</tr>
<tr>
<td>CERN</td>
<td>European Organization for Nuclear Research</td>
</tr>
<tr>
<td>CMB</td>
<td>Cosmic Microwave Background</td>
</tr>
<tr>
<td>CryoEM</td>
<td>Cryo-electron microscopy</td>
</tr>
<tr>
<td>CS</td>
<td>Chemical Science</td>
</tr>
<tr>
<td>DAQ</td>
<td>Data acquisition</td>
</tr>
<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
</tr>
<tr>
<td>DESC</td>
<td>Dark Energy Science Collaboration</td>
</tr>
<tr>
<td>DLA</td>
<td>Direct Laser Acceleration</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
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<tr>
<td>DOE</td>
<td>Department of Energy</td>
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<tr>
<td>DHHS</td>
<td>Department of Health and Human Services</td>
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<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
</tr>
<tr>
<td>EERE</td>
<td>Energy Efficiency and Renewable Energy</td>
</tr>
<tr>
<td>EFRC</td>
<td>Energy Frontier Research Center</td>
</tr>
<tr>
<td>ESTB</td>
<td>End Station Test Beam</td>
</tr>
<tr>
<td>eV</td>
<td>Electronvolt</td>
</tr>
<tr>
<td>EXO</td>
<td>Enriched Xenon Observatory</td>
</tr>
<tr>
<td>FACET</td>
<td>Facility for Advanced Accelerator Experimental Tests</td>
</tr>
<tr>
<td>FEH</td>
<td>Far Experimental Hall</td>
</tr>
<tr>
<td>FEL</td>
<td>Free-Electron Laser</td>
</tr>
<tr>
<td>FES</td>
<td>Fusion Energy Science</td>
</tr>
<tr>
<td>FGST</td>
<td>Fermi Gamma-ray Space Telescope</td>
</tr>
<tr>
<td>fs</td>
<td>Femtosecond</td>
</tr>
<tr>
<td>FTE</td>
<td>Full Time Equivalent</td>
</tr>
<tr>
<td>GCEP</td>
<td>Global Climate and Energy Project</td>
</tr>
<tr>
<td>GeV</td>
<td>Gigaelectronvolt</td>
</tr>
<tr>
<td>GHz</td>
<td>Gigahertz</td>
</tr>
<tr>
<td>GPP</td>
<td>Programmatic General Plant Projects</td>
</tr>
<tr>
<td>HED</td>
<td>High Energy Density</td>
</tr>
<tr>
<td>HEP</td>
<td>High Energy Physics</td>
</tr>
<tr>
<td>Hz</td>
<td>Hertz</td>
</tr>
<tr>
<td>ICCB</td>
<td>Institutional Change Control Board</td>
</tr>
<tr>
<td>IGPP</td>
<td>Institutional General Plant Projects</td>
</tr>
<tr>
<td>IR</td>
<td>Interaction region</td>
</tr>
<tr>
<td>JCAP</td>
<td>Joint Center for Artificial Photosynthesis</td>
</tr>
<tr>
<td>JCESR</td>
<td>Joint Center for Energy Storage Research</td>
</tr>
<tr>
<td>KEK</td>
<td>High Energy Accelerator Research Organization, in Japan</td>
</tr>
<tr>
<td>keV</td>
<td>Kiloelectronvolt</td>
</tr>
<tr>
<td>KIPAC</td>
<td>Kavli Institute for Particle Astrophysics and Cosmology</td>
</tr>
<tr>
<td>kV</td>
<td>Kilovolt</td>
</tr>
<tr>
<td>LAT</td>
<td>Large Area Telescope</td>
</tr>
<tr>
<td>LBNE</td>
<td>Long-Baseline Neutrino Experiment</td>
</tr>
<tr>
<td>LCLS</td>
<td>Linac Coherent Light Source</td>
</tr>
<tr>
<td>LDRD</td>
<td>Laboratory Directed Research and Development</td>
</tr>
<tr>
<td>LHC</td>
<td>Large Hadron Collider</td>
</tr>
<tr>
<td>LSST</td>
<td>Large Synoptic Survey Telescope</td>
</tr>
<tr>
<td>LZ</td>
<td>LUX-ZEPLIN Experiment</td>
</tr>
<tr>
<td>mA</td>
<td>Milliamps</td>
</tr>
<tr>
<td>MEC</td>
<td>Matter in Extreme Conditions</td>
</tr>
</tbody>
</table>
MeV  Megaelectronvolt
MFX  Macromolecular Femtosecond Crystallography
MHz  Megahertz
mJ  Millijoule
MS  Materials Science
N  Nitrogen
NASA  National Aeronautics and Space Administration
NERSC  National Energy Research Scientific Computing center
NIGMS  National Institute of General Medical Sciences
NIH  National Institutes of Health
NLCTA  Next Linear Collider Test Accelerator
nm  Nanometer
NNSA  National Nuclear Security Administration
ns  Nanosecond
NSF  National Science Foundation
ONR  Office of Naval Research
PAL  Pohang Accelerator Laboratory
PIE  Precourt Institute for Energy
PPA  Particle physics and astrophysics
ps  Picosecond
PSLB  Photon Science Laboratory Building
PULSE  Photon Ultrafast Laser Science and Engineering
PW  Petawatt
PWFA  Plasma Wakefield Acceleration
QCD  Quantum Chromodynamics
R&D  Research and Development
RIXS  Resonant Inelastic X-ray Scattering
RF  Radio Frequency
RPV  Replacement Plant Value
RSB  Research Support Building
SC  Office of Science
SiMES  Stanford Institute for Materials and Energy Science
SLAC  SLAC National Accelerator Laboratory
SLI  Science Laboratory Infrastructure
SMB  Structural Molecular Biology (SSRL Program)
SPEAR  Stanford Positron Electron Accelerating Ring, now SPEAR3
SPP  Strategic Partnership Projects
SRF  Scientific Research Computing Facility
SSRL  Stanford Synchrotron Radiation Lightsource
STEM  Science, Technology, Engineering, and Mathematics
SUNCAT  SUNCAT Center for Interface Science and Catalysis
SuperCDMS  Super Cryogenic Dark Matter Search (CDMS)
SUSB  Scientific User Support Building
TeV  Teraelectronvolt
THz  Terahertz
TID  Technology and Innovation Directorate
TIMES  Theory Institute for Materials and Energy Science
TW  Terawatt
UED  Ultrafast Electron Diffraction
UEM  Ultrafast Electron Microscopy
WFO  Work for Others
WIMP  Weakly Interacting Massive Particle
X-ray FEL  X-ray Free Electron Laser