FY07 Self-Evaluation

Contractor Performance Evaluation and Measurement Plan

For

Management and Operations of the

Stanford Linear Accelerator Center

Volume 1, Science and Technology, Goals 1 – 3

Submitted to the U.S. Department of Energy
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Table of Contents

Introduction

Leland Stanford Junior University (Stanford University) is under contract with the Department of Energy (DOE) to manage the Stanford Linear Accelerator Center (SLAC). Clause H.15 of Contract Number DE-AC02-76-SF00515 states that "performance-based management shall be the key enabling mechanism for establishing the DOE Contractor expectations on oversight and accountability." Moreover, the specific mechanism for evaluating the performance-based approach (mission accomplishment, stewardship, and operational excellence) from October 1, 2006 to September 30, 2007 (fiscal year) is the FY07 Contractor Performance Evaluation and Measurement Plan (PEMP), which is organized by Performance Goals (Goals), Performance Objectives (Objectives), Performance Measures (Measures), and Performance Targets (Targets). The performance-based approach focuses on SLAC's performance against these Goals. The DOE Office of Science (SC) mandates that each SC Laboratory establish the same eight goals in the PEMP. The eight goals are:

- Provide for Efficient and Effective Mission Accomplishment
- Provide for Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities
- Provide Effective and Efficient Science and Technology Program Management
- Provide Sound and Complete Leadership and Stewardship of the Laboratory
- Sustain Excellence and Enhance Effectiveness of Integrated Safety, Health, and Environmental Protection
- Deliver Efficient, Effective, and Responsive Business Systems and Resources that Enable the Successful Achievement of the Laboratory Mission(s)
- Sustain Excellence in Operating, Maintaining, and Renewing the Facility and Infrastructure Portfolio to Meet Laboratory Needs
- Sustain and Enhance the Effectiveness of Integrated Safeguard and Security Management (ISSM) and Emergency Management Systems

SC also requires each SC Laboratory to use the same Objectives to measure progress against the Goals.

This document reports SLAC's success in achieving the three science and technology (S&T) Goals (Goals 1 through 3) and Objectives. The report also incorporates performance outside of the specific Goals and Objectives, including identifying key achievements and opportunities for improvement.

Executive Summary

The SLAC Mission, which articulates the Vision for the Laboratory, has three components:

- To make discoveries in photon science at the frontiers of the ultrasmall and the ultrafast in a wide spectrum of physical and life sciences,
- To make discoveries in particle physics and astrophysics to redefine humanity's understanding of what the universe is made of and the forces that control it, and
- To operate a safe laboratory that employs and trains the best and the brightest, helping to ensure the future economic strength and security of the nation.

This mission did not change from FY06 to FY07.

The following sections describe the work at SLAC in more detail, highlighting the accomplishments made during the past FY07.

As will be detailed below, SLAC did well in the accomplishment of the science mission, exceeding expectation both in the impact of results on the field and in the quality of the leadership provided. The recognition of the work of long time SSRL user, Roger Kornberg, with a Nobel Prize certainly was the most outstanding measure of scientific accomplishment at the Laboratory. However, another important example has been the impact of the D mixing result from *BABAR* on our understanding of models for new physics at the TeV scale.

However, SLAC has not met expectations in some areas of facility design, fabrication, construction and operations. Both the Linac Coherent Light Source (LCLS) and LCLS Ultrafast Science Instruments (LUSI) projects have struggled and better support for those projects is an area of improvement that SLAC needs to demonstrate in FY08. The operations of PEP-II in FY07 did not meet expectation as delivered luminosity was only 70% of the overall goal for the year.

In the areas of S&T program management, the Laboratory also failed to meet expectation in several areas. Program planning for LUSI was very rocky and a lack of effective communication between the Laboratory and DOE contributed. Development of the LCLS user program needs more emphasis. Poor communication between the Laboratory and the High Energy Physics (HEP) program office during a very challenging time of program transition is an area where improvement is clearly needed.

For each of the three S&T Goals, performance was in the range from A to B+ using the DOE letter grade/numeric score scales established in the PEMP. The Laboratory's overall score is 3.24 (B+).

Science and Technology Score Calculation

Element		Letter Grade	Numerical Score	Goal Weight	Weighted Score	Total Score
1	Provide of Efficient and Effective Mission Accomplishments	A	4.06	20%	0.81	
2	Provide for Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities	B+	3.03	60%	1.82	
3	Provide Effective and Efficient Science and Technology Program Management	B+	3.04	20%	0.61	
Total Science and Technology Score						**3.24**

Goal 1 Provide Effective and Effective Mission Accomplishment

The Contractor produces high-quality, original, and creative results that advance science and technology; demonstrates sustained scientific progress and impact; receives appropriate external recognition of accomplishments; and contributes to overall research and development goals of the Department and its customers.

The weight of this Goal is 20%.

The Provide for Efficient and Effective Mission Accomplishment Goal measures the overall effectiveness and performance of the Contractor in delivering science and technology results which contribute to and enhance the DOE's mission of protecting our national and economic security by providing world-class scientific research capacity and advancing scientific knowledge by supporting world-class, peer-reviewed scientific results, which are recognized by others.

BES (60%)

Element		Letter Grade	Numerical Score	Objective Weight	Weighted Score	Total Score
1	Provide of Efficient and Effective Mission Accomplishments					
1.1	Science and Technology Results Provide Meaningful Impact on the Field	A	4.0	50%	2.000	
1.2	Provide Quality Leadership in Science and Technology	A	4.0	20%	0.800	
1.3	Provide and Sustain Science and Technology Outputs that Advance Program Objectives and Goals	Pass	4.3	15%	0.645	
1.4	Provide for Effective Delivery of Science and Technology	Pass	4.3	15%	0.645	
					BES Science and Technology Score	4.09
					BES Funding Weight (60%)	**2.45**

HEP (39%)

Element		Letter Grade	Numerical Score	Objective Weight	Weighted Score	Total Score
1	Provide of Efficient and Effective Mission Accomplishments					
1.1	Science and Technology Results Provide Meaningful Impact on the Field	A	4.0	30%	1.20	
1.2	Provide Quality Leadership in Science and Technology	A	4.0	30%	1.20	
1.3	Provide and Sustain Science and Technology Outputs that Advance Program Objectives and Goals	Pass	4.3	30%	1.29	
1.4	Provide for Effective Delivery of Science and Technology	Pass	4.3	10%	0.43	
					HEP Science and Technology Score	4.12
					HEP Funding Weight (39%)	**1.61**

Total Goal 1 Score: 4.06 (A)

While the PEMP scoring system would award an A+ to Goal 1, we believe this is not an appropriate calculation since it results from two 'A' grades and two 'Pass' grades. We have chosen to leave the grade at an A.

BES

A ▪ Stanford Synchrotron Radiation Laboratory (SSRL)

The Stanford Synchrotron Radiation Laboratory (SSRL) is a national user facility that provides synchrotron radiation to a broad user community to investigate objects at the atomic and molecular level, allowing a wide variety of research in basic and applied studies on the structure of matter. About 2,000 researchers use SSRL each year from industry, government laboratories and universities and represent the fields of astronomy, biology, chemical engineering, chemistry, electrical engineering, molecular environmental science, geology, materials science, medicine, and physics.

The SSRL facility currently provides 27 end-stations on 20 beam lines (BL), as well as ancillary equipment and supporting infrastructure. Additional end-stations are undergoing or awaiting upgrades for SPEAR3 compatibility. SSRL also has ongoing training opportunities to disseminate information, technological and theoretical developments, and to encourage reciprocal exchange of information and thought, from both pure science and practical perspectives. The audience is broad and topics typically include methodological and instrumentation developments, highlights of new capabilities developed at SSRL, accelerator upgrades, theoretical applications, etc. Much of this information is also provided on-line via the SSRL web (www-ssrl.slac.stanford.edu). SSRL also manages the Gateway program, which is an educational program tailored specifically for Mexican-American and Mexican communities in undergraduate and graduate education by engaging student scholars in science and engineering research programs at all levels.

SSRL provides beam lines, instrumentation and supporting facilities to enable its user research programs in the following areas.

Studies of Condensed Matter – (a) structures of materials including amorphous solids and liquids, polymer systems, catalysts, doped semiconductors, magnetic storage materials and environmentally relevant systems; (b) structures of and phase transitions in surfaces, interfaces, and thin surface layers; (c) the determination of electronic states in metals, semiconductors, magnetic systems, superconductors, ultra-thin layers, interfaces and small clusters; (d) kinetics of structural changes in materials; (e) fundamental x-ray scattering and absorption physics; and (f) chemical reactivities in the gas phase.

Structural Molecular Biology – (a) protein structure and function through macromolecular crystallography studies; (b) protein metal active site structure and function through x-ray absorption spectroscopy (edge and extended fine structure) studies; (c) solution protein structure studies, static and time-resolved protein folding studies by small angle x-ray scattering. Specialized facilities for handling biological materials are available. A high brightness wiggler beam line for structural molecular biology provides three experimental stations (funded by the Office of Biological and Environmental Research [BER]). The construction of a new in-vacuum undulator-based beam line for macromolecular crystallography, funded by a gift from the Gordon and Betty Moore Foundation via California Institute of Technology, is complete and is now in its construction and is now in commissioning.

Facility Research and Development (R&D)

Development of new experimental capabilities is usually undertaken by SSRL faculty and staff scientists often in collaboration with users once the users' needs have been assessed through workshops or other meetings. By actively driving research on the beam lines, the SSRL faculty and scientific staff are able to develop and maintain state-of-the-art experimental capabilities at SSRL as well as create new user communities. These programs are quite varied and many of the new programs will take advantage of the higher brightness capabilities of SPEAR3 through the implementation of advanced spectroscopic capabilities, coherence and microfocusing.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

SSRL carries out a broad user-based research program in the physical, chemical and biological sciences as well as in targeted research areas through its facilities R&D activities. The user research is best seen through the extensive publications list presented in the Publications Appendix[1] and through the SSRL Highlights, which are available on the SSRL website. Selected accomplishments from the SSRL facilities R&D activities are described below.

Inelastic Scattering and Advanced Spectroscopy Facility for SPEAR3: The high resolution x-ray spectrometer on BL6-2 has been upgraded with parts for a second multi-crystal component which will double the efficiency to a total of 14 analyzers. We have commissioned the instrument. The first Fe RIXS (resonant inelastic x-ray scattering) spectra were taken and the first Mn Kβ XES (x-ray emission spectroscopy) studies were also performed. These experiments are part of a program on time resolved studies that will employ wavelength dispersive XES optics. Two XRS (x-ray resonant scattering) studies on water in ambient and confined conditions were performed at BL6-2 and these were the first XRS studies successfully carried out at SSRL, demonstrating the feasibility of the XRS work. We have transferred much work XRS work previously carried out at the Advanced Photon Source (APS) to SSRL BL6-2. We will use this beam line until a dedicated beam line becomes available, as has been proposed.

Molecular Environmental and Interface Science: Molecular Environmental and Interface Science (MEIS) research focuses on the fundamental interfacial, molecular- and nano-scale processes that control the reactivity of contaminants in the environment, nutrient cycling in soils and natural waters, and the properties of complex natural materials such as nano-biominerals. This research makes significant use of SSRL-based synchrotron x-ray absorption spectroscopy (XAS), wide-angle x-ray scattering (WAXS), small-angle x-ray scattering (SAXS), x-ray standing wave (XSW) spectroscopy, and photoemission spectroscopy (PES) to provide direct *in-situ* probes of physical and electronic structure. Research in these areas contributes directly to contaminant remediation technologies, cost mitigation and accelerated clean-up of contaminated DOE sites, improved storage of high level radioactive waste, the discovery of new materials and structures that can be used in energy-related applications, and improved understanding of the surface and environmental reactivity of materials used in advanced nuclear systems.

A programmatic effort to build microspectroscopy and microdiffraction MEIS programs for environmental remediation science continued in FY07 with the commissioning of the imaging and XAS capabilities. In addition, the development of significant new data acquisition and analysis software tools was completed. This facility has quickly developed a large user community.

Chemical Physics of Surfaces and Liquids: This research program uses x-ray and electron spectroscopies to address chemical bonding on surfaces and in aqueous solutions. PES, XES, XAS and x-ray Raman spectroscopy provides an atom specific projection of the electronic structure. Problems related to systems in catalysis, energy technologies, electrochemistry and molecular environmental science are studied using these and density functional theory (DFT) calculations. Probing hydrogen bonding and the structure of liquid water in aqueous systems are new and novel applications of x-ray spectroscopic techniques.

Instrument development is an important part of the activity to provide new spectrometers, and enable measurements at high gas pressures and at liquid interfaces. A wide range of problems is being addressed.

Development of Resonant Coherent X-ray Scattering: This research has developed lensless imaging with sub 20 nm spatial resolution and includes investigation of charge and spin dynamics by

[1] http://www-group.slac.stanford.edu/oa/selfevaluation/2007/PubsAppendix.pdf

x-ray photon correlation spectroscopy, magnetization dynamics by spatially resolved absorption intensity fluctuation spectroscopy and resonant small angle scattering of incoherent photons to study spin fluctuations in the vicinity of the ferro to paramagnetic phase transition.

Small and Wide Angle Scattering Studies of Soft Matter and Colloids: Small angle scattering is an important tool for the study of polymers and nanomaterials. Work carried out in FY07 includes: (1) Studies of block copolymers using small-angle x-ray scattering demonstrated that reversible order-disorder transitions are obtained in these materials even when the cross-linking density is larger than that required to obtain a gel; and (2) Alloy nanoparticles which have been proposed as a solution to problems with platinum catalysts used in fuel cells. However, these systems undergo degradation processes involving sintering and partial delayering under electrochemical operation. *In-situ* small angle scattering is being used to understand these processes in real time and has confirmed the proof of concept; initial experiments have been completed.

Structural Properties of Novel Materials: X-ray diffraction is being used to study the detailed structure of a wide variety of materials systems. Several major subgroups of materials studied include the local structure of noncrystalline materials, thin films, and nanoporous materials. Examples include: (1) PBTTT, a semiconducting polymer that forms thin film transistors (TFTs) with high field effect mobility on silicon dioxide dielectrics that are treated with alkyltricholorosilanes (~0.2 to 0.5 cm^2/Vs), but forms TFTs with poor mobility on bare silicon dioxide (< 0.005 cm^2/Vs). Results suggest that electrical transport in PBTTT films is strongly affected by the domain size of the crystalline regions and the disordered regions between them; (2) Rare earth ® tri-tellurides ($R\mathrm{Te}_3$) are ideal materials in which to study charge density waves (CDW), since the CDW gap is large and large crystals can be grown. The transition temperature increases monotonically with increasing $R\mathrm{Te}_3$ lattice parameter by an extraordinarily large amount suggesting that this behavior, and a secondary transition for the heaviest members of the series, is intimately linked to the effect of chemical pressure on the degree of bilayer splitting of the Fermi surface; and (3) the structure, phase, strain and particle size and composition distributions in Co-Pt and Cu-Pt fuel cell nanoparticle electrocatalysts were measured, demonstrating the complexity in these multiphase materials with respect to catalyst activity and degradation. From this information, Synthesis-Structure-Activity relationships have been derived.

Ultra-trace and Microanalysis: The NASA Stardust Preliminary Examination period was extremely successful, resulting in two publications with SSRL co-authors as part of a focused **Science** issue. Two important points were raised: synchrotron x-ray microprobe facilities are crucial for nondestructive analysis of the cometary material collected by the Stardust mission, and the silica aerogel used to capture the cometary material creates real challenges for the analysis of the material because there is considerable mixing of cometary material with the aerogel. The SSRL/Lawrence Livermore National Laboratory (LLNL) collaboration developed analytical methods to quantify the cometary material in each deceleration track. This involves defining a threshold surface of Fe contamination within the aerogel matrix which is subtracted from the total Fe signal at each pixel of the map. A Transmission X-ray Microscope (TXM) from Xradia Inc. was delivered in October 2006 and commissioned during 2007, and demonstrated a resolution of 40 nm. Phase contrast imaging was demonstrated on biological materials and images were obtained across the iron absorption edge. This microscope will provide significant capabilities for materials science, environmental and biological applications.

XAS Studies as a Probe of Electronic Structure/Contribution to Function: Experimental and theoretical approaches are developed, coupled with new beam line instrumentation, combining metal K-, ligand K-, and metal L-edge XAS and PES to determine the electronic and geometric structure of metal active sites in biologically- and catalytically-relevant systems. The synchrotron-based data are correlated to results from other spectroscopic methods (including Magnetic Circular Dichroism (MCD), Electron Paramagnetic Resonance (EPR), and resonance Raman), as well as to density functional calculations to maximize insight into the reactivity of these systems.

User and Staff Awards

Kornberg, Roger	Stanford University	SSRL User	2006 Nobel Prize, Chemistry
Zachara, John	PNNL	SSRL User	2007 DOE Lawrence Award
Hodgson, Keith	SLAC	SLAC Faculty	Elected Fellow of the American Association for the Advancement of Science (AAAS)
Hodgson, Keith	SLAC	SLAC Faculty	2007 Association of Environmental Engineering and Science Professors Outstanding Paper Award
Brown Jr, Gordon	SLAC & Stanford University	SLAC and Stanford University Faculty	2007 Roebling Medal, Mineralogical Society of America
Brown Jr., Gordon	SLAC & Stanford University	SLAC and Stanford University Faculty	2007 Patterson Medal, The Geochemical Society
Brown Jr., Gordon	SLAC & Stanford University	SLAC and Stanford University Faculty	2006 Hawley Medal, Mineralogical Association of Canada
Brown Jr., Gordon	SLAC & Stanford University	SLAC and Stanford University Faculty	2007 Association of Environmental Engineering and Science Professors Outstanding Paper Award
Yano, Junko	Lawrence Berkeley National Laboratory (LBNL)	SSRL User	2007 Robin Hill Award, given by the International Society for Photosynthesis Research
Schimmel, Paul	Scripps Research Institute	SSRL User	Stein and Moore Award from The Protein Society
McGehee, Michael	Stanford University	SSRL User	2007 Materials Research Society Outstanding Young Investigator
Pianetta, Piero	SLAC	SLAC Faculty	Elected Fellow of the American Physical Society
Vey, Jessica	MIT	SSRL User	2007 Melvin Klein Award, presented at the SSRL Users' Meeting
Harris, Hugh	U. of Adelaide	SSRL User	2007 Spicer Award, presented at the SSRL Users' Meeting
Cavalieri, Adrian	Max-Planck	SSRL User	Co-winner of the 2006 W.E. Spicer Young Investigator Award

Publication in journals outside the field indicating significant impact

Archimedes Project: The Archimedes project (see the Publications Appendix) received enormous national and international press coverage following the initial results in May 2005 and then again after the third experimental run in August 2006. Both **Nature** (News@Nature, May 16, 2005, and **Nature**, 435, 257, 2005) and **Science** (Science, 313, 744, 2006) have reported on the project, as well as many leading news journals, TV and radio news stations in the United States and around the world. On August 2, 2006, the Archimedes x-ray project was the most e-mailed news story on the **BBC News** website. On August 3, it was listed as the most popular story of the previous five days. A partial list of the 2006 press coverage as compiled on August 11 by the SLAC Communications Office is included as a separate section of the Publications Appendix.

Other publications in popular literature include:

- *Elemental Magnetism*, INTUTE, June 8, 2007
- *Carbon Joins the Magnetic Club*, **PULSE magazine**, US Department of Energy, June 4, 2007
- *Carbon's mysterious magnetism*, **Science News Magazine** June 2, 2007, featured in the online version of the Encyclopedia Britannica
- *First Proof of Ferromagnetic Carbon*, Advanced Light Source (ALS) science highlight July 2007
- *Carbon Joins the Magnetic Club*, SSRL Science highlight May 29, 2007

- *Parallel and Antiparallel Interfacial Coupling in AF-FM bilayers*, ALS science highlight August 2006. Pushkar, et al. **JBC**, 282, 7198, 2007 was the cover article and chosen as paper of the week by the Journal of Biological Chemistry.
- *Magnetic properties of Carbon Identified*, **The Stanford Daily** May 22, 2007
- *Carbon Joins the Magnetic Club - Element holds promise for information technology*, **Stanford Report** May 16, 2007
- *Carbon Joins the Magnetic Club*, SLAC press release May 11, 2007
- *Parallel and Antiparallel Interfacial Coupling in AF-FM bilayers*, **ALS Activity Report 2006**

Publications

Invited Presentations by SSRL Staff numbered 67 and are listed in the Publications Appendix.

Publications resulting from work done at SSRL (includes users and staff) number over 500.

See the Publications Appendix: “SSRL 2006 Publications” and “SSRL 2007 Publications.” Both years are included because the FY06 papers received very heavy citations in FY07.

NOTEWORTHY PRACTICES

Inelastic Scattering and Advanced Spectroscopy Facility for SPEAR3

The design of the SSRL x-ray emission spectrometer represents an advance in throughput and flexibility over existing systems. The design of this system will lead the way in this field.

Scientific Support Programs at SSRL

The scientific support in all the different research areas at SSRL (including molecular environmental science, materials and chemical science and structural molecular biology) are integrated into the user operations in such a way that developments by the scientific staff are rapidly deployed into the user program.

SPEAR3 Emittance Improvement

A new magnetic lattice has been implemented in SPEAR3 that has lowered the emittance from 16 to 9.8 nm-rad, bringing SPEAR3 into the operational range of brightness typical for the newer generation of intermediate energy light sources and enhancing its competitiveness. This has reduced SPEAR3 emittance to ~60% of its original design value, providing enhanced capabilities in microfocusing and coherence studies. This new mode has produced tangible improvements in the quality of the focused photon beams that SPEAR3 delivers to its users.

SPEAR3 Low Alpha Mode

R&D has been carried out in FY07 that has shown that short bunches can be created using a “low alpha” mode in the accelerator optics that allow SPEAR3 to produce electron bunches as short as one picosecond to allow for timing experiments.

State of the Art Macromolecular Crystallography Beam Line Installed at SSRL

Exploiting the high brightness electron beams from SPEAR3, SSRL has installed a state of the art beam line for macromolecular crystallography on its first in-vacuum undulator located in a chicaned, 7.5 meter long straight section that was formerly the “East Pit” interaction region. The beam line, currently in commissioning, was financed through the Gordon and Betty Moore foundation in collaboration with Cal Tech and was built on-time and on-budget. This beam line will enable the study of very small protein crystals in the 5-10 μm size range, making SSRL competitive with the best facilities in the world. Coupling this to the advanced automation developed at SSRL and to the high operational reliability (>95%) of SPEAR3, this beam line will continue to enable forefront structural biology research as exemplified by the Nobel Prize winning work of Roger Kornberg. The investment in this beam line is also providing significant leverage to SSRL and DOE by making available a second straight section in the chicane that will allow for a second beam line to be installed at a later date with potentially even higher capabilities once superconducting undulator technology is realized.

Macromolecular Crystallography

The macromolecular crystallography program has developed an integrated automation system that allows for fully remote instrument control and data taking. The Blue Ice user software interface has been adopted as a standard by many of the synchrotron radiation laboratories in the world.

OPPORTUNITIES FOR IMPROVEMENT

Advances in X-ray Diffraction Capabilities

The x-ray diffraction capabilities at SSRL could be greatly advanced by the use of large area detectors in conjunction with the diffractometers. A plan has been developed and, with adequate funding, can be started in 2008.

Inelastic Scattering and Advanced Spectroscopy Facility for SPEAR3

Currently this experimental apparatus requires installation and removal from the beam line for each experimental run. SSRL recognizes that performance and efficiency gains can be achieved by locating this semi-permanently in a hutch until a new undulator beam line can be built.

Small and Wide Angle Scattering Studies of Soft Matter and Colloids

Small angle scattering research at SSRL could be significantly improved with a tunable source that fully utilizes the high brightness capabilities of SPEAR3. Recognizing this fact and obtaining validation through a user workshop and a focused review, SSRL has submitted a proposal to DOE to build a new beam line for small angle scattering.

Advanced Area Detectors for X-ray Protein Crystallography Diffraction Studies

Just becoming available is a new generation of pixel array detectors (PAD arrays). PADs offer distinct advantages in both signal-to-noise and readout speed. Retrofitting of existing experimental stations with such detectors would offer significant performance gains. Proposals are being developed to acquire this new technology for SSRL.

Objective 1.2 Leadership in Science and Technology

Photon Science faculty (one of the two facilities at SLAC) and SSRL staff are leaders in the international community as seen in the list of advisory and review committees on which they serve.

Bergmann, Uwe

- Proposal Review Panel member at National Synchrotron Light Source (NSLS)
- System Concept Review of the LCLS X-ray Transport, Optics and Diagnostics (XTOD), 2006

Brennan, Sean

- Member, NSLS-II Conceptual Design Review Panel, Sept. 2007
- Chair, APS proposal review panel on Applied Materials Scattering

Corbett, Jeff

- Australian Synchrotron International Machine Advisory Committee

DeBeer, Serena

- APS spectroscopy proposal review panel

Hedman, Britt

- Member, BioCAT Advisory Committee, Advanced Photon Source, Argonne National Laboratory (ANL)
- Member, Scientific Advisory Committee, Canadian Light Source, Canada
- Member, Committee for the Scientific Evaluation of the MAX IV Light Source Proposal,

Lund, Sweden

- Member, National Institutes of Health (NIH) National Center for Research Resources (NCRR) Special Study Section Site Visit Team for NCRR Research Resource
- Member, International Review Committee for The Danish National Program for Research Infrastructure

Hodgson, Keith

- Member, US Department of Energy's Biological and Environmental Research Advisory Committee (BERAC)
- Member, Bio-X Interdisciplinary Initiatives Committee, Stanford University
- Member, U.K. Central Laboratory Research Council Science Advisory Committee, Rutherford
- Member of the International Advisory Committee for the Oxford Protein Production Facility, Oxford
- Member and Chair, Photon Factory International Science Advisory Committee, Tsukuba, Japan
- Member, NSRRC Light Source International Advisory Committee, Hsinchu, Taiwan

Nilsson, Anders

- Member of the review panel in Catalysis for the President's Hydrogen Fuel Initiative, 2007

Ohldag, Hendrik

- Co-Program Chair 2006 ALS Users' Meeting
- Member of the ALS proposal reviewer pool
- Reviewer for the major Research Instrumentation Program at the National Science Foundation (NSF)
- Reviewer, Physical Review Letters, Physical Review B, Applied Physics Letters, Magnetism and Magnetic Materials

Pianetta, Piero

- Scientific Advisory Committee, APS
- Scientific Advisory Committee, National Center for X-ray Tomography, LBNL

Pople, John

- Proposal review panel National Institute of Standards and Technology (NIST) Neutron Facility

Soltis, Michael

- Served on the review committees for the macromolecular crystallography beam lines at the APS (IMCA-CAT and SGX-CAT), and the European Synchrotron Radiation Facility (ESRF, BM14)

Stöhr, Jo

- Scientific Advisory Committee, Advanced Photon Source, ANL
- Scientific Advisory Committee, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory (ORNL)

Toney, Michael

- Member of NIST Center for Neutron Research Beam Time Allocation Committee, 2005-present.
- Member of APS Scattering Applied Materials Proposal Review Panel (PRP), 2007-present.

Tsuruta, Hiro

- NIH NCRR P41 Review Panel (Nov 2006)
- General User Proposal Review Panel in small angle scattering for the Advanced Photon Source

Macromolecular Crystallography: When Roger Kornberg began using synchrotron radiation for his research on RNA polymerase around 1998, which led to his 2006 Nobel Prize, it was clear that a large amount of crystal screening at SSRL was needed for the research to move significantly forward. More efficient use of beam time accommodated this need. This was a decision with significant risk at the time that resulted in a very significant pay-off.

Development of Research Using Circularly Polarized Radiation: SSRL is currently installing a new beam line (BL13) to provide circularly polarized radiation for programs in chemical physics of surfaces and liquids, the resonant coherent x-ray scattering and scanning tunneling microscopy of magnetic films. These programs were being threatened by delays of over a year due to vendor problems in quality control in producing the undulator for this beam line. However, we were able to move and reconfigure an existing undulator from BL5 that also produces circularly polarized x-rays although over a narrower energy range than what will ultimately be desired. It should be noted that this undulator was originally developed in-house over 10 years ago. That decision, both risky and innovative at the time, allowed us to get the research started early in FY07, well before the new beam line was installed, by using part of BL5, and continue it without interruption on BL13 while the new undulator is being completed.

Molecular Environmental and Interface Science (MEIS): SSRL continues to be a world leader in the field of MEIS both by significantly contributing to the beginning of the field as well as continuing to the present with a growing user community that takes advantage of existing beam lines (such as BL11-2, 7-2, 10-2 and 2-3), new beam lines such as BL4-1 and a future beam line for nano-focusing spectroscopy that will be proposed within the next year.

Development of Resonant Coherent X-ray Scattering: This is an area which has the potential for high risk and high reward. Current developments include methods of imaging magnetic systems using Fourier transform holography techniques as well as ways of improving the signal to noise of this method using multiple scattering points. With the development of BL13, this facility will have a permanent home and will continue to attract a broad international user community.

XAS for Structural Molecular Biology (SMB) and Material/Chemical Sciences: SSRL has a world class XAS program that serves both an external and internal user community and receives high marks in external peer reviews. The research quality depends on developments by SSRL staff in beam line stability, sample environments and detector developments. These new capabilities are continuing with the development of single crystal XAS that adds the capability of using the polarization of the beam to highlight particular bonds and determine their structure.

Development of New Research Centers: SSRL has been the source of new developments in the area of photon science at SLAC that have come to fruition in FY07. The X-ray Laboratory for Advanced Materials (XLAM) now has its own section in this report. LCLS originated as a long term, risky endeavor within SSRL and has resulted in the construction of the world’s first x-ray free electron laser (XFEL). As a result of the attention being focused on the LCLS developments by the SLAC staff, an idea for performing ultrafast research with x-rays using the SLAC linac was developed by SSRL and SLAC accelerator staff and resulted in the SPPS which was very successful in producing femtosecond level research. These results are listed in the Photon Ultrafast Laser Science and Engineering (PULSE) Center report. The PULSE Center is also another SSRL spin-off resulting from its work on the LCLS and Sub Picosecond Pulsed Source (SPPS). Plans are being developed for a new Center for Energy and the Environment at SLAC that would focus on new energy-related materials and processes, microbial-solid interactions, and the chemistry of interfacial processes of relevance to molecular environmental science.

Outreach, Training and Planning for Future Research: SSRL provides training and outreach for users through workshops held at the SSRL User meeting and throughout the year. Such workshops include SMB workshops in spring and fall of 2007, and a hard x-ray scattering workshop in the spring of 2007. Planning workshops were held to obtain user input for the development of new capabilities in the areas of hard x-ray scattering (winter of 2006) and scanning transmission x-ray microscopy for MEIS chemical/material science applications (summer 2007). SSRL manages the Gateway program, which is an educational program tailored specifically for Mexican-American and Mexican communities in undergraduate and graduate education, some of which is performed at SSRL.

NOTEWORTHY PRACTICES

Outreach, Training and Planning For Future Research

Workshops provide training to users in the effective use of SSRL beam lines resulting in more efficient use of beam time as well as introducing new users to the capabilities of SSRL. In addition, the planning workshops during FY07 provided important inputs to SSRL for the development of new capabilities in the area of hard x-ray scattering and guidance on the capabilities that should be included in a future proposal for a scanning x-ray microscopy facility.

Development of Research Using Circularly Polarized Radiation

By working closely with the vendor of the BL13 undulator, SSRL determined that the vendor would not be able to meet the delivery deadline for installation during the summer 2007 shutdown early enough to develop an interim plan, which allowed the beam line to operate during the FY07 run.

OPPORTUNITIES FOR IMPROVEMENT

Development of New and Unique Research Capabilities

SSRL has been uniformly praised by DOE reviews and the SSRL Scientific Advisory Committee with the caution that the staff is stretched. Although SSRL optimizes the efficient use of its beam lines, the inability to hire new staff has hampered SSRL's ability to fully exploit the capabilities of SPEAR3 and threatens its long term viability as a leading center for synchrotron based research.

X-Ray Microscopy

With the new transmission x-ray microscope, SSRL has the opportunity to develop a broad user community in both materials science and biology. Additional outreach during FY08 will definitely be important to achieve this goal.

X-Ray Diffraction and Scattering

A high priority in the implementation of CCD detectors and new sample environments will be instrumental in developing a leadership role in the area of x-ray diffraction and scattering.

Objective 1.3 Provide and Sustain Science and Technology Outputs that Advance Program Objectives and Goals

SSRL research output can be measured in the number of publications by staff and users and the invited talks by staff. In 2006, the total was 281 publications and 11 PhD theses. As of this writing, the partial list for 2007 yields 279 publications and 9 theses. The numbers for 2007 are expected to grow as publication data continues to be collected beyond the close of the FY. The number of invited talks by the relatively small SSRL staff was 64.

Objective 1.4 Provide for Effective Delivery of Science and Technology

Inelastic Scattering and Advanced Spectroscopy Facility for SPEAR3: The deployment of the apparatus for x-ray emission spectroscopy occurred on schedule by partnering with a vendor of optical instrumentation to design a custom system integrating that vendor's standard components. Both costs and time to completion were greatly reduced, and the system is easily expandable by simply purchasing additional units.

Scientific Support Programs at SSRL: Use of unified software and hardware platforms for beam lines that support the same applications, leveraged the relatively small scientific staff to provide excellent research output and user support.

SPEAR3 Improvements: Higher flux on sample, greater stability and greater uptime improved the quality of the scientific output, achieved by incrementally improving the capabilities of SPEAR3 beyond its original specifications.

MEIS: Micro-XAS capabilities were developed and commissioned in 2007 on BL2-3 with a superb data collection and analysis package that gives users the ability to take data on their own very quickly. This has greatly increased the throughput of the beam line and the quality of the data as well as drawn users to this beam line.

Chemical Physics of Surfaces and Liquids: Significant developments are being made available to users through developments in the high resolution core level photoemission system that was opened to outside users in 2007.

Transmission X-ray Microscopy: The TXM was brought into operation within one week of installation. This allowed us to continue commissioning the different capabilities of the instrument while allowing outside users to pursue research with the instrument.

XAS Studies: SSRL has been able to leverage the Basic Energy Sciences (BES), BER and NIH programs to supply state of the art capabilities for XAS in fields ranging from biology to materials science. This includes state of the art detector systems and single crystal XAS capabilities. SSRL maintains world class capabilities in XAS including the study of dilute systems.

NOTEWORTHY PRACTICES

Inelastic Scattering and Advanced Spectroscopy Facility for SPEAR3

Partnering with industry on the development of major components reduces cost and advances deployment of advanced capabilities.

Scientific Support Programs at SSRL

Leveraging common hardware and software platforms allows for efficient user support and user training.

OPPORTUNITIES FOR IMPROVEMENT

Micro-XAS and Micro-Fluorescence Capabilities

Several different microfluorescence capabilities are being developed at SSRL. There is an opportunity to unify the data collection software between the different beam lines to ease the ability of users to work on the different beam lines without additional training.

Advanced Detectors for XAS and Diffraction

One of the limitations of many of the experiments being done at SSRL is the detector. The addition of advanced detectors with higher throughput for XAS will greatly improve detection limits and signal to noise. In addition, the use of CCD detectors for diffraction will improve throughput and allow for *in-situ* studies of time varying processes.

B ▪ Linac Coherent Light Source (LCLS)

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

The LCLS XFEL facility will offer unprecedented scientific capability for performing pulsed x-ray experiments starting in FY09. SLAC has been coordinating a worldwide effort to anticipate the scientific impact of LCLS, and to plan for the experimental programs that will make use of this facility. This planning process involves significant outreach to the scientific community through topical meetings and workshops, formation of an LCLS Users community, close coordination with related groups such as the PULSE center, and major re-examination of priorities within the laboratory. The process is coordinated by SLAC Management, and includes many layers of external review and coordination with BES program officers.

Objective 1.2 Leadership in Science and Technology

The LCLS is widely considered to be the most exciting construction project currently supported by DOE BES. It has the potential to enable revolutionary studies in several scientific areas. Since it relies on novel techniques and instrumentation, it also involves some risk.

The LCLS project has made a strong effort to mitigate risks associated with innovation by assembling top scientists and engineers to carry out the design and commissioning of the facility, seeking out the best advice through international workshops and design reviews, and by carefully adhering to DOE project management guidelines.

During FY07, this effort was rewarded by performance measurements for the new LCLS electron injector which not only exceeded the LCLS early design goals, but set a new world record for electron source quality.

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

The established electron beam brightness of the LCLS Injector is a major milestone in the realization of a linac-based XFEL based on self-amplified spontaneous emission (SASE). The gun performance and commissioning efforts were presented at an invited talk at the FEL Conference in Novosibirsk, Russia in August, 2007. The LCLS injector is, at the time of writing, the brightest free electron laser (FEL) injector in the world.

Objective 1.4 Provide for Effective Delivery of Science and Technology

LCLS has achieved all of its major project milestones to date on time. Technical performance of the portions of the facility commissioned to date has exceeded early design goals.

At several points during the project, and particularly in FY07, the LCLS project schedule has been required to adapt to BES-directed changes. This has been accomplished without undue inefficiencies, and without major compromises in project scope.

C ▪ PULSE

PULSE’s mission is to conduct research in ultrafast science, which supports the research program of the LCLS. A wide range of experiments probing ultrafast dynamics in chemistry, materials science, AMO (atomic, molecular, and optical physics), and structural biology, have recently begun and are showing important results which inform the first experiments to be carried out at the LCLS. In FY07, a collaboration was formed with researchers at the soft x-ray free electron laser in Hamburg, Germany (FLASH). Experiments at FLASH will assist in the development of the LCLS program, providing access to similar x-ray intensities but at softer x-ray wavelengths. Another project is starting to produce attosecond pulses in the extreme ultraviolet that will have significant impact on future attosecond operational modes at the LCLS, associated with enhanced SASE and the use of carrier-envelope phase-stabilized lasers to control the LCLS pulse shape.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

Timing System for Time Resolved Scanning X-Ray Microscopy: The time structure of synchrotron radiation allows time resolved experiments with sub-100 ps temporal resolution using a pump-probe approach. However, the relaxation time of the samples may require a lower repetition rate of the pump pulse. Use of the x-ray pulse alone immediately following the pump pulse is inefficient and often requires special operation modes where only a few buckets of the storage ring are filled. A novel software defined photon counting system was designed that allows a variety of pump probe schemes at the full repetition rate. The high number of photon counters allows response detection of the sample at multiple time delays simultaneously, thus improving the efficiency of the experiment. The system has been successfully applied to time resolved scanning transmission x-ray microscopy. However, this technique is applicable more generally.

Electro-Optic Bunch Length Monitor and Timing Diagnostic: A noninvasive technique was developed and tested at SPPS to record femtosecond electron bunches arrival time with respect to a pump laser pulse. Although the arrival time fluctuates from pulse-to-pulse, this information can be used to place repetitive measurements in sequence with femtosecond resolution. The optical properties of an electro-optic crystal placed adjacent to the electron beam are strongly modified as a result of the electric field of the electron bunch as it passes. A femtosecond laser pulse propagating through the crystal at the same time as the transient birefringence is induced has its polarization state altered and can thus be used as a probe of the relative arrival time of the electron bunch. By making use of cross-beam geometry, a range of times is measured and the timing information, including electron bunch length information, is imprinted on the spatial profile of the transmitted laser beam.

Coherent Imaging: A collaboration with FLASH includes experiments probing high intensity, nonlinear interaction of x-rays with materials, radiation chemistry in liquids, and catalysis on surfaces.

Attosecond Pulses: A new project focuses on producing attosecond pulses in the extreme ultraviolet. In a short time we have become world competitive in the analysis of high harmonics from aligned molecules, and have novel results that impact the interpretation of electron wave functions in HHG processes.

THz: During FY07, we commissioned a laboratory-scale setup for generating high field THz half-cycle pulses, generating among the highest fields ever produced from a table-top source, using a setup that is simple and easily adopted. Evidence of performance comes from the very large number of publications, invited talks, and awards in FY07.

Awards and Invited Papers

- SSRL William E. Spicer Young Investigator Award (co-winner)
  - D. M. Fritz, Menlo Park, CA, awarded October 2006
- University of Michigan Rackham School of Graduate Studies Distinguished Dissertation Award
  - D. M. Fritz, Ann Arbor, MI, awarded May 2007
- Freie Universitaet Ernst Reuter Prize for best PhD thesis
  - M. Gühr, Berlin, Germany, awarded December 2006

The invited papers list is incorporated into the Publications Appendix. In all, PULSE staff presented 45 invited papers in FY07.

Notable Publications

Software Defined Photon Counting System For Time Resolved X-Ray Experiments, Y. Acremann, V. Chembrolu, J. P. Strachan, T. Tyliszczak and J. Stöhr, **Rev. Sci. Instrum., 78**, 014702 (2007)

> We designed a novel software defined photon counting system that allows implementation of a variety of pump-probe schemes at full repetition rate. The high number of photon counters allows one to detect the response of the sample at multiple time delays simultaneously, thus improving the experiment's efficiency. The system has been successfully applied to time resolved scanning transmission x-ray microscopy, yet is applicable more generally.

Magnetization dynamics: ultra-fast and ultra-small, Y. Acremann, **Comptes Rendus - Physique**, accepted for publication

> Ultrafast magnetic processes are of great scientific interest but also form the basis of high density magnetic recording applications. We demonstrate the uniqueness of time resolved, high resolution magnetic x-ray microscopy, and show that the motion of a magnetic vortex core can be imaged. The vortex core direction is hidden to most experimental techniques, but has a decisive influence on the dynamics of the magnetic structure.

Dynamics of Electronic States and Spin-Flip for Photodissociation of Dihalogens in Matrices: Experiment, Semiclassical Surface-Hopping and Quantum Model Simulations for F2 and ClF in Solid Ar, M. Bargheer, A. Cohen, R. B. Gerber, M. Gühr, M. V. Korolkov, J. Manz, M. Y. Niv, M. Schröder and N. Schwentner, **J. Phys. Chem. A.**, in print (2007)

> We present an experimental and theoretical study of the ultrafast dynamics of F2 and ClF in solid argon including the molecular singlet to triplet and intertriplet transition dynamics. We find very fast population redistribution after the electronic excitation that is selective in spin, lambda and omega quantum numbers of the molecule.

The Future of Attosecond Spectroscopy, P. H. Bucksbaum, **Science, 317**, 766 (2007)

> Attoscience is the study of physical processes that occur in less than a fraction of a cycle of visible light, in times less than a quadrillionth of a second. The motion of electrons inside atoms and molecules that are undergoing photoionization or chemical change falls within this time scale, as does the plasma motion that causes the reflectivity of metals. The techniques to study motion on this scale are based on careful control of strong-field laser-atom interactions. These techniques and new research opportunities in attosecond spectroscopy are reviewed.

Dissociative Wave Packets and Dynamic Resonances, D. Cardoza, B. Pearson and T. Weinacht, **J. Chem. Phys., 126**, 084308 (2007)

> We attribute control mechanisms found using closed-loop learning control to the presence of dynamic resonances. We use methods developed previously to examine the behavior of the control, and find that dynamic resonances are an efficient mechanism for controlling molecular fragmentation.

Femtosecond Diffractive Imaging with a Soft-X-ray Free-electron Laser, H.N. Chapman, A. Barty, M.J. Bogan, S. Boutet, M. Frank, S.P. Hau-Riege, S. Marchesini, B.W. Woods, S. Bajt, W.H. Benner, R.A. London, E. Plönjes, M. Kuhlmann, R. Treusch, S. Düsterer, T. Tschentscher, J.R. Schneider, E. Spiller, T. Möller, C. Bostedt, M. Hoener, D.A. Shapiro, K.O. Hodgson, D. van der Spoel, F. Burmeister, M. Bergh, C. Caleman, G. Huldt, M.M. Seibert, F.R.N.C. Maia, R.W. Lee, A. Szöke, N. Timneanu and J. Hajdu, **Nature Physics, 2**, 839-843 (2006)

> Demonstrates ability to carry out "lensless" x-ray microscopy at wavelength limited resolution on nonperiodic, nanostructured materials. This includes the instrumentation and methodology and firmly establishes this novel approach as a means to do at or near atomic resolution imaging with LCLS.

High Harmonic Generation Induced by Non-thermal Melting of In Sb, H. Enquist, H. Navirian, T. N. Hansen, A. M. Lindenberg, P. Sondhauss, O. Synnergren, J. S. Wark and J. Larsson, **Phys. Rev. Lett., 98**, 225502 (2007)

> This work represents the first time-resolved observation of large amplitude strain waves launched by a solid-to-liquid phase transition. An ultrafast deflection of an x-ray beam is observed, with possible applications to x-ray switches.

Ultrafast Bond Softening in Bismuth: Mapping a Solid's Interatomic Potential With X-Rays, D. M. Fritz, D. A. Reis, B. Adams, R. A. Akre, J. Arthur, C. Blome, P. H. Bucksbaum, A. L. Cavalieri, S. Engemann, S. Fahy, R. W. Falcone, P. H. Fuoss, K. J. Gaffney, M. J. George, J. Hajdu, M. P. Hertlein, P. B. Hillyard, M. Hornvon Hoegen, M. Kammler, J. Kaspar, R. Kienberger, P. Krejcik, S. H. Lee, A. M. Lindenberg, B. McFarland, D. Meyer, T. Montagne, E. D. Murray, A. J. Nelson, M. Nicoul, R. Pahl, J. Rudati, H. Schlarb, D. P. Siddons, K. Sokolowski-Tinten, Th. Tschentscher, D. von der Linde and J. B. Hastings, **Science, 315**, 633-636 (2007)

> We demonstrated that a repetitive laser pump x-ray probe measurement could be performed at a synchrotron facility with time resolution superior to the timing jitter between the laser and x-ray pulses. We also confirmed that DFT calculations provide an accurate description of the

interatomic potential even for the highly electronically excited system investigated experimentally.

Imaging Atomic Structure and Dynamics with Ultrafast X-ray Scattering, K. J. Gaffney and H. N. Chapman, **Science, 316**, 1444-1448 (2007)

We discussed recent advances in ultrafast x-ray science and x-ray coherent imaging, as well as the tremendous opportunity the impending FEL facilities will have on these areas of science.

High Harmonic Generation for N_2 and CO_2 Beyond the Two Point Model, M. Gühr, B. K. McFarland, J. P. Farrell and P. H. Bucksbaum, **J. Phys. B: At. Mol. Opt. Phys., 40**, 3745-3755 (2007)

We study how the electron orbital structure of molecules influences the generation of strong field high harmonics of an intense laser. We compare simulations for N_2 and CO_2 to the predictions of a simple model and present its applicability limits. Our results lead to a reinterpretation of experimental studies in CO_2.

Ultrafast Dynamics of Halogens in Rare Gas Solids, M. Gühr, M. Bargheer, M. Fushitani, T. Kiljunen and N. Schwentner, **Phys. Chem. Chem. Phys., 9**, 779 - 801 (2007)

We present a complete study of the coherent electronic and vibrational wave packet dynamics of small halogen molecules in rare gas crystals. In contrast to many other studies of solvated molecules, we find long lasting electronic and vibrational coherences that are supported by the cage structure. We use the long lasting coherences to excite double and triple wave packet structures on the electronically excited state and get detailed information about the multiple-level decoherence.

Imaging of Conical Intersections, M. Gühr, **Bulletin of the American Physical Society, 52** (7), J6.00011 (2007)

Conical intersections (CI) are crucially involved in light harvesting, primary visual processes, DNA UV stabilization and atmospheric chemistry. A wave packet typically moves through the intersection on a femtosecond time scale, demonstrating the need for ultrafast tools that are sensitive to the electronic state change occurring in passing the CI. We propose a novel femtosecond pump probe scheme based on HHG. A first pulse (pump) creates a molecular wave packet on excited electronic surfaces, and the time delayed, high intensity probe pulse produces HHG on the excited molecule as it moves through the CI region. We use the symmetry of the electronic wave functions to detect the electronic state change in the CI via HHG. Furthermore, we use two center interference effects in the HHG to determine the nuclear dynamics that is accompanied by the CI passage. To demonstrate our scheme, we perform simple model calculations on the triatomic molecule SO_2, which will be ideally suited for experiments because of its high UV excitation cross sections for pumping the wave packet to the CI region.

Carrier-density-dependent Lattice Stability in Sb, P. B. Hillyard, K. J. Gaffney, A. M. Lindenberg, S. Engemann, R. A. Akre, J .Arthur, C. Blome, P. H. Bucksbaum, A. L. Cavalieri, A. Deb, R. W. Falcone, D.M. Fritz, P. H. Fuoss, J. Hajdu, P. Krejcik, J. Larsson, S. H. Lee, D. Meyer, A. J., Nelson, R. Pahl, D. A. Reis, J. Rudati, D. P. Siddons, K.Sokolowski-Tinten, D.von der Linde and J. B. Hastings, **Phys. Rev. Lett., 98**, 125501 (2007)

We experimentally identified the carrier dependent onset of interatomic potential softening and the carrier dependent onset of interatomic potential inversion.

Ultrafast Electron Pulses From a Tungsten Tip Triggered By Low-Power Femtosecond Laser Pulses, P. Hommelhoff, C. Kealhofer and M. A. Kasevich, **Phys. Rev. Lett., 97**, 247402 (2006)

We present an experimental and numerical study of electron emission from a sharp tungsten tip triggered by sub-8-fs low-power laser pulses. This process is nonlinear in the laser electric field, and the nonlinearity can be tuned via the direct current voltage applied to the tip. Numerical simulations of this system show that electron emission takes place within less than one optical period of the exciting laser pulse, so that an 8 fs 800 nm laser pulse is capable of producing a single electron pulse of less than 1 fs duration. Furthermore, we find that the carrier envelope phase dependence of the emission process is smaller than 0.1% for an 8 fs pulse but is steeply increasing with decreasing laser pulse duration.

Rotational Wave Packets Probed By High Harmonic Generation, B. K. McFarland, **Bulletin of the American Physical Society, 52** (7), J6.00010 (2007)

We prepare an aligned distribution of cold N_2 molecules by the interaction with an intense nonresonant fs laser pulse (pump pulse). The distribution is probed by HHG using a time delayed probe pulse. The high harmonics show an enhancement if the molecules are aligned with the probe pulse polarization and suppression if the molecules are aligned orthogonal to the polarization. We observe a first alignment 300 fs after the pump pulse. For longer time delays, we observe fractional and full revivals (the later at about 8 ps) of the rotational wave packet. We measure the relative phase of high harmonics from N_2 and Ar at the half revival for N_2, with a phase jump at the 23rd harmonic. The alignment contrast and phase relation among the high harmonics is discussed in the context of the two-center model.

Phonon Dispersion Relations and Softening in Photoexcited Bismuth From First Principles, E. D. Murray, S. Fahy, D. Prendergast, T. Ogitsu, D. M. Fritz and D. A. Reis, **Phys. Rev. B, 75**, 184301 (2007)

The phonon dispersion relations for equilibrium and photoexcited bismuth are calculated from first principles density-functional perturbation theory. The results are in agreement with available experimental data, providing justification to the assumptions used in the calculations. This advances our understanding of the interplay between the electronic and ionic components that comprise a solid.

Magnetism From Fundamentals to Nanoscale Dynamics, H.C. Siegmann and J. Stöhr, *Springer Series in Solid-State Sciences* , Vol. 152, 2006, XVII, 820 p. 325 illus., Hardcover, ISBN: 978-3-540-30282-7

The book covers both the classical and quantum mechanical aspects of magnetism and novel experimental techniques. Perhaps uniquely, it discusses spin transport and ultrafast magnetization dynamics phenomena associated with atomically and spin engineered nano-structures against the backdrop of spintronics and magnetic storage and memory applications.

Synchronized and Configurable Source of Electrical Pulses for X-Ray Pump Probe Experiments, J. P. Strachan, V. Chembrolu, X. W. Wu, T. Tyliszczak and Y. Acremann, **Rev. Sci. Instrum., 78**, 054703 (2007)

The pulse generator described here is used to excite magnetic nanostructures with current pulses. Having an excitation system which can match the high repetition rate of a synchrotron allows for utilization of the full x-ray flux and is needed in experiments that require a large photon flux. The fast rise times allow for picosecond time resolution in pump-probe experiments.

NOTEWORTHY PRACTICES

Timing System for Time Resolved Scanning X-Ray Microscopy

Currently, the scanning x-ray setup that we created is used by several groups in the magnetism community using the scanning transmission x-ray microscope in Berkeley.

Electro-Optic Bunch Length Monitor and Timing Diagnostic

The bunch length monitor and timing diagnostic that PULSE developed was duplicated at the FLASH FEL in Hamburg and will be implemented at the LCLS.

Terahertz Pulses

Because of this simplicity, we believe this technique will become part of the arsenal of time-resolved techniques that will be used at the LCLS, for performing both THz pump - x-ray probe and x-ray Pump - THz probe experiments.

Attosecond Pulses

In the HHG/attosecond lab, we are studying the influence of the molecular electronic orbital symmetry on the emitted strong field harmonics. We have implemented new phase measure approaches by using a reference oscillator in the HHG process, and have also developed new simulations of the HHG process. These results will have a significant impact on the electron orbital imaging schemes using high harmonics and will be an elegant way to shape attosecond pulses in amplitude and phase during their generation.

OPPORTUNITIES FOR IMPROVEMENT

Timing System for Time Resolved Scanning X-Ray Microscopy

We started to develop an improved version of the x-ray timing system that will offer the possibility to be used for many experiments by the time resolved x-ray community.

Electro-Optic Bunch Length Monitor and Timing Diagnostic

This EO bunch length monitor makes possible a wide range of repetitive measurements with time-resolution limited by the pump and probe durations instead of the intrinsic jitter between pump and probe. Relative timing information from spatially-resolved EO measurements could be extended to a resolution of order 5 fs, matching the projected performance of future X-Ray FELs (XFELs) into the foreseeable future.

Coherent Imaging

The coherent imaging experiments at FLASH will greatly assist in the development and success of the LCLS program, providing access to similar x-ray intensities at soft x-ray wavelengths.

Attosecond Pulses

The attosecond pulse project will have a significant impact on future attosecond operational modes at the LCLS, associated with enhanced SASE and the use of carrier-envelope phase stabilized lasers to control the LCLS pulse shape.

Objective 1.2 Leadership in Science and Technology

PULSE members are international leaders, as illustrated in the following list of major FY07 local, regional and international advisory positions.

Bucksbaum, Philip

- Chair of the Department of Photon Sciences, SLAC
- Chair, AMO 2010, the National Academy of Sciences decadal study of AMO physics
- Editor of the Virtual Journal of Ultrafast Science
- Divisional Associate Editor of **Physical Review Letters**
- Chair, AMO Screening Panel, National Academy of Sciences
- Member of the National Academy of Sciences Board on Physics and Astronomy
- Member of the Board of Directors of the Optical Society of America
- Member of the BESAC Grand Challenges Committee
- Member of the Advisory Committee of **Physics Today**
- Member of the Science Advisory Committee for the LCLS
- Member of the External Advisory Board for the Advanced Light Source at Berkeley
- Member of the **Physics Today** Advisory Committee for the American Institute of Physics
- Member of the External Advisory Board for the NSF Extreme Ultraviolet (EUV) Engineering Research Center, Colorado State University

- Member of the External Visitors Committee for IQCD, University of California at Santa Barbara

Hodgson, Keith

- Member, US Department of Energy's Biological and Environmental Research Advisory Committee (BERAC)
- Member, Bio-X Interdisciplinary Initiatives Committee, Stanford University
- Member, U.K. Central Laboratory Research Council Science Advisory Committee (SAC), Rutherford
- Member of the International Advisory Committee for the Oxford Protein Production Facility, Oxford
- Member and Chair, Photon Factory International Science Advisory Committee, Tsukuba, Japan
- Member, Taiwan NSRRC International Advisory Committee, Hsinchu, Taiwan

Gaffney, Kelly

- Team leader for pump probe instrument, LCLS

Hastings, Jerry

- Member, ESRF SAC
- Member, Swiss Light Source (SLS) SAC
- Member, Pohang Light Source (PLS) SAC
- Member, Elettra Machine Advisory Committee
- Member, DESY Extended Science Council
- Member, NSLS II Experimental Facilities Advisory Committee

Hajdu, Janos

- Member, Photon Science Committee of DESY
- Member, Scientific and Technical Issues (STI) Working Group of the European XFEL
- Member, München Centre for Advanced Photonics

Ultrafast Summer School: PULSE hosted its first ultrafast x-ray summer school, offering discussions of FELs, ultrafast AMO science, attosecond physics, materials science and imaging with FELS, high energy density science, and time-resolved absorption and scattering. Expert scientists as well as many young students presented talks.

Attoscience: We are taking on high-risk/high payoff/long-term research problems. One example is our High Harmonic/Attoscience research project. Very few groups world-wide study systems on the frontier of technical possible timescales; this type of science has just started. This has to do with the limited experimental possibilities of attosecond pulses from high harmonic sources. The pulses lie in the vacuum- and extreme ultraviolet spectral range, which makes their handling difficult and expensive, due to special optics. They are weak, so that all optical pump probe schemes and especially nonlinear optics becomes extremely difficult, if not impossible.

High Harmonics: We have set up a special carrier envelope stabilized laser to produce high harmonics. Currently, it produces strong field high harmonics from simple molecules like nitrogen. This type of research has a high impact on the fundamental understanding of HHG. For example, we are clarifying the influence of other molecular orbitals besides the HOMO in the generation process.

Carrier-Envelope-Phase (CEP) Stabilization: We are currently using rare gas filled hollow core fibers to broaden the spectra of amplified 25 fs pulses and compress them by chirped mirrors to sub 6 fs. The CEP locking is achieved by f-2f interferometry and a feedback of this signal to the oscillator pump-power. Moreover, experimental systems can be identified soon in our attosecond lab before bringing it to the large LCLS facility, where beam time is much more expensive.

Magnetic Nanostructures: Magnetic nanostructures are essential as an inexpensive and reliable way to store large amounts of data. Magnetization reversal by a spin polarized current is a very recent development in magnetism and has been observed in resistance measurements. So far, however, the nanoscale magnetization distribution during the switching process has remained hidden. We imaged for the first time, the magnetic switching process using advanced pump-probe x-ray microscopy. We observe that the switching process is initiated and determined by the lateral motion of a magnetic vortex driven by the spin current. Motion pictures with 200 picosecond time resolution show that the switching process is based on the motion of a magnetic vortex, leading to C-like patterns which may decay later into a uniform magnetic state. Our measurements show the fundamental role played by the curled Oersted field which necessarily accompanies the spin injection current.

Resonant X-ray Scattering: We plan to explore the nonperturbative x-ray probe limits in solids using resonant soft x-ray scattering to determine the complex refractive index as a function of x-ray pulse fluence. The resonant aspect of the x-ray scattering combines the structural with the electronic and magnetic information of the system. The latter makes this technique highly sensitive to changes in the electronic structure. The electronic structure responds to the excitation of core electrons and the successive secondary processes on the time scales of the x-ray pulse duration (femtosecond regime). We will investigate the earliest stages of radiation chemistry in liquids (primarily water), extending from a few femtoseconds to many picoseconds. Prior pulsed electron beam studies of radiolysis have not covered this temporal range, and the fs optical laser studies cannot produce the electron cascade fundamental to the interaction of EUV/soft x-ray radiation in water.

Catalysis: The microscopic understanding of heterogeneous catalysis requires a detailed understanding of the dynamics of elementary processes at surfaces including adsorption, formation of different intermediates, and desorption, which can be stimulated by laser pumping and then probed with XES or X-ray Photoelectron Spectroscopy (XPS) using FEL soft x-ray pulses. During the reaction there are important charge and energy transfers between the different adsorbates and the catalytic substrates that determine many of the important steps. Ultrafast pump (optical lasers) and probe (FEL-XES, XPS) experiments can be used to identify short lived reaction intermediates, inaccessible to a more conventional and static XES and XPS. From detailed knowledge of the electronic structure, how the electrons flowed between the substrate and reactants can be derived and related to changes in the nuclear coordinates.

Collaborations

PULSE has a very large number of active collaborations.

- PULSE contributor: Y. Acremann;
  Title: *Magnetic Imaging*;
  Collaboration partners and institutions: Olaf Henrik, Hitachi, Steffan Eisebitt, DESY
- PULSE contributor: A. R. Nielsson;
  Collaboration partners and institutions: Prof. Lars G.M Pettersson, Stockholm University, Sweden; Dr. Michael Odelius, Stockholm University, Sweden, Prof. Lars Ojamäe, Linköping University, Sweden; Prof. Shik Shin, Tokyo University, Japan, Dr. Yoshi Harada, Spring 8, Japan; Dr. Osamu Takahashi, Hiroshima University, Japan
- PULSE contributors: Y. Acremann, H.C. Siegmann, J. Stöhr;
  Title: *Transformation of a Metal into an Insulator: Breakdown of Ohm's Law in High Electric Fields*;
  Collaboration partners and institutions: S. J. Gamble, Mark H. Burkhardt, SLAC, Stanford University, and Department of Applied Physics, Stanford University,; Walter A. Harrison, Department of Applied Physics,; A.B. Kashuba, Landau Institute for Theoretical Physics; Rolf Allenspach, IBM Research, Zurich Research Laboratory; Stuart S. P. Parkin, IBM Almaden Research Center.
- PULSE contributors: Y. Acremann, H.C. Siegmann, J. Stöhr;
  Title: *Ultrafast High Resolution Magnetic Microscopy*;
  Collaboration partners and institutions: J. Katine, M.J. Ceary, Hitachi Global Storage, San Jose; T. Tylisczczak, ALB Berkeley

- PULSE contributors: A. Nilsson, A. Lindenberg, K. Gaffney, Y. Acremann, A. Scherz, J. Stöhr,
  Title: *Probing Matter with High Fluence X-Ray Pulses*;
  Collaboration partners and institutions: FLASH facility, Hamburg, Germany
- PULSE contributor: K.J. Gaffney;
  Title: *Electron Transfer Dynamics in Organometallic Compounds*;
  Collaboration partners and institutions: U. Bergmann, SSRL; Shin-Ichi Ohkoshi, University of Tokyo.
- PULSE contributors: Markus Gühr, Brian McFarland, Joseph Farrell, Philip Bucksbaum;
  Title: *Nonadiabatic Molecular Dynamics in Molecular High Harmonic Generation*;
  Collaboration partners and institutions: Olga Smirnova, Serguei Patchkovskii, Misha Ivanov, Steacie Institute for Molecular Sciences National Research Council of Canada.
- PULSE contributors: Markus Gühr, Brian McFarland, Joseph Farrell, Philip Bucksbaum;
  Title: *High Harmonic Phase Measurements*;
  Collaboration partners and institutions: Hamed Merdji, Pascal Salieres, CEA-Saclay
- PULSE contributors: Markus Gühr;
  Title: *Coherent Dynamics of Small Molecules in Solid State Environment*;
  Collaboration partners and institutions: Heide Ibrahim, Nikolaus Schwentner, Institut für Experimentalphysik, Freie Universität Berlin; Matias Bargheer, Institut für Physik, Universität Potsdam; Mizuho Fushitani, Institute for Molecular Science, Japan.
- PULSE contributors: A.M. Lindenberg, K. Gaffney, P.H. Bucksbaum;
  Title: *Real-Time Measurements of Fluctuations in the Structure of a Liquid*;
  Collaboration partners and institutions: S. Engemann, P.B. Hillyard, D.M. Fritz, J. Arthur, R.A. Akre, M. J. George, A. Deb, J. Hajdu, D.A. Meyer, P. Krejcik, J.B. Hastings, SLAC; K. Sokolowski-Tinten, M. Nicoul, Institut fur Experimentelle Physik, Universität Duisburg-Essen; C. Blome, Th. Tschentscher, Deutsches Elektronen-Synchrotron DESY; A.L. Cavalieri, Max-Planck-Institute of Quantum Optics; R.W. Falcone, Department of Physics, University of California, Berkeley; D.A. Reis, FOCUS Center, Departments of Physics and Applied Physics, University of Michigan; S.H. Lee, Length/Time Metrology Group, Korea Research Institute of Standards and Science; J. Rudati, Advanced Photon Source, ANL; R. Pahl, Center for Advanced Radiation Sources, The University of Chicago; P. Fuoss, Material Science Division, ANL; A. Nelson, LLNL; D. Siddons, NSLS; P. Lorazo, Departement de Genie Physique, Ecole Polytechnique de Montreal; Jorgen Larsson, Lund Institute of Technology.
- PULSE Contributors: A.M. Lindenberg, H. Wen;
  Title: *Strong-Field THz Control of Carrier Dynamics in Semiconductors*;
  Collaboration partners and institutions: M. Wiczer, Physics Dept., University of Illinois
- PULSE Contributors: A.M. Lindenberg, H. Wen;
  Title: *Ultrafast soft x-ray measurements of bond-breaking in liquid water*;
  Collaboration partners and institutions: R.W. Schoenlein, N. Huse, P.A. Heimann, R.W. Falcone, ALS, LBNL.
- PULSE contributor: Phil Bucksbaum;
  Title: *Understanding Control of Isomerization in Bacteriorhodopsin*;
  Collaboration partners and institutions: David Cardoza, James L. White, Department of Physics, Stanford University; Andrei Florean, Prof. Roseanne Sension, University of Michigan; Prof. Janos Lanyi, University of California, Irvine
- PULSE contributor: Keith O. Hodgson, Sébastien Boutet, Janos Hajdu;
  Title: *Femtosecond Diffractive Imaging with a Soft-X-ray Free-electron Laser*;
  Collaboration partners and institutions: Henry N. Chapman, Anton Barty, Michael J. Bogan, Matthias Frank, Stefan P. Hau-Riege, Stefano Marchesini, Bruce W. Woods, Sascarona Bajt, W. Henry Benner, Richard A. London, Richard W. Lee, Abraham Szöke, University of California, LLNL; Henry N. Chapman, Stefano Marchesini, Richard A.

London, David A. Shapiro, Center for Biophotonics Science and Technology, University of California, Davis; David van der Spoel, Florian Burmeister, Magnus Bergh, Carl Caleman, Gösta Huldt, Marvin Seibert, Filipe R. N. C. Maia, Richard W. Lee, Abraham Szöke, Nicusor Timneanu, Laboratory of Molecular Biophysics, Department of Cell and Molecular Biology, Uppsala University; Elke Plönjes, Marion Kuhlmann, Rolf Treusch, Stefan Düsterer, Thomas Tschentscher, Jochen R. Schneider, DESY, Eberhard Spiller, Spiller X-ray Optics, Livermore, California ; Thomas Möller, Christoph Bostedt, Matthias Hoener, Institut für Optik und Atomare Physik, Technische Universität Berlin.

NOTEWORTHY PRACTICES

Ultrafast Summer School

This summer school provided an important means by which PULSE can provide leadership in future scientific directions associated with ultrafast science.

High Harmonics

We concentrate on the relation between the electronic orbitals of the molecules and the emitted high harmonic amplitude and phase, for which we established novel measurement schemes with a reference radiator. The information can be used to image the molecular orbitals.

CEP

We would like to invest more energy in the future to gain more control over the pulse shape on one hand, and create single attosecond pulses instead of a train on the other hand. We plan to attack the first aim by writing specific electronic, vibrational and rotational coherence on the molecule by visible and UV light that can all be used to control the attosecond pulse shape. The second approach can be achieved by using few cycle pulses and combining them with spectral selection in the attosecond pulse spectrum or by use of polarization gating in the generation process. The attosecond science will also have a tremendous impact on LCLS research, as stated above. The production of CEP locked pulses in the few cycle regimes is necessary to produce well defined pulses below 1 fs from LCLS. We are training people in this lab on technological and scientific issues of attosecond science before LCLS has started to run.

Magnetic Nanostructures

Recently we found a way to numerically simulate the possible switching processes and mapped the simulations to experimental data. This leads to a unified picture of magnetization reversal by spin injection. The different nonuniform states can be described by magnetic vortex cores that are either real inside the samples or virtual outside the sample. The motion of these vortex cores describes the switching mechanism and switching dynamics. Analytic calculations show that magnetization reversal by spin injection amplifies magnetic nonuniformities.

OPPORTUNITIES FOR IMPROVEMENT

Attoscience

Almost all experiments so far used the attosecond streak camera idea: electrons are emitted by an attosecond pulse and gain kinetic energy in an overlapped strong IR field. The electron energy can be correlated to their time of birth, and such a time trace of electron emission can be constructed. The technique is applicable to diluted gases and surfaces only. It will therefore be important for the future of attoscience to get a broader range of experimental schemes.

High Harmonics

In the future we will work on more complicated molecules that can undergo a prototype chemical process in passing a CI between different electronic states. High harmonic imaging will be an ideal tool to follow very fast changes in the electronic orbitals. In all those studies, we are already generating trains of attosecond pulses, and since they are generated in molecules, they are shaped in amplitude and phase.

CEP

It remains challenging to deduce from the spectral range in the attosecond lab, which is in the extreme UV to LCLS's hard x-ray pulses.

Magnetic Nanostructures

The same group of PULSE researchers also planned experiments on FLASH, which are intended be carried out in collaboration with other FLASH users. The experiments investigate the effect of the x-ray beam on materials and take advantage of the unique peak power of the x-ray beam. In addition, these experiments are relevant to explore nonlinear effects at high peak fluences. We believe that these experiments are very important for future experiments at FELs. We are currently preparing an experiment to investigate the influence of the x-ray pulse intensity on x-ray spectra measured in absorption or fluorescence. The high peak intensity of X-ray FELs can have a dramatic influence on the electronic structure of the sample. As electron dynamics involves processes on the femtosecond time scale, it is expected that the x-ray probe pulse itself leads to modification of a measured x-ray absorption and fluorescence spectrum. It is essential for all FEL based experiments to test the limits of the nonperturbative probe regime.

Resonant X-ray Scattering

FLASH is the first soft x-ray free electron laser in the world with each x-ray laser pulse possessing 50 μJ of transversely coherent x-ray energy in a roughly 10 fs pulse duration. The combination of ionizing photon energies and ultrashort pulse duration makes the FLASH ideally suited to investigate the perturbative effects of ionizing radiation, as well as the ability to probe the effects of photo-ionization with x-ray spectroscopy and optical probing. We will use FLASH's ultra-short x-ray pulse to initiate and then use both the FLASH x-ray pulse and optical laser sources to monitor the radiolysis process in liquids.

Catalysis

Knowledge of the time-dependent evolution of reactants, products and intermediates will allow for the construction of detailed kinetic models and estimations of the various activation barriers in catalytic reactions.

Objective 1.4 Provide for Effective Delivery of Science and Technology

PULSE research output: number of publications (26), number of invited talks (48), and the sponsored research totals (approximately $2M).

Bucksbaum Lab: We successfully commissioned several labs during the last FY. On the Stanford campus, the Bucksbaum labs are headed by David Cardoza (coherent control) and Markus Guehr (HHG/Attosecond). Both labs are prototypes for the new PULSE labs in SLAC Building 40. Their commissioning was accomplished on schedule. Planning started summer 2006 and first construction activities started at the end of 2006.

Gaffney Lab: We have made significant progress on the commissioning of an ultrafast spectroscopy laboratory under direction of K. Gaffney at SLAC. The construction of the building finished in the fall of 2006, the laser safety hardware was installed in winter of 2007, and we had a laser safety Standard Operations Procedures approved by the laser safety officer in March 2007. We have since commissioned our regenerative amplified femtosecond Ti:sapphire laser system, as well as three optical parametric amplifiers (OPA). We are currently commissioning three separate experimental set-ups.

Collaborations

Numerous collaborations leverage the capabilities of SLAC facilities and other labs, such as:

- With the ALS at LBNL for the x-ray microscopy experiments, as well as collaboration with Hitachi Global Storage Technology for the sample preparation.
- Research on materials under extreme conditions during the electron beam of the SLAC

linear accelerator is only possible by leveraging the existing linear accelerator to generate the extreme magnetic fields as well as collaborations with IBM for sample preparation and magnetic imaging.

- Several PULSE experiments use the FEL in Hamburg and therefore provide a unique way for SLAC to explore science that will not be accessible before LCLS is in operation. These results will be very important to plan future experiments at LCLS and will save time and resources in future projects at LCLS.

Noteworthy Practices

Bucksbaum Lab

These labs are equipped for the specific research in AMO science, and are prototypical for a laser lab. For the HHG/Attosecond lab, the requirements on acoustical insulation were very high to facilitate interferometric experiments with very short wavelengths. Therefore, separate closets for the vacuum roughing pumps with an isolated cooling air handling system were created. The laser power supplies and chillers were placed in a commercially available server cooling rack. The rack damps the noise from the supplies and dissipates their heat by cooling them with a built in fan-heat exchanger unit that uses the lab cooling water circuit. The table overhead structure was installed to follow exactly the laser table shape. Flow boxes were installed on top of the table to keep the optical equipment clean for long times. Whereas the PULSE lab already had a laser that gained great stability because of the noise and thermal drift reductions, the new lab was equipped with a laser system, nonlinear optics and pulse shaping devices for coherent control. The PULSE lab is equipped with a versatile HHG vacuum chamber and an extreme EUV spectrometer. The apparatus has been optimally tuned and has produced experimental results before and after the remodeling of the lab.

The coherent control lab purchased an amplified femtosecond laser system (Thales), which arrived in April 2007, was used to pump a home-built Noncollinear Optical Parametric Amplifier (NOPA). The NOPA pulses are shaped in an AMO pulse shaper to control prototypical biosystems like bacteriorhodopsin. The whole optical setup operated after only a few weeks and first data are already available from this lab.

The HHG/Attosecond laboratory received the vacuum ultraviolet (VUV) spectrometer in November 2006. First HHG spectra were taken in December 2006, but the lab work stopped until April 2007 because of the renovations. After lab renovation, a pump-probe setup was used to probe the alignment of molecules during HHG. Furthermore, interferometric measurements were realized proving the noise reduction of the lab. Currently, the High Harmonic phase is measured in this lab, using a reference oscillator. This will give insight in the attosecond pulse shaping possibilities as well as the generation mechanism of the harmonics in molecules.

A laser lab in SLAC Building 130 has provided experience with a custom-built laser system. With safety procedures and requirements in mind, we have implemented retrofits for older equipment that brings their safety up to the high standards of the DOE and SLAC.

Gaffney Lab

A pump-probe configuration with an OPA for tuning the frequency of the pump pulse and a white light probe for observing transient changes in the absorption spectrum of materials. These transients will be detected with a monochromator and CCD camera. A 512 element InGaAs diode array detects transients in the near-IR.

A four wave mixing set-up was designed to conduct transient grating and photon echo experiments. The set-up will use diffractive optics for wavelengths ranging from 800 nm to 400 nm, using the output of the same OPA used for the pump-probe set-up.

A multidimensional vibrational spectroscopy set-up will allow us to conduct a wide area of time resolved vibrational spectroscopy measurements, including pump-probe and heterodyne detected photo-echo experiments. We have a 32X2 element HgCdTe diode array for simultaneous measurement of the vibrational spectrum.

We anticipate first experiments will be conducted in the fall of 2007.

D ▪ XLAM

The XLAM goal is to conduct research directed towards the understanding of matter (primarily condensed matter) using synchrotron radiation as well as complementary techniques and instrumentation. The program includes material synthesis and characterization, theoretical and computational support, further development of synchrotron radiation sources, and ultrafast science.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

Spectroscopy and Scattering Study of Complex Materials (Shen, Greven): Shen's group has made two important discoveries in high-Tc superconductors. The first is the anomalous Fermi surface dependent pairing where they found that the superconducting gap in a multilayer compound exhibits a strong dependence on the Fermi surface sheet [Chen et al., **Phys. Rev. Lett. 97**, 236401 (2006)]. The second is the discovery of distinct Fermi-momentum dependent energy gaps in deeply under doped Bi2212 [Tanaka et al., **Science, 314**, 1910 (2006)]. The Shen group also developed better ways to record and analyze Angle-Resolved PhotoEmission Spectroscropy (ARPES) data from complex oxides. A related effort is the understanding of cuprate electronic structure over a broader energy range, where a hierarchy of several energy scales is identified [Meevasana et al., **Phys. Rev. B 7**5, 174506 (2007)]. This group has also developed ARPES experiments using low photon energy synchrotron or laser beam as excitation sources. We expect significant improvements in angular resolution with this approach. The initial focus has been on the nodal quasiparticles in cuprates, whose dynamics are hard to study but can be much better resolved using this approach [Yamasaki et al., **Phys. Rev. B 75**, 140513(2007)].

Novel Materials and Model Systems for the Study of Correlated Phenomena (I. R. Fisher, M. R. Beasley, T. H. Geballe): In the area of negative-U impurities, a multistep synthesis route was developed to produce high-quality single crystals of the unusual superconductor (Pb1-xTlx)Te, and have worked on detailed measurements to characterize the thermodynamic, transport and spectroscopic properties of these samples. Our work has inspired several theoretical studies, and a large number of collaborative experimental investigations. In particular, collaborative projects exploring the optical conductivity (L. DeGiorgi et al., ETHZ, Switzerland) indicate a hidden 1-dimensionality to these materials – for the most part a direct consequence of the weak hybridization between px and py bands in the Te planes comprising the crystal structure [**Phys. Rev. B. 74**, 125115 (2006).) . Additional experiments probing the effect of external pressure confirm the role of chemical pressure in this system [A. Sacchetti, et al., **Phys. Rev. Lett. 98**, 026401 (2007)]. The goals of the novel oxide materials and systems program are to synthesize model systems to study nanoscale electronic inhomogeneities that result from coulomb interactions in correlated electronic materials, and ultimately to study these inhomogeneities using scanning probes. In the area of superconductivity and magnetism, we also continue to deposit and study thin films of $SrRuO_3$, a rare example of a 4d itinerant ferromagnet, and of $CaRuO_3$, which oddly is a only a paramagnet. With the group of Lior Klein, we are examining the magnetotransport in these materials. We have also been studying various physical properties of the films [**Phys. Rev. B** 378-380, 490 (2006) and **Phys. Rev. B 73**, 85109 (2006)]. Perhaps more interestingly, we find that the role of nonstoichiometry in these materials is nontrivial. Specifically, the introduction of Sr deficiency in $SrRuO_3$ leads to changes in the electronic density of states in a way that suggests that the degree of correlation in the material is changing, which may have significant impact on the theoretical picture of these materials.

Theory of Condensed Matter (S. Kivelson, R. Laughlin and S. Zhang): Zhang has: (1) Predicted the Pair Density Wave (PDW) state, a charge-ordered state of Cooper pairs, and argued that it is seen scanning tunneling microscope measurements of under doped high-T_c cuprates. His group identified the key signature of this state to be a Fourier-transformed local density of states that is an even function of the bias energy; (2) Proposed a way to eliminate spin decay in semiconductors due to spin-orbit coupling, in the process discovering a new type of SU(2) spin rotation symmetry. Both the theory and the experimental papers have been published in **Phys. Rev. Lett.**; (3) Predicted a new topological quantum phase transition between a conventional insulator and a Quantum Spin Hall state. The latter is characterized by a single pair of helical edge states. The group proposed to look for this effect in HgTe/CdTe semiconductor quantum wells. This paper has been published in **Science**.

Using Local Probes for the Study of Nanoscale Phenomena in Complex Materials (A. Kapitulnik, H. Manoharan, K.A. Moler): In magneto optics, the Polar Kerr effect (PKE) in the spin-triplet superconductor Sr_2RuO_4 was measured with high precision using a Sagnac interferometer with a zero-area Sagnac loop. This material is presently of wide interest to the theory community as both an unconventional superconductor and a candidate material for quantum computation. PKE is sensitive to time reversal symmetry (TRS) breaking since it measures the existence of an antisymmetric contribution to the real and imaginary parts of the frequency-dependent dielectric tensor. Our results imply a broken time reversal symmetry state in the superconducting state Sr_2RuO_4. While our experiment determines that TRS is broken, coupled with other experiments it is strong evidence in favor of p+ip order parameter. **Physics Today** and **Science** featured the results. In Magnetic Imaging, a He-3 based scanning Hall probe microscope with a new generation of Hall probes with 100 nm spatial resolution was developed. An instrumentation paper on this topic was submitted to **Applied Physics Letters**. In High Resolution STM Studies, we observed the propagation of localized phonon modes through a 2D electron gas on the surface of Cu(111) by using molecular impurities, atomic manipulation, and inelastic tunneling spectroscopy. In addition, inelastic tunneling measurements were performed on diamondoid solids to look for vibrational structure. Mapping of electronic structure of diamondoid monolayers as a function of molecule packing arrangement was completed. In the area of scanning tunneling spectroscopy (STS) on ordered electronic structures, we used STS to study the unidirectional CDW system $TbTe_3$. Using large area scans in a wide range of bias-voltage, a previous ambiguity was resolved regarding the size of the CDW wave-vector. Evidence was shown of the fully incommensurate nature of the CDW. Topographic data at different bias-voltage highlight two spontaneous symmetry-breaking effects in breaking the lattice point group symmetry by forming the 1D CDW, and the effect of dimerization, both demonstrated in real space for the first time.

Behavior of Charges, Excitons and Plasmons at Organic/Inorganic Interfaces (M. D. McGehee, N. Melosh, M. Brongersma): As electronic device dimensions shrink to nanometer scales and the range of desirable applications grows, two trends are emerging. First, the range of materials under serious development is growing and many device structures consist of both organic and inorganic building blocks. Second, many physical phenomena that were heretofore only observed within academic experiments are becoming important for technologically relevant devices. Consequently, many technical issues need to be solved before these new possibilities become technologically viable. These include reproducible device performance on this length scale, sample heterogeneity, interface state control, defect properties, thermal transport and surface roughness. In addition, physical phenomena such as electron tunneling, Förster coupling, and plasmon-excitation quenching begin to severely impact device behavior at length scales less than 10 nm. This is particularly true within the emerging subset of structures that utilize both organic and inorganic materials, such as solar cells, electronic paper, molecular electronics, and organic light emitting displays. Our team has identified the need to understand excited state behavior within organic species close to inorganic surfaces as a key problem for future applications of these materials.

Excited state phenomena within organic materials are often complicated by the multiple length scales, morphology, multiple competing decay processes, and inorganic surface interactions that affect the overall behavior of the system. Current studies of realistic devices are complicated by simultaneous excitation decay via a number of different processes within different regions of the sample. These decay processes, in which the charge or energy of an excited state in a molecule is transferred to an adjacent metal electrode, depend strongly upon the molecule to metal spacing.

Development and Mechanistic Characterization of Alloy Fuel Cell Catalysts (A. Nilsson): This research program investigates mechanistic aspects of fuel cell catalysis on metal surfaces. A challenge for the Hydrogen Fuel Initiative is to develop cost efficient electrocatalysts with high durability for the next generation of fuel cells. Synchrotron radiation based x-ray diffraction and spectroscopy methods are needed that allow *in-situ* probing of the intermediates in the catalytic cathode process where both species identification, geometric and electronic structure properties are fully characterized. In parallel to the fundamental synchrotron work, theory-guided combinatorial synthesis and high throughput electrochemical screening methodologies for fuel cell cathode catalysts will be developed and applied to link mechanistic hypotheses and catalyst testing under realistic conditions in high dimensional compositional and process parameter spaces.

Magnetic Materials Research (J. Stöhr): New techniques and approaches are developed to study magnetic and correlated materials in the form of thin films, multilayers and nanostructures and explore the origin of magnetic phenomena associated with such materials. A new effort has been started to use coherent x-ray imaging to understand the spin, orbital and charge orderings and their spatial and temporal correlations across phase transitions in strongly correlated electron systems. Transition metal oxides like manganites and cuprates exhibit phase transitions with intrinsically inhomogeneous phases due to the coexistence of several isoenergetic competing ground states with differing charge, spin and orbital degrees of freedom. Our goal is to investigate a spatiotemporal phase space that has remained unexplored so far. X-rays are unique in that they allow the observation of nanoscale orbital and spin textures and their dynamics on time scales down to microseconds. Other nanoscale imaging techniques are unable to explore dynamic processes down into the microsecond regime so that fluctuating phases would simply remain hidden in time-averaged measurements.

Awards

Brongersma, Mark

- Stanford University Gores Award for Excellence in Teaching

Manoharan, Hari

- A. J. Kumar Award
- Firestone Medal

McGehee, Michael

- Materials Research Society Outstanding Young Investigator Award (2007)

Publications

In addition to 94 invited talks listed in the Publications Appendix, XLAM scientists also published 73 other papers in 2007. See the Publications Appendix for details.

NOTEWORTHY PRACTICES

Coupling to Stanford University

XLAM has enhanced the coupling between SLAC and Stanford University. It has brought Stanford's human resources to the DOE mission and has brought DOE opportunities to Stanford.

OPPORTUNITIES FOR IMPROVEMENT

As the XLAM grows, there will be opportunities for increased coupling between Stanford University researchers and SLAC. Such opportunities include the possibility of starting a SLAC/Stanford initiative on sciences related to the DOE core mission in energy, environment, and technology as well as developing large scale instrumentation and new scientific tools, such as detectors or computational tools.

Objective 1.2 Leadership in Science and Technology

XLAM faculty members are leaders in the scientific community as illustrated by the list of advisory committees in which they participate.

Beasley, Malcolm

- Program Review Committee of the Solid State Sciences Division of ORNL

Goldhaber-Gordon, David

- Review Committee for Center for Nanophase Materials Sciences, ORNL

Kapitulnik, Aharon

- Member of Executive Committee of Division of Condensed Matter Physics, APS
- Member of NSF review panel on Gravitational physics

Nilsson, Anders

- Member of the review panel in Catalysis for the President's Hydrogen Fuel Initiative, 2007

Stöhr, Jo

- Scientific Advisory Committee, APS, ANL
- Scientific Advisory Committee, Center for Nanophase Materials Sciences, ORNL

Research being performed at XLAM has set the standard in a number of fields including the research of (1) Z.-X. Shen in the area of correlated materials in which ultra-high energy and angle resolved photoemission is being pioneered to study the electronic structure of novel materials; (2) I. R. Fisher, M. R. Beasley, and T. H. Geballe in the growth of novel materials for the study of correlated systems; (3) S. Kivelson, R. Laughlin and S. Zhang for theory of condensed matter; (4) A. Kapitulnik, H. Manoharan, K.A. Moler in the area of using local probes for the study of nanoscale phenomena in complex materials; (5) M.D. McGehee, N. Melosh, M. Brongersma for study of the behavior of charges, excitons and plasmons at organic/inorganic interfaces; (6) A. Nilsson for the development and mechanistic characterization of alloy fuel cell catalysts; and (7) J. Stöhr for magnetic materials research. In addition, XLAM staff has participated in organizing workshops in cooperation with both SSRL and the ALS.

XLAM has a very large number of active collaborations, as described below.

- XLAM faculty member: Z.-X. Shen
  Title: *Spectroscopy & Scattering Study of Complex Materials*
  Collaborators: D. Basov (UCSD), Bontemps (ESPCI, France), P. Bourges (LLB, France), F. Briges (UCSC), S.E. Brown (UCLA), D. Casa (APS), T. Gog (APS), S. Grenier (BNL), K. Ishii (SPring-8, Japan), Y.J. Kim (Toronto), M.V. Klein (UIUC), D. van der Marel (Geneva, Switzerland), J. Mizuki (SPring-8, Japan), N.P. Ong (Princeton), D. Petitgrand (LLB, France), M. Rubenhausen (Hamburg, Germany), Y. Uemura (Columbia University), O.P. Vajk (Missouri), N. Nagaosa (Univ. Tokyo), F. Ronning (LANL), K.M. Shen (UBC), N.P. Armitage (Johns Hopkins), A. Damascelli (UBC), L.L. Miller (Ames), C. Kim (Yonsei), B. Wannberg (Scienta), V. Brouet (U. of Pairs), D. Dessau (U. of Colorado), Z. Hussain (LBNL), Junren Shi (ORNL), T. Yoshida (U. of Tokyo), Yoichi Ando (Criepi, Japan), Z.X. Zhao (IOP, Beijing), T. Sasagawa (U. of Tokyo), H. Eisaki (AIST, Japan), S. Uchida (U. of Tokyo), A. Fujimori (U. of Tokyo), Zhengyu Zhang (ORNL), E.W. Plummer (ORNL), R.B. Laughlin (Stanford), J. Osterwalder (Zurich), N.J.C. Ingle (UBC), I.R. Fisher (Stanford), J.F. Mitchell (ANL), J. Zaanen (Leiden), A. Ino (Hiroshima), O. Rosch (MPI Stuttgart), O. Gunnarsson (MPI Stuttgart), W.H. Xie (MPI Stuttgart), O. Jepsen (MPI Stuttgart), O.K. Andersen (MPI Stuttgart), C.T. Lin (MPI Stuttgart), A. Lanzara (Berkeley), D.L. Feng (Fudan U.), D.v.d. Marel (U. of Geneva), A.P. Mackenzie (St. Andrews), S. Danzenbacher (U. of Dresden), S.L. Molodtsov (Dresden), T. Tohyama (Tohoku U.), S. Maekawa (Tohoku), Akira Iyo (AIST, Japan), T. Fujii (Waseda U.), I. Terasaki (Waseda U.), D.J. Scalapino (UCSB), R.S. Markiewicz (Northeastern), A. Bansil

(Northeastern), M. Taniguchi (Hiroshima U.), Seiki Komiya (Criepi, Japan), M. Takano (Kyoto U.), H. Takagi (U. of Tokyo), J.i. Shimoyama (U. of Tokyo).

- XLAM faculty members: I. R. Fisher, M. R. Beasley, and T. H. Geballe
  Title: *Novel Materials and Model Systems for the Study of Correlated Phenomena*
  Collaborators: L. Balicas (NHMFL, Tallahassee), D. Basov (UCSD), D. Blank (Twente University, Netherlands), F. Bridges (UCSC), V. Brouet (U. Paris Sud, France), S. Brown (UCLA), D. Casa (APS, ANL), K. Char (Seoul University, Korea), L. DiGiorgi (ETH Zürich, Switzerland), S. Dugdale (Bristol University, UK), E. M. Forgan (Birmingham, UK), T. Gog (APS), C. Gough (Birmingham, UK), S. Grenier (Rutgers State University and Brookhaven), W.A. Harrison (Stanford), Z. Islam (APS, ANL), Y.J. Kim (Toronto),L. Klein (Bar Elan University, Israel), M.V. Klein (Urbana), J. Krystek (NHMFL, Tallahassee), G. Lukovsky, North Carolina State), A. Mackenzie (St Andrews, UK), J. Reiner (Yale), S. Reymond (Lausanne), Z. Schlesinger (UCSC), J. Schmalian (Ames Lab), M. Toney (SSRL).
- XLAM faculty members: S. Kivelson, R. Laughlin and S. Zhang
  Title: *Condensed Matter Theory*
  Collaborators: E. Arrigoni (Graz), P. Dai (Oakridge), Eduardo Fradkin (UIUC), L. Molenkamp (Wuerzburg).
- XLAM faculty members: A. Kapitulnik, H. Manoharan, K.A. Moler
  Title: *Using local probes for the study of nano-scale phenomena in complex materials*
  Collaborators: K. Kishio, J. Shimoyama, H. Eisaki, A. Fujimori (University of Tokyo), Y. Maeno (Kyoto University), I. Fisher, M. Greven, M.R. Beasley, T.H. Geballe, R.B. Laughlin, S. Doniach, S. Kivelson, S.C. Zhang (Stanford University), A. Heinrich, C.P. Lutz, D.M. Eigler (IBM Almaden), E. Heller (Harvard University), S. Kivelson (Stanford), Eduardo Fradkin (UIUC), P.C.E. Stamp (UBC) and G. Fiete (UCSB), D.J. Scalapino (UCSB).
- XLAM faculty members: M.D. McGehee, N. Melosh, M. Brongersma
  Title: *Study of the Behavior of Charges, Excitons and Plasmons at Organic/Inorganic Interfaces*
  Collaborators: F. Stoddart (University of California Los Angeles), M. Toney (SSRL), J. Anthony (University of Kentucky).
- XLAM faculty member: A. Nilsson
  Title: *Development and Mechanistic Characterization of Alloy Fuel Cell Catalysts*
  Collaborators: H. Ogasawara, P. Strasser, M. Toney, L. Pettersson (Stockholm University, Sweden), J. Nørskov (Danish Technical University, Denmark), B. Ingham (SSRL), P. Strasser (University of Houston).
- XLAM faculty member: J. Stöhr;
  Title*: Magnetism Research*;
  Collaborators: T. Tylisczak (ALS), J. Katine (Hitachi Global Storage Systems), H. Ohldag, D. Bernstein, S. Sarkar, M. Burkhardt, Y. Acremann and H. Siegmann.

NOTEWORTHY PRACTICES

Spectroscopy and Scattering Study of Complex Materials

Collaborating with SSRL to create new capabilities for ultra-high-resolution photoelectron spectroscopy studies of correlated materials that has expanded the user community for BL5 and will lead the way to even more advanced capabilities.

Using Local Probes for the Study of Nanoscale Phenomena in Complex Materials

Development of a He-3 based scanning Hall probe microscope with a new generation of Hall probes with 100 nm spatial resolution and development of a Sagnac interferometer with a zero-area Sagnac loop.

OPPORTUNITIES FOR IMPROVEMENT

Spectroscopy and Scattering Study of Complex Materials

Higher capabilities in ultra-high resolution photoelectron spectroscopy of complex materials will be realized by upgrading BL5 with a new undulator and monochromator to allow higher energies to be reached.

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

XLAM's research output can be measured in the number of publications and invited talks by faculty and staff. As of this writing, there were 94 publications in 2007 and 73 invited talks by XLAM faculty and staff.

Objective 1.4 Provide for Effective Delivery of Science and Technology

As indicated above, a significant number of new instruments were developed and discoveries made in FY07. The capabilities of XLAM can also be seen through the large number of collaborations, indicating that scientists from all over the world look to XLAM for both measurement and synthesis capabilities.

NOTEWORTHY PRACTICES

Spectroscopy and Scattering Study of Complex Materials

The high level of performance in both the SSRL-based and laboratory-based instruments that are part of this effort has brought collaborators to the project and new users to SSRL.

HEP

E ▪ PEP-II

The PEP-II program provides data to the *BABAR* detector collaboration and carries out accelerator physics for High Luminosity Colliders. Many accelerator and *BABAR* publications arose from the PEP-II accelerator work.

Conceptual Design Reports

- PEP-II Staff, et al, "SuperB: A High Luminosity Asymmetric e^+e^- Super Flavour Factory," SLAC PUB R-856, March 2007.

PEP-II accelerator papers (See the Publications Appendix)

- Three invited at PAC 2007
- Other contributed accelerator physics papers: 18.

The PEP-II accelerator staff also contributed to several successful program and technology reviews throughout the DOE complex and throughout the world, as listed below.

- J. Seeman, Lehman Review of NSLS-II, Brookhaven, New York, December 2006
- J. Seeman, KEKB Accelerator Review Committee, Tsukuba, Japan, February 2007
- J. Seeman, Committee of Visitors Review, Office of High Energy Physics (OHEP), Germantown, Maryland, June 2007
- J. Seeman, Directors Review of ERL@CESR, Cornell, New York, August 2007
- J. Seeman, International Linear Collider (ILC) Machine Review Committee, Manchester, England, January 2007
- J. Seeman, ILC Machine Review Committee, Fermi National Accelerator Laboratory (FNAL), Illinois, April 2007
- U. Wienands, Project Review of NSLS-II, Brookhaven, New York, September 2007
- A. Fisher, Review of the LHC Accelerator Research Program (LARP) Luminosity Monitor, LBNL, Berkeley, California, August 2007

F ▪ *BABAR* at PEP-II

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

The *BABAR* experiment investigates the origin of charge parity (*CP*) symmetry breaking in elementary constituents of matter which relates to the origin of the imbalance of matter and antimatter in the universe. This phenomenon is a key element of DOE's science mission. The experiment has made enormous strides including establishing the first evidence for *CP* symmetry breaking in decays of *B* mesons. *BABAR* results, and those from Japan's *B* Factory Belle experiment, have now established that the Standard Model is the main source of observed *CP* violation effects. New *CP* breaking effects beyond the Standard Model must explain the matter / antimatter asymmetry in nature. *BABAR* aims to perform precision measurements of a range of processes sensitive to the effects of New Physics and may shed light on this fundamental question. The *BABAR* B physics program encompasses three main goals: (1) study of *CP* violation in *B* meson decays and tests of the CKM paradigm through measurement of a complete set of *CP*-violating asymmetries and *CP* conserving observables in *B* meson decays; (2) the effects of physics beyond the Standard Model, through exploration of rare decay processes; and (3) studies to elucidate dynamics of processes involving heavy quarks. Goals (1) and (2) test the Standard Model, measure its parameters, and search for effects of new physics, while Goal (3) is designed to elucidate the interplay between electroweak and strong interactions in heavy-quark processes. The physics reach of the experiment includes topics in charmed hadron physics, tau lepton decays, and strong interaction effects. Measurements thus far have yielded the first observation of particle antiparticle oscillation in the charmed system (D^0 mixing), observation of new charmed mesons states, and new resonances that indicate existence of exotic states of quantum chromo-dynamics (QCD).

The *BABAR* experiment continues to provide physics results with significant impact on the field.

- Articles in refereed journals: 77
- Invited talks by *BABAR* collaborators: 151
- New physics results presented at major conferences: 80
- Citations to *BABAR* papers: 1,483

Since 1999, the collaboration has published 314 articles in refereed journals and currently publishes about 1.4 journal articles each week. *BABAR*'s discovery of D^0 mixing was extensively covered by various science journals and a number of on-line science forums.

In FY07, the muon identification system upgrade was completed, followed by the January 2007start of Run 6. Run 6 ended on September 3, 2007, yielding an integrated luminosity of 87/fb of data. Data collection efficiency remained at approximately 97%, the highest efficiency of any previous high energy physics experiment. The combined Run 1-6 data set corresponds to an integrated luminosity of 487/fb.

Highlights of *BABAR*'s most important physics results follow.

Observation of D^0 Mixing: A significant finding by *BABAR* in FY07 was first observation of D^0 mixing, a process highly sensitive to the effects of physics beyond the Standard Model. This result is highly cited, and stimulated many theoretical papers on its implications for models of New Physics. The observation, confirmed by the Belle experiment, was a major physics result discussed at the 2007 winter and summer conferences. Major conferences devoted special "Hot Topic" invited talks to the D^0 mixing observation.

Tests of the CKM Paradigm: A major goal of *BABAR* has been to test the CKM paradigm by over-constraining the CKM unitarity triangle. A complete set of measurements is required of the three angles (α, β and γ) and the sides of the unitarity triangle. As the available data sample increases, it has now become possible to determine the angles α and γ. *BABAR* continued to extract more information from its data that relate to this goal. Among key measurements are:

- A more precise measurements of *CP* violation in B decays to double-charm final states B→DD(bar),
- The time-dependent *CP* violation in the decay B→$\rho^0\rho^0$,
- The semileptonic branching fractions in B decays.

The *CP* violation measurements in the decays B→DD are consistent with the Standard Model and rule out large direct *CP* violation in this mode. The time-dependent *CP* asymmetry measurement in B→$\rho^0\rho^0$ represents a major step in removing the ambiguities in the determination of the angle α. The measurements continue to hold to the CKM picture, which imposes significant constraints on models of physics beyond the Standard Model, including the supersymmetric extensions of the Standard Model.

Search for the Effects of Physics Beyond the Standard Model: A key element of the *BABAR* physics program is seeking the effects of New Physics through loop-dominated rare decays of B mesons. A clean set of observables sensitive to the effects of New Physics are time-dependent *CP* violating parameters in the so-called $b \to s\bar{s}s$ penguin diagrams containing virtual quarks and vector bosons. While such modes, including $B^0 \to \varphi K^0$, $B^0 \to \eta' K^0$ and a number of related channels, should show the same *CP* asymmetry as the benchmark charmonium result for sin2β, they are also sensitive to New Physics at high mass scales *BABAR* has performed a comprehensive set of measurements of *CP* asymmetries in these channels. *BABAR* presented new results based on Runs 1-5, including a complete time-dependent Dalitz analysis of the decay *B*→$K\pi^+\pi^-$. The “naïve” average of the measurements continues to show a nearly 2.5 standard deviation discrepancy with the predictions of the Standard Model. Improving precision of these measurements is among the highest priorities of the experiment.

A set of measurements of the decays B→$D^{(*)}\tau\nu$, which complete the semileptonic picture of B meson decays, provide yet another window on physics beyond the Standard Model, owing to dependence of the branching fractions on the mass of the charged Higgs. At current uncertainty levels, the data is consistent with the Standard Model.

Analysis and Simulation Tools: The *BABAR* collaboration has developed or contributed to many analysis and simulation software tools now in use in high energy physics and other fields. In FY07, the Stat Pattern Recognition package for multivariate classification and “data mining,” that is now maintained as open-source software and used outside HEP, was further developed with additional capabilities, and was used to provide significant improvements in particle identification performance. *BABAR* members contributed to a similar package, TMVA, which is also now in wide use.

The RooFit package for data modeling, developed within *BABAR* to address complex requirements of time-dependent *CP* fits, continues to be developed. It is now distributed as part of the ROOT system, almost universally used in high energy physics and increasingly adopted in other scientific communities.

In FY07 *BABAR* members also contributed to the validation of new releases of the standard particle-interaction simulation toolkit, GEANT4, widely used in HEP, nuclear physics, medical imaging, and beyond. A *BABAR* collaborator is also a member of the core GEANT4 development team.

Objective 1.2 Leadership in Science and Technology

The *BABAR* experiment at SLAC is the leading experimental program in the US and among the leading programs worldwide, focused on investigating *CP* symmetry breaking using the decays of *B* mesons. The collaboration includes 543 physicists from 77 institutions in 10 countries: the US, Canada, France, Germany, Italy, Netherlands, Norway, Russia, Spain and UK. There are also 520 associate members. The *BABAR* collaboration, with a young researcher base of about 150 PhD graduate students and 90 postdoctoral research associates, is one of the leading institutions worldwide that trains future high energy physicists.

BABAR collaboration members serve the physics and high energy physics community in many capacities:

- Current chair and chair-elect of the Division of Particles and Fields (DPF) of the American Physical Society
- Current and former collaboration members serve as directors of major laboratories, including SLAC, the FNAL, LAL (Orsay, France), CPPM (Marseille, France) and LAPP (Annecy, France).
- Numerous national and international panels, including review committees at FNAL, CERN, DOE, and the NSF.
- Editor of Review of Modern Physics
- Associate editor of Annual Review of Nuclear and Particle Sciences
- Principal organizers of European Physical Society High Energy Physics conference (HEP 2007), the CKM workshop Flavor Physics and *CP* violation conference (FPCP).

NOTEWORTHY PRACTICES

Early in its operation, a major problem was identified with the muon identification system performance. Over the next few years, the collaboration sought a solution, which led to replacement of the Resistive Plate Chamber (RPC) detectors with Limited Streamer Tubes (LST) and additional absorbers. The upgrade program, completed in FY07, has confirmed that the *BABAR* muon identification system performance has been fully restored.

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

The *BABAR* experiment continues to produce high quality physics results with significant impact on the advancement of our understanding of elementary particle physics and the scientific direction of the field. A summary of the various statistical measures of the scientific productivity and impact of the experiment in FY07 was presented in Objective 1.1 above

A major milestone for advancement in understanding the phenomenon of *CP* violation has been the determination of *CP* asymmetry in the charmonium decay channels, $\sin 2\beta$, to an accuracy of 0.04 or better. The measurements from the *B* Factory experiments have already passed this milestone (at 0.038).

Objective 1.4 Provide for Effective Delivery of Science and Technology

A key measure of *BABAR*'s effectiveness in delivering science is its ability to record efficiently the data from PEP-II collisions, and to process and make available the data for physics analysis in time for presentations at major conferences and for publications in peer reviewed journals. In FY07, the collaboration also began reprocessing its full data set to implement event reconstruction improvements. The collaboration also engaged in processing live data from the detector. The availability of both the live data as well as the reprocessed data was critical to the success of its science program. Although data processing was affected by computer resource delays, the key milestones and goals were met, because temporary resources at offsite computing Tier-A centers were used. The science program's success also depends on the collaboration's ability to organize its resources and scientific manpower throughout its 77 institutions. The scientific output of the experiment presented above speaks to the collaboration's effectiveness in achieving this goal.

The successful planning and execution of the muon identification system upgrade also a measure of the collaboration's effectiveness in delivering high quality science. As described above, the collaboration accurately identified the origin of the failure with its muon identification system early in its operation and found a solution, which led to a detector upgrade completed in FY07. The data recorded with the upgraded detector has verified the full restoration of the muon identification capability of the detector.

G ▪ Astrophysics Program at the Kavli Institute

The Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) is jointly administered by SLAC and the Stanford School of Humanities and Science, with affiliations to the Physics and Applied Physics Departments. The Institute engages in theoretical, observational, and experimental research in astrophysics and technology, ranging from the structure and evolution of the universe, to the physics of compact objects, like black holes and neutron stars.

During the past year, KIPAC researchers were especially productive, generating over 150 publications in the professional literature (see details in the Publications Appendix). Thomson Scientific, an organization that tracks citations to scientific publications, has determined that Stanford/SLAC had the highest percentage increase in total citations in the field of Space Science (including astronomy and astrophysics) over this period for any institution in the world.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

Some results that attracted particular attention included the following.

- The demonstration that an analysis of time delays among the separate images in the strong gravitational lens, B1608+656, can be used to derive constraints on the Hubble constant that are competitive with the best available from other techniques.
- Analysis of a subset of highly relaxed and spherical rich clusters of galaxies, which allowed accurate constraint of the matter density of the universe. Combining these results with supernova and cosmic microwave background data gives a value of the dark energy pressure-density ratio of $w = 1.01 +/- 0.09$, consistent with a pure cosmological constant.
- Analysis of the weak lensing, strong lensing, and x-ray images of the bullet cluster, has demonstrated unambiguously that dark matter is collisionless, and can separate from the baryonic matter associated with stars and x-ray emitting hot gas. Useful constraints on the self-interaction cross section of dark matter have resulted.
- Observations of the blazar, Mrk 501, with the MAGIC TeV gamma-ray telescope show that the source varies on the remarkably fast timescale of two minutes. This has significant implications for physical conditions in the source. Gamma-ray Large Area Space Telescope (GLAST) observations of similar objects are guaranteed to be highly prescriptive.
- The HESS observation analysis of the supernova remnant J1713.7-3946 shows that this remnant appears to be accelerating protons up to energies of order 0.3 PeV. This implies that the magnetic field must be strongly amplified in the acceleration region, a result confirmed through observations of x-ray variability in this source, using the Suzaku x-ray observatory.

GLAST is a satellite-based experiment to measure the cosmic gamma-ray flux in the energy range from 20 MeV to greater than 300 GeV, with supporting measurements for gamma-ray burst (GRB) transients in the energy range 10 keV to 25 MeV. With a sensitivity 30 times that of the Energetic Gamma Ray Experiment Telescope (EGRET) detector on the Compton Gammy Ray Observatory mission, GLAST will open an important window on many high-energy phenomena, including super-massive black holes and active galactic nuclei, GRBs, supernova remnants and cosmic ray acceleration, as well as searches for new phenomena. Delays in the observatory integration and test program have postponed the GLAST launch to spring 2008.

The Large Area Telescope (LAT) is the primary science instrument on GLAST. The LAT collaboration joins particle physicists and high energy astrophysicists.

As of September, 2007 the collaboration numbers 88 scientific members, 81 affiliated members and 28 postdocs. The LAT Principal Investigator and Spokesperson is Professor Peter Michelson (Stanford and SLAC). The LAT has been developed in a partnership between NASA and the DOE, with substantial contributions from Italy, Japan, France and Sweden. The LAT project is managed at

SLAC.

GLAST

Objective 1.2 Leadership in Science and Technology

SLAC scientists have made several LAT presentations at science conferences over the past year and the first GLAST Symposium was held at Stanford University

Two LAT collaboration meetings were held in FY07.

Objective 1.4 Provide for Effective Delivery of Science and Technology

The completed LAT was delivered in September, 2006 and successfully integrated onto the GLAST spacecraft in December, 2006. Major activities in the GLAST integration and test program include completion of the first GLAST comprehensive performance test, and the start of the GLAST environmental test program. The GLAST observatory underwent an electromagnetic interference and compatibility test with no major LAT performance issues. LAT scientists performed an absolute timing test of the LAT and the GLAST spacecraft, using a muon telescope. LAT flight software development has continued. Occasional resets of LAT on-board computers during LAT and GLAST testing were traced to collisions of nearly simultaneous interrupts in the processors, and successfully fixed with a flight software update. An initial version of on-board gamma-ray burst detection was incorporated into the LAT flight software. One more installation of LAT flight software is planned before GLAST thermal-vacuum testing begins.

The LAT Instrument Science Operations Center (ISOC) at SLAC will operate the LAT in conjunction with the GLAST Mission Operations Center (MOC) and GLAST Science Support Center (GSSC) at NASA’s Goddard Space Flight Center (GSFC), and will process LAT detected event data and provide reduced data to NASA and the LAT collaboration. Tests of LAT command and monitor started in February 2007 in GLAST End-to-End (ETE) testing. To date, two of six GLAST ETE tests have been completed. The mission support room has been used to support GLAST operations testing including ETE tests. In preparation for launch, the ISOC held its second workshop for LAT collaboration members at SLAC in April 2007 and will be holding its first operations simulation to rehearse the on-orbit commissioning of the LAT at SLAC in October 2007.

SLAC continues to support preparations for the LAT science mission after launch. The LAT Service Challenge is being used to generate datasets to improve techniques for analyzing LAT data and verify instrument models and simulations. Major datasets being produced through the Service Challenge include a 55-day simulation of the observations expected during the initial on-orbit commissioning and checkout of the LAT, and a one-year simulation of the sky survey to be performed in the first mission year. The LAT program at SLAC now has 400 processing cores in the Scientific Computing and Computing Services (SCCS) computer pool at SLAC and has recently purchased 50 TB of disk, with plans to purchase another 150 TB to prepare for launch readiness.

Following beam tests at CERN during July to September, 2006 beam tests of the LAT Calibration Unit were completed at GSI in Germany in November, 2006. The LAT Calibration Unit (CU) uses spare modules of the LAT assembled into a mechanical support grid. The CU is currently being installed on a mechanical support frame for installation in the LAT dataflow lab at SLAC. Analysis of the beam test data continues, using the test data to refine LAT event simulations, particularly in the areas of track multiplicity and total energy calibration.

LSST

Objective 1.2 Leadership in Science and Technology

The Large Synoptic Survey Telescope (LSST) is proposed as a large-area, wide-field, ground-based telescope to provide deep images of roughly half the optical sky every few nights. These surveys would provide a critical resource for several astrophysical investigations—e.g., studies of small bodies in the solar system, programs that map the outer regions of the Milky Way, and searches for faint optical transients on a wide range of time scales. The LSST concept has been repeatedly endorsed as a priority US scientific initiative by national advisory groups and reviews, including the most recent NAS/NRC Astronomy and Astrophysics Research Committee ("Astronomy and Astrophysics in the New Millennium," 2001) and the influential "Quarks to the Cosmos" Committee. In September 2005, the NSF awarded four-year funding for the LSST design and development effort, with a view to advancing LSST construction to Major Research Equipment and Facility Construction (MREFC) "new start" status in FY 2010.

LSST would provide detailed constraints on the nature of dark energy, through several distinct and complementary techniques. Four of these techniques: measurement of baryon acoustic oscillations; surveys of clusters of galaxies; photometry of Type 1a supernovae; and measurement of cosmic shear using weak gravitational lensing, were highlighted in the Dark Energy Task Force (DETF) report commissioned by the AAAC and High Energy Physics Advisory Panel (HEPAP). The DETF report concluded that no single technique alone is both sufficiently powerful and well enough established to yield the necessary constraints, but that the combination of all four (as provided by LSST) is especially compelling. The DETF indicated that a Stage IV Large Survey Telescope (modeled on LSST) could make a major advance in our understanding of dark energy. On the basis of the DETF report, and its own evaluation of the project, the P5 subcommittee of HEPAP recently recommended that DOE-OHEP initiate a program of R&D on LSST, leading to a CD-2 review in FY09.

A large team from the astronomy and particle physics communities is pursuing the LSST concept. LSST would be developed as a multi-agency public/private partnership, with NSF as the lead agency providing the bulk of telescope, site, and data management funding, and DOE-OHEP supporting the fabrication of the LSST camera, with members of the particle physics community providing data handling and science analyses. Private and/or international funding, some of which is already in-hand, will enable production of the telescope mirrors, which are long-lead, expensive items that must be started before federal funding for proposed construction is officially authorized.

LSST will produce an enormous volume of data, roughly 30 terabytes per night, leading to a total database over its ten years of operation of several tens of petabytes. Processing such a large database—and archiving it in useful form for access by the community—is a major challenge for the project. The data management system is configured in three "layers:" an infrastructure layer consisting of the computing, storage, and networking hardware and system software; a middleware layer, which handles distributed processing, data access, user interface, and system operations services; and an applications layer, which includes the data pipelines and products, and the science data archives.

Collaboration: SLAC leads the R&D program for the LSST camera, and plays a key role in including other high energy physics groups: BNL, LLNL, ORNL, Harvard University, the University of Pennsylvania, Brandeis University, the University of Illinois at Urbana-Champaign, Purdue University, Ohio State University, the Rochester Institute of Technology, the University of California at Santa Cruz, the University of Cincinnati, and Wayne State University.

Leadership: SLAC Professor Steven Kahn is the Deputy Director of the LSST Project and the Lead Scientist for the camera, while SLAC Physicist Kirk Gilmore is the Camera Project Manager. In addition, SLAC scientists and engineers have taken lead technical roles in the camera thermal and mechanical design, as well as in the calibration strategy for the telescope.

Objective 1.4 Provide for Effective Delivery of Science and Technology

Over the last year, significant progress has been made in key aspects of the camera design: (1) Prototype sensors have been acquired and successfully tested. (2) A detailed design of the camera body and mechanisms has been developed and modeled to demonstrate conformance with tight mechanical and environmental constraints. (3) A complete thermal analysis has been performed and evaluated.

In February, 2007 a formal construction proposal for LSST was submitted to the NSF as a MREFC project. In the spring of 2007, a SLAC-led team successfully proposed an R&D program on the LSST camera in response to a DOE-OHEP call for proposals for research on dark energy. In September, 2007 NSF convened a Conceptual Design Review for the LSST Project, with detailed presentations on the telescope, camera, and data management subsystems. The review panel gave very high marks to the state of the technical design of the project and recommended that LSST proceed on to a Preliminary Design Review in fall 2008.

SNAP

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

The SuperNova Acceleration Probe/Program (SNAP) project will be a competitor for the Joint Dark Energy Mission (JDEM) mission. The SLAC group on SNAP is responsible for two key elements of the SNAP instrument: the fine-guidance star tracker and the data acquisition electronics. Electronics responsibilities include overall systems electronics engineering, management data acquisition flight electronics, and electronic ground support electronics. The fine-guidance star tracker is responsible for maintaining a 20 milli-arcsec pointing accuracy, crucial for the weak lensing measurement of dark energy.

The nature of dark energy is one of the leading questions in physics today. The SNAP experiment will greatly advance our understanding of dark energy through accurate measurements of the dark energy content of the universe and the dark energy equation of state.

The SLAC group brings its expertise, gained from the GLAST mission, in state-of-the-art space-based data acquisition electronics and integration and test of space-based experiments to the SNAP collaboration. In addition, the SLAC data acquisition effort is solving similar data acquisition system (DAQ) needs in experiments ranging from SNAP to LUSI (at LCLS) by applying common design, electronics, and software wherever possible.

Both weak and strong gravitational lensing are very active research topics at SLAC and throughout the community. The SNAP experiment will enable next-generation studies of both types of gravitational lensing, for cosmological and astrophysical research.

Objective 1.2 Leadership in Science and Technology

SNAP will lead to a significant advance in our understanding of dark energy. It represents a unique wide field-of-view space-based telescope, with a novel multiband digital focal plane. As a 'fourth-generation' dark energy experiment, SNAP will represent a large step forward. SNAP is a medium sized collaboration, with a small but highly effective SLAC group already taking major responsibilities on DAQ electronics and the fine-guidance star tracker. The DAQ electronics takes advantage of the most recent electronics systems designs, while the star tracker uses a novel through-the-focal-plane approach to minimize systematic pointing errors and distortions. The study of strong gravitational lensing may be a third cosmological probe for SNAP.

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

The JDEM mission was recently recommended for a 2009 start by the Beyond Einstein Program Assessment Committee (BEPAC). In no small part this recommendation was due to the demonstration of technical readiness by the SNAP collaboration. Both aspects of the SLAC group's responsibility, the star-tracker and the DAQ electronics were important elements of the technical readiness determination.

H ▪ ILC Program

After the decision in 2004 to choose superconducting technology for the International Linear Collider (ILC), SLAC has been a leader in the ILC design effort.

For work leading to the recently-released Reference Design Report (RDR), SLAC physicists were Area Leaders for every section of the machine except the damping ring, including both electron and positron sources, the bunch compressors, the main linacs and the beam delivery system. SLAC contributions to the damping ring design include the lead on electron cloud suppression and studies of the fast ion instability. SLAC physicists are Technical or Global System Leaders for four areas. Eight members of the Global Design Effort (GDE) are from SLAC including the Lead Accelerator Physicist for the Americas Region, the Electronic Document Management System (EDMS) Committee Chair, the Systems Integration Engineer and the Lead Editor for the RDR.

An extensive ILC R&D program includes the beam delivery system (BDS), electron and positron sources, RF power sources and high availability hardware systems

Engineering Design Phase

The ILC effort has entered an Engineering Design Phase to refine the design and cost estimate over 3 years, to culminate in a detailed Engineering Design Report (EDR) in 2010. SLAC has chosen to focus engineering work on four main areas—the electron source, the beam delivery system, the main linac overall systems design and the RF power sources—and will lead these areas through the EDR and into construction. SLAC also has primary responsibility for systems integration and for developing an installation model. For the damping rings, SLAC will continue a major effort on the vacuum system design, in particular on electron cloud, fast-ion and collective effects. This work is in collaboration with LBNL and Cockcroft Institute. SLAC continues to play a supporting role in the positron source and bunch compressors.

The SLAC accelerator complex provides facilities to support a wide range of ILC R&D. These are discussed in other sections of this report.

Reviews, Meetings and Publications

The ILC group participates actively in the national and international community through reviews and meetings. The SLAC ILC group played a major role in formulating the shape and content of the three ILC GDE Meetings in November 2006, February 2007 and May 2007. SLAC ILC Department members made significant contributions to leadership of area, technical and global groups and as working group conveners.

SLAC ILC members presented papers at the 17th International Spin Physics Symposium (SPIN06), the IEEE Nuclear and Sciences Symposium, and the Workshop on Polarized Sources and Targets, the Asian Particle Accelerator Conference (APAC07), the International Workshop on Electron-Cloud Effects (ECLOUD07), and the Computational High Energy Physics conference (CHEP-07). SLAC had a major presence at the Particle Accelerator Conference (PAC 07) with five invited papers, four contributed talks and more than 39 papers.

SLAC hosted the US High Gradient Research Workshop (HG 2007) and a Workshop on IR Engineering (IRENG07).

SLAC ILC physicists participated in the RDR cost reviews. They also made presentations at the ILC Machine Advisory Committee (MAC) meetings.

SLAC ILC members participated in many advisory and review committees including HEPAP, P5, MUTAC, the DPB Executive Committee, the NSF and DOE Committees of Visitors, the LCLS Facilities Advisory Committee, the CLIC and FNAL Accelerator Advisory Committees, the FNAL Steering Group, the SLAC director and associate director search committees, the advisory board for the SLAC/FNAL joint SciDAC project (COMPASS), and numerous conference scientific and program committees.

Collaborations

The ILC Department has a long history of collaboration with KEK and, within the US, with ANL, BNL, FNAL, LBNL and LLNL. Additional collaborations are ongoing with DESY, CERN, the UK - in particular with the Cockcroft Institute/Daresbury Laboratory and the John Adams Institute/Oxford University, and with the French laboratories CEA Saclay and CEA Orsay.

The KEK collaboration on Accelerator Test Facility (ATF) and on RF technology has been extended by a Memorandum of Understanding (MOU) to the ATF-2 project. The spokesman, the ATF-2 International Collaboration Board chair, and two members of the ATF-2 Technical Board are from SLAC.

The End Station A (ESA) Test Facility is a collaboration between SLAC and US and UK universities. Most of the specific experimental proposals have at least one spokesperson from a university in either the UK or the US.

ILC Outstanding Practice: Safety

At SLAC and in the ILC Department, concern for safety is an integral part of our culture. Work authorization procedures at the Next Linear Collider Test Accelerator (NLCTA), a major test facility operated under the ILC Program, have been used as a model for other facilities at SLAC. The ILC Conventional Facilities engineers continue to contribute to the lab-wide effort implementing electrical risk mitigation measures. ILC engineers and physicists participate in the various Citizens' Committees such as Radiation Safety and Earthquake Safety.

Large Hadron Collider (LHC) Accelerator Research Program (LARP) Collimators

The LHC collimator R&D program, operating as part of the ILC program at SLAC, began from a CERN request to study the applicability to the LHC of the 'consumable' collimator technology developed for the Next Linear Collider (NLC). As the project became better defined, it was added to the US LHC Accelerator Research Proposal. Funding for this program flows through LARP, but is administered by the ILC Department, which originated the technological concepts.

The LHC collimation system will be installed in two phases. The first phase devices are carbon-jaw collimators that can survive the direct impact of up to 8 nominal-intensity bunches. The system will have adequate efficiency and low enough impedance for start-up luminosity of 10% nominal design or 1×10^{33} cm-^{2}s^{-1}. Phase II metal collimators with improved efficiency and lower impedance must be devised and installed before the LHC can reach the full design luminosity of 1×10^{34} cm-^{2}s^{-1}.

These LHC Phase II collimators will be an extrapolation of the design prototyped for the NLC. The basic concept replaces classic rectangular jaws with cylindrical jaws that can rotate to present a fresh surface to the beam if the surface is damaged in an accidental beam abort. The LHC jaws must be longer, of a smaller diameter and each provided with approximately12 kW of water cooling. The optimal design of the collimators with relevant 3-D CAD design drawings was assembled into a conceptual design report (CDR) for a first collimator prototype.

In 2007 metallurgical and vacuum examination of the short samples produced in FY06 proceeded in parallel with the fabrication and examination of a third short prototype and many test pieces constructed to investigate the optimal way to attach the collimator's molybdenum shaft to its copper jaw structure. The rotation mechanism was fully developed and one sample fabricated. With the molybdenum-copper joint design finalized, machining of the full length parts began. In parallel, a clean area for collimator tests was developed with all the required electrical power, cooling, heater power supplies, precision table, sensors and data acquisition system. The project's first postdoc was hired in late July 2007. The remaining design issue is the rf contacts that return the image current and avoid the presence of trapped rf modes.

The LARP Group invited talks are listed in the Publications Appendix. In 2007 this group gave five invited presentations at national and international venues and completed a design update (2007-03-31, "Rotatable Collimator Design Update," T. Markiewicz, et al.). Others of their published papers are included in the count for the ILC program listed above.

Major related committees/leadership roles

- US LARP Accelerator Systems (L1) Leader
- US LARP Collimation Task (L2) Leader
- US LARP Rotatable Collimator SubTask (L3) Leader
- US/CERN LARP Committee

National/international review teams

- LHC Phase I Collimator Design Review Committee

Leadership role in US/international HEP activities: Thomas W. Markiewicz

- SLAC LHC Accelerator Research Department, Head
- SLAC ILC Department Executive Committee
- SLAC ILC Department Experiments and Prototypes Supervisor
- SLAC ILC Beam Delivery System member
- ILC GDE member
- ILC EDMS Selection Committee, Chair
- ILC Change Control Board, member
- ILC Dumps & Collimators Technical System Americas Regional Coordinator
- ILC Machine Detector Interface Committee, member
- ALCPG Machine Detector Interface and Backgrounds Coordinator
- Silicon Detector Concept (SiD), member
- SiD Detector, Advisory Board member
- SiD Detector, Machine-Detector Interface Liaison
- SiD Detector, Engineering Group Member

How do these influence the LARP community?

Influence within LARP through L1, L2 and L3 roles is direct and obvious. As part of LARP senior management Markiewicz influences LARP through contact with DOE, CERN and LARP Regional representatives.

The newly formed SLAC LHC Accelerator Research Department is the direct outgrowth of initial LARP collimation activities. SLAC will participate in LHC R&D bilaterally with CERN and through LARP.

ILC leadership activities benefit LARP by the ability to identify synergies and overlaps. For example, ILC Crab Cavity R&D, LARP Crystal Collimation and Rotatable Collimator R&D, Collective Effects (Impedance, Electron Cloud effects) all benefit from cross fertilization.

I ▪ Accelerator Research

High Gradient Research

At the moment, the only place in the US capable of doing high gradient research at frequencies of S-band or above is SLAC. SLAC serves as the primary experimental site for the US high gradient research collaboration. At X-band, SLAC has several experimental stations producing uncompressed pulses of 50-100 MW, and some of these stations have an associated pulse compressor for powers up to 500 MW. The capabilities of these stations vary, and they are not all capable of supporting all types of experiments. To minimize the cost of these experiments and to make experimental time more efficient we implemented the following upgrades:

- To minimize the amount of vacuum work, installed novel vacuum valves that allow ultra high power rf to go through them. These are newly designed and developed devices.
- We are renovating and refurbishing the general infrastructure for diagnostics, so experiments can run in parallel.
- We improved the pulse compression system so one can change the compression ratio from 1 to about 4 or 8, depending on the station and without breaking vacuum.

The programs/users that these stands served, so far, include the following.

- SLAC's experiments on geometries and materials
- CERN structures
- Omega-P/Yale's structures
- MIT structures
- Test structures manufactured by KEK
- Dielectric structure done by ANL
- Test structures proposed by Hamison Research Corporation (HRC), but scaled to 11.4 GHz rather than at 17 GHz

17 GHz Accelerator Laboratory at MIT

The MIT Plasma Science and Fusion Center has a 25 MeV, 17 GHz electron accelerator. We will conduct experimental studies of novel, advanced high gradient accelerator structures at this facility. The novel structures will be tested at high microwave power (25 MW) using the 17 GHz HRC relativistic klystron. We are in the process of improving the MIT 17 GHz facility for testing high gradient structures and make it available as a user facility. The beam line connected to the HRC linac will be dedicated for high gradient accelerator research. Outside users/collaborators will easily be able to use this facility. The HRC linac will be powered with 10 MW from the klystron, and the structure under test will be separately powered with about 10 MW of power.

30 GHz Test Facility at CERN

Through collaboration with CERN we will be able to use the available source built as part of CLIC Test Facility 3 (CTF3). We use that to test scaled structures at 30 GHz.

NRL X-band Facility

The heart of the Naval Research Laboratory (NRL) X-band Facility is a frequency-doubling magnicon amplifier. The 11.424 GHz magnicon provides up to 25 MW in 200-ns pulses and up to 12 MW in 1 µs pulses. In collaboration with SLAC, this facility is being upgraded to serve as a test bed for new ideas. After an initial test has been performed, the experiments can move to SLAC for testing with higher powers and longer pulse length.

Yale Magnicon Facility

This facility has a 34 GHz magnicon which is still under development. If successfully commissioned, it will provide a source for conducting experiments at Ka-band, in addition to the CTF3 facility.

Current Activities

The program to date concentrated on establishing experimental facilities, at SLAC, MIT, NRL and made some progress towards updating the CERN CTF3 facility by adding an active pulse compressor.

In parallel, a large number of experiments were conducted at SLAC that included standing and traveling wave accelerator structures, built by a variety of laboratories including SLAC, CERN, KEK, and ANL. These experiments started to scratch the surface in terms of the open problems described above. As a result we now have operational structures that achieved more than 100 MV/m accelerating gradient

By the end of CY08, the experimental program will be in full swing, utilizing most of the upgraded facilities. This program is complimented by a strong theoretical research program centered at the University of Maryland in collaboration with SLAC.

Also by 2008 we will be transitioning from a program based on studying on the fundamental to a program based on testing full scale accelerator structure with sophisticated features such as wake field damping.

Objective 1.2 Leadership in Science and Technology

The US collaboration on High Gradient Research for future colliders was formed in 2006. The specific goal is to establish the best frequency and accelerator structure design for a future multi-TeV collider. The work plan assumes a period of 5 years. SLAC is the host of this collaboration and research activities include theoretical and experimental studies of the rf breakdown phenomenon. This work aims to establish a better understanding of the frequency scaling of the limiting gradient, as well as its dependence on material, surface preparation, structure design, pulsed heating, etc. It explores the high gradient barriers that result from choices made in current linear collider programs. The experimental effort entails test facility upgrades and the development of new high-power rf sources designed for high gradient testing. The goal is to produce and test at very high gradient an accelerator structure suitable for use in a multi-TeV two-beam linear collider.

SLAC experimental facilities are made available to collaborators for experiments supported within the collaboration.

The problems and potential solutions for high accelerating gradient include the following.

- Frequency scaling
  - CERN and SLAC experiments have shown less frequency dependence than expected; however, frequency links other parameters such as pulse length, filling time, power, energy, and geometry.
- Geometry dependence
  - There is a clear geometry dependence; e.g., accelerator structures with different a/λ, and circuit dependence; e.g., standing wave vs. traveling wave; the origin of this dependence is not clear.
- Energy, power and pulse length
  - There is clear pulse length dependence; however, the laws that govern it are debatable and differ from one experimental setup to another.
- Materials
  - Very little is known about materials and DC voltage data does not seem to apply. There may be opportunities for significant development here.
- Surface processing technique (etching, baking, etc.)
  - There are known practices that have been proven to help; however, the basic physics is still under debate, and the question of processing vs. initial condition of the surface is in question.
- Theory
  - There is no robust theory to date, although several attempts at particle tracking, scaling with surface physics, and surface atom dynamics have been put forward.
- Wake field damping
  - At the moment several ideas are being explored fro strong wake field damping. This is important because it allows shortening the pulse length for the same train of bunches, hence enable higher gradient. At the moment the most advanced technique was the one developed for the NLC with moderate damping.

Accelerator Structure Research Program for the ILC

Accelerator structures for the ILC positron source

An improved alternative design for the L-Band normal conducting accelerating system for both the ILC positron source and electron source is being developed. Results appear in the ILC RDR.

Due to the extremely high energy deposition from positrons, electrons, photons and neutrons behind the positron target, normal conducting structures must be used up to an energy of 400 MeV. This normal-conducting section must sustain high accelerator gradients during millisecond-long pulses in a strong magnetic field, provide adequate cooling in spite of high rf and particle loss heating, and produce a high positron yield with the required emittance. The proposed design contains both standing-wave (SW) and traveling-wave (TW) L-band accelerator structures. The capture region has two 1.27 m SW accelerator sections at 15 MV/m and three 4.3 m TW accelerator sections at 8.5 MV/m accelerating gradient. All accelerator sections are surrounded with 0.5 T solenoids.

The high gradient (15 MV/m) positron capture sections are 11-cell π mode SW accelerator structures with a more effective cooling system, higher shunt impedance with larger aperture (60 mm), lower rf pulse heating, apparent simplicity and cost savings. The mode and amplitude stability under various cooling conditions for this type of structure have been theoretically verified. The TW sections are 4.3 m long, 3π/4 mode constant gradient accelerator structures. The "phase advance per cell" has been chosen to optimize rf efficiency for a large aperture TW structure allowing lower pulse heating, easy installation for long solenoids, no need to use circulators for rf reflection protection, apparent simplicity and cost savings.

Each accelerator section has an individual rf station powered by a 1300 MHz, 10 MW peak power pulsed klystron. For the SW structures, rf circulators are needed to protect the klystrons from reflected power.

To gain fabrication experience and make high power tests at full gradient and pulse length with an existing 5 MW peak power L-Band klystron, we have designed a 5-cell L-Band test structure with coupler cell at one end and all necessary features for positron capture.

Accelerator structures for the ILC electron source

The work for the ILC EDR phase includes design of rf parameters and power efficiency, thermal calculations and stability studies for two subharmonic bunchers, 5-cell prebuncher; rf distribution system; key rf components R&D like phase shifters, attenuators, circulators and rf window as well as detailed parts count and cost estimation. We hope to design and fabricate a short test section for the L-band traveling wave accelerator section.

Accelerator structures related work and studies for the LCLS project

We support all accelerator structures work for the LCLS. This work includes tuning and evaluating rf guns and all new installed accelerator and deflector sections.

After the successful tuning and characterization of the first rf gun, it was installed in the LCLS injector. We did *in-situ* microwave measurements to confirm its excellent performance.

The second gun was tuned and finally tested in March 2007. Based on the experiences gained from the first rf gun, the job was done quickly and without problems.

Other accelerator structure related research

Studies of an X-band TW structure for ultra-fast rf kicker

- If the *B* Factory were converted into a very strong FEL light source, to pick up single bunches from the bunch-train a 0.75 m long 2π/3 mode TW structure with a 4.8ns filling time and vertical deflecting voltage of more than 5 MV, a realistic driving rf power of 400 MW is needed. Preliminary design has started.

Studies of high-efficiency rf deflector for LCLS bunch length measurements

- To understand the FEL operation, the time-resolved electron bunch diagnostics needs extension to the scale of 10-20 fs using a transverse rf deflector cavity, which might be located after the FEL undulator. A preliminary electrical design is in process for a 1.5 m long 2π/3 mode TW structure with a 160 ns filling time and vertical deflecting voltage greater than 39 MV at an effective driving rf power of 30 MW.

Beam Instabilities and Diagnostics Group

In 2007 a LLRF-Beam dynamics model was expanded to understand high-current operational limits and stability margins in PEP-II. These models predicted that existing PEP-II rf systems would be unstable at currents anticipated for the final year of operation, limiting the luminosity achievable in the machine. A series of studies showed that nonlinear effects in the then-existing LLRF system were the source of the current limitations, and new amplifiers were specified, purchased and installed in 16 rf stations. Accelerator measurements of the improved system, in conjunction with the dynamics modeling, now predict stable operation of the PEP-II machine for 3800 mA low energy ring (LER) current and 2200 mA high energy ring (HER) current. The techniques used to characterize the LLRF imperfections, and the development of new control techniques to extend the operating currents in PEP-II, expand the state of the art for impedance-controlled LLRF systems.

The R&D effort in broadband coupled-bunch instability control technology continues with our collaborators at KEK and LNF. Last year focused on fundamental noise limits to stability control via a study of transverse receiver architectures and detection techniques. The laboratory effort centers on developing a realistic beam signal and motion signal source, to allow controlled evaluation of various detection techniques.

The group has a significant role in graduate education, and is supporting two Stanford PhD thesis projects in instability modeling and wideband instability control architectures. John Fox taught two graduate courses in instrumentation techniques for the Stanford Applied Physics department, as well as an undergraduate applied physics seminar course. John Fox presented a special lecture on Particle Accelerators to the members of the Science Undergraduate Laboratory Intern (SULI) program.

Plasma Acceleration and E-167

E-167 was a collaboration of scientists at SLAC, UCLA and USC that used beams from the SLAC linac to study beam-plasma physics in the context of the beam driven plasma wakefield accelerator concept. E-167 concluded with the decommissioning of the SLAC Final Focus Test Beam (FFTB) facility in April 2006. The results of the final round of experiments were published in the journal **Nature** in 2007 and demonstrated a world record combination of accelerating gradient (50 GeV/m) and energy gain (43 GeV) for plasma accelerators. These results are recognized as the preeminent work in this field and results were made possible by the unique high-energy, high peak-current, low-emittance beams available at SLAC, combined with the expertise of our university collaborators in plasma physics and the numerical methods used to simulate the interactions.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

The E-167 collaboration demonstrated world record energy gain and accelerating gradients in a plasma wakefield accelerator. The new record displaced the collaboration’s previous world record from just two years ago. The latest results demonstrated that plasma could be used to double the energy of some of the 42 GeV beam electrons produced by the 3,000 meter long linac in just 85 cm of plasma. This is a significant advancement for the entire advanced accelerator field and verified the predicted dramatic increase in accelerating gradient for wakes driven by short bunches in high-density plasmas. These results have been recognized around the world with interviews on **BBC Radio** and commentaries in **Nature** and the **CERN Courier**.

NOTEWORTHY PRACTICES

High-Gradient Acceleration

The high-energy, high peak-current, low-emittance beams from the SLAC linac have been used to successfully drive wakes with accelerating fields in excess of 50GeV/m. The short bunches match with plasmas with correspondingly higher density and larger fields. The low emittance and optics of the FFTB allowed the high energy beams to be focused to the spot size matched to the plasma density, typically a radius of a few microns. The high energy allowed the interaction to proceed in a regime with very large fields over extended distances (~1 meter corresponding to > 30 betatron wavelengths).

Field Ionized Plasmas

A challenge for any plasma accelerator concept is creating the uniform high-density plasmas that will form the accelerating structure for the beam. This collaboration pioneered a new type of plasma source that uses the large radial electric fields of the electron beam to field (tunnel) ionize a neutral vapor column and create the plasma. This technique produces uniform, meter-scale plasmas precisely at the moment they are needed. This technique has now been successfully demonstrated in experiments and promises the ability to construct the more than ten meter long plasma sources envisioned for future accelerators.

Optical Transition Radiation (OTR) Profile Monitors

The plasma experiments in the FFTB pioneered and developed many of the ideas for single shot diagnostics which are now finding their way into other programs on site such as the LCLS. The plasma experiments in the FFTB were the first to demonstrate that OTR could be used to measure the beam profile of a multi-GeV beam in a single shot. Our collaboration later improved this technique by testing ultra-thin metallic foils (1 inch diameter, 1 micron thick titanium) created by vapor deposition to minimize emittance growth in the foils, while improving spatial uniformity.

Bunch Length Diagnostics

Our collaboration developed much of the instrumentation and techniques that utilized the coherent transition radiation (CTR) emitted by the electron beam passing through a metallic foil to measure the relative bunch length on a pulse-to-pulse basis. These techniques became the *de facto* standard for all experiments using compressed bunches in the FFTB. Many of the ideas have directly impacted the design of the bunch length diagnostics in the LCLS.

A second technique developed by this collaboration uses a noninvasive off-axis profile monitor to measure the energy spectrum of the incoming bunch. A small wiggler placed in an energy dispersive plane creates a stripe of synchrotron radiation whose intensity profile is a measure of the beam transverse profile and thus the energy spectrum. The energy spectrum of the compressed pulses from the linac is strongly dependent on the bunch length. By measuring the spectrum on a pulse-to-pulse basis with large dynamic range, the spectrum is matched to computer simulations to retrieve the longitudinal phase space and indirectly measure the current profile.

Trapped Particles

Recent experiments discovered striking new phenomena when the accelerating fields exceeded 10 GeV/m trapped particles. The large amplitude wakes in the plasma give rise to a process that traps plasma electrons in an accelerating phase of the wake. The bunches that exit the plasma have some intriguing properties: multi-GeV energy, with transverse normalized emittance and longitudinal bunch length both an order of magnitude smaller than the incoming beam that drives the wake. These offer the possibility of creating a very bright electron source with plasma.

Opportunities for Improvement

There are still many questions that must be answered to understand whether plasmas can offer a viable path to the energy frontier. Answering these questions requires a facility to replace the unique properties of the FFTB beams (multi-GeV energy, 30 kA peak current, 12 micron rms bunch length, few micron rms radius). In addition to the capabilities of the FFTB, there are further capabilities needed—most notably the ability to create dual bunches spaced in time by a fraction of a plasma period (100s of femtoseconds) and compressed positron bunches. Dual bunches will allow experiments to measure efficiency and demonstrate the creation of high energy bunches with narrow energy spread from the plasma, not just particles. Compressed positrons will enable experiments to examine high-gradient positron acceleration in field ionized plasmas for the first time.

Objective 1.2 Leadership in Science and Technology

Awards

- Mark Hogan elected to APS Fellow (December 2006).

Publications

The following are included in the Publications Appendix. Unreviewed publications are included in the Spires database.

- Peer Reviewed Publications: 3
- Student Theses: 1 PhD
- Invited Presentations: 7

HEP Community Leadership

Hogan, Mark

- Organizing Committee for the Advanced Accelerator Concepts Workshop (2006, 2008).
- Technical consultant for the BNL DOE HEP Program review (2006-2007).

Ischebeck, Rasmus

- Working Group Leader, Beam Driven Concepts, Advanced Accelerator Concepts Workshop 2006.

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

E-167 has a strong publication and presentation history with an additional large educational component (one PhD completed and three PhDs in progress).

Objective 1.4 Provide for Effective Delivery of Science and Technology

- Consistently good reviews: SLAC DOE HEP Program review; the SLAC Scientific Policy Committee and the Experimental Program Advisory Committee.
- Attracts world class researchers and students to the collaboration while providing trend-setting work in the advanced accelerator field.
- Invited talks annually at PAC, APS, AAC and other venues.

NLCTA and E-163

R&D conducted at the NLCTA leads the world in (1) high-gradient rf (HGRF) technology at X-band and (2) laser-driven structure-based acceleration. Work directly supports DOE's accelerator-based high energy physics mission by developing techniques to be used to build future accelerators. Techniques and apparatus for high-power rf device conditioning and characterization are sought out by users the world over.

Novel approaches to acceleration with microwave and laser radiation are being pursued, leading to new rf pulse power components, and new optical devices. Selection of 12 GHz technology by CERN for the next-generation linear collider (CLIC) provides strong evidence that the long-term investment in high-frequency rf technology will pay off. Collaborators from CERN and Russia come to the NLCTA to use its unique facilities. Staff members are leaders in their fields.

The development of a new class of electro-optic devices to use laser light to accelerate electrons is unique in the world and has already led to world-leading demonstrations of two new acceleration mechanisms, and high-sensitivity high-precision techniques for diagnosing micron- and femtosecond-class beams. Collaboration is interdisciplinary and the members are leaders in their respective fields.

X-band structures sent for test have been successfully tested and characterized. Preparatory work for rf switch testing was completed. Construction of the experimental apparatus for conducting laser-driven acceleration experiments was completed, and the new beam line and experiment were successfully commissioned and used in scientific experiments.

Work conducted at the NLCTA was featured in 3 invited talks, and 14 papers (4 refereed). Both the microwave and laser-driven acceleration programs have achieved their respective performance goals.

Accelerator Materials Development

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

The Surface and Materials Science Department (SMS) supports the development of electron sources and high-surface electric field accelerating structures. Current focus areas include: (1) producing high-quality copper photocathodes for the LCLS photoinjector; (2) applying surface-analytical R&D on methods for the suppression of collective electron instabilities in high current positron/proton storage rings, and; (3) producing a long-life high polarization-high current electron source for the ILC. SMS also performs failure analyses and metallographic quality control on materials for critical accelerator component fabrication.

LCLS Photo-injector Cathode Materials R&D: Using a photo-electron spectrometer, a hydrogen-ion bombardment technique was developed to remove fabrication contamination from copper cathode surfaces. The resulting copper surfaces exhibited excellent cleanliness and maximum possible photoelectric quantum efficiency (QE), essential to use as the LCLS photocathode material. QE increases progressively with hydrogen ion bombardment time.

SMS applied this cleaning technique to actual LCLS cathodes; a clean cathode surface proved essential to the excellent operational results obtained during recent LCLS injector commissioning.

Suppressing "Electron Cloud:" Electron Cloud disruption of positively-charged beams is a significant problem for the ILC positron damping ring. Synchrotron radiation from the circulating positron beam generates electrons at the beam chamber wall; the relevant parameter is the secondary electron yield (SEY) of the wall material. SMS made laboratory SEY measurements for yield-suppression techniques applied to surfaces of beam chamber aluminum, including material returned to the lab, under vacuum, after radiation exposure in the PEP-II LER. Particularly successful was grooving of the wall and coating with titanium nitride, which together has a cumulative yield-lowering effect.

Work is continuing with ILC on the effect of bending magnetic field on the SEY emission.

Stabilizing Photocathode Emission: Cathode photoemission stability is critical to maintaining good data collection rates at the LCLS and ILC. A program is in place to passivate LCLS copper cathodes with carbon compounds. Test layers deposited so far have not reduced QE but also have not been sufficiently protective when exposed to air. Coherent layers using a self-assembled monomolecular organic compound are to be tested next.

An alternative to coating copper cathode material is to replace the copper surface with a more robust semiconductor cathode material cesium bromide, a project in progress with SSRL and LCLS. The ILC high-polarization gallium arsenide electron source is also extremely sensitive to QE-poisoning by adsorbed water and carbon dioxide. SMS, in a DOE Small Business Innovation Research (SBIR) collaboration with Saxet Surface Science of Austin, TX, is developing a new cathode coactivation procedure that shows cathode lifetime improvement through "site blocking" of the adsorbing poison gases.

Metallographic Analysis and Quality Assurance: SMS ASTM-qualifies copper material used in the fabrication of mission-critical accelerator and storage ring components. Bulk analysis of welds and brazes, as well as failure analysis of existing components form a large database of results useful for future machine design. For example, an FY07 metallographic examination of a SLAC Linac 30-year old accelerating section showed that the use of the linac for filling the LCLS is assured to at least 2027, when the first external water cooling lines will show pitting corrosion failure (at 1 mil/year). This type of analysis assures that the LCLS will operate without interruption from materials failure.

SMS has produced 7 technical publications and conference papers with our collaborators. They are listed in the Publications Appendix.

Noteworthy practices

Secondary Electron Yield Measurements

SMS possesses a unique ultra-high vacuum (UHV) instrument for the coupled measurement of SEY and photo-electron spectra. Data have been collected on material samples from other DOE laboratories, for the ILC, and from laboratories in Europe and Japan.

Accelerator Materials R&D System Modifications

SMS experimental systems are easily reconfigurable for new R&D projects, examples being the LCLS photocathode cleaning program and the SBIR project with Saxet Surface Science. These types of reconfigurations leverage existing equipment and reduce funding requirements. A portable UHV loadlock design was copied for use in the LER, to return material from the beam chamber to the lab for SEY measurement. New samples could then be placed in the LER for further testing. This loadlock design was originally used for ILC electron cathode work.

Test Experiment Program

The FY07 program was tied to LCLS beam development work in the final section of the linac. A suite of tests to develop beam diagnostic techniques for ILC was carried out. In addition, a study of the LCLS beam properties was done using the ILC instrumentation. A second setup measured the effectiveness of beam dump shielding and the codes used to simulate the processes. A separate radiation exposure of the LCLS undulator material was carried out. An experiment with a low flux secondary beam investigated a miniaturized and therefore low background and potentially high resolution Cherenkov photon detection system for fused silica particle identification detectors.

There was strong cooperation and tight coordination between the groups involved. As a consequence, all the scheduled test experiments were able to run and achieve their data goals.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

ILC Beam Instrumentation

T-475, 480, 487, 488, 491 / M. Woods

Six ILC beam instrumentation tests took data in FY07 running parasitically with PEP-II with single damped bunches at 10 Hz, beam energy of 28.5 GeV and bunch charge of 1.6×10^{10} electrons. This ESA test beam has beam parameters for bunch charge, bunch length and bunch energy spread similar to those of the ILC. It uses a four-magnet chicane (reusing SPEAR injection dipoles). Five weeks of running during Run 3, March 7-26 and Run 4, July 9-26, were successfully completed. FY07 data analysis is continuing.

Nine papers related to these experiments were contributed to the 2007 Particle Accelerator Conference (PAC07).

BPM Energy Spectrometer

T-474/491 / Cambridge, DESY, Dunbar, Royal Holloway, UC London, UC Berkeley, Notre Dame, SLAC

This experiment uses precise rf beam position monitors in a magnetic chicane to study the capability and design issues for an ILC energy spectrometer that can achieve 100 part-per-million accuracy (ppm). Two BPM triplets (BPM3-5 and BPM9-11) are mounted upstream and downstream of the chicane. BPM4 on a mover was relocated to the mid-chicane location. A new BPM7 on a mover at the mid-chicane location, and new BPM processing and calibration electronics were provided by the UK collaborators. An interferometer system, provided by Notre Dame University, was reconfigured to monitor mechanical motion between BPM stations at the pre-chicane and mid-chicane locations. Analysis of FY07 results is well advanced and a paper to be submitted to the **Nucl. Inst. & Methods** journal is nearing completion.

Synchrotron Stripe Energy Spectrometer

T-475 / U. of Oregon, SLAC

This spectrometer also has the goal of achieving 100 ppm accuracy for energy measurements at ILC. To do this it measures synchrotron radiation from wiggler magnets in a chicane. A wiggler magnet was refurbished and commissioned in the third leg of the T474/491 chicane. A new quartz fiber detector system with readout by a multianode photo-multiplier tube was provided by U. of Oregon and installed.

Collimator Wakefields

T-480 / Birmingham U., CCLRC – ASTeC, CERN, Lancaster U., Manchester U., TEMF TU Darmstadt, SLAC

This experiment measures collimator wakefield kicks to determine the optimal material and geometry for ILC beam-halo collimators, and to verify simulation codes. The T-491 BPMs are used to measure the wakefield kicks. For this run, eight new sets of collimators, manufactured in the UK, were delivered to SLAC and tested. The collimators include one identical in geometry and material to that used in Runs 1 and 2 as a reference. The others include both Cu and Ti-alloy collimators to distinguish resistive and geometric effects, versions with different surface roughness, one with a flat section in the collimator at the minimum gap, and one collimator with a nonlinear taper. Analysis of results is continuing.

Smith-Purcell Bunch Length Diagnostics

T-487 / Oxford U., Rutherford Appleton Lab, U. of Essex, Dartmouth College, SLAC

This experiment measures coherent microwave radiation emitted as the beam passes close to a grating. It can provide a noninvasive bunch length diagnostic for the ILC. This was a new experiment in FY07. A diagnostic module containing a carousel of three different gratings, insertable filters and an array of 11 pyroelectric detectors was delivered from the UK to SLAC and installed. Good signal-to-background was achieved and data were taken for different bunch charge and bunch length settings.

Interaction Point (IP) BPM Background Studies

T-488 / Oxford U., Daresbury Lab, SLAC

This experiment studies background effects for the IP feedback BPMs at the ILC due to copious production of low energy e^+e^- pairs from beamstrahlung that shower in nearby material. Three thin radiators (1% r.l., 3% r.l., and 5% r.l.) were installed on a target mover frame upstream of the BPM module. Data were taken with the new foils that generated charged “spray” together with the primary beam. Data were also taken to repeat the data taken in Run 2, with a bunch charge of about 1×10^7 incident on the low-Z carbon absorber and “BeamCal” mockup upstream of the BPM. This experiment is now complete and has demonstrated that backgrounds from beamstrahlung e^+e^- pairs do not constitute a significant background for the IP feedback BPM performance.

EMI Studies

U. Oregon, SLAC

Tests were performed to characterize beam-induced electromagnetic interference (EMI) along the outside of the ESA beam line, and to study an EMI failure mode in electronics from the SLD vertex detector. A ceramic gap was relocated to the drift length between chicane dipoles B1 and B2 to facilitate these studies. A 23-GHz diode detector was added to the existing low-frequency broadband antenna diagnostics. EMI radiation levels and electronics failures were studied for different shielding configurations, and with penetrations of different sizes in the shield, and with a BNC feed through penetration.

LCLS Beam to ESA

T-490 / P. Emma, M. Woods

This was a collaboration between the ILC and LCLS teams. It allowed energy spread and jitter measurements, and cross-calibrated the LCLS beam charge instrumentation comparing toroids in the LCLS injector, the SLAC linac, the A beam line, and ESA. This work was also used as a check-out for the T-experiment program that followed.

Measurement of Induced and Residual Radioactivity

T-489 / S. Roesler

This collaboration between groups at CERN and SLAC employed the ESA beam and utilized the shielding capacity to permit beams of 28 GeV, with 2×10^9 per pulse, to be stopped in a dump near the east wall. Material samples were mounted at various distances from the dump and, following strict radiological protection procedures, their dose and activation were measured. A “Faraday cup” measurement of total beam charge was made to calibrate the experiment and cross-calibrate the beam toroids. This encountered technical difficulties, but procedures have been developed to achieve the precision needed. Gamma spectroscopy and dose rate techniques were used to quantify the induced radio-nuclides. The results are under analysis, centering on a comparison with simulations using the most recent version of FLUKA with enhanced treatment of fragmentation, MARS, and other codes normally used in the process of shielding design. First results are anticipated in winter 2008.

Resolution of Compact DIRC Particle Identification System

T-492 / J. Va’vra, J. Schwiening

This experiment seeks to find and overcome impediments to enhanced particle identification in DIRC-type systems, as used at *BABAR* and potentially in future installations. It takes advantage of the space, crane coverage and communication plant provided in the End Station. The beam, tuned to 10 GeV with 0.2 electrons per pulse, was generated by directing the LCLS beam at a beryllium target in the beam switchyard. The beam was at 10 to 30 Hz for parasitic operation of T-492, and the arrangement worked well. A set of various pixellated photomultiplier and microchannel detectors was used to study the Cherenkov light patterns collected from a fused silica bar similar to those employed in *BABAR* for particle identification. Pulse amplitude and fast timing information was collected for each electron traversing the bar. An additional beam hodoscope and fast-timing counter were deployed to constrain the beam particle trajectory and timing. Substantial detector improvements included increased pixellation and analog-to-digital coverage, and a new, highly compact, electronics system from University of Hawaii (G. Varner). The latter was used to permit detailed correlation between pulse charge and fast pulse timing.

From six full days of data, 800k good single electron events were obtained. The data analysis is ongoing; preliminary observations were presented at the RICH2007 Workshop in the fall 2007.

Undulator Magnetic Material Irradiation Experiment

T-493 / H-D. Nuhn

The goal of this experiment was to quantify the susceptibility of the LCLS undulator permanent magnet material to radiation damage. The outcome will determine the nature of beam-loss measurement and protection systems to be deployed. The LCLS beam was directed to the same beam dump as used for T-489, and similar diagnostic techniques were employed. The activity in the test samples was allowed to decay, and they are now undergoing magnetic measurements, with results expected in the next months.

Objective 1.2 Leadership in Science and Technology

Refereed journals

- D. Williams et al., **Int. J. Mod. Phys.**, A2151 (2006) 35 (T-460)

- J. W. Belz et al., **Astropart. Phys.**, 25 (2006) 129 (T-461)
- J. Va'vra et al., **NIM A** 572 (2007) 459 (T-469)

Conference proceedings

- IEEE Nuclear Science Symposium, San Diego, CA Oct 2006
- J. Benitez et al., SLAC-PUB 12236 (T-469)
- IEEE/APS Particle Accelerator Conference 2007, Albuquerque, NM
- P. Burrows et al., EUROTEV-REPORT-2007-031 (T-488)
- A. Lyapin et al., EUROTEV-REPORT_2007-039 (T-474)
- G. Bower et al., SLAC-PUB-12612, PAC07 p3094 (EMI Studies)
- S. Molloy et al., SLAC-PUB-12598, PAC07 p4201 (T-490)
- S. Molloy et al., EUROTEV-REPORT-2007-044, PAC07 p4207 (T-480)

One member is on the Steering Group for the Nuclear Science Symposium, a major detector instrumentation conference.

Beam Physics

The Beam Physics Department has made significant contributions to the accelerator community in the past year:

- Supported the operation of PEP-II through improved machine optics.
- Led an FEL study on "PEP as a future light source" as a part of investigations for the future of SLAC.
- Continued calculations of beam instabilities for the ILC damping rings.
- Made major progress in understanding spin dynamics, impedance calculation, and theory of controlling beam instabilities, resulting in nine publications in peer-reviewed journals.
- Hosted an international workshop for the LHC beam-beam compensation as a part of LARP efforts.
- Continued educational activities and taught four courses on accelerator theory and beam physics in the US Particle Accelerator School and universities.

Objectives 1.2 and 1.3
Leadership and Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

The following papers present research highlights in FY07.

- *Matrix Formalism for Spin Dynamics Near a Single Depolarization Resonance*, Alexander W. Chao, **Phys. Rev. Special Topics – Accelerators and Beams 8**, 104001 (2005).
- *Experimental Test of the New Analytic Matrix Formalism for Spin Dynamics*, V.S. Morozov et al, **Phys. Rev. Special Topics – Accelerators and Beams 10**, 041001 (2007).
- Experimental Verification of Striking Predicted Oscillations Near a Spin Resonance, V.S. Morozov, et al., submitted to **Phys. Rev. Lett**. (2007).

NOTEWORTHY PRACTICE

New matrix formalism was proposed that represented the first generalization of the well-known Froissart-Stora formula, which has been used for over 60 years. This formalism predicts some striking interference effects in spin dynamics. The latter two papers present experiments yielding results in almost perfect agreement with the prediction.

J ▪ EXO Double-Beta-Decay Experiment

Objective 1.2 Leadership in Science and Technology

The Enriched Xenon Observatory (EXO) proposes to use a large quantity (>1 ton) of xenon enriched in the Xe^{136} isotope as both a decay and detection medium for neutrinoless double-beta decay. The double beta decay process,

$$Xe^{136} \rightarrow Ba^{136++} + e^{-} + e^{-} \ (+ 2\nu)$$

can proceed in the two-neutrino ($2\nu\beta\beta$) mode expected from the Standard Model (already observed in several nuclei other than Xe^{136}), or possibly in the neutrinoless ($0\nu\beta\beta$) mode. The $0\nu\beta\beta$ process is expected to occur only if neutrinos are Majorana particles (in which case neutrinos are their own antiparticles), and at a rate proportional to the square of an "effective" neutrino mass, and hence its observation would serve as both a mass measurement and as the first demonstration that Majorana neutrinos occur in nature.

A prototype device is under construction. This phase I experiment (EXO200) will use approximately 200 kg of enriched xenon and will be placed in the DOE-operated underground facility WIPP (Waste Isolation Pilot Plant) in Carlsbad, NM.

Progress in FY07 includes:

- Completion of modular clean-room facility at Stanford's HEPL End-station III.
- Assembly of cryostat, refrigeration, xenon handling, power supply and data monitoring and control systems in the clean rooms.
- Operation and test at HEPL.
- Dissassemble HEPL-based equipment and ship to WIPP.
- Reassemble clean rooms underground at WIPP (nearly complete); recommissioning of apparatus started
- Liquid xenon time projection chamber detector construction continues at SLAC/Stanford.
- R&D for barium tagging continued at Stanford.

In FY07, the EXO collaboration has published four papers in either **NIM** or the **Physical Review** – these papers covered technical issues relating to the R&D for EXO 200 and barium tagging, and the radiopurity qualification of materials used for construction of the apparatus.

Plans for the upcoming year include:

- Recommissioning of the cryostat at WIPP.
- Completion and testing of the liquid xenon TPC at SLAC/Stanford.
- Preparation for TPC shipping to and installation at WIPP.
- Continuing R&D for barium tagging including new efforts at SLAC.

K ▪ Theoretical Physics

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

The work of the SLAC Theoretical Particle Physics Group covers a large number of topics spanning the whole range of interests in particle physics. We discuss eight specific examples of highly influential papers published by the Theory Group in the past year.

For each paper, we quote the current number of citations from SPIRES. These are citations from the first fraction of a year after publication and should not be compared to the eventual total citation impact.

Work is highly collaborative with other institutions. Authors from the SLAC Theory Group are starred.

Determination of Dark Matter Properties at High-Energy Colliders, by Baltz (SLAC-KIPAC), Battaglia, Peskin*, and Wizansky**, Phys. Rev. D74**:103521, 2006. (51 citations)

> This paper introduced a computationally-intensive technique to quantify the relative and complementary impacts that collider and astrophysical experiments will have on the question of the identity of the particle of cosmic dark matter. This paper was a major reference for the cosmology section of the ILC RDR.

Hadronic Spectra and Light-front Wavefunctions in Holographic QCD, by Brodsky* and de

Teramond, **Phys. Rev. Lett. 96**:201601, 2006. (43 citations)

This paper developed a new predictive theory of hadron wave function based on the AdS/CFT connection between strong-coupling gauge theories and quantum gravity. The theory has direct applications to exclusive and low-energy reactions in QCD.

Comment on Form-factor Shape and Extraction of |V(ub)| from B ---> pi l nu, by Becher and Hill*, **Phys. Lett. B633**:61-69, 2006. (28 citations)

This paper developed the quantitative bridge between lattice gauge theory computations and experimental measurements of B meson semileptonic decays. This is the future of high-precision measurements of the fundamental weak interaction parameters Vub and Vcb.

Direct Mediation of Meta-Stable Supersymmetry Breaking, by Kitano*, Ooguri, and Ookouchi, **Phys. Rev. D75**:045022, 2007. (42 citations)

This paper presented a new, simple, explicit model of supersymmetry breaking based on new ideas in the mathematical theory of strongly-coupled supersymmetric models.

Bootstrapping One-Loop QCD Amplitudes with General Helicities, by Berger*, Bern, Dixon*, Forde*, and Kosower. **Phys. Rev. D74**:036009, 2006. (46 citations)

This paper was part of the development by this group of a new method for computing QCD radiative corrections to multi-jet processes, results essential to the interpretation of the LHC experiments. This paper gave the first computation of the one-loop radiative corrections to 2->4 gluon amplitudes, overcoming a major barrier to future progress.

The Four-Loop Planar Amplitude and Cusp Anomalous Dimension in Maximally Supersymmetric Yang-Mills Theory, by Bern, Czakon, Lance J. Dixon*, Kosower, and Smirnov. **Phys. Rev. D75**:085010, 2007 (61 citations)

This paper gave the first computation of a gauge theory anomalous dimension at four loops. This not only represents the state of the art in Feynman diagram computation but also gives a highly nontrivial data point for studies in mathematical physics of the conjectured integrability of N=4 super-Yang-Mills theory.

Flux Compactification, by Douglas and Kachru*. **Rev.Mod.Phys.79**:733-796, 2007. (97 citations)

This article reviews the new strategy for obtaining solutions of string theory introduced by Giddings, Kachru, and Polchinski in 2002 (in a paper that now has 746 citations) that has been actively pursued since that time by Kachru and his group. This method, which gave answers to many of the traditional problems that string theory encountered in the 1980s, has allowed the construction of large families of new solutions, including string models with cosmological inflation and dark energy.

Observational Signatures and Non-Gaussianities of General Single Field Inflation, by Chen, Huang, Kachru*, and Shiu**. JCAP 0701**:002, 2007. (42 citations)

This paper gave the dictionary that relates properties of an explicit model of cosmological inflation to properties that can be measured experimentally. It provides a foundation for testing string theory and other models of the very early universe.

In the following, we describe work in the Theory Group on long-term, high-risk research programs. These include early analysis and championing of many of the current major projects in DOE High Energy Physics.

- Our group played a central role in the definition of the experimental program for the *B* factories. We directed one of the earliest studies for the experimental program of the ILC. We introduce new physics ideas to be explored at ILC. We contributed significantly to the planning for experiments at the Tevatron Run II and the LHC.

- Many of the influential papers listed above directly impact these physics programs.

Significant awards

In October 2006, Stanley Brodsky was awarded the J. J. Sakurai Prize of the American Physical Society.

Invited talks

The members of the theory group are frequent invited lecturers in the US and international physics communities. A sampling of invited talks and special school contributions follow.

Brodsky, Stan

- 24 invited talks, including a department colloquium at the University of Kentucky and a lecture to the Thomas Jefferson Laboratory National Accelerator Facility (JLab) Users' Meeting
- Lectures at the 2007 Erice Summer School of Subnuclear Physics
- The prize lecture for the J. J. Sakurai Prize of the APS

Dixon, Lance

- 23 invited talks, including department colloquia at Arizona State University, University of Pennsylvania, Brown University and CERN.
- Five invited talks at conferences, including the plenary review of Perturbative QCD at the 2007 Lepton-Photon Conference in Daegu, Korea.

Peskin, Michael

- 15 invited talks, including department colloquia at Arizona State University, Syracuse University, and Columbia University
- Winter/summer school lecture series at the retreat of the MIT Center for Theoretical Physics, the 2007 ICTP summer school on particle physics, and the 2007 PiTP School of the Institute for Advanced Study

Hewett, JoAnne

- 12 invited talks, including department colloquia at the University of Kentucky and ANL.
- A plenary summary lecture at the ILC Workshop (LCWS07) at DESY.

Kachru, Shamit

- 11 invited talks, including department colloquia at UC Santa Barbara, the University of Arizona, and MIT invited plenary lectures at the April meeting of the APS and at the international conference, Strings 07.

Other members of the Theory Group gave an additional 45 invited lectures (at least) at various departments, institutes, and conferences. These included:

- Berger, Carola: Dirac lectures at Florida State University
- Graham, Peter: CERN Theory Colloquium
- Kitano, Ryuichiro: Lectures at the 2007 Summer Institute of the Yukawa Institute for Theoretical Physics, Kyoto

Tools and techniques

Almost all of our papers introduce new theoretical techniques that we invent for the purpose. Many of these have become widely used.

We have also created a number of special-purpose computer programs that we make available to the community. Recent or recently updated codes are:

Dixon, Lance

- Vrap: A code for computing vector boson rapidity distributions in hadron collisions at the NNLO level of QCD.

Weinstein, Marvin

- Feynmangraphs: A Maple package for drawing Feynman graphs
- Raytracing: A Maple package for raytracing and lens design
- PX commutator: A Maple package for quantum mechanics calculation
- FITS: A Maple package for data visualization.
- These programs are available from the Maplesoft web site

Maitre, Daniel

- HypExp II: A Mathematica package for expanding hypergeometric functions. This program is available from the Mathematica web site.

Alwall, Johan

- A member of the development team for MADGRAPH/MADEVENT.

Objective 1.2 Leadership in Science and Technology

We are a theoretical physics group. The level of innovation in our solutions is the number one measure of quality in our own assessment and in ratings by external reviewers. Illustrations of our innovations are noted below.

While members of our group take part in short-term projects and respond actively to new experimental results, much Theory Group work is based on long-term programs that seem extremely risky when first conceived. We continue to take risks, and we hope that through new programs the group will have similar long futures. Much work begun as long ago as the 1970s is coming to experimental fruition now in *B* Factory, QCD, LHC, ILC design and other current work.

The Theory Group collaborates widely. Our ability to attract top postdoctoral scientists is remarkable. The acceptance to our postdoctoral positions outranks all other major theoretical HEP groups around the world.

Out staff members also hold visible leadership positions.

Brodsky, Stan

- member, Scientific Advisory Board of the Hadron Physics Integrated Structure Initiative of the European Commission
- member, Scientific Advisory Committee for the CERN LHeC
- member of the advisory committee for the Nuclear Theory Center, Indiana University
- member, Stanford University Committee on Research
- associate editor, **Nuclear Physics B**

Dixon, Lance

- member of the Executive Committee of the SLAC Users Organization
- consultant for the annual DOE Program of BNL

Hewett, JoAnne

- member of the HEPAP and of the HEPAP P5 subpanel
- member of the FNAL Program Advisory Committee
- member of the steering committee for the NSF LHC Theory Initiative
- member of the American Linear Collider Physics Group Executive Committee
- member, German Excellence Initiative Review Panel of the Deutsche Forschungsgemeinschaft

Peskin, Michael

- consultant for the annual DOE Program Review of FNAL
- chair, American Physical Society Publication Oversight Committee
- member, Physics Committee, A. P. Sloan Research Fellowships

Kachru, Shamit

- editor, **JHEP**

In addition, we have organized or helped to organize the following conferences.

Brodsky, Stan

- founding organizer of the Light Cone series of conferences

Hewett, JoAnne

- SLAC Summer Institute

Peskin, Michael

- organizer of the West Coast LHC Theory series of workshops (FY07 workshops at UC Davis and UC Irvine)

Kachru, Shamit and Silverstein, Eva

- organizers of the KITP workshop on String Phenomenology, fall 2006
- 2007 Trieste Spring School of the ICTP
- TASI 2007 Summer School, University of Colorado

Rizzo, Tom

- ILC/LHC Workshop, FNAL, 2007

The SLAC library lists 106 articles in peer-reviewed journals published by members of the Theory Group in FY07. The breadth and impact of selected articles was discussed above.

Objective 1.4 Provide for Effective Delivery of Science and Technology

The work of Lance Dixon has been the subject of feature articles in **New Scientist** (Nov 4, 2006) and in **Nature Physics** (July, 2007) and was a **Physical Review Letters** Editor's Suggestion, (April 20, 2007).

JoAnne Hewett of our group and Risa Wechsler of the Kavli theoretical group are contributors to Cosmic Variance (www.cosmicvariance.com), one of the most widely read science blogs.

Contributions to Summer Institutes, conferences, and publications are discussed above.

Other

L ▪ Scientific Computing

Scientific Computing at SCCS

SLAC Scientific Computing supports the SLAC science mission by designing, building and operating state-of-the-art computing facilities and conducting research in computing areas where SLAC needs to push against the limits of current technologies and understanding. Facilities and expertise now serving the *BaBar*, GLAST, ATLAS, astronomy and astrophysics programs will act as the foundation for agile computing serving the needs of photon science, especially with the emergence of LCLS.

SLAC is an internationally recognized leader in petabyte-scale data management, the simulation of particle interactions with structures and detectors, measuring the performance for science of the worldwide Internet, and cyber security in an open distributed environment.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

SLAC is the leading North American member of the international Geant4 Collaboration. The Geant4 software toolkit is used to simulate particle interactions with complex detectors by a majority of HEP experiments worldwide. The SLAC team has been instrumental in extending applicability to US space and medical programs and expects to be able to apply Geant4 in modeling LCLS/LUSI instruments. The key published paper (2003) describing the toolkit has been cited over 900 times in published works, and was second in the list of **NIM-A** articles most downloaded in the last three months of FY07.

Mission-driven network research at SLAC is internationally recognized, most notably for work associated with Internet end-to-end Performance Measurements (IEPM) where SLAC leads the world in quantifying the networking "digital divide" between different nations and regions. SLAC is an international leader in measuring the performance of the global Internet in support of distributed data-intensive science, driven by a science program for which high-performance data transfer is vital.

SLAC conducts R&D in scientific database design, and in scalable data management technology. Programmatic needs have driven SLAC to become one of the leaders in defining policies, procedures and technologies to allow distributed "Grid" computing to be both open and secure.

Objective 1.2 Leadership in Science and Technology

SLAC leads the key areas of hadronic physics and overall architecture for the Geant4 Collaboration, a consortium of over 130 scientists from over 60 institutes in North America, Europe and Asia. SLAC provided the Chair of the Geant4 Collaboration Board from 2001 to 2007. Key members of the SLAC Geant4 team were recruited internationally as the acknowledged experts in their fields. The IEPM activities and Grid security efforts both involve international collaboration in which SLAC plays a leading role.

SLAC scientists working on the design of responsive petabyte-scale databases have achieved a leadership role in designing the database systems for the LSST program. The excitement of this work has proven attractive to an outstanding software architect who has left a more lucrative job at a major Silicon Valley employer to work in SLAC Scientific Computing on LSST.

SLAC's PetaCache project is exploring a novel approach to high-performance data analysis involving the use of a multi-terabyte flash-memory data cache.

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

In FY07 SLAC Scientific Computing published six papers in refereed journals in addition to contributing to over 70 *BABAR* and GLAST papers. Scientific Computing members gave 12 conference presentations and over 20 presentations at workshops. A peer review of Geant4 in June 2007 showed major progress in line with the recommendations of earlier reviews, but with some significant areas where the progress fell short of that desirable.

Objective 1.4 Provide for Effective Delivery of Science and Technology

Delivering results and products to the community is a priority in SLAC Scientific Computing. This priority has resulted in SLAC organizing one or more workshop/tutorial weeks each year to help the high-energy physics, space and medical communities get full benefit from Geant4. In 2007 a tutorial week was held at SLAC and SLAC collaborated with the Jet Propulsion Laboratory (JPL) to organize a space users' workshop there.

In other areas, such as the Andrew File System, and some aspects of Parallel Computing where SLAC Scientific Computing has significant competence, every opportunity is taken to organize workshops and deliver lectures and tutorials to the Stanford and wider US community.

Advanced Computations Department

The Advanced Computations Department (ACD) develops and applies high-performance computational tools for the design, optimization and analysis of existing and future accelerator projects in the Offices of HEP, BES and Nuclear Physics within DOE. Under the support of the SciDAC computation initiative, these codes solve the most challenging computational problems facing accelerator designers and builders using the most powerful computers in the DOE Office of

Science. Essential to the ACD program is a strong collaboration with the SciDAC Centers for Enabling Technologies and Institutes, established to deploy state-of-the-art applied mathematics and computer science techniques for advanced application codes. The resulting modeling and simulation capabilities have had a tremendous impact on complex accelerators, and will have on others such as the ILC as it enters the engineering design phase.

Objective 1.1 Science and Technology Results Provide Meaningful Impact on the Field

Development of Parallel Electromagnetic and Beam Dynamic Codes

ACD develops high-performance electromagnetic and beam dynamics modeling tools for accelerator design, optimization and analysis. The parallel electromagnetic tools developed by ACD are based on the high-order finite-element method, which enables high-fidelity, high-accuracy simulations of large accelerator systems. The suite of codes includes cavity design, wakefield computation, multipacting analysis, and self-consistent particle-field simulation for rf guns and sheet beam klystron guns. The parallel beam dynamic codes focus on studying beam-beam effects in circular machines such as the LHC. These modeling tools are in production mode on DOE flagship supercomputers at LBNL National Energy Research Scientific Computing Center and ORNL National Center for Computational Sciences.

Computational Support for the ILC

The electromagnetic codes have provided immediate computational support for the ILC toward its engineering design phase. The modeling activities are summarized as follows.

- Investigate wakefield effects in the Main Linac rf superconducting cavity due to cavity imperfection arising from the cavity fabrication and the tuning process.
- Investigate an alternative cavity design to improve operational efficiency and reduce cryogenic loss.
- Determine the efficiency of beamline absorbers in the Main Linac cryomodule used to mitigate heating effects from beam-excited power.
- Using simulations to corroborate high-power processing experiments at SLAC, extensive multipacting analyses have been carried out for the Main Linac cavity coupler.
- The BDS crab cavity, based on a FNAL design, has been optimized for improved wakefield damping and better power handling. A prototype cavity based on SLAC optimized coupler design is being fabricated at the Cockcroft Institute in the UK.
- Impedance calculation for the Damping Rings, in close collaboration with designers outside SLAC to develop engineering prototypes.

Invited talks

ACD staff presented eight invited talks at international conferences in FY07. See the Publications Appendix for details.

Awards

Gordon Bell Award

- Dr. Volkan Akcelik, a SLAC computer scientist, is a recipient of the prestigious **Gordon Bell Prize**, which is awarded to an individual each year at the Supercomputing Conference for outstanding achievements in high-performance computing applications.

INCITE Award

- Computational Design of the Low-loss Accelerating Cavity for the ILC

NOTEWORTHY PRACTICES

The electromagnetic eigensolver Omega3P has been distributed to FNAL, JLab, ANL and the University of Texas A&M. ACD has trained scientists at these institutions to use the code to model their respective applications. The investment of DOE on high performance electromagnetic computing has thus benefited a wide community of scientific research.

Finite-Element Particle-in-Cell Method

The finite-element approach in electromagnetic modeling is well established in the scientific community, but the treatment of particle-field interactions in a self-consistent manner on unstructured grids remains an active area of research. ACD has successfully demonstrated the viability of a finite-element particle-in-cell code based on higher-order finite-elements. The 2-dimensional version of this code, Pic2P, has been applied to evaluate the emittance of the LCLS rf gun and has shown superior computational accuracy and efficiency to existing simulation tools. The 3D version, Pic3P, is under development.

Multiphysics Analysis for Virtual Prototyping

A parallel, multiphysics analysis tool using the finite-element method, TEM3P, which integrates electromagnetic, thermal and mechanical effects, is being developed for design and optimization of cavities. This provides the accelerator community with a comprehensive and efficient tool for virtual prototyping of accelerator components. Benchmark calculations for the LCLS rf gun have validated the implementation of the new thermal and mechanical solvers in TEM3P, and have demonstrated the fast turnaround time of the simulation cycle from parallel processing.

Collaborative Research in Computer Science and Applied Mathematics

A key component of the SciDAC computing initiative is the collaboration between application scientists from SciDAC application projects and applied mathematicians/computer scientists from SciDAC Centers for Enabling Technologies or Institutes (CETs/Institutes). Advances were made on numerical algorithms in the areas of shape optimization, scalable linear solver, adaptive mesh refinement, and, parallel code performance and optimization. Two notable accomplishments:

- *Shape Determination of Superconducting Cavity* – in collaboration with SciDAC CET TOPS and ITAPS. The ILC Main Linac cavity shape is deformed during fabrication and tuning. As a result, the damping properties of beam-excited wakefields deviate from those predicted from an ideal cavity. A shape determination algorithm through an inverse minimization problem has been developed to determine the true cavity shape from measured data.
- *Scalable Linear Solver for Large Systems* – in collaboration with SciDAC CET TOPS. The simulations of large accelerator structures, such as the ILC cryomodule which consists of 8 cavities, have remained challenging computational problems as they require large computing resources, both in CPU time and computer memory.

Collaborating Institutions

Under the SciDAC COMPASS project, collaborations have been established among scientists in the following SciDAC CETs/Institutes and scientific institutions to develop and deploy advanced applied mathematics and computer science tools to enhance SLAC application codes.

- Towards Optimal Petascale Simulations (TOPS) – LBNL, UC Berkeley, O. U of Texas, Austin, Columbia
- Interoperable Technologies for Advanced Petascale Simulations (ITAPS) – LLNL, SNL, ANL, RPI
- Combinatorial Scientific Computing and Petascale Simulations: (CSCAPES) – KSNL
- Center for Scalable Application Development Software (CScADS) – Rice
- Institute for Ultra-Scale Visualization (IUSV) – UC Davis
- UC Davis – Z. Bao
- ORNL – R. Barrett, S. Hodson, R. Kendall
- LLNL – R. Vuduc, D. Quinlan

Objective 1.3 Provide and sustain Science and Technology Outputs that Advance Program Objectives and Goals

Publications

Most of ACD scientific results are published in conference proceedings, with a total of 14 published papers. A paper on the numerical algorithms of determining the shape of a superconducting cavity from measured data has been accepted for publication in the **Journal of Computational Physics**.

NOTEWORTHY PRACTICES

ILC Computational Grand Challenge

Recommended by the ILC GDE for the SciDAC COMPASS team, the Computational Grand Challenge, issued as a problem of national scientific interest, is to calculate wakefield effects in a 3-cryomodule rf unit of the ILC Main Linac including realistic cavity dimensions and misalignments. The size of this problem is several orders of magnitude larger than any currently computed. As a first step in simulating the 3-croyomodule rf unit, ACD has been able to successfully calculate wakefield effects in a cryomodule. This was achieved early in the COMPASS project, and is attributed to the advances in parallel numerical algorithms through collaboration with SciDAC CETs/Institutes.

Objective 1.4 Provide for Effective Delivery of Science and Technology

The modeling tools have delivered scientific results to the ILC R&D in a timely manner. Multipacting simulation using Track3P has helped understand the phenomenon of high power processing of the ILC Main Linac cavity fundamental coupler experiments conducted at SLAC. Based on the FNAL crab cavity design, the eigensolver Omega3P has been used to enhance wakefield damping and improve power handling capabilities of the cavity.

M ▪ Klystron/Microwave Department

The SLAC Klystron and Microwave Department (KMD) develops and manufactures klystrons and other high power microwave components for use in present and future HEP and BES programs. The department operates and maintains these klystrons and supporting rf systems, and provides technical support and experimental facilities in areas such as high gradient experiments, vacuum electronic assembly, coatings, low level rf design, and high power rf components.

Although the department’s activities center around it core competency – engineering, design, manufacturing, and operations support of microwave equipment and systems at SLAC, the department’s R&D and technical support functions are heavily matrixed out to the various SLAC programs. Briefly stated, KMD’s goals are to provide R&D and technical support to other SLAC programs (customers) in an efficient, effective, and safe manner. The following briefly describes the primary activities and progress of the KMD.

Linac PEP-II Operations Technical Support

A main technical support function of KMD is to ensure an uninterrupted supply of microwave power for linac operation. The SLAC two-mile linac utilizes 242 65-MW pulsed klystrons (known as the 5045 klystron) to supply this power. These klystrons are manufactured, maintained and supported by KMD.

During FY07, the department manufactured twelve 5045 klystrons for the SLAC linac. These 65-MW S-band pulsed-power klystrons have proven to be an extremely reliable and economical rf source for the SLAC two-mile accelerator. The lifetime and reliability of this klystron continues to improve. Current mean time between failures is 75,000 hours and there are now more than 25 gallery klystrons with over 100,000 accumulated operating hours.

The department also supplies and supports the large 1.2 MW CW klystrons supplying power to the rf cavities in the PEP-II storage rings. In FY07, the last of the 12 SLAC designed and manufactured klystrons was completed and installed. These SLAC designed klystrons have now replaced all but four of the original industrial klystrons. The improved power and reliability of the new klystron has contributed significantly to PEP-II luminosity.

KMD also provides both low and high level rf engineering, maintenance, and operations support. The group's primary focus is the maintenance and operation of the low level and high power rf systems in the SLAC Linac, damping rings, and PEP-II storage rings.

The KMD Microwave Engineering and Maintenance group provides primary operational and engineering support for the PEP transverse feedback systems which are tuned, operated, and maintained by the group. During FY07, installation of the LBNL digital delay and filter chassis for PEP transverse feedback was successfully completed and the units are operational.

The gallium-germanium (GaGe) board diagnostic system allows physicists to view bunch by bunch motion of all stored bunches in PEP several milliseconds before an abort. The nature of the bunch train motion before the abort helps to diagnose the abort's cause. A powerful library of MatLab© analysis functions is made easily available through a GUI.

Also in FY07, the final two high-powered rf stations were installed and commissioned.

The group contributes rf engineering assistance to smaller projects throughout SLAC, including SPEAR, End Station experiments, and ILC.

Technical Support for the LCLS Project

In FY07 the LCLS rf gun was installed in the Sector 20 LCLS injector and has been operated as part of initial LCLS injector commissioning. Gun performance easily met all the LCLS commissioning goals.

A second gun was assembled and baked out and ready for installation in the KMD Test Lab Accelerator Structure Test Area (ASTA) bunker. Gun #2 will undergo high power rf testing in the ASTA bunker and will serve as the LCLS spare.

KMD provided extensive support to several aspects of the injector and linac elements of the LCLS construction project.

Fabrication, installation, and commissioning of the LCLS injector and linac rf systems were completed. The rf system consists principally of four racks of mainly custom-built low noise rf chassis in a temperature-stabilized room. A total of 40 chassis were built, tested, installed and commissioned for this past run. A low noise 4-channel 16-bit digitizer board was designed for the LCLS rf system. Sixty of the boards were built and used in the LCLS rf, BPM, toroid and bunch length monitor systems.

The low level rf system exceeded many of the specifications. The injector rf stations achieved below 50 fs rms of rf jitter, less than half of the 100 fs specification.

A conceptual design of an accelerator with built-in focusing was proposed in SLAC-PUB-12257.

KMD fabricated and installed the XL4 (X-band rf source) and associated rf components for the bunch compressor system.

ILC

In the tradition of extending state-of-the-art klystron design, KMD is currently working on the next generation of rf power sources to power the ILC accelerator. This developmental klystron, known as a Sheet Beam Klystron (SBK), uses a broad sheet-like electron beam rather than the intense round beams used in traditional klystrons. This will allow the device to operate at lower voltage and higher current than conventional klystrons, while having the low beam current densities required for high operating efficiencies. Furthermore, the wide beam geometry allows for greater internal surface area of the klystron, thereby reducing beam interception and circuit heating problems that have plagued earlier conventional klystrons.

The ILC L-band SBK design effort has increased significantly in FY07 with the goal to complete the mechanical design and fabrication of a beam test diode and klystron in FY08. The electrical design of the device was completed in FY07 along with much progress on the mechanical design and drafting, as well as initial long lead fabrication operations. Successful completion of this project will constitute a major breakthrough in high power microwave tube design benefiting myriad HEP and industrial applications.

Other areas of KMD support for ILC activities.

- Fabricated the first warm 'L-Band" accelerator structure for ILC positron capture application. The prototype room-temperature structure is currently being installed at the NLCTA in End Station B (ESB), where it will be tested with one-millisecond pulses at an accelerating gradient of 15 MV/m.
- Provided the ILC project with support in design and fabrication of several L-band microwave components needed for the rf distribution system tests planned for the ESB program. This included the new 3 dB hybrid coupler, variable take-off, coupler processing cavity, coax couplers, and block windows.
- Initiated R&D on the design of a ±5 kV @50 Ω, 3-4 ns, 3 MHz pulser for the ILC damping ring injection/extraction kicker. A pulser design with such parameters would significantly reduce the circumference of the ILC damping ring reducing costs. Development of 3-4 ns tool (probes, etc.) was part of the pulser design for FY07. Three HV broadband dividers with 0.2-0.3 ns resolution were designed, manufactured, and tested.
- Broadband kicker design for ILC damping ring was initiated. The proposed transverse electric modes kicker topology possesses lower beam impedance than other known schemes. Reducing the kicker beam impedance would improve damping ring beam dynamics. One proposed kicker structure was simulated in FY07.

R & D

The primary focus of KMD's R&D effort is the L-band SBK, which has been described above.

The department has also been engaged in the development of a 95 GHz SBK. In FY07, a full power version of the 95 GHz Sheet Beam Klystron has been completed and is currently being tested. Although this particular device does not have an immediate HEP accelerator application, this program has had a direct benefit to the overall goal of developing the Sheet Beam Klystron Technology. The program has been funded by outside sources (UC Davis, MURI) and will end with the testing of the current device.

High Gradient Research Program

KMD supports the Accelerator Research Department's high gradient research program. Many experiments conducted at SLAC for this program occur with the extensive support of the KMD Test Lab group. KMD Test Lab has 12 test stands capable of producing high power rf. Currently four of the test stands are being utilized in the high gradient program. The rf power source for these experiments is the X-band klystron (XL4) developed and produced by KMD for the NLC R&D program. This klystron is currently in demand for many current experiments requiring X-band power. The High Gradient Program also utilizes the Test Lab's "ASTA" bunker for high gradient accelerator tests. This facility accommodates experiments in which the generation of x-rays requires significant shielding. In addition to providing support for experiments, KMD provides mechanical engineering, design, and fabrication for many of the high gradient test devices.

KMD Papers and Review Participation

KMD produced five published papers in FY07 and has participated in three reviews. The papers are listed in the Publications Appendix.

Reviews

- Erik Jongewaard served on the SPX Cavity Design Review at ANL, August 23-24, 2007.
- Andrew Haase participated in the Undulator Vacuum Chamber review conducted on September 27 and 28, 2006.
- Ron Akre served on the "Pre-installation Readiness Review for ALS Injector Upgrade" LBNL, September 26, 2006

N ▪ Science Education

"Rising Above the Gathering Storm," released by the National Academy of Sciences in 2005, poignantly describes the challenges the US faces for economic prosperity and national security in a fast-paced economy. Key recommendations are to "vastly improve K-12 science and math education" and "to strengthen the nation's commitment to long-term basic research."

To address these concerns, Jonathan Dorfan created the SLAC Education Task Force Committee to assess our current educational outreach programs and to make specific recommendations to engage SLAC scientists with students and teachers to improve K-12 science education.

Implementation of SLAC Education Task Force Report

In FY07, based on the Education Task Force recommendations, SLAC:

- Created an Office of Education within the Communications Department;
- Hired an Education Officer, Dr. Susan E. Schultz, with extensive experience in conducting teacher professional development workshops, designing curricula, teaching strategies to promote student learning, and evaluating science programs;
- Reassigned staff from the Communications Office to work with Education Officer;
- Reorganized duties of staff and redirected focus of Educational Outreach;
- Posted a job requisition for a new Tour Coordinator to redesign and revitalize the program; and
- Formed new partnerships with local community stakeholders (see below for details).

Educational Outreach Programs

K-12 Student Programs

DOE Regional Science Bowl

- Hosted at SLAC on Saturday, February 10,2007
- 120 high school students representing 16 local schools participated in the competition
- 50 SLAC staff served as content experts, scorekeepers, and scientific judges
- Sponsors and supporters included Sun Microsystems, Cisco Systems, Robert Half International, Google, The Classical Archives, and Stanford University

Undergraduate Programs

DOE SULI

This has been SLAC's most successful educational outreach program for over thirty years. The FY07 program consisted of:

- 23 undergraduate students, including students from traditionally underrepresented groups who collaborated with SLAC scientists on state-of-the-art research;
- 26 SLAC mentors contributed time and expertise to cultivate their students' appreciation of the discipline, to enable students to experience the rigors of research and ultimately to foster the next generation of scientists;
- 100% participation by SULI students to complete the DOE evaluation data consisting of research abstracts and papers, pre- and post- survey on the program components, and an independent survey conducted by Grinnell College;
- Joshua Lande, undergraduate from Marlboro College, Vermont, received the Ernest Coleman Memorial Award for Scholarship and Citizenship based on recognition from his

SLAC mentor and the other SULI students;
- Each year, SLAC recognizes two current SULI mentors who receive the Outstanding Mentor Award for their work with SULI students.

In addition to the SULI program, SLAC directly funds five Stanford undergraduate students who work on various research projects throughout the lab and awards an additional undergraduate student each year through the Katherine Pope Fellowship, who participates in a SLAC research project. SLAC user groups work with approximately 30 undergraduate students who conduct research at the lab but are funded through other sources.

Graduate and Postdoctoral Programs

SLAC Summer Institute (SSI) is a two week program sponsored by DOE and Stanford University

- 259 graduate students, postdocs, and scientists participated
- This year's topic "Dark Matter—From the Cosmos to the Laboratory" provided an opportunity for a fusion between particle physics and astrophysics;
- Featured speakers included: Scott Dodelson on "Cosmology for Particle Physicists;" Jonathan Feng speaking on "Supersymmetry for Astrophysicists;" KIPAC's Steve Allen on use of dark matter theory to calculate the properties of the universe at large; and the landmark observations of dark matter in isolation made by KIPAC's Maruša Bradač and colleagues. These observations were named the third most important science story of 2006 by **Science** magazine.

The SSRL Short Course on X-ray Absorption Spectroscopy and Structural Molecular Biology Applications was held at SSRL on May 13-16, 2007.
- Eighteen graduate students and postdocs from the US and Canada attended.
- The workshop focused on providing understanding of basic theory, experimental considerations, and scientific applications through lectures and practical sessions, include hands-on data collection at the synchrotron beam lines and data analysis.

The SSRL School on Synchrotron X-ray Scattering Techniques in Materials and Environmental Sciences was held at SSRL on May 15-17, 2007.

- More than 45 researchers, mostly graduate students and postdocs, attended the workshop.
- The aim of this workshop was for students, postdocs, and researchers to gain practical knowledge in x-ray scattering methods with an emphasis on information that cannot be found in text books.
- Copies of the talks have been posted on the SSRL website.

The SSRL Structural Molecular Biology Summer School was held September 9-14, 2007.
- It was attended by 34 researchers, mainly graduate students and postdocs, representing four countries.
- The program included tutorials and practical sessions in the underlying theory and experimental aspects of the research techniques macromolecular crystallography, small-angle x-ray scattering and x-ray absorption spectroscopy. A range of scientific presentations on structural biology applications were given by established scientists.

The Photon Science PULSE Center held its first Summer School at SLAC during June 18-22, 2007.
- The school presented comprehensive lectures and an open forum for discussions about FEL including vuv FELs and HHG; multiphoton physics with x-ray FEL; Ultrafast atomic, molecular, cluster physics; attosecond physics; material science and imaging molecules with XFELs; high energy density science, time-resolved absorption and x-ray scattering. The program covered both fundamentals of HHG, soft x-ray, hard x-ray FEL and their use in spectroscopy and diffraction as well as a broad range of scientific applications.
- The goal of the school was to disseminate information about scientific opportunities in ultrafast science and train students and post docs on the new FEL facilities as well as inform researchers who are interested to join this exciting new field.

- The School was attended by >120 participants, mainly graduate students and postdocs that in many cases were new to the field.

SSRL manages the Gateway program, which is an educational program tailored specifically for Mexican-American and Mexican communities in undergraduate and graduate education by engaging student scholars in science and engineering research programs at all levels, some of which is performed at SSRL.

In addition, SLAC funds approximately 86 graduate students and 59 postdocs who work on various research projects throughout the lab. An additional 300 graduate students and 269 postdocs are supported by SLAC user groups and are funded from other sources.

General Public Programs

SLAC Public Tours

- Provide free tours for school groups and the general public.
- Learn about SLAC research through an overview talk and visit to the Klystron Gallery.
- Total visitors participating in SLAC tours during FY07 were 9,094, which includes significant increases in: middle school (1,218) and high school (1,271) students; community college students (100); other undergraduate students (1,150); graduate students and postdocs (489); and general public visitors (3,220).
- Hired a new tour coordinator to redesign and expand the tour program due to anticipated increased demand for partnerships with local school districts and community college faculty.

SLAC Public Lecture Series

- Offered six public lectures to capacity (300 people) audiences.
- All lectures are video-taped and can be viewed on the SLAC Public Lecture website.

NOTEWORTHY PRACTICE

Noteworthy practices are given in the performance summary above.

OPPORTUNITIES FOR IMPROVEMENT

New Initiatives for FY08

Developing New Partnerships

- Initiated partnerships and conducted a needs assessment with science teachers from a local school district and with faculty from four local community colleges;
- Form a partnership with the newly formed Stanford K-12 Initiative, co-chaired by Helen Quinn (SLAC) and Kenji Hakuta (Stanford University), to improve science education and outreach within Stanford University departments as well as local school districts;
- Submitted a proposal to Stanford K-12 Initiative to fund a pilot Science Teacher Institute for Research (STIR) at SLAC.

Possible Addition of New DOE Programs

In FY08, the SLAC Education Office hopes to receive funding to implement two DOE Office of Science Programs:

- Academies Creating Teacher Scientists (ACTS). SLAC is hoping to obtain funding from both the DOE ACTS program and the Stanford University K-12 Initiative to pilot a new program, called the Science Teacher Institute for Research at SLAC. The program will enable high school science teachers to: engage in an authentic research experience at SLAC; design investigative module(s) to be used with their students; participate in follow-up throughout the academic year; and enhance their leadership skills to become instructional change agents within their districts.
- Community College Internships (CCI). The program mirrors the SULI program except it targets students from community colleges. The DOE Office of Science is proposing to

expand the CCI program to also include internships preparing qualified technical people for laboratory employment. SLAC's partner community colleges are interested in both CCI programs.

O ▪ Scientific and Technical Information Management

Objective 1.4 Provide for Effective Delivery of Science and Technology

This year, InfoMedia processed 1,252 scientific and technical information (STI) documents and made all appropriate copies publicly accessible. During this year, all documents were reported using the Office for Scientific and Technical Information's (OSTI) XML harvesting method.

SLAC identifies STI publication products as preprints, preprint leaks, and reprints, as defined below.

- Preprint
  - Original manuscript submitted to SLAC for publication. When preprints are published, preprint numbers are assigned and electronic announcement records are harvested by OSTI, which includes a link to the electronic version.
- Preprint Leak
  - Manuscript submitted to SLAC after publication elsewhere, but the original manuscript is available to SLAC. When preprints leaks are published preprint numbers are assigned and electronic announcement records are harvested by OSTI, which includes a link to the electronic version.
- Reprint
  - Manuscript first published elsewhere—typically a journal—and the original manuscript is not available to SLAC. SSRL makes up the bulk of reprints due to the proprietary nature of that work. When reprints are processed, reprint numbers are assigned and electronic announcement records are harvested by OSTI, but a link to the text from the SLAC publications server is not provided.

This year there was a 22% increase in the number of STI documents processed. The increase in preprint totals was 6%. In contrast, the number of reprint documents, typically non-HEP journal articles, increased by 48%. The overall increase is due, in part, to the addition of a part-time person working on this. For reprints specifically, there is typically a delay between notification of the actual journal publication date and the hands-on parsing of that metadata into SLAC's publishing system. InfoMedia continues to work to streamline and improve these processes and supporting systems.

Table 1 Total OSTI Announcements Reported

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Total STI reported to OSTI	886	1,156	1,244	1,580	1,207	974	1,252

Table 2 OSTI Preprint Announcements

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Preprints	260	305	299	417	418	463	521
Preprint Leaks	69	207	435	438	370	263	250
Total Submitted to OSTI	329	512	734	855	788	726	771
Leaks as Percentage of Total	21%	40%	59%	51%	47%	36%	32%

Table 3 OSTI Reprint Announcements

	FY01	FY02	FY03	FY04	FY05	FY06	FY07
SSRL Reprints	57	499	176	528	318	180	446
SLAC-HEP Reprints	500	145	334	207	101	68	35
Total Submitted to OSTI	557	644	510	735	419	248	481

FY07 Accomplishments

Harvesting of SLAC's Legacy Documents

- The legacy list received from OSTI consisted of both hardcopy legacy document submissions as well as all electronic submissions where OSTI does not find a link to a PDF document. This list has been audited by InfoMedia, and issues requiring discussion with OSTI were determined and categorized. See below for further action.

Outreach Efforts

- To support SLAC's STI mandates, guidelines for SLAC authors, staff, and users about their responsibility to register and submit their written work to InfoMedia was added to the institutional policy repository, and added to the Human Resources New Employee Orientation handbook, and Human Resources website.

Improvements to STI Accessibility

- Completed repository audit and cleanup of multi-part PDF files for legacy document harvesting.
- Developed requirements and functional specifications for the STI document repository upgrade (SciDoc), scheduled to be launched first quarter FY08.
- Continued data collection for the new SLAC document management repository.

OPPORTUNITIES FOR IMPROVEMENT

FY08 Plans

- Launch SciDoc
- Develop requirements for eConf Proceedings Repository Redesign
- Harvest SLAC's Legacy Documents

Goal 2 Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities

The Contractor provides effective and efficient strategic planning; fabrication, construction and/or operations of Laboratory research facilities; and responsive to the user community.

The weight of this Goal is 60%.

The Provide for Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities Goal shall measure the overall effectiveness and performance of the Contractor in planning for and delivering leading-edge research facilities to ensure the required capabilities are present to meet today's and tomorrow's complex challenges. It also measures the Contractor's innovative operational and programmatic means for implementation of systems that ensures the availability, reliability, and efficiency of facilities; and the appropriate balance between R&D and user support.

BES (94%)

Element		Letter Grade	Numerical Score	Objective Weight	Weighted Score	Total Score
2	Provide for Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities					
2.1	Provide Effective Facility Design(s) as Required to Support Laboratory Programs	B+	3.4	10%	0.34	
2.2	Provide for the Effective and Efficient Construction of Facilities and/or Fabrication of Components	B-	2.6	60%	1.56	
2.3	Provide Efficient and Effective Operation of Facilities	A	4.0	20%	0.80	
2.4	Utilization of Facility to Grow and Support Lab's Research Base and External User Community	B+	3.4	10%	0.34	
					BES Science and Technology Score	3.04
					BES Funding Weight (94%)	**2.86**

HEP (6%)

Element		Letter Grade	Numerical Score	Objective Weight	Weighted Score	Total Score
2	Provide for Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities					
2.1	Provide Effective Facility Design(s) as Required to Support Laboratory Programs	A-	3.7	20%	0.74	
2.2	Provide for the Effective and Efficient Construction of Facilities and/or Fabrication of Components	NA	NA	0%	NA	
2.3	Provide Efficient and Effective Operation of Facilities	B-	2.6	80%	2.08	
2.4	Utilization of Facility to Grow and Support Lab's Research Base and External User Community	NA	NA	0%	NA	
					HEP Science and Technology Score	2.82
					HEP Funding Weight (6%)	**0.17**

Total Goal 2 Score: 3.03 (B+)

BES

A ▪ Stanford Synchrotron Radiation Laboratory (SSRL)

Objective 2.1 Provide Effective Facility Design(s) as Required to Support Laboratory Programs

The SPEAR3 Beam Line Upgrade Program was brought one step closer to completion with the upgrade and commissioning of BL7. BL12, a new macromolecular crystallography beam line funded by the Gordon and Betty Moore Foundation, was completed and began commissioning. Improvements were made on SPEAR3 including the commissioning of a new, higher brightness lattice.

SSRL did not have any formal construction projects during FY07, however, a number of projects were being carried out as capital equipment projects with both DOE and external funding. These projects are described below.

Beam Line 7 Upgrade: BL7 which was part of the SPEAR3 Beam Line Upgrade Program. The original beam line was an existing beam line prior to the SPEAR3 upgrade and could not be operated at 500 mA. Part of SSRL's long term planning included decommissioning of this beam line, demolition and then construction of a new, modern beam line in its place. The beam line was commissioned in FY07 and brought into user operation with a new sagittally focusing monochromator on BL7-2 and leveraged the existing end station facilities.

Beam Line 12 Construction: BL12, funded by the Gordon and Betty Moore Foundation, was installed and commissioned on time and on budget. This beam line represented a number of firsts for SSRL—it is SSRL's first hard x-ray undulator and first in vacuum undulator. In addition, this beam line required the development of a chicane in the long SPEAR3 "east pit" region with modified electron optics to allow for a small gap undulator as well as provide a second straight section for a future insertion device thus leveraging the capabilities afforded by the long straight section for a future beam line. These developments were successful and resulted in a high performance beam line for macromolecular crystallography with a 10 μm diameter photon beam on the sample. In order to maintain a stable beam, a pitch feedback system is being developed to stabilize the beam in both the horizontal and vertical directions.

Beam Line 4 Upgrade: BL4 is the last remaining SSRL beam line that is not capable of operation at 500 mA. Because of the very high user demand on BL4-2 (biological small angle scattering), planning for this upgrade resulting in the decision to build the upgrade in a new location in B130 allowing for construction to start before the end of the 2007 run and thus minimize user down time. Construction is well underway with commissioning anticipated to start at the beginning of CY08. With the completion of BL4, all beam lines will be able to operate at 500 mA.

Beam Line 13 Construction: BL13 is being installed in B130 to provide for circularly polarized soft x-rays for materials science. This beam line is leveraging the monochromator and end station facilities previously being used at BL5-1 and BL5-2 to provide for a new, state of the art capability. This beam line at SPEAR3 is recognized as having the potential for world leading capabilities.

NOTEWORTHY PRACTICES

BL 4 Upgrade

Planning of the upgrade to take into account minimization of user downtime by recognizing that the beam line could be rebuilt in a new location, thus minimizing the impact on the operation of the existing beam line.

BL 7 Upgrade

The BL7 upgrade leveraged the existing end station hardware and radiation enclosures, thus minimizing the required changes to the experimental hardware.

BL 13 Construction

The construction of BL 13 leveraged existing end station hardware from BL5-1 and BL5-2, thus accelerating the ability to generate scientific results and reducing costs.

BL12 Construction

This project leveraged the availability of a long straight section in the "east pit" region of SPEAR3 to provide for a second future beam line through the development of the electron optics for a second straight section.

Opportunities for Improvement

Opportunities for improvement in such construction and upgrade projects include constant monitoring of schedules and operational requirements to optimize availability of beam time.

Objective 2.2 Provide for the Effective and Efficient Construction of Facilities and/or Fabrication of Components

The beam line upgrade projects described above involved the design and fabrication of sophisticated components in order to provide the design performance. SSRL has been able to leverage component designs for mirror and monochromators by utilizing the same designs on multiple beam lines. In the case of BL12, accelerator physics studies showed that a chicane lattice would not only satisfy the requirements of the beam line but would provide for an increased scope by the creation of a second straight section for a future beam line without impacting the overall budget or schedule. As a result, BL12 was built on schedule and on budget and will provide future capabilities for an additional beam line. The construction of BL13 has experienced a problem with a vendor failing to deliver the insertion device in time for installation before the beginning of the FY08 run. Failure to have an insertion device would make it impossible to operate the beam line for a full year. However, by being in close contact with the vendor, the SSRL BL13 engineering staff was able to recognize the problem in time to put a contingency plan into effect. As a result, an existing insertion device is being adapted to the beam line for use in FY08. In parallel, SSRL is working with the vendor and the SLAC purchasing department to address the delivery as well as quality control issues.

Noteworthy practices

BL12 Construction Increased Scope

The SPEAR3 "east pit" straight section was reconfigured to provide the capability for a second beam line by developing a chicane with two insertion device straight sections.

BL12 Construction Safety Recognition

The safety culture for the BL12 construction project was recognized by the SLAC site as a "*SAFE '07* Success Story" in the June 12, 2007 issue of *SLAC Today*. A quote from the article states: "Last March, a new beam line opened at SSRL, thanks to three years of work by the Beam Line Development Group and about 50 designers, technicians, physicists, electricians and construction workers. It was a complex task that was completed without incident due to a strong culture of safety."

Opportunities for improvement

Project Performance

Problems with vendor delivery of components can affect any project. It is extremely important for the project engineers to be in close contact with the vendors and understand possible issues sufficiently ahead of time to allow for alternate solutions to be put into place.

Project Safety

The recognition of the success in construction safety for a project, such as happened for BL12, is a good way of emphasizing and encouraging safe work practices. We should consider ways of using this mechanism in future projects.

Objective 2.3 Provide Efficient and Effective Operation of Facilities

Availability, Reliability, and Efficiency of the Facility: In 2007, SSRL's operation as a user facility was outstanding, running for a total of 5,424 hours. The facility proved to be exceptionally reliable, providing very stable beam for a very high fraction (>98%) of the scheduled time. This is higher than the average uptime over the past five years of 96.6%. This uptime, which exceeded expectations, was partially due to the fact that the day-to-day operation was very reliable with short injection times and that there were no major unscheduled downtimes due to equipment failure during the FY07 run. SSRL provided 27 stations on 21 simultaneously operating beam lines. During the FY07 run, scientists on 423 different proposals received beam time in a total of 1,300 experimental starts involving 1,732 users, with approximately 1,124 users on-site or remote accessing beam-line equipment. Approximately 62% of the users came from universities and other laboratories in the United States, 18% from DOE and US government laboratories, 6% from US industry, and 14% from international institutions.

At the end of each of their individual runs, users are asked a set of questions to gauge their satisfaction with the performance of the facility. In FY07, the responses for the categories "overall scientific experience" and "beam performance and quality" were approximately 75% excellent and 15% very good indicating a high level of user satisfaction.

Configuration of the Facility to Support the Community: The configuration of the beam lines is regularly reviewed as part of the semiannual proposal review process in which the mix of proposals is examined in light of previous periods. In addition, the oversubscription rate in the beam time request process is also reviewed. Finally, the user end or run summaries are reviewed and disseminated by the User Research Administrator. These data points serve as guides to SSRL management for determining priorities for beam line support and where scarce resources should be placed. One such example was the recognition that requirement that the x-ray emission spectrometer for the Advanced Spectroscopy Facility be installed into BL6-2 prior to every run was wasting beam time due to the high demand for this instrument. As a result, SSRL management decided to reconfigure BL6-2 to create a permanent location for this facility.

R&D to Develop and Expand Facility Capabilities: SSRL is continuously developing its capabilities. In particular, a number of accelerator improvements are being carried out which will improve the overall operation and provide for a more stable beam. These developments include: (1) implementation of the fast orbit feedback system; (2) addition of precision level sensors for SPEAR3 components to determine causes for beam motion as appear; (3) development of an improved synchrotron light monitor to characterize the SPEAR3 beam to higher precision; (4) R&D to allow for the implementation of top-off operation which will greatly contribute to the stability of optical components; (5) R&D to determine the expected operating characteristics of the BL13 undulator; (6) continued development of a short bunch operation mode to allow for timing experiments at the ps level to be performed at SPEAR3; (7) development of a new, higher brightness lattice (the development of this lattice was so successful that it was implemented during the 2007 run); (8) development of a laser-assisted photocathode mode for the operation of the injector electron gun to provide for higher currents in support of top-off injection. All of these accelerator R&D studies are in support of enhanced user operations.

Many of the beam line R&D developments have been dominated by what has been required for beam line upgrades and construction of new beam lines. Developments beyond what are required for new beam lines include: (1) design of an indirectly cooled sagittally focusing second monochromator crystal; (2) pitch-feedback system to stabilize the mirrors that focus x-rays onto the sample; (3) design and implementation of a motor control/data acquisition system to allow for continuous fluorescence data collection during rapid scanning of samples; (4) development of automation and remote data collection capabilities for macromolecular crystallography; (5) development of a unified interface and data collection hardware and software suite that provides uniformity between SSRL beam lines. This latter development has been critical in allowing the small SSRL staff to effectively manage a large number of beam lines and be able to provide outstanding user support.

Quality of the Process Used to Allocate Facility Time to Users: SSRL has had and continues to have an exemplary system for allocating beam time in which user proposals are sent our for peer review followed by rating by an external review panel of experts. This process has served SSRL well for many years and discussions with the SSRL Users Executive Committee have indicated that users feel this is a fair process. However, as fields change, it has become apparent that different fields need slightly different approaches. In particular, some fields need rapid access modes to satisfy rapidly changing needs and SSRL management has been sensitive to these needs. This has resulted in the institution of rapid access mechanisms for macromolecular crystallography, XAS, and biological x-ray scattering.

NOTEWORTHY PRACTICES

Unified Beam Line Hardware/Software Solutions

The ability to have a well defined set of hardware and software solutions for the SSRL beam lines has allowed our small scientific staff to support a large number of beam lines and provide high quality service to our users.

SSRL Proposal Review Process

The use of peer review and a proposal review panel has provided for a high quality process for rating proposals and assigning beam time at SSRL with a very low number of appeals to the ratings from users (less than one per year).

OPPORTUNITIES FOR IMPROVEMENT

SSRL Proposal Review Process

Although proposal submissions are via the web, the current proposal submission and review process requires a significant amount of manual intervention. Development of a modern web-based system would greatly improve and streamline the process.

Objective 2.4 Utilization of Facility to Grow and Support Lab's Research Base and External User Community

SSRL provides research facilities that are used by a broad-based scientific community. This is evidenced by the different types of beam lines that are made available to users. A partial list below includes the following facilities and their associated user communities.

- **Macromolecular Crystallography:** This area of research has the most number of beam lines at SSRL and is internationally recognized for the quality of the facilities and the scientific program brought by the users, as evidenced by the 2006 Nobel Prize in chemistry award to Roger Kornberg who has been a major user at SSRL for a number of years;
- **Correlated Materials:** The main facility used for this research is BL5, which is used to study the electronic structure of correlated materials and has garnered international recognition through its publications both for Stanford Faculty, staff and students as well as outside users. The Stanford work is led by Z.X. Shen and is described in the XLAM report.
- **Biological XAS:** This program draws an international user community and is world class especially in the area of dilute XAS of biological systems. The program is supported through a BER and has an NIH NCRR and receives very high marks in the joint BER/NIH peer reviews that take place every five years.
- **MEIS:** The MEIS program, started by G. Brown of Stanford, opened up this field to the international community and is growing rapidly at SSRL. It is recognized for the quality of both in-house and user-based research and has contributed to the solution to a number of remediation problems of interest to the DOE.

- **Magnetism:** A strong in-house research effort by J. Stöhr has led to developments that benefit the user community by the creation of user facilities in the areas of coherent imaging and in the future scanning transmission microscopy.
- **Materials Science:** This is a broad area of research involving facilities to perform both x-ray diffraction and XAS. Research in this area ranges from studies of polymer materials to shape memory alloys and to fundamental studies of the structure of water. The research by users and in-house staff is very broad.
- **X-ray Microscopy:** A new facility has been developed at SSRL to provide capabilities for imaging at 40 nm resolution, which is at the state-of-the-art. This is a new program with the facilities in the commissioning phase but it illustrates the new directions in which SSRL is moving.
- **Sub-picosecond Photon Source (SPPS):** Although this program ended last FY and the ultrafast effort has been taken over by the PULSE Center, it is important to note that the SPPS program was conceived and executed by SSRL scientists creating a new field for SLAC and increasing the laboratory's research base in a significant direction.

Finally, SSRL has an active user outreach program as evidenced by its workshops including Structural Molecular Biology workshops in spring and fall of 2007, a workshop on macromolecular crystallography remote data collection (winter 2007) and a hard x-ray scattering workshop in the spring of 2007. Planning workshops were held to obtain user input for the development of new capabilities in the areas of hard x-ray scattering (winter of 2006) and scanning transmission x-ray microscopy for MEIS and chemical/material science applications (summer 2007). These workshops are in addition to the annual SSRL Users' Meeting, which in FY07 included three workshops in the areas of:

- Electron Dynamics in Spin Systems
- Joint Macromolecular Crystallography Workshop: Using the Uni-Puck and Web-Ice at ALS and SSRL
- Ultrafast Dynamics on Surfaces and in Liquids.

With the advent of the LCLS, the FY07 Users' Meeting is being held jointly with the LCLS to insure cross fertilization of ideas between the two areas. SSRL also has a very active Users' Organization whose Executive Committee meets 3–4 times per year and provides important input on user issues, which it obtains for the user community as a whole through individual interactions and user surveys.

NOTEWORTHY PRACTICES

Spin-off of User Programs (SPPS)

The SPPS program is a good example of how close cooperation between accelerator scientists at SLAC and beam line scientists at SSRL resulted in an outstanding set of cutting edge experiments that both showed the feasibility of doing ultrafast science with a linear accelerator based source as well as delivering new scientific results. Then this effort ultimately spun off into the PULSE Center which is creating a whole new area for SLAC.

B ▪ Linac Coherent Light Source (LCLS)

LCLS is a SASE XFEL project presently under construction at SLAC. The project has met schedule and budget milestones, as well as technical goals, with project completion anticipated in 2010.

In FY07 the LCLS project continued its construction phase. Conventional Facilities broke ground on new beamline enclosures. The LCLS Injector facility was installed and successfully met or exceeded its commissioning goals. Fabrication of the FEL undulator system and other beamline components are proceeding in anticipation of FY09 installation.

During LCLS project activities, project performance is closely monitored by external reviews and BES oversight. External reviews include both the LCLS Facilities Advisory Committee and the

LCLS Scientific Advisory Committee to ensure that the completed facility will meet the community's needs.

Objective 2.1 Provide Effective Facility Design(s) as Required to Support Laboratory Programs

The LUSI project is closely associated with LCLS; it will provide three state-of-the-art instruments for performing scientific experiments using LCLS x-rays. These instruments will address three of the high-impact scientific areas identified by the LCLS Scientific Advisory Committee. LUSI is now in its early design phase, having achieved its CD-1 milestone in FY07. LUSI will present a design for Critical Decision 2 Baseline approval in the first part of CY08 (dependent on resolution of the FY08 CR.

The LUSI design work underway is being closely coordinated with the ongoing LCLS construction, to assure optimum integration of these projects. LUSI is organized as a unit within the LCLS management structure, and uses some common design, management, and review resources.

OPPORTUNITIES FOR IMPROVEMENT

Project Integration

The integration of LUSI and the LCLS project is extremely important to ensure a strong start to LCLS ultra-fast science. Establishing LUSI requirements formally and communicating these requirements across both projects will ensure that the LUSI instruments include their full function capability. Additionally, including LUSI engineers in the LCLS Integration Management Team (IMT) will help to ensure these requirements are communicated across both projects.

Project Safety

The recognition of the success in construction safety for a project, such as happened for BL12, is a good way of emphasizing and encouraging safe work practices. We should consider ways of using this mechanism in future projects.

Objective 2.2 Provide for the Effective and Efficient Construction of Facilities and/or Fabrication of Components

During FY07 the LCLS project team made satisfactory progress on the construction of the new facilities that comprise the LCLS new construction. The facilities include the Beam Transfer Hall (BTH), the Undulator Hall Tunnel (UHT), the Electron Beam Dump (EBD) area, the Front End Enclosure (FEE), the Near Experimental Hall (NEH), the X-ray Tunnel (XRT), and the Far Experimental Hall (FEH). The physical percent complete exceeds the 50% mark with all but the FEE, EBD and portions of the BTH having the roof installed. Closing the structures with the roofs provides for continued progress on the remaining portion of the work through the rainy season with little or no weather delays.

The management team has proactively maintained schedule for early and beneficial occupancy by using a modified integrated project team approach to prepare schedule recovery plans, value engineering to control costs in a highly volatile and contractor-friendly marketplace, and by prioritizing the funding for civil construction.

Although the trade contracts exceeded the engineering estimates, the change order percentage to date has been managed to a minimal 4–5%, or roughly half of the industry norm for this type of construction.

The LCLS management obtained specialized construction experience including cost estimators, construction inspectors with tunneling and heavy civil experience, and increased the number of University Technical Representatives (UTRs) through training of existing and new staff. We also filled the position of Associate Director of Civil Construction, to provide experience and guidance to the Conventional Facilities group, Procurement and Contract Administration and the Project Office. The Associate Director also interfaces with the Contractor providing the construction manager/general contractor (CM/GC) services.

Injector beam line components were fabricated and installed. The LCLS Injector facility was installed and successfully commissioned. All 112 meters of FEL undulators were fabricated and delivered to SLAC, on schedule and well under budget. Beamline components were designed and fabricated in anticipation of installation in FY08.

The LCLS Project was assessed by DOE as a "red" project at the beginning of FY07 due to a large draw on contingency to cover the high trade contracts associated with the LCLS civil construction. The project had adequate contingency to cover the civil contracts, however the LCLS project remains in the "red" due to the concern of adequate cost and schedule contingency caused by the CR. Based on the July 10-12, 2007 SC project review findings, the project is preparing a Baseline Change Request to address the effects of the CR and ensure that the project has a high probability of successfully meeting its commitments to DOE. A limited external independent review by Office of Engineering and Construction Management (OECM) is planned for October, with an ESAAB with S-2 in the November 2007 timeframe.

OPPORTUNITIES FOR IMPROVEMENT

Project Management

Strengthening the LCLS project management team is essential to restoring the project to a "green" status and ensuring that the project delivers its commitments to DOE on cost and on schedule. The project team recognizes that the integration of the LUSI project and the first major systems of the LCLS moving into operations, a strong and robust management team is necessary for the successful completion of the LCLS project and a smooth transition into LCLS Operations.

Project Safety

Construction safety must be emphasized through the use of safe work processes and controls, diligent training of new contractors to the LCLS jobsite, and regular site walkthrough to ensure a safe working environment.

Objective 2.3 Provide Efficient and Effective Operation of Facilities

The LCLS injector section, from drive-laser and rf photocathode gun through first bunch compressor chicane, was installed in fall 2006. The first phase of system commissioning with an electron beam was completed during the months of April through August 2007. This machine commissioning effort includes the new photo-cathode drive laser system, rf photocathode gun, linac booster section, S-band and X-band rf systems, first bunch compressor chicane, and the various beam diagnostics and controls. First electrons from the new photocathode rf gun were observed on April 5 and beam was quickly established to the full injector energy of 250 MeV in the main SLAC linac on April 14, 2007. Over the next few months, all of the new systems were commissioned and most injector parameters have now achieved their design values. The electron bunch charge and transverse normalized emittance have attained their design levels of 1 nC and 1.2 microns, respectively, already meeting the design requirements for the LCLS. The LCLS injector performance is a significant advance over previous designs, providing a 1-micron transverse emittance at up to 1-nC of bunch charge at 30 Hz continuously, 24 hours per day for four of the five commissioning months.

NOTEWORTHY PRACTICES

The design of the laser system was driven by the required emittance of the electron beam, resulting in a set of laser specifications that had never been previously achieved. During the April through August commissioning period, the laser system provided ultra-violate (UV) light to the cathode 24 hours per day with less than 3% interruption to the planned up-time.

The established electron beam brightness is a major milestone in the realization of a linac-based x-ray FEL based on SASE. The many years of gun R&D at the SLAC/SSRL GTF was used to design and build a new generation of rf photo-cathode electron gun, the LCLS gun. The gun performance and commissioning efforts were presented at an invited talk at the FEL Conference in Novosibirsk, Russia in August, 2007.

OPPORTUNITIES FOR IMPROVEMENT

Transition to Operations

A smooth hand-off to the LCLS operations will ensure the first science experiments have adequate support. Staffing of the LCLS operations in the areas of safety, user program, and beamline support will play a major role in effectively delivering the first experimental results of LCLS science.

Objective 2.4 Utilization of Facility to Grow and Support Lab's Research Base and External User Community

While the LCLS FEL facility is under construction, preparations are being made for performing pulsed x-ray experiments starting in FY09. SLAC has been coordinating a worldwide effort to anticipate the scientific impact of the LCLS, and to plan for the experimental programs that will make use of this facility. This planning process involves significant outreach to the scientific community through topical meetings and workshops, formation of an LCLS Users community, close coordination with related groups, such as the PULSE Center, and major reexamination of priorities within the laboratory. The process is coordinated by SLAC Management, and includes many layers of external review and coordination with BES program officers.

OPPORTUNITIES FOR IMPROVEMENT

User Program Development

Developing a world-class user program with outreach to the user community and coordinated with BES program support is necessary for the effective delivery of the first experimental results of LCLS science.

C ▪ PULSE

PULSE is a research laboratory, so our only participation in facility construction is our consultation on the renovation of Building 40. We feel that we are providing excellent information and help to keep the project on time and on budget.

Objective 2.1 Provide Effective Facility Design(s) as Required to Support Laboratory Programs

The PULSE Center was originally schedule to be housed in the CLOC building, which was dropped from the LCLS scope midway through the construction project, leaving SLAC to find alternative housing for PUSLE. We were actively involved in this search and eventually decided to seek funds to renovate the SLAC Central Lab (Building 40) for PULSE. This year we have been working hard to reprogram our laboratories into the Building 40 envelope and this process continues. The renovation will cost $11M, and we have been working to lower the renovation costs to fit within this envelope, leveraging the existing facilities within the lab and bringing in science partners.

NOTEWORTHY PRACTICES

We standardized laboratory layouts to improve efficiency and reduce cost.

We also have successful innovated a new and far safer and simple design for laser laboratory egress, reducing the complexity of the PPS while improving its overall robustness.

OPPORTUNITIES FOR IMPROVEMENT

In the renovation project, we will continue to discover innovative ways to use the constraints of the existing layout.

Objective 2.2 Provide for the Effective and Efficient Construction of Facilities and/or Fabrication of Components

The PULSE Center is not yet in operation at SLAC. We did provide outstanding utilization of temporary and borrowed facilities at SLAC, and off-site facilities, mostly at Stanford. Our stewardship of these facilities is abundantly evident in the large number of research papers and other evidence of research output.

Objective 2.3 Provide Efficient and Effective Operation of Facilities

PULSE faculty were the major users of SPPS before 2007, and we will be major users of LCLS, but neither of these facilities operated in 2007, so we could not use either during this FY. We did a tremendous amount to attempt to recruit an impressive international user community for LCLS. This included organizing a summer school and workshops for the User Meeting. We also invited scientists to collaborate with us on projects that will extend far beyond this year, into LCLS operations. All of this is adequately quantified and documented in the Goal 1 section of this report.

D ▪ XLAM

XLAM is a research laboratory, so the only participation in facility construction is the upgrade of the end station instrumentation on BL5 which, in cooperation with SSRL, has been carried out very effectively to insure that the user community is well served.

Objective 2.3 Provide Efficient and Effective Operation of Facilities

XLAM scientists collaborated with SSRL in operating BL5 with high success giving users access to state of the art capabilities with high operational efficiency. In addition, the apparatus in the campus facilities, although not user facilities, were operated efficiently and gave state-of-the-art results.

Objective 2.4 Utilization of Facility to Grow and Support Lab's Research Base and External User Community

By carrying out state of the art research, users have been attracted to SSRL in the areas of ultra-high resolution photoemission, coherent scattering and surface catalysis.

HEP

E ▪ PEP-II

Objective 2.1 Provide Effective Facility Design(s) as Required to Support Laboratory Programs

PEP-II is an electron-positron collider in a 2.2 kilometer tunnel located at SLAC. PEP-II has two rings: a 9 GeV HER and a 3.1 GeV LER. At the interaction region the two beams are brought together to collide to produce B-meson physics to the *BABAR* detector and collaboration. Beams in PEP-II are stored in both rings after being injected by the SLAC three kilometer linac aided by two damping rings and a positron production system. The PEP-II collider is a very complex technological instrument which started construction in 1993 and began delivering data in 1999. DOE-OHEP has determined that PEP-II will finish data taking in September 2008.

The overall DOE goals for PEP-II for FY07 were to deliver 130 fb^{-1} to *BABAR*. The actual data delivered was 90.3 fb^{-1}, which is 70% of the goal. The total integrated luminosity depends on the average running time and the peak luminosity. The lost luminosity was due largely to a loss of 5 weeks of running time due to a delay in startup, a vacuum leak in the HER, and damage to a magnet coil.

OPPORTUNITIES FOR IMPROVEMENT

Improvements in the vacuum system will be addressed during the fall 2007 down.

The luminosity goal for FY07 was 1.4×10^{34}; achieved peak luminosity was 1.2×10^{34}. PEP-II is routinely running at four times the design peak luminosity and seven times the design integrated luminosity.

Improvements planned for FY08 should allow us to achieve an increase in peak, integrated luminosity and reliability.

Machine development studies during the FY07 were used to explore the feasibility of strategic improvements which would lead to luminosity gains in FY08. Proposals will be reviewed by the PEP-II Machine Advisory Committee in November 2007.

Objective 2.4 Utilization of Facility to Grow and Support Lab's Research Base and External User Community

The success of the science goals of the *BABAR* experiment is primarily dependent on the efficient operation of the PEP-II accelerator at SLAC, its ability to deliver highest possible luminosity in electron-positron collisions and the experiment's ability to record the data with high efficiency. These realities have served as the driving forces in keeping accelerator at the leading edge of the luminosity frontier and the data collection efficiency of the experiment at nearly 97% over its lifetime. The experiment also makes maximal use of the computing facilities at the lab to reconstruct and perform the physics analysis of its data set.

The data-taking phase of the *BABAR* experiment will conclude on September 30, 2008. In FY07, the collaboration carried out an extensive study to understand and design a computing and analysis program for performing physics measurements with *BABAR*'s final data set beyond the data-taking phase of the experiment.

F ▪ BABAR at PEP-II

Objective 2.1 Provide Effective Facility Design(s) as Required to Support Laboratory Programs

A multiphase plan to execute the upgrade the muon identification system was started in 2002. The final four sextants were installed in a four-month period that ended in the first quarter of FY07, as scheduled and under budget. Accomplishing the entire multiphase operation, which was concluded without injury to personnel, required extensive coordination by the chief engineer and the technical coordinator (both laboratory personnel) working with the project managers and engineers from US and Italian institutions. The success of the effort is demonstrated by the steady performance enhancements in muon identification efficiency from 2002 to 2007.

A major upgrade of the data acquisition system was carried out during the calendar year shutdown, with much of the work taking place in the first quarter of FY07. The upgrade was motivated by preparing for the increased luminosity expected in FY07 and FY08, and represents the final stage of hardware improvements to data acquisition.

The combination of improvements allow the continuation of the existing *BABAR* "open triggering" strategy through the end of data taking in FY08 and preserving the capacity for *BABAR* to make discoveries in areas other than *B* physics by retaining sensitivity to low-multiplicity events.

Objective 2.3 Provide Efficient and Effective Operation of Facilities

The ultimate measure of success of operations at a high luminosity 'factory' accelerator like PEP-II is the efficient acquisition of high quality data.

- The experiment is live ('eyes open') 97% of the time that PEP-II is providing colliding beams to the experiment.
- This efficiency of operations is matched by the high efficiency in recognizing and acquiring ('triggering on') events of interest.
- Triggering efficiencies for all topologies are over 90%, and for the hallmark core physics

of *BABAR*, states used for *CP* violation studies, it is close to 100%.

The small data-taking inefficiency of 3% is due to a combination, in equal parts, of unscheduled detector down time and of data acquisition dead time. The down-time fraction has remained at this low level even though many of the detector components have been in operation since 1999.

Three upgrades completed in years prior to FY07—the DIRC electronics rate handling capability, improvements to the Trigger, and the drift chamber readout electronics upgrade—performed well during FY07.

NOTEWORTHY PRACTICES

The *BABAR* computing staff achieved its goal of generating a new set of skims in early 2007 in a total processing time of three weeks for the entire *BABAR* dataset, an unprecedented accomplishment.

OPPORTUNITIES FOR IMPROVEMENT

Improvements to SVT dead-time contributions and tighter triggers are expected to further reduce inefficiency in Run 7 in FY08.

Once data have been acquired, the *BABAR* data production computing system continues to be able to deliver fully calibrated and reconstructed events to analysts in a short time. Events are made available for "skimming"—categorization of events into groups of interest for different physics analysis—within ten days; thus maximizing the luminosity available for deriving *BABAR*'s publicly announced results.

Development work continued in FY07 on further improvements which we expect to apply in FY08 with additional refinements to charged particle tracking, the recognition of converted photons, the energy resolution for photons showers starting in the DIRC, and revisions to the data simulation to improve modeling of the detector and take into account what has been learned about *B* and *D* physics in recent years.

G ▪ Astrophysics Program at the Kavli Institute

Objectives 2.1, 2.2, and 2.3
Design, Fabrication, Construction and Operations of Research Facilities

GLAST

Construction was completed on the ISOC's GLAST mission support areas in the Central Lab Annex in January, 2007. These comprise a mission support room containing workstations and displays, an office area for operations staff, and a dataflow lab housing a full-scale replica of the LAT data acquisition electronics and eventually the flight-spare detectors (the LAT Calibration Unit). The mission support room has been used to support GLAST operations testing including End-to-End tests. The LAT program at SLAC now has 400 processing cores in the SCCS computer pool at SLAC and has recently purchased 50TB of disk, with preparations for purchasing another 150TB of disk in preparation for launch readiness. In addition, preparations for using the LAT data processing pipeline software in European processing centers are underway.

LSST

In connection with the LSST project, three laboratory facilities have been constructed at Stanford University, two at SLAC, and one in the Physics/Astrophysics building on the main campus. A Class 10,000 clean room, originally developed for GLAST, has been retrofitted to serve as the integration facility for the LSST cryostat and camera. In addition, a thermal test facility and contamination test chamber was constructed. Finally, a metrological facility, suitable for verifying the flatness of the LSST focal plane at the 1 micron level over roughly 1 meter, has been developed in the campus laboratory. All of these facilities were made operational in the last year.

SNAP

The SLAC effort on SNAP aims to take advantage of existing research facilities and expertise. SLAC will design and build both Electronic Ground Support Equipment (EGSE) and flight electronics for SNAP, using the existing electronics design infrastructure. SLAC may play a part in the integration and test of SNAP – in this case, the infrastructure from the GLAST mission may be used.

Objective 2.4 Utilization of Facility to Grow and Support Lab's Research Base and External User Community

The research possible with the SNAP experiment will make major advances in our understanding of Dark Energy and the origin and fate of the universe. Our participation in the SNAP experiment will provide significant synergies with other parts of the SLAC program. For example, LSST and SNAP will both measure weak gravitational lensing, but with different survey sizes and systematic uncertainties. The two surveys should be complementary. In addition, both surveys may be used to study strong gravitational lensing, and here SNAP measurements will yield accurate mass measurements of strong lenses, while repeated LSST measurements will detect the lensing of time-varying phenomena. The combination will provide another measurement of dark energy. More widely, a range of cosmological and astrophysical research is ongoing at KIPAC at SLAC and in the larger community served by KIPAC. SNAP data will undoubtedly provide this community with a huge range of research topics.

H ▪ ILC Program

ILC is in a preconceptual design phase. The work reported here has contributed to the RDR and is laying the groundwork for portions of the EDR expected by 2010. The EDR work will continue for the next several FYs. This next phase will require significant international negotiation and decision making, possibly in a liaison between DOE and the Department of State, since international agreements will need to be in place prior to awarding CD-0 or its equivalent.

Objective 2.1 Provide Effective Facility Design(s) as Required to Support Laboratory Programs

Reference Design Report (RDR)

Completion of the RDR continued to be a major activity for the SLAC ILC group through much of FY07. Although a draft of the accelerator section of the RDR was presented to the ILCSC in February at Beijing, the final four volume report went to press September 1. Not only were SLAC staff responsible for the design and costing of five of the six area systems, the major shift to a central injector was proposed and implemented under the guidance of the Systems Integration Engineer at SLAC. The RDR Lead Editor was at SLAC, and SLAC made much more contributions to the report than was anticipated. SLAC staff formatted, edited and frequently rewrote sections of the report, and the SLAC publications group recreated more than two dozen figures to make them high quality.

L-band rf Source R&D

SLAC is planning to evaluate the technical options for the rf sources (modulators, klystrons, and rf distribution) to be ready for an EDR in 2010. As part of this program, a new Marx modulator prototype has been built and tested successfully to full voltage in May. The need for more extensive safety and interlock systems than originally planned delayed this project by several months, and although it has demonstrated the feasibility of the concept, it is not yet ready for routine operation. A new bouncer-style modulator was to be delivered from Diversified Technologies in FY07 as part of the SBIR program, but they failed to complete the project and, at present, they are in negotiations with SLAC and DOE over the final steps.

OPPORTUNITIES FOR IMPROVEMENT

Design has begun for a second-generation, designed for manufacture, Marx modulator.

A 10 MW multibeam klystron has been purchased from industry for delivery in early FY08. A 10

MW sheet-beam klystron is being fabricated at SLAC. A first test of a beam-stick version should take place in May 2008, and a test of the full klystron in July.

SLAC is evaluating different components for the rf distribution system to increase flexibility and reduce cost. A prototype variable tap-off system has been built and is being tested. SLAC had planned to assemble an eight cavity feed system for the first FNAL assembled cryomodule in FY07 but both the cryomodule at FNAL and the rf distribution were delayed into FY08.

SLAC has built a coupler test stand to study the performance of individual subassemblies. This test stand uses the L-band rf source constructed in ESB in FY06. It was completed in early FY07. Component tests have begun and been compared to multipactoring simulations. These results will indicate how the couplers may be redesigned for improved operation. SLAC is also in the process of developing a clean room facility to be used to clean and assemble couplers for the cryomodules assembled at FNAL. The clean room bid has been awarded and it will be completed in early FY08, depending on budget. SLAC will process at least eight couplers for the next FNAL cryomodule in FY08.

To make room for two new rf test stands in ESB in FY08, a concrete block shielding wall was removed, and water and power connections prepared. These modifications were completed in FY07, and will be ready for installation of the prototype Marx modulator and multibeam klystron in FY08. Interlocks and controls are in preparation to allow 24/7 unattended operation for lifetime testing.

Although some elements of the L-band rf program are being developed more slowly than initially planned, critical items that are needed as part of our collaborations are being produced as necessary.

ILC Electron Source Design and R&D

SLAC is developing a ‘proof of principle’ of the laser needed for the ILC electron source as part of the EDR. The SLAC laser facility was upgraded during FY06, and components required for constructing the prototype purchased in FY07. SLAC continues to have an active program on polarized photocathode research, focused on reoptimizing the cathode parameters for the ILC bunch train format and on further improvements in available quantum efficiency and polarization. In FY08, the laser system will start to be assembled.

A major effort in FY07 was completing the design of the electron source for the RDR. The bunchers had to be redesigned to match the damping ring rf frequency and the damping ring injection modified for the central injector. A new idea to use a traveling wave buncher has yielded much higher capture efficiency, > 98%. Beam line simulations with the new bunching have been completed starting from the electron gun through the trans-relativistic region of the bunching system up to the damping ring injection point. In FY08, this work will continue to be refined to specify the beamline components and locations in detail.

ILC Positron Source Design and R&D

In FY07, SLAC had the leadership role in coordinating the world-wide activities for positron source design and R&D. SLAC is working closely with US and international collaborators. For the RDR, a full design model for the ILC positron source was developed with all major components identified, specified, and costed. Significant effort was directed towards cost and design optimization. The primary positron R&D effort at SLAC was fabrication of a five-cell normal conducting structure for the capture section. The fabrication of this prototype was slowed in the shops due to higher priority projects for PEP-II and LCLS, but it was completed in late FY07 and has been installed in the NLCTA. It will be tested in FY08. Another R&D effort is to determine feasibility of utilizing a strong (~7 T) dc solenoid in conjunction with a spinning target for efficient positron collection. In mid-FY07, the GDE decided to pass the leadership of the positron source to Daresbury Laboratory in the UK. SLAC will continue to support the design and R&D efforts in FY08, but at a much reduced level of effort.

ILC Damping Ring (DR) Design and R&D

SLAC continues to play an important role in the design of the ILC damping rings and development of the related technical subsystems, in particular to develop a realistic impedance model, evaluating classical instabilities, and studying and finding mitigation techniques for the electron cloud and fast ion instabilities, and developing a fast injection and extraction kicker. A grooved vacuum chamber with diagnostics was installed in PEP-II and measured with the position beam. These tests showed the grooves are effective at suppressing the electron cloud formation. Ti-N coatings are also effective, after conditioning with beam. Further tests of grooved chambers in a bend magnet are planned in FY08 and installation of the magnets and chambers is underway.

The SLAC-LLNL Kicker pulser was returned to ATF for further tests. SLAC is also collaborating on testing a new device, a Drift Snap Recovery Diode, DSRD, that showed 1 ns rise and fall for a multi kV pulse, with some pre-and after-baseline effects. This is under an SBIR program. Plans for FY07 included construction of a new prototype that could meet all specifications including full power operation at +/-10 kV, 3 MHz CW, but this was delayed.

ILC Ring to Main Linac Design and R&D

For the RDR, the SLAC ILC group took the lead in the design and cost estimation of the Ring to Main Linac (RTML) transfer line. In collaboration with physicists from DESY and Cornell University, a complete optics design for the RTML, including all necessary pulsed extraction systems, instrumentation, and other beamline elements was completed. The SLAC group proposed a number of design changes to reduce the system cost, including the significant redesign required to support the Central Injector layout. In mid-FY07, the GDE decided that responsibility for the RTML would shift to FNAL. SLAC prepared detailed documentation to facilitate this shift and will now serve only a supporting role.

ILC Main Linac (ML) Design and R&D

In FY07, work was planned to demonstrate with 90% confidence that the emittance budget of the ILC can be achieved; to demonstrate multiple steering and alignment algorithms; and to independently verify simulation results. Much of this could not be done because of other work on the RDR and preparation for the EDR.

The ACD and Beam Physics Groups use analytical models and computer simulations to try to understand issues related to wakefields in the ILC linac cavities, and multipactoring in the high-power cavity couplers. The main goals in FY07 were to (1) develop a model of the cavity shape distortions that will explain the variations observed in the lowest-band dipole mode properties, (2) use this model to verify that the spectrum of (R/Q)*Qext for lowest band modes will not produce significant beam breakup in the ILC Linacs, (3) extend this analysis to trapped modes over multiple cavities for frequencies up to ~ 8 GHz, which will require massively parallel computer processing and (4) complete the multipacting evaluation of the TTF-3 coupler and suggest design changes to reduce this phenomenon. Most of this work was accomplished.

Another focus of linac design R&D is to develop a superconducting quadrupole (SC quad) and BPM that meet the requirements of beam-based quad alignment techniques A TESLA SC linac quad prototype was obtained (on loan) from CIEMAT in Spain. At SLAC, a cryostat was constructed in FY06 and completed in FY07 along with cryogenic supply system. The magnet will be tested at the SLAC Magnetic Measurement Lab using a rotating coil system capable of submicron precision. In parallel, three cavity BPM prototypes were constructed and tested at ESA. Resolutions of 400–800 nm were achieved, better than the level required in the ILC linacs.

ILC Beam Delivery System Design and R&D

SLAC plays a leading role in the international collaboration on the design of the BDS, both for the RDR and the EDR, including development of required hardware, instrumentation and test facilities. Major changes to the configuration were adopted for the RDR as part of the cost optimization, including the 14 mrad crossing angle optics developed at SLAC, and the adoption of one beamline with two detectors in a push-pull configuration. This is a significant engineering challenge and SLAC organized and hosted an IR Engineering Workshop in September 2007. SLAC is developing a coordinated plan for the R&D and design work distribution among global partners.

The experimental studies to support a reliable BDS design are being conducted at ESA and will later be conducted at ATF2 at KEK. The ATF2 is being constructed by an international collaboration. It will use the uniquely small emittance ATF beam to achieve a beam size of about 35 nm, develop methods of tuning and maintaining a small beam size for an extended duration, and eventually stabilize the beam with nanometer precision. In FY07, SLAC built magnets and High Availability power supplies for the ATF2. These will be completed and installed in FY08. SLAC also contributed to the development of BPM electronics for the ATF2 proposal. In FY08 and beyond, SLAC will continue to contribute in-kind hardware for construction and will be involved in the precommissioning evaluation of ATF2 hardware.

The SLAC linac can deliver to ESA a high-energy test beam with beam parameters similar to ILC for bunch charge, bunch length and bunch energy spread. ESA beam tests run parasitically with PEP-II with single damped bunches at 10 Hz, beam energy of 28.5 GeV and bunch charge of $(1.5\text{-}2.0)\cdot 10^{10}$ electrons. Four experiments were approved and took data in FY06. There were two further runs in FY07 with the addition of a magnetic chicane, undulator magnet and new BPMs for the energy spectrometer tests (T-474 and T-475), new collimators for wakefield measurements (T-480) and a new bunch length measurement experiment using Smith-Purcell radiation (T-487). There are 22 institutions collaborating on the ILC test beam program in ESA.

Diagnostics and Controls R&D

In FY07, SLAC continued to work with the GDE Controls Collaboration to define system architectures for both hardware and software, and develop first order cost models for all components down to the interfaces of controls with front end instrumentation and major technical subsystems. Integrated with this effort was collaboration with University of Illinois on testing a commercial modular computing standard called ATCA which features the critical high availability features that ILC requires to be a successful machine.

Conventional Facilities Design and Installation

For the RDR, the SLAC Conventional Facilities (CF), partnering with the FNAL-CF engineers and European and Asian colleagues, developed a concept design and associated cost estimate for the ILC Conventional Construction. This effort included many 3-D visualization drawings which facilitated a top-level assessment of the major choices, as well as a set of concept designs that could provide cost effective, safe underground and surface facilities. In addition, SLAC has devoted a major effort in initiating, organizing and setting-up a complete and comprehensive cost model plan for the ILC Installation Global System.

Thermal Mechanical Testing of the First Full Length Collimator Jaw (LARP Program)

The main FY07 hardware deliverable was the first full length jaw and the set of thermal mechanical measurements that will validate the design. Delays were incurred for a variety of reasons: the need for extensive prototype fabrication and testing, unforeseen complications due to a critical molybdenum-copper braze, competition in the SLAC brazing and vacuum shops from time critical LCLS work, and the limited size of the LARP collimator science and engineering team.

This jaw should be fabricated by the end of 2007 and tested in early 2008.

NLCTA Operations

The NLCTA is operated by the ILC Department in support of ILC R&D and advanced accelerator R&D including X-band structure testing and laser acceleration experiments. The operating funds for the NLCTA do not come from the ILC R&D funds but out of the SLAC operating budget. In FY05, the NLCTA was modified to provide beam for the SLAC E-163, a ‘Laser Acceleration at NLCTA’ experiment. The original thermionic gun was removed and replaced with an S-band rf photocathode gun capable of short pulses. In late FY07, the normal conduction L-band structure for the positron capture section was installed on the NLCTA beamline for testing in early FY08.

I ▪ Accelerator Research

NLCTA

Objective 2.3 Provide Efficient and Effective Operation of Facilities

Ongoing x-band device testing makes effective use of the NLCTA facilities to support the DOE mission. The newly completed experimental area for conducting laser-driven accelerator research leverages the existing NLCTA facilities effectively to provide beam-test capabilities that are unique.

The NLCTA facility delivered more than 600 hours of beam time for experimenters. Downtimes and maintenance activities took place as scheduled. Ongoing R&D was conducted to improve beam quality and expand the capabilities of the facility.

The NLCTA facility is strengthened by the resident research community, which invests time and equipment to expand the facility's capabilities. Time is allocated to both internal and external users by the Director, acting on the advice of the Experimental Program Advisory Committee, which is largely composed of external experts.

Other

L ▪ Scientific Computing

Scientific Computing at SCCS

Objective 2.3 Provide Efficient and Effective Operation of Facilities

SLAC Scientific Computing Facilities are designed, installed and operated with the twin goals of meeting the target mission need and contributing to a coherently designed and operated SLAC-wide suite of computing facilities.

Partnership with major SLAC programs is key to achieving effective and efficient designs for computing. For major programs, SLAC Scientific Computing collaborates in creating and maintaining multiyear plans, taking into account the expected evolution of computing technology and science needs. Typically such plans are reviewed and approved by the International Finance Committee (committee of funding agency representatives) for major programs, advised as necessary by additional peer reviews.

SLAC's multiyear planning process for the power and cooling needed by Scientific Computing facilities proved imperfect in FY07. These needs have had to be met by acquiring "computer-center-in-a-box" facilities from Sun Microsystems.

SLAC Scientific Computing advises the science programs in the choice of hardware that will maximize cost-effectiveness, taking into account acquisition and operation costs. Following this advice on hardware and operating system choices, the first phase of the Western Tier 2 Computing Center for the ATLAS experiment and a 90-node Infiniband cluster for particle astrophysics were installed in FY07.

In FY07 the availability of SLAC Scientific Computing facilities was 99.6% to be compared with the average for the ten previous years of 99.3%. Almost all the lost time was due to planned or unplanned power outages. By engineering systems for optimal reliability, appropriate redundancy and remote manageability, SLAC Scientific Computing Staff members provide 24x365 coverage, with staff rarely on-site outside of normal working hours.

In FY07, the level of facility R&D was driven down below the optimum, by an increasing workload caused by SLAC's increasingly diverse science programs.

SLAC Scientific Computing aims to serve the entire community of SLAC users. As an example, the Western Tier 2 facility was proposed by SLAC, with the active support of seven other universities and laboratories who are now involved in steering the expansion and operation of the facility.

Goal 3 Efficient and Effective Science and Technology Program Management

The Contractor provides effective program vision and leadership; strategic planning and development of initiatives; recruits and retains a quality scientific workforce; and provides outstanding research processes, which improve research productivity.

The weight of this Goal is 20%.

The Provide Effective and Efficient Science and Technology Program Management Goal shall measure the Contractor's overall management in executing S&T programs. Dimensions of program management covered include: 1) providing key competencies to support research programs to include key staffing requirements; 2) providing quality research plans that take into account technical risks, identify actions to mitigate risks; and 3) maintaining effective communications with customers to include providing quality responses to customer needs.

BES (60%)

Element		Letter Grade	Numerical Score	Objective Weight	Weighted Score	Total Score
3	Efficient and Effective Science and Technology Program Management					
3.1	Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision	B	2.9	40%	1.16	
3.2	Provide Effective and Efficient Science and Technology Project/Program Planning and Management	B	2.9	30%	0.87	
3.3	Provide Efficient and Effective communications and Responsiveness to Customer Needs	B	2.9	30%	0.87	
					BES Science and Technology Score	2.90
					BES Funding Weight (60%)	**1.74**

HEP (39%)

Element		Letter Grade	Numerical Score	Objective Weight	Weighted Score	Total Score
3	Efficient and Effective Science and Technology Program Management					
3.1	Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision	A-	3.6	40%	1.44	
3.2	Provide Effective and Efficient Science and Technology Project/Program Planning and Management	B+	3.4	40%	1.36	
3.3	Provide Efficient and Effective communications and Responsiveness to Customer Needs	B-	2.7	20%	0.54	
					HEP Science and Technology Score	3.34
					HEP Funding Weight (39%)	**1.30**

Total Goal 3 Score: 3.04 (B+)

BES

A ▪ Stanford Synchrotron Radiation Laboratory (SSRL)

SSRL provides for effective and efficient science and technology program management by developing state-of-the-art experimental resources for our user community, as well as scientific and technical staff to support these efforts. In addition, the scientific and engineering staff is encouraged to pursue new technical directions that will bring additional capabilities to the Laboratory. Research plans are developed in conjunction with the user community and are validated through user workshops, technical reviews and through the SSRL Scientific Advisory Committee.

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

Efficiency and Effectiveness of Joint Planning (e.g., Workshops) with Outside Community

SSRL actively sponsors workshops to bring together user communities to develop new research directions and establish cooperation with other laboratories. For example, SSRL held a “Joint Macromolecular Crystallography Workshop: Using the Uni-Puck and Web-Ice at ALS and SSRL” with the ALS at the FY07 SSRL Users’ Meeting to educate users in the joint use of SSRL and the ALS as well as obtain feedback in order to better serve the macromolecular crystallography community. In December, 2006 a workshop titled “New Directions in X-ray Scattering” was held to solicit user input on the new directions that the SSRL materials science scattering program should take to optimally address the needs of material and chemical sciences and maximally utilize the improved source characteristics that the SPEAR3 upgrade provides. In February, 2007 a workshop titled “SSRL Macromolecular Crystallography Remote Data Collection” was held in Australia by SSRL to demonstrate and obtain feedback on the remote data collection capabilities developed by SSRL for macromolecular crystallography. In June, 2007 a workshop was held to identify opportunities and define capabilities for scanning transmission x-ray microscopy facilities for MEIS and chemical/material science applications. This workshop brought together an international community to help define these new directions.

Articulation of Scientific Vision and Development of Core Competencies, Ideas for New Facilities and Research Programs

SSRL’s scientific vision is articulated through its strategic plan which was finalized for FY07 in April. Discussion on the plan were held with the SSRL User Executive Committee in October, 2006 and with the SSRL Scientific Advisory Committee the following February. This plan serves both as a starting point to define SSRL’s present core competencies and define areas for future growth. These areas include development of advanced spectroscopy and diffraction, x-ray microscopy and microspectroscopy, and time resolved research that will complement the LCLS. In addition, it describes the formation of a task team to develop long range plans for new photon sources at SLAC.

Ability to Attract and Retain Highly Qualified Staff

In reviews by the DOE and by SSRL Scientific Advisory Committee, SSRL has received the strong message that the scientific staff at SSRL is of very high quality. Recognizing this fact, SSRL created a scientific staff task on retention and promotion to help identify ways to better retain and hire excellent staff. This task force provided a report to the SSRL director, who has implemented a number of the recommendations that included creation of multiple levels for the scientific staff ranging from entry level through a career position, senior and distinguished positions, creation of groups for the beam line scientists where common interests could be discussed and the availability of funds for these groups to perform small upgrades to the experimental stations. The quality of the staff scientists is also evidenced by the number of advisory committees on which they serve as previously in this report. SSRL has been attracting highly talented faculty as evidenced by the recent hires of Inger Andersson at SSRL (from University of Uppsala, Sweden), Tom Devereaux at SSRL (from University of Waterloo, Canada), and Wendy Mao jointly with Geology (from LANL).

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

SSRL plans in a number of different ways. For example, long-term technical and scientific planning is done through the strategic plan, which is then used to develop the plans that are incorporated into the annual field work proposal. These plans are updated at regularly held senior management meetings in which the current needs of the facility are integrated with the budget. Project budgets are reviewed on a regular basis and adjustments are made in spending profiles and expected project completion dates to reflect the budget realities. Several months before the start of FY06 when reduced budgets were expected, projects were cut proactively and a beam line was shut down to give enough of a buffer for SSRL to have adequate funding for FY06 and continuing into FY07. Since SSRL is a user facility, much of the planning revolves around developing a running schedule that fits with the user needs as well as site needs for power outages and installation of new beam lines and facilities. SSRL has been very successful in running a large number of hours and limiting shutdowns to the minimum necessary only for beam-line installations. Facility upgrades are also carried out during these times which in FY07 included the start of seismic retrofit activities in the SSRL injector facility and Building 120. Again, these activities required careful planning to not interfere with ongoing shutdown and insuring that they were completed in time for accelerator startup. Planning is underway to create new office space in an existing building for SSRL staff anticipated to be hired as a result of the FY08 budget. This requires careful planning to relocate the existing functions to new locations. Planning is accomplished through a biweekly meeting with project engineers, space planners and financial staff.

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Customer Needs

SSRL has had excellent communication with BES at a number of different levels. SSRL has responded to HQ requests for information thoroughly and in a timely fashion (and, in fact, in real time when a real time response is requested by HQ). SSRL management has worked with HQ to make sure that requests are sent to the right people at SSRL so they receive prompt attention. SSRL prides itself in not letting requests “fall through the cracks.” There are excellent direct lines of communication between SSRL and HQ, as well as the program officers.

B ▪ Linac Coherent Light Source (LCLS)

The LCLS project is now in the midst of its construction phase, with project completion anticipated in 2010. The associated LUSI MIE project achieved its CD1 milestone in FY07, is now in design phase and expects completion in FY12. To date, both projects have met schedule and budget milestones and achieved technical goals

During the duration of LCLS and LUSI project activities, project performance is closely monitored by external reviews and BES oversight.

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

In FY07, LCLS and LUSI sponsored a number of technical workshops and began hosting annual Users Meetings. The workshops brought together a range of scientists from around the world to discuss topics such as the scientific opportunities that LCLS will provide for studying laser-excited dynamics, and the best way for LCLS to image single nano-particles. The LCLS Users Meeting, combined with the annual SSRL Users Meeting, included tutorial talks on the instrumentation that will be available for LCLS users for initial experiments in 2009-2010, as well as discussion of the experiment proposal process that is being developed for LCLS. In addition, LCLS helped to support the Summer School on Ultrafast X-ray Science organized by the PULSE center, and contributed to several SSRL workshops on expected future developments in x-ray science.

LCLS initiated the growth of a new core competency at SLAC, laser technology and engineering. This new laser technology and engineering group will develop into a resource for SLAC researchers and the LCLS user community. Lasers will be a key enabling technology for several growing research areas at SLAC.

Stanford University and SLAC have attracted and recruited five scientists for faculty level appointments with strong interest in research areas enabled by LCLS. LUSI has attracted four outstanding researchers, early in their careers, to design and operate LCLS instruments. LCLS has hired two similarly promising scientists to support the AMO science instrument and the development of array detectors capable of exploiting LCLS performance.

SLAC and LCLS staff have developed concepts for expansion of the LCLS facility to two or three high performance FEL sources without construction of new buildings. These concepts are under active consideration by SLAC Management.

LCLS will be a national scientific user facility, open to access by independent researchers. Access will be allocated based on peer review of proposals for experiments. To facilitate effective user proposals, LCLS is making detailed technical information available about its x-ray instruments. LCLS has written a Physics Requirements Document (PRD) for the Atomic Physics instrument it is building. LUSI has created a CDR describing the three instruments that it will create for LCLS. These documents are publicly available and written based on input and review by groups of prospective LCLS users who represent approximately 250 scientists.

OPPORTUNITIES FOR IMPROVEMENT

User Program Development

Developing a world-class user program with outreach to the user community and coordinated with BES program support is necessary for the effective delivery the first experimental results of LCLS science.

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

LCLS is planning initial experimental operation in FY09, involving a mix of FEL R&D and the delivery of x-ray beams for experiments. Leading up to the operations phase, a program of pre-operations accelerator R&D started in FY07 with the commissioning of the LCLS electron gun, and will be expanded in FY08 as additional LCLS accelerator components are installed and commissioned. The pre-operations R&D strategy has been developed by the LCLS accelerator physics group, with extensive advice and oversight from external review committees. So far, LCLS accelerator performance has met or exceeded its pre-operations milestones.

Considerable effort has been devoted to identifying and mitigating technical risks at LCLS. The project maintains a Risk Registry, reviewed and updated as necessary on a monthly basis. The results of commissioning the LCLS Injector Linac during 2007 verify that technical risks have been controlled in a very effective manner. The electron beam has met all performance goals to support the LCLS mission, and is the best-performing FEL injector in the world at this time.

Planning for the LCLS operations phase includes several components:

- Basic technical parameters for the LCLS operations were developed over several years through numerous open workshops, design proposals, and external reviews. The LCLS Scientific Advisory Committee approved and formalized these design parameters.
- The details of the LCLS technical plans are reviewed frequently as part of the Project Execution Plan (PEP). In addition, risks to project goals are identified and monitored, and mitigation plans are developed as part of the PEP.
- Continuing refinement of the LCLS plans for its operations phase, including plans for user access and future LCLS upgrades, is being carried out by SLAC Management with review by the SAC. In FY07, a working group of senior SLAC managers was directed to develop a proposal for near-term upgrades to LCLS.

Opportunities for improvement

Strategic Planning

Long-term strategic planning for SLAC recognizes a fundamental shift in laboratory resources from support of High-Energy Physics programs to support of Photon Science programs, including LCLS operations. A lab-wide exercise involving top managers is evaluating the roles that each SLAC group will play in the new environment. This exercise will result in shifts of priorities so that they are optimally aligned with the mission of the laboratory.

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Customer Needs

In addition to semiannual formal BES reviews of LCLS project performance, LCLS Management conducts weekly telephone conferences with BES project managers. Project management also meets with the federal project director weekly, and with the SLAC Director and federal project director twice per week. The federal project director attends all Project CCB meetings. Safety experts from the DOE/SSO tour LCLS construction sites weekly. When specific events occur that could influence project performance, additional BES reviews are held. The LCLS organization chart codifies the project line management roles and responsibilities.

Opportunities for improvement

LCLS and LUSI Integration and Transition to LCLS Science

Continued emphasis on the integration of LCLS and LUSI and the transition into operations must be well-coordinated and staffed accordingly to maximize the potential of LCLS world-class science.

C ▪ PULSE

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

Efficiency and Effectiveness of Joint Planning (e.g., Workshops) with Outside Community

In FY07, PULSE sponsored a summer school on ultrafast x-ray science, bringing to SLAC experts in ultrafast science from the AMO, materials science, and accelerator physics community together with students to focus on opportunities for new science at LCLS and other accelerator-based short pulse x-ray sources. Also, a workshop was held as part of the SSRL User's Meeting entitled "Ultrafast processes on surfaces and in liquids," focusing on opportunities for probing femtosecond surface dynamics and liquid phase dynamics with x-rays. This was widely attended by scientists from around the world.

Articulation of Scientific Vision, and Development of Core Competencies and Ideas for New Facilities and Research Programs

These were detailed through the PULSE proposal and many new ideas are currently in the process of being carried to fruition. PULSE has also started a detailed strategic planning process as part of the larger laboratory effort to define the future of SLAC. We are developing ideas for applying the power of the LCLS to technological areas like information science, materials processing, and solar energy research. We are also planning for experiments probing the earliest time-scale electron dynamics in atoms and during chemical reactions, and the development of electronic correlations in materials.

Ability to Attract and Retain Highly Qualified Staff

PULSE has been successful in this regard. We are in the process of recruiting a leader in the field of ultrafast x-ray science to join PULSE. Aaron Lindenberg joined the Photon Science Faculty/PULSE, joint with Materials Science and Engineering at Stanford as of April, 2007. Markus Guehr was promoted from postdoc to a staff scientist, and we successfully countered and attempt to hire him away by our European competition.

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

Since the PULSE Center has been officially funded for less than 6 months, and still occupies temporary space, project planning has been our prime activity. The output of FY07 follows. Taken together, these elements constitute our strategic plan in the just ending FY:

- Our planning is included in the PULSE program proposal to DOE. This proposal was reviewed by DOE program managers in BES (including the Materials and Chemical Sciences Divisions) and by anonymous peer reviewers selected by BES. The program was reviewed by the Office of the Dean of Research at Stanford University and by the Photon Science Director at SLAC, since these two offices have joint formal oversight responsibility for PULSE. These anonymous reviews gave the Center its highest rating for scientific merit.
- Revisions to the Proposal, following guidance from BES, form the second official revision of our strategic plan. These included an increased role of the Stanford Office of Research in areas such as administrative support and the formation of an External Advisory Board. This required that we make some difficult decisions to advance areas of immediate interest to the MS and CS programs, while temporarily reducing our effort in source development. These decisions were made and a budget was successfully implemented approximately 4 weeks following notification of the approval of our program by DOE.
- The third element is the formation in, August, 2007 by the Director, of a long-range strategic planning group, with participation by the junior permanent staff of the Center. This process just started, but is intended to aid the Director in the formation of longer term goals.
- The fourth element of our strategic planning is the PULSE participation in site-wide strategic planning in advance of the SLAC contract recompetition, led by Acting Director Drell. PULSE has pushed for a greater strategic emphasis on laser science as we move towards XFEL operations to enhance the scientific impact of LCLS. We are currently working with the LCLS Director and members of the Photon Science Faculty to define a path towards this goal.

Dealing with Technical Risks and Challenges

Our greatest challenge has been to deal with the near total lack of adequate laboratory space for ultrafast laser science on the SLAC site. To manage this challenge and mitigate the risk of reduced activity with no space, we have established off-site laboratories on the Stanford Campus. The first of these were commissioned in FY07 and are now running well. The laboratory physical infrastructure was largely financed by the Stanford Management, with equipment and supplies from the ultrafast programs that preceded the PULSE Center.

We have been actively involved in development of new laboratory space for our center in B40 (Central Lab). We successfully obtained approval by BES for renovation funds in the FY08 and FY09 budget plans for BES. SLAC appointed a project management team, and PULSE personnel have been meeting with them and with architects and engineers on a weekly basis to build and keep to a timeline for successful completion of the renovations. Our decision to do this now is based on our analysis that early occupancy will enable us to avoid technical problems that may arise as we get closer to the start date for LCLS.

Synergy

PULSE has common research interests with many in the local and international community, and we are working to build those ties to strengthen our research output, to leverage our research resources, and to build a stronger future center. Our many research collaborations are listed in Goal 1 and are also evident in the Publications Appendix, which includes coauthors from SSRL, SPPS, and LCLS within SLAC, and with Stanford Varian Physics faculty, staff, and students; and with other institutions in the US and Europe.

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Customer Needs

Discussions with BES over the PULSE program and budget have gone very well, and have been very intense and interactive. We have been able not only to start the PULSE program in a difficult “no new start” CR environment, but our output in our first year has been appreciated very much by our sponsors. In this case the challenge of good communication has been complicated by the fact that we are sponsored by two different divisions in BES, and traditionally they have different points of contact within the lab.

NOTEWORTHY PRACTICES

We have learned that communication should never be taken for granted, and that every opportunity to connect with Germantown should be used as fully as possible.

OPPORTUNITIES FOR IMPROVEMENTS

The opening of two new programs in BES devoted to Ultrafast Science, one in Chemical Sciences and one in Material Sciences, will create an opportunity for PULSE to have a much more productive and responsive dialog with the DOE. We would like to have similar connections to the Facilities Division for research support in the area of Source Science (XFELs and relativistic beams) and will be seeking this in the future.

E ▪ XLAM

XLAM provides effective and efficient stewardship of scientific capabilities and program vision by leading the research effort at SLAC and Stanford in the understanding of matter by using synchrotron radiation based along with complementary tools for that purpose.

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

Efficiency and Effectiveness of Joint Planning (e.g., Workshops) with Outside Community

XLAM Faculty participates at all levels in workshops to plan for the future of materials research.

Articulation of Scientific Vision, and Development of Core Competencies and Ideas for New Facilities and Research Programs

This vision is articulated in proposals and program reviews. XLAM is engaging in activities to enhance the core technical competencies at SLAC including detectors and large scale instrumentation development. XLAM is developing plans to participate in LCLS with a soft x-ray scattering program for condensed matter physics. XLAM has also developed a strong synergy with the PULSE Center through interests in ultrafast phenomena in the area of ultrafast surface chemistry and catalysis.

Ability to Attract and Retain Highly Qualified Staff

XLAM has a world class faculty and staff. In addition, two significant joint appointments have been made with SLAC in FY07. These are Tom Devereaux in the area of condensed matter theory which will ultimately lead into developments in computational materials science and Wendy Mao (jointly with the Department of Geological and Environmental Sciences) who will lead the effort in the area of high-pressure materials research.

HEP

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

SLAC has been a world leader in particle physics especially in electron accelerators, detectors, phenomenology and theoretical studies. It has long been involved in comparing SLAC results with those of proton accelerators and colliders. With the completion of the data taking phase of the *B* Factory, SLAC will continue to pursue our vision to understand the fundamental questions on matter and energy by completing the analysis of *BABAR*, joining the proton collision experiments about to begin at LHC, collaborate with the astrophysicists at Kavli to understand observations of matter and energy interactions in the universe, and develop new techniques in particle acceleration for potential future accelerators.

F ▪ BABAR at PEP-II

The *BABAR* experiment at the PEP-II *B* Factory plays a major role in setting the direction of the research in the field of HPE, yielding results that significantly impact our understanding of the Standard Model and the direction of the search for physics beyond the Standard Model, as well as tests of the predictions of the QCD. In FY07, the collaboration organized a number of workshops involving theoretical physicists active in flavor physics and other experimenters working in this area to improve the interpretation of the experimental results and stimulate further theoretical developments. These include a workshop on Lattice QCD at SLAC in December 2006, and a workshop on experimental and theoretical issues of determining the sides of the CKM elements “Vxb workshop.”

Several members of the *BABAR* collaboration are engaged in developing the next generation of accelerators and experiments required for precision studies of flavor physics, aiming for a nearly two order of magnitude increase in integrated luminosity. A major focus of these studies has been on the study of physics potential and feasibility of the proposed SuperB accelerator and experiment at the Frascati laboratory in Italy. Important accelerator tests are being planned in the near future to examine some of the fundamental ideas recently put forward to achieve a peak luminosity of ~ 10^{36}cm^2/s.

G ▪ Astrophysics Program at the Kavli Institute

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

SLAC has enlarged it’s view and capabilities into a vision jointly shared with the Kavli Institute to pursue a better understanding of the essential nature of matter and energy in the universe through experimental and theoretical studies in particle astrophysics. This enlarged view has attracted many new researchers to the SLAC campus who share this vision.

GLAST

SLAC has effectively planned jointly with NASA an important mission that is at the forefront of gamma-ray astrophysics - GLAST. The LAT payload is currently completed and being readied for launch in 2008. SLAC is in final preparations and testing of the ISOC at SLAC to process the data and make it available to the community. The excitement has allowed the SLAC/NASA team to attract the best researchers in this field. While the road has not always been smooth, SLAC has added to its core competencies substantial experience with all aspects of placing a detector in space. This experience is expected to be tapped for future projects.

LSST

LSST is proposed as a large-area, wide-field, ground-based telescope to provide deep images of roughly half the optical sky every few nights. These surveys would provide a critical resource for several astrophysical investigations—e.g., studies of small bodies in the solar system, programs that map the outer regions of the Milky Way, and searches for faint optical transients on a wide range of time scales. The LSST concept has been repeatedly endorsed as a priority US scientific initiative by national advisory groups and reviews, including the most recent NAS/NRC Astronomy and Astrophysics Research Committee (“Astronomy and Astrophysics in the New Millennium,” 2001) and the influential “Quarks to the Cosmos” Committee. In September 2005, the NSF awarded four-year funding for the LSST design and development effort, with a view to advancing LSST construction to MREFC “new start” status in FY 2010.

SLAC is pursuing an LSST R&D program while awaiting a decision to move ahead with the project.

SNAP

The last decade has seen the phenomena of both Dark Energy and Dark Matter come to the forefront of particle physics. The discovery that the Standard Model particles comprise only a small fraction of the matter and energy content in the universe is a profound one. Part of the scientific vision at SLAC is to ensure that particle physics includes this new dark component. Cosmological experiments, such as SNAP, directly address this vision.

One core competency at SLAC is the design, construction and commissioning of high-speed, state-of-the-art, data acquisition (DAQ) electronics. Our contribution to the SNAP experiment will take advantage of SLAC expertise in custom DAQ electronics, and especially in the development of flight-ready DAQ systems. This work builds on the expertise developed for the GLAST mission, and so will continue SLAC's development of space-qualified electronics. In addition, SLAC was responsible for the Integration and Test (I&T) for the GLAST mission, and we hope to exploit this core competency for the SNAP experiment as well. It is worth mentioning that the SLAC staff in these areas could easily move into Silicon Valley positions, but the SLAC environment, its freedoms, and the opportunity to contribute to world class science makes the laboratory an attractive place to work.

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

The SLAC group on SNAP has focused on areas that mesh best with existing SLAC expertise and experience, such as the DAQ, EGSE electronics, and I&T. In the case of DAQ electronics, typical systems build on prior ones. In the case of the SNAP design, it is derived from the GLAST DAQ, and in turn both systems are derived from systems built for particle physics experiments such as *BABAR*. In addition, the DAQ work being done for SNAP has applicability for other projects such as LUSI at LCLS. The management of electronics systems is done with an eye towards a multiplicity of use, to allow the maximum return on resource investments.

I ▪ Accelerator Research

Throughout its life SLAC has pursued enhancements to the technology of accelerating electrons and building novel and capable machines for use in several branches of science.

Plasma Acceleration and E-167

The E-167 collaboration is recognized as the world leaders in beam driven plasma accelerator concepts. E-167 ran parasitically to the PEP-II *B* Factory and used beam pulses not required to fill the HER and LER. For the modest incremental costs of powering the magnets in the FFTB, the E-167 collaboration was able to utilize the unique resources of the SLAC linac to break new ground in advanced accelerator research with world class results. The unique capabilities of the SLAC electron accelerator have attracted both staff and users here to pursue this science. Future facilities at SLAC are envisioned to continue this attractive area of research.

NLCTA and E-163

The R&D conducted at the NLCTA develops and maintains core competencies in high power rf devices, high power laser devices, and beam testing of components. Recent peer review of this work has demonstrated that it holds value to DOE and the broader scientific community.

Program management and review is accomplished through five levels of planning: by the DOE during annual laboratory reviews and external collaborator program reviews, at the directorate level through program approval, at the facility level through long-term schedule approval, at the day-to-day level via operations and work planning meetings. Factors such as technical risk, quality of R&D, and the long-term facility strategic plan are monitored and maintained through this multilayer planning mechanism.

Both the microwave and laser R&D efforts are interdisciplinary, requiring expertise from materials science and laser science.

An accelerator readiness review was conducted in December 2006 to approve operation of the laser-driven structure experiment. The review committee approved the operation, praising the diligence and preparation of the NLCTA management.

Accelerator Materials

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

SMS contributed a plan for a Cathode Development Lab (CDL) as part of a proposed Injector Test Facility for the LCLS. Research on cathodes in this lab would include cooperative research and sharing of equipment with other DOE laboratories and universities, including the use of a portable loadlock system for moving candidate cathode materials under vacuum between labs. The focus of the CDL is to produce cathodes of high QE and low emittance, suitable for laser operation in the visible.

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

SMS joined LCLS in a collaborative venture with LBNL to improve metal photo-cathode quality for rf injectors. Regular meetings were held at which progress in each of the programs was presented and discussed. Cathode material was provided by SMS/LCLS to LBNL for thermal emittance measurements and imaging photo-microscopy.

K ▪ Theory

Joint Planning with Outside Community: The members of our group are strongly involved with the major efforts to plan the future of high-energy physics. See Goal 1 for details.

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Customer Needs

The HEP program strives to be responsive and aligned to the needs of the national and international community. The major user program, BaBar, has been especially effective in working its user community. We are, however, still working to develop a similarly strong and responsive relationship with the GLAST user community and SLAC is still working to define its role with respect to the US ATLAS community in the LHC era.

Communications with the SC HEP program office have been quite problematical in the past year. While significant effort has been expended on both sides, clear deficiencies can be observed. The error in the FY08 President’s budget for SLAC of approximately $10M can only be attributed to a failure to communicate effectively and the laboratory must bear responsibility for that. While both sides have attempted to be responsive, the communication can not be judged as either efficient or effective.

Overall HEP

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Customer Needs

The HEP program strives to be responsive and aligned to the needs of the national and international community. The major user program, BaBar, has been especially effective in working its user community. We are, however, still working to develop a similarly strong and responsive relationship with the GLAST user community and SLAC is still working to define its role with respect to the US ATLAS community in the LHC era.

Communications with the HEP program office in Office of Science have been quite problematical in the past year. While significant effort has been expended on both sides, clear deficiencies can be observed. The error in the FY08 President’s budget for SLAC of approximately $10M can only be attributed to a failure to communicate effectively and the laboratory must bear responsibility for that. While both sides have attempted to be responsive, the communication can not be judged as either efficient or effective.

Other

O ▪ Scientific Computing

Scientific Computing at SCCS

SLAC Scientific Computing has articulated a vision of a continuing successful partnership with experimental HEP that also supports a steady growth of astrophysics computing, and makes vital expertise available to the rapidly expanding Photon Science program.

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

The vision for SLAC Scientific computing emphasizes the excitement of a Laboratory whose experimental program has, and will continue to push hard against the limits of data-intensive scientific computing. This vision attracts and succeeds in retaining key staff in the presence of greater financial attractions in Silicon Valley. The upcoming SLAC workshop on Extremely Large Databases is an example of how SLAC can bring together the intellectual leadership in computing from academia and industry to address the most exciting challenges.

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

SLAC is currently reviewing its strategic plan for Scientific Computing to determine the activities and resources at all levels from power, cooling and space infrastructure to the continued development of leading scientific software tools. This review was initiated by Particle Physics and Astrophysics, the current major stakeholder in Scientific Computing.

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Customer Needs

SLAC Scientific Computing has historically worked in partnership with the HEP program at SLAC. As partners, Scientific Computing and the science program have established a close relationship, including the open sharing of all relevant problems. The future diversity of Scientific Computing at SLAC demands a greater formalization of the process for establishing and developing a productive partnership relationship with those programs with challenging needs. This formalization is in progress.

Advanced Computations Department

SLAC is member of the SciDAC COMPASS Management Committee, which sets the goals and milestones, and devises plans for meeting them. The committee sets priorities, decides on funds allocation, ensures work is completed on schedule, and coordinates with SciDAC CETs/Institutes for target applications. ACD participates in the Management Committee meetings and ensures that the SciDAC activities are executed to meet the needs of accelerator projects.

Objective 3.1 Provide Effective and Efficient Stewardship of Scientific Capabilities and Program Vision

The SciDAC is a sustained, high-profile national program that helps retain and attract scientists to ACD, especially in the area of computer science where the market place extends far beyond the boundary of a national laboratory.

ACD has established itself as a world leader in electromagnetic accelerator modeling using high-performance computing. The successes have depended on the unique combination of scientific expertise in electromagnetics, applied mathematics, and computer science of the staff members. This core competency will benefit the development of high-performance computing in specific areas of beam dynamics accelerator simulations as well. The work in beam dynamics will be conducted in collaboration with the Beam Physics Department, which has tremendous expertise in beam dynamics theory and will be targeted to problems such as beam-beam, coherent synchrotron radiation and free electron laser.

The SciDAC activities at SLAC have been documented in details as Statement of Work in the COMPASS proposal. New tasks and change of priorities to meet customer needs are discussed and set by the Management Committee, and reported at all-hands meetings.

Objective 3.2 Provide Effective and Efficient Science and Technology Project/Program Planning and Management

The successful planning and management of SciDAC activities to address the computational needs of the accelerator community depends on the effective collaboration between SLAC and SciDAC CETs/Institutes to develop and deploy advanced computational tools to enhance modeling capabilities of ACD application codes.

Appendix A Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
ACD	Advanced Computations Department
ALS	Advanced Light Source
AMO	Atomic, Molecular, and Optical physics
ANL	Argonne National Laboratory
APS	American Physical Society
APS	Advanced Photon Source (synchrotron facility) at the Argonne National Laboratory
ARPES	Angle-Resolved PhotoEmission Spectroscopy
ASTA	Accelerator Structure Test Area
ATF	Accelerator Test Facility
ATLAS	A Toroidal LHC ApparatuS (Particle physics experiment at CERN)
BDS	Beam Delivery System
BEPAC	Beyond Einstein Program Assessment Committee
BER	Biological and Environmental Research
BERAC	Biological and Environmental Research Advisory Committee
BES	Basic Energy Sciences
BL	Beam Line
BNL	Brookhaven National Laboratory
BPM	Beam Position Monitor
CCD	Charge Control Device or Charge-Coupled Device
CDR	Conceptual Design Report
CDW	Charge Density Wave
CEP	Carrier-Envelope-Phase
CI	Conical Intersections
CLEO	Cornell magnetic detector at CESR.
CP	Charge Parity
CTF3	CLIC Test Facility 3
CTR	Coherent Transition Radiation
CU	Calibration Unit
CY	Calendar Year
DAQ	Data AcQuisition system
DETF	Dark Energy Task Force
DPF	Division of Particles and Fields
EDMS	Electronic Document Management System
EDR	Engineering Design Report
EGRET	Energetic Gamma Ray Experiment Telescope
EGSE	Electronic Ground Support Equipment
EMI	Electromagnetic Interference
ESA	End Station A
ESB	End Station B
ESRF	European Synchrotron Radiation Facility
ETE	End-to-End
EUV	Extreme Ultra Violet
EXAFS	Extended X-ray Absorption Fine Structure
EXO	Enriched Xenon Observatory
FEL	Free-Electron Laser
FFTB	Final Focus Test Beam
FLASH	Free-electron LASer in Hamburg (DESY)
FNAL	Fermi National Accelerator Laboratory
FY	Fiscal Year
GDE	Global Design Effort
GFSC	Goddard Space Flight Center

GLAST	Gamma-ray Large Area Space Telescope
GRB	Gamma-ray Burst
GSSC	GLAST Science Support Center
HEP	High Energy Physics
HEPAP	High Energy Physics Advisory Panel
HER	High Energy Ring, in PEP-II
HHG	High Harmonic Generation
HOMO	Highest Occupied Molecular Orbit
HRC	Haimson Research Corporation
IEPM	Internet end-to-end Performance Measurements
IEPM	Internet End-to-end Performance Monitoring
ILC	International Linear Collider
IP	Interaction Point
ISOC	Instrument Science Operations Center
JDEM	Joint Dark Energy Mission
JLab	Thomas Jefferson Lab National Accelerator Facility
JPL	Jet Propulsion Laboratory
KIPAC	Kavli Institute for Particle Astrophysics and Cosmology
LARP	LHC Accelerator Research Program
LAT	Large Array Telescope
LBNL	Lawrence Berkeley National Laboratory
LCLS	Linac Coherent Light Source
LER	Low Energy Ring, in PEP-II
LHC	Large Hadron Collider
LLNL	Lawrence Livermore National Laboratory
LSST	Large Synoptic Survey Telescope
LST	Limited Streamer Tubes
LUSI	LCLS Ultrafast Science Instruments
MAC	Machine Advisory Committee
MEIS	Molecular Environmental and Interface Science
MOC	Mission Operations Center
MOU	Memorandum of Understanding
MREFC	Major Research Equipment and Facility Construction
NCRR	National Center for Research Resources
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NLC	Next Linear Collider
NLCTA	Next Linear Collider Test Accelerator
NOPA	Noncollinear Optical Parametric Amplifier
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSLS	National Synchrotron Light Source
OHEP	DOE Office of High Energy Physics
OPA	Optical Parametric Amplifiers
ORNL	Oak Ridge National Laboratory
OTR	Optical Transition Radiation
PAD	Pixel Array Detectors
PEMP	Performance Evaluation and Measurement Plan
PEP-II	Upgraded SLAC PEP electron-positron collider
PES	PhotoEmission Spectroscopy
PKE	Polar Kerr Effect
PLS	Pohang Light Source
PULSE	Photon Ultrafast Laser Science and Engineering
QCD	Quantum Chromo-Dynamics
QE	Quantum Efficiency

R&D	Research and Development
RDR	Reference Design Report
RIXS	Resonant Inelastic X-ray Scattering
RPC	Resistive Plate Chamber
S&T	Science and Technology
SAC	Scientific Advisory Committee
SASE	Self-Amplified Spontaneous Emission
SAXS	Small-Angle X-ray Scattering
SBIR	Small Business Innovation Research
SBK	Sheet Beam Klystron
SC	Office of Science
SCCS	Scientific Computing and Computing Services
SEY	Secondary Electron Yield
SiD	Silicon Detector concept for the ILC
SLAC	Stanford Linear Accelerator Center
SLS	Swiss Light Source
SM	Standard Model
SMB	Structural Molecular Biology
SMS	Surface and Materials Science
SNAP	SuperNova Acceleration Probe/Program
SPEAR	Stanford Positron Electron Asymmetric Ring
SPEAR3	Upgraded SPEAR ring, synchrotron radiation source at SSRL
SPPS	Sub Picosecond Pulsed Source
SSRL	Stanford Synchrotron Radiation Laboratory
STI	Scientific and Technical Information
STS	Scanning Tunneling Spectroscopy
SULI	SLAC Undergraduate Laboratory Intern Program
SVT	Silicon Vertex Tracker
SW	Standing-Wave
TFT	Thin Film Transistors
TOPS	Towards Optimal Petascale Simulations
TRS	Time Reversal Symmetry
TW	Traveling-Wave
TXM	Transmission X-ray Microscopy
UHV	Ultra-High Vacuum
VUV	Vacuum UltraViolet
WAXS	Wide-Angle X-ray Scattering
WIPP	Waste Isolation Pilot Plant
XAS	X-ray Absorption Spectroscopy
XES	X-ray Emission Spectroscopy
XFEL	X-ray Free Electron Laser
XLAM	X-ray Laboratory for Advanced Materials
XPS	X-ray Photoelectron Spectroscopy
XRS	X-ray Resonant Spectroscopy
XSW	X-ray Standing Wave
XTOD	X-ray Transport, Optics and Diagnostics

Publications Appendix

This appendix is located on line at http://www-group.slac.stanford.edu/oa/selfevaluation/2007/pubsappendix.pdf