Statement of

Dr. Patricia M. Dehmer
Deputy Director for Science Programs
Office of Science
U.S. Department of Energy

Before the
Subcommittee on Energy and Environment
Committee on Science and Technology
U.S. House of Representatives

Regarding the Basic Energy Sciences Program Reauthorization
September 10, 2008

Thank you Mr. Chairman, Ranking Member Inglis, and Members of the Committee for the opportunity to appear before you to provide testimony on the Basic Energy Sciences (BES) Program in the Department of Energy's (DOE's) Office of Science. I served as the director of the Office of Basic Energy Sciences for 12 years, from 1995 through 2007, and I am pleased to share with you my perspectives on that program.

Overview of the Basic Energy Sciences Program

Like other programs in the Office of Science, there are two signature components of the BES program. First, the BES program supports a robust program of fundamental research strategically structured to serve DOE's missions, primarily its energy mission. This program supported nearly 5,000 Ph.D. scientists and more than 1,500 students in FY 2007. Second, the BES program supports the design, construction, and operation of an unparalleled collection of major scientific user facilities, which provide the most advanced tools for materials research in the world. These facilities are a critical component of maintaining U.S. leadership in the physical sciences. Together these facilities hosted more than 9,000 users in FY 2007. In FY 2007, the BES program funded research in more than 173 academic institutions located in 48 states and in 13 Department of Energy laboratories located in 9 states. Approximately 40 percent of the research activities were sited at academic institutions.

The research disciplines that the BES program supports – condensed matter and materials physics, chemistry, geosciences, and aspects of physical biosciences – are those that help us understand, predict, and ultimately control the material world around us. The research provides the knowledge base for:

- *The discovery and design of new materials with novel structures, functions, and properties.* Examples come from the world of nanoscale materials, where the unusual properties of materials at the nanoscale are exploited for energy technologies. For example, nanoscale particles permit a new-class of thermoelectrics, materials that convert heat into electricity. By embedding nanoscale structures into bulk thermoelectric materials, researchers have melded nanoscale electronic control with bulk-level microstructural tailoring, leading to very high thermoelectric conversion efficiencies. Such advances are especially critical for the conversion of waste heat in vehicles into useful electricity, which increases fuel efficiency.

- *The control of the physical and chemical transformations of materials.* An example is the control of chemical reactivity through catalysts that are more selective, more specific, and "greener" than those of past decades and that are used daily in the chemical, fuels, and biotechnology industries.

In the 20th century, scientists learned to observe and understand the interactions among atoms and molecules that determine material properties and processes. Now, scientists are poised to begin to direct and control the outcomes on an atom-by-atom and molecule-by-molecule basis. This will not be easy. We don't yet know how to achieve these capabilities. But their development is critical if we are to meet the formidable energy and environmental challenges that confront us now.

The central tenet of the BES program is that discovery science is at the foundation of innovation and future technologies. Many stories demonstrate that new knowledge can be quickly transferred to applications and technology development. One recent example is in the area of battery research.

A basic research project initiated by the BES program at the Massachusetts Institute of Technology more than a decade ago led to the discovery of a new nanostructured cathode[1] material for battery applications. Based on the knowledge gained, the faculty member that BES supported founded a high-tech start-up company, A123Systems in Watertown, Massachusetts, to commercialize this new battery technology. The development was further supported by a DOE Office of Science Small Business Innovation Research grant starting in 2002 and by a grant from the DOE Office of Energy Efficiency and Renewable Energy starting in 2006. Within the last three years, the A123Systems' batteries reached the commercial marketplace in power tools produced by North America's largest toolmaker, Black and Decker, and they currently are being implemented in hybrid and plug-in hybrid electric vehicles, among other applications. In August 2007, A123Systems and General Motors (GM) announced the co-development of A123Systems' nanophosphate battery for use in GM's electric drive E-Flex system for its hybrid vehicles. This joint effort is expected to expedite the development of batteries for both electric plug-in hybrid vehicles and fuel cell-based vehicles.

There are many illustrations of the importance of BES fundamental research, but I am particularly proud of five broad program areas that have had significant and long-term impacts in:

- *the design and discovery of new materials*, which have led to improved magnetic materials, superconductors, semiconductors, ceramics, alloys, and a host of new and exotic materials of potential technological importance;

[1] Electric current flows out of the cathode.

- *the determination of the mechanisms of catalysis and the rational design of new catalysts,* which have impacted virtually all of the DOE energy missions including conversion of crude oil, natural gas, coal and biomass into clean burning fuels and the development of less-energy-demanding routes for the production of basic chemical feedstocks;
- *the conversion of energy from the sun* to electricity and to useful fuels through comprehensive programs integrating chemistry, materials sciences, and biosciences;
- *the determination of the chemical and physical properties of the heavy elements* (the actinides, their fission products, and the transactinides), which supports DOE missions in advanced nuclear fuels, predictions of how spent nuclear fuels degrade, and how radionuclides are transported under repository conditions; and
- *the development of major tools of the physical sciences* for visualizing materials at the atomic level and in real time, particularly the tools and facilities for x-ray, neutron, and electron beam scattering and the tools for ultrafast chemistry.

These activities represent comprehensive national programs and, in most cases, these are truly unique national programs.

The conviction that basic research in the physical sciences is a wellspring of new energy technologies was the inspiration for a series of *Basic Research Needs* workshops linking the basic research, applied research, and development communities in topical areas relevant to energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation. The workshops, which were initiated in 2001, created levels of excitement and energy in the basic research communities supported by the BES program that I had never before experienced.

The workshops described how basic research could help address short-term showstoppers in energy technologies (such as the development of storage materials for hydrogen) and also how basic research must address grand science challenges to provide the foundation for new, transformational technologies. The workshops helped create a research portfolio in the BES program that both serves the present and shapes the future. Such a portfolio can underpin a national decades-to-century energy strategy.

Together, these workshop reports highlighted a remarkable scientific journey that took place during the past few decades. The resulting scientific challenges, which no longer were discussed in terms of traditional scientific disciplines, described a new era of science — an era in which materials functionalities would be designed to specifications and chemical transformations would be manipulated at will.

Over and over, the recommendations from the workshops described similar themes — that in this new era of science we would design, discover, and synthesize new materials and molecular assemblies through atomic scale control; probe and control phonon[2], photon, electron, and ion interactions with matter; perform multi-scale modeling that bridges multiple length and time scales; and use the collective efforts of condensed matter and materials physicists, chemists, biologists, molecular engineers, and those skilled in applied mathematics and computer science.

[2] A phonon is a quantized vibration in the crystal structure of a solid.

The importance of the nanoscale was another recurring theme. At the root of the opportunities provided by nanoscience is the fact that all of the elementary steps of energy conversion (e.g., charge transfer, molecular rearrangement, and chemical reactions) take place on the nanoscale. Thus, the development of new nanoscale materials, as well as the methods to characterize, manipulate, and assemble them, create an entirely new paradigm for developing new and revolutionary energy technologies. The five new Nanoscale Science Research Center user facilities, which the BES program recently completed, were conceived because of this, and they have become the signature contribution of the DOE to the National Nanotechnology Initiative.

To become as proficient – or ideally even more proficient – than nature in making and transforming materials will require knowledge that we do not yet have. This challenge cannot be overstated. Even basic concepts elude us. For example, we do not understand the mechanism of high-temperature superconductivity, which was discovered more than 20 years ago; yet without such understanding the rational design of new superconductors is impossible. We have limited ability to conceptualize, calculate, or predict processes far from equilibrium; yet all natural and most interesting human-induced phenomena occur in systems that are away from the equilibrium. All living systems exist far from equilibrium. Quite succinctly, we can articulate the challenges, but today's scientific tools are not sufficient to address them. We are looking for new concepts and theories to understand how nature works. The disciplines supported by the BES program seek a 21^{st} century equivalent to the development of quantum mechanics 100 years ago.

The scientific user facilities that the BES program supports – five Nanoscale Science Research Centers and the world's largest suite of synchrotron radiation light source facilities, neutron scattering facilities, and electron-beam microcharacterization centers – enable the fabrication of new materials and the examination of materials and their transformations at the atomic scale through x-ray, neutron, and electron beam scattering. These facilities derive directly from the needs of the research program. Once the province of a few hundred specialists, mostly physicists, these scattering facilities now are used by nine thousand researchers annually from dozens of disciplines and subdisciplines.

The BES program facilities were driven by the need to correlate the microscopic structure of materials with their macroscopic properties, a topic that long predates our knowledge of the existence of atoms. The visible light microscope, invented about four hundred years ago and based on optics studies dating back one thousand years, gave us an initial glimpse of nature's assemblies. The microscope opened the world of mineral, plant, and animal structures and even showed us individual cells. Although now superbly perfected, the fundamental laws of physics limit the resolution (i.e., the smallest features that can be seen) of visible light microscopes to features equal to the wavelength of visible light, roughly a few hundred nanometers. The typical size of an atom is tenths of a nanometer. Thus, instruments with resolutions one thousand times better than the best visible light microscopes are required to see atoms. The laws of physics, which explain why these first microscopes fail to resolve individual atoms, also point to the solution. To see atoms, we must use substitutes for visible light – probes that are themselves as small as the atoms under investigation. Three such probes are x-rays, electrons, and neutrons. The ability of these probes to teach us about the arrangements of atoms in materials was realized soon after their discovery in the early 1900s.

The resulting facilities for x-ray, electron, and neutron scattering that were planned, constructed, and are now operated by the BES program have revolutionized our understanding of materials. These facilities – and their availability to the broad national and international communities – are one of the great success stories of the BES program and the DOE.

During the past 10 years, the BES program has delivered nearly $2 billion of facilities and upgrades on schedule and within budget. Among others, this includes the Spallation Neutron Source, the complete reconstruction of the Stanford Synchrotron Radiation Laboratory, five Nanoscale Science Research Centers, and numerous instrument fabrication projects. On the drawing board and under construction are future generations of each of these facilities as well as future generations of the instruments used at them. Many of these new facilities will be complex, costly, and time consuming to construct. Billion-dollar-class facilities with construction times of six to eight years will not be unusual. As in the past, continued sound planning for them is critical.

In what follows, I provide additional details on the BES program and its subprograms; some likely future priorities for both research and facilities, including the mechanisms for establishing these priorities; and the importance of a program of R&D integration that recognizes the respective roles of discovery, innovation, application, development, and deployment.

Addressing the Nation's Energy Challenges in the New Era of Science

The 21st century has brought with it the recognition of staggering challenges for advanced energy technologies. Finite supplies of fossil fuel resources, uneven distribution of those resources, and the negative global effects of their use demand change. It is unlikely that incremental advances in current energy technologies, many of which are rooted in 19th century discoveries and 20th century development, will meet the need for the projected doubling or tripling of world energy consumption by the end of the 21st century.

BES and its predecessor organizations have supported a program of fundamental research focused on critical mission needs of the nation for over five decades. The federal program that became BES began with a research effort initiated to help defend our nation during World War II. The diversified program was organized into the Division of Research with the establishment of the Atomic Energy Commission in 1946 and was later renamed Basic Energy Sciences as it continued to evolve as a result of provisions included in the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, the Department of Energy Organization Act of 1977, and the Energy Policy Acts of 1992 and 2005.

Today the research supported by the BES program touches virtually every aspect of energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation. Research in materials sciences and engineering leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety of energy generation, conversion, transmission, storage, and use. Research in chemistry leads to the development of advances such as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for the production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. Research in geosciences results in advanced monitoring and measurement techniques for reservoir definition and an understanding of the dynamics of complex fluids, such as oil, flowing through porous and fractured subsurface rock. Research into the molecular and biochemical nature of photosynthesis aids the development of solar photo-energy conversion.

As described above, in 2001 the Basic Energy Sciences Advisory Committee conducted a major study to assess the scope of fundamental scientific research that must be considered to address the DOE missions in energy efficiency, renewable energy resources, improved use of fossil fuels, safe and environmentally acceptable nuclear energy, future energy sources, and reduced environmental impacts of energy production and use. The results of the week-long workshop were published in early 2003 in the report *Basic Research Needs to Assure a Secure Energy Future*. That report inspired a series of ten follow-on *Basic Research Needs* workshops over the next five years, which together attracted more than 1,500 participants from universities, industry, and DOE laboratories. The topics of the ten workshops were: the hydrogen economy, solar energy utilization, superconductivity, solid-state lighting, advanced nuclear energy systems, combustion of 21st century transportation fuels, electrical-energy storage, geosciences as it relates to the storage of energy wastes (the long-term storage of both nuclear waste and carbon dioxide), materials under extreme environments, and catalysis for energy-related processes.

After the first workshop in early 2003, *Basic Research Needs for the Hydrogen Economy*, the BES program issued solicitations for FY 2005 funding for individual investigator and small-group awards in areas of hydrogen production, storage, and use. An astounding 668 qualified preapplications were received in five submission categories: novel materials for hydrogen storage; membranes for separation, purification, and ion transport; design of catalysts at the nanoscale; solar hydrogen production; and bio-inspired materials and processes. Three of the five focus areas—novel storage materials, membranes, and design of catalysts at the nanoscale—accounted for about 75 percent of the submissions. Following a review, principal investigators on about 40 percent of the preapplications were invited to submit full applications; 227 full applications were received; and 70 awards were made totaling $21,473,000. Additional funding of $7,205,000 was awarded in subsequent years. BES involved staff from the DOE Office of Energy Efficiency and Renewable Energy (EERE) in the preapplication review process to ensure basic research relevance to technology program goals. Furthermore, BES program staff began participating in the DOE Hydrogen Program Annual Merit Review, which also involved EERE and the DOE Offices of Fossil Energy and Nuclear Energy, to promote information sharing. Beginning in FY 2006, the BES program staff organized parallel sessions at that meeting for the BES principal investigators.

This funding has enabled significant advances in understanding hydrogen-matter interactions. Recent accomplishments include:

- the discovery of atomic-scale mechanisms explaining reversible hydrogen storage within complex metal hydrides;
- the development of novel micro- and nano-patterning syntheses for a new generation of fuel cell membranes with superior power output;

- theoretical predictions and experimental validation of new architectures and compositions of catalyst alloys for efficient hydrogen production from fossil fuels as well as for fuel cell applications;
- the synthesis of mixed metal oxide photoelectrodes for solar hydrogen production;
- the identification of chemical pathways to convert biomass to hydrogen and other fuels; and
- advances in the development of oxygen-tolerant enzymes for bio-inspired hydrogen production.

A number of these accomplishments have led to follow-up developments by the applied research programs. Of particular note is the successful development of electrocatalysts with ultra-low platinum content that are 20 times more active by mass and more stable than pure platinum for converting hydrogen to electricity in fuel cell applications and dramatically reduce the cost of potential future fuel cell systems.

The Energy Frontier Research Centers

Very similar scientific themes emerged from multiple workshops in the *Basic Research Needs* series, and it became clear that in the future we would need broader solicitations than those used to support work in hydrogen production, storage, and use. The workshops also showed that the challenges of energy research transcend any single discipline and very often require many different disciplines to join together. In addition, during the years that the workshops were underway (2001-2007), we saw the advent of energy/environment centers at universities across the Nation and at DOE laboratories. Requests for funding from both the academic sector and the laboratory sector became commensurately larger and more multidisciplinary as groups of researchers joined together to tackle difficult problems in energy research. This prompted discussions over the past few years about the establishment of Energy Frontier Research Centers to complement the existing single-investigator awards and small-group (but largely single-discipline) awards.

With completion of the final *Basic Research Needs* workshop in late 2007, the BES program was primed to propose and implement an Energy Frontier Research Centers program in the FY 2009 Presidential Budget Request. The Energy Frontier Research Centers should be viewed as a funding mechanism, along with the more traditional single-investigator and small-group grants, rather than a new program. The Energy Frontier Research Centers represents about 15 percent of the total BES research portfolio in FY 2009. Depending on the results of the first solicitation, it is possible that the program might grow to a maximum of perhaps 25 percent of the total BES research portfolio over a period of 5-10 years.

The Energy Frontier Research Centers awards are expected to be in the $2-5 million range annually for an initial five-year period. A 2008 Funding Opportunity Announcement requested applications from the scientific community in a competition open to academic institutions, DOE laboratories, and other institutions as well as to partnerships among them. The Energy Frontier Research Centers are expected to bring together the skills and talents of multiple investigators to enable research of a scope and complexity that would not be possible with the standard individual investigator or small group awards. Up to $100,000,000 will be awarded in FY 2009, pending appropriations, and will support perhaps 25 to 35 individual centers. No building construction will be part of the awards. As the program matures, it is anticipated that competitions will be held every few years and that renewal submissions will be openly competed with new submissions.

General Comments on R&D Integration

As is demonstrated by the *Basic Research Needs* workshop series, the BES program is committed to R&D integration. The workshops and their follow-on solicitations seek to partner the BES program with its counterparts in the DOE technology offices. More broadly, DOE coordinates its basic research efforts in the Office of Science programs with the Department's applied technology offices through a number of processes and mechanisms. These include:

- scientific and technical workshops such as the *Basic Research Needs* series;
- structured, targeted research efforts driven by program manager-level coordination between the basic and applied R&D programs;
- joint program planning and/or program reviews;
- joint funding solicitations or jointly coordinated solicitations;
- shared grantee/contractors meetings and conferences to bring the research communities together;
- portfolio assessment efforts by structured oversight groups (DOE R&D Council); and
- coordination working group efforts guided by senior management (DOE S&T Council).

Coordination between the basic and applied programs is also enhanced through joint programs, jointly funded scientific facilities, the program management activities of the DOE Office of Science Small Business Innovation Research and Small Business Technology Transfer Programs, and the Experimental Program to Stimulate Competitive Research. DOE program managers have established formal technical coordinating committees (e.g., the Energy Materials Coordinating Committee) that meet on a regular basis to discuss R&D programs with wide applications for basic and applied programs. Additionally, co-funding research activities and facilities at the DOE laboratories and using funding mechanisms that encourage broad partnerships are also means by which DOE facilitates greater communication and research integration within the S&T communities. Taken in sum, these coordination activities are widespread and have contributed significantly to DOE's capabilities and success in achieving mission goals.

Basic Energy Sciences Subprogram Details

The Basic Energy Sciences program has two subprograms: Materials Sciences and Engineering, which supports research and all of the facility operations, and Chemical Sciences, Geosciences, and Biosciences, which supports research. The two research components and the facility operations component are described below.

Materials Sciences and Engineering Research

This activity supports fundamental experimental and theoretical research to provide the knowledge base for the discovery and design of new materials with novel structures, functions, and properties.

In *condensed matter and materials physics*—including activities in experimental condensed matter physics, theoretical condensed matter physics, materials behavior and radiation effects, and physical behavior of materials—research is supported to understand, design, and control materials properties and function. These goals are accomplished through studies of the relationship of materials structures to their electrical, optical, magnetic, surface reactivity, and mechanical properties and of the way in which materials respond to external forces such as stress, chemical and electrochemical environments, radiation, and the proximity of materials to surfaces and interfaces. The activity emphasizes strongly correlated materials, which are a wide class of materials that show unusual, often technologically useful, electronic and magnetic properties. Intensively studied strongly correlated materials include the high-temperature superconductors.

In *scattering and instrumentation sciences*—including activities in neutron and x-ray scattering and electron and scanning probe microscopies—research is supported on the fundamental interactions of photons, neutrons, and electrons with matter to understand the atomic, electronic, and magnetic structures and excitations of materials and the relationship of these structures and excitations to materials properties and behavior. Major research areas include fundamental dynamics in complex materials, correlated electron systems, nanostructures, and the characterization of novel systems. The development of next generation neutron, x-ray, and electron microscopy instrumentation is a key element of this portfolio.

In *materials discovery, design, and synthesis*—including activities in synthesis and processing science, materials chemistry, and biomolecular materials—research is supported in the discovery and design of novel materials and the development of innovative materials synthesis and processing methods. Major research thrust areas include nanoscale synthesis, organization of nanostructures into macroscopic structures, solid state chemistry, polymers and polymer composites, surface and interfacial chemistry including electrochemistry and electro-catalysis, synthesis, and processing science including biomimetic and bioinspired routes to functional materials and complex structures.

Chemical Sciences, Geosciences, and Biosciences Research

This activity supports experimental and theoretical research to provide fundamental understanding of chemical transformations and energy flow in systems relevant to DOE missions.

In *fundamental interactions*, basic research is supported in atomic, molecular, and optical sciences; gas-phase chemical physics; ultra-fast chemical science; and condensed phase and interfacial molecular science. Emphasis is placed on structural and dynamical studies of atoms, molecules, and nanostructures, and the description of their interactions in full quantum detail, with the aim of providing a complete understanding of reactive chemistry in the gas phase, condensed phase, and at interfaces. Novel sources of photons, electrons, and ions are used to probe and control atomic, molecular, and nanoscale matter. Ultra-fast optical and x-ray techniques are developed and used to study chemical dynamics.

In *photochemistry and biochemistry*, research is supported on the molecular mechanisms involved in the capture of light energy and its conversion into chemical and electrical energy through biological and chemical pathways. Natural photosynthetic systems are studied to create robust artificial and bio-hybrid systems that exhibit the biological traits of self assembly, regulation, and self repair. Complementary research encompasses organic and inorganic photochemistry, photo-induced electron and energy transfer, photoelectrochemistry, and molecular assemblies for artificial photosynthesis. Photoelectrochemical conversion is explored in studies of nanostructured semiconductors. Biological energy transduction systems are investigated, with an emphasis on the coupling of plant development and microbial biochemistry with the experimental and computational tools of the physical sciences.

In *chemical transformations*, the themes are characterization, control, and optimization of chemical transformations, including efforts in catalysis science; separations and analytical science, actinide chemistry, and geosciences. Catalysis science underpins the design of new catalytic methods for the clean and efficient production of fuels and chemicals and emphasizes inorganic and organic complexes; interfacial chemistry; nanostructured and supramolecular catalysts, photocatalysis and electrochemistry, and bio-inspired catalytic processes. Heavy element chemistry focuses on the spectroscopy, bonding, and reactivity of actinides and fission products; complementary research on chemical separations focuses on the use of nanoscale membranes and the development of novel metal complexes. Chemical analysis research emphasizes laser-based and ionization techniques for molecular detection, particularly the development of chemical imaging techniques. Geosciences research covers analytical and physical geochemistry, rock-fluid interactions, and flow/transport phenomena; this research provides a fundamental basis for understanding the environmental contaminant fate and transport and for predicting the performance of repositories for radioactive waste or carbon dioxide sequestration.

Scientific User Facilities Operations
This activity supports the R&D, planning, and operation of scientific user facilities for the fabrication of materials and for the examination of materials through x-ray, neutron, and electron beam scattering.

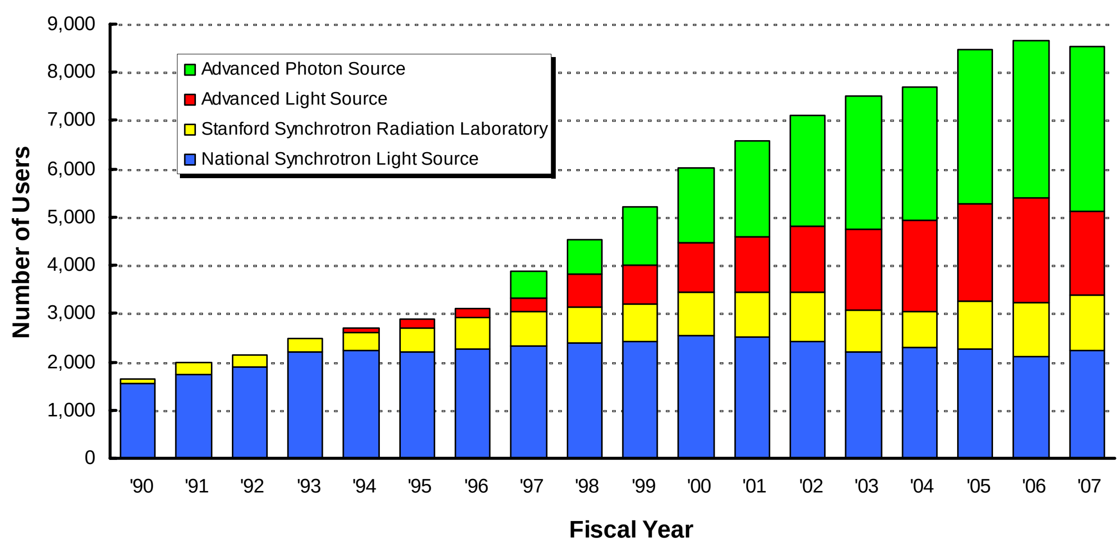
For approved, peer-reviewed projects, operating time is available without charge to researchers who intend to publish their results in the open literature. The synchrotron light sources, producing mostly soft and hard x-rays, examine the fundamental parameters used to perceive the physical world (energy, momentum, position, and time). The unique properties of synchrotron radiation – high flux and brightness, tunability, polarizability, and high spatial and temporal coherence, and the pulsed nature of the beam – afford a wide variety of experimental techniques in diffraction and scattering, spectroscopy, and spectrochemical analysis, imaging, and dynamics. Neutron sources take advantage of the electrical neutrality and special magnetic properties of the neutron to probe atoms and molecules and their assembly into materials. With unique characteristics such as sensitivity to light elements, neutron scattering has proven to be invaluable to polymer and biological sciences. The high penetrating ability of neutrons allows property measurements and nondestructive evaluation deep within a specimen. Neutrons have magnetic moments and are thus uniquely sensitive probes of magnetic species within a sample. The Nanoscale Science Research Centers provide the ability to fabricate complex nanostructures using chemical, biological, and other synthesis techniques, to characterize them, to assemble them, and to integrate them into devices.

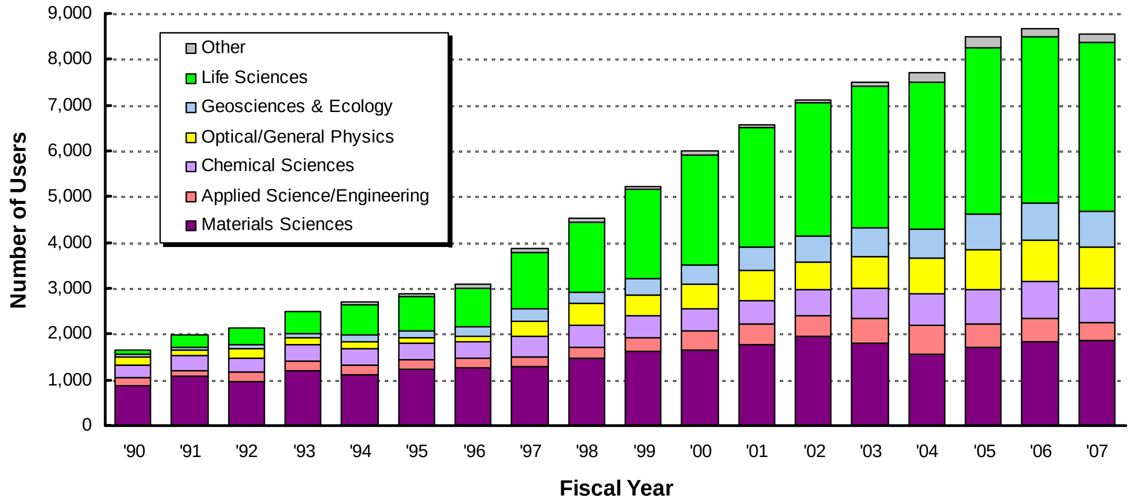
Because of the large numbers of users who visit the synchrotron radiation light sources – nearly half of all users of the Office of Science facilities – the light sources are of particular interest. The size and demographics of the user community have changed dramatically since the 1980s when only a few hundred intrepid users visited the light sources each year.

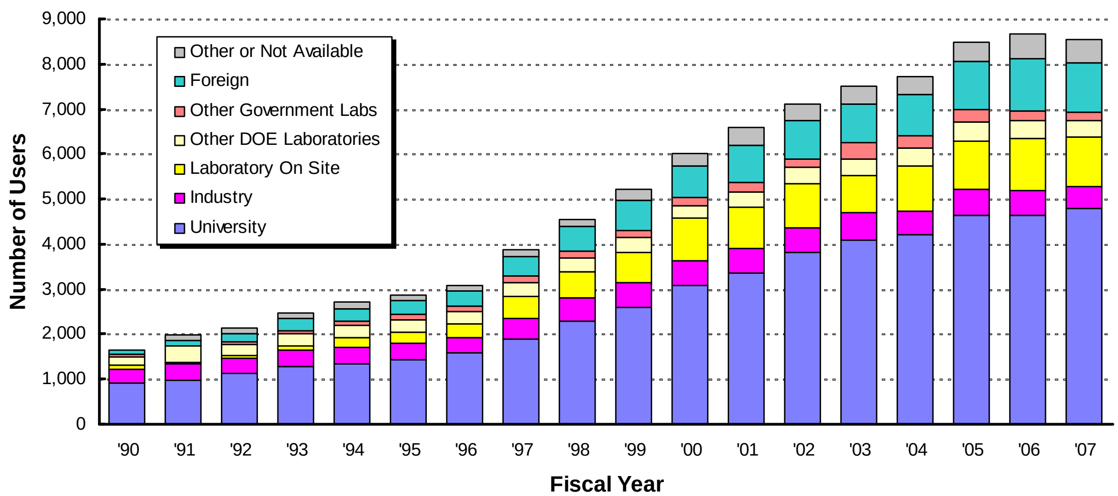
In the charts below, many demographic trends are illustrated. Among other things, the commissioning of the Advanced Light Source at Lawrence Berkeley National Laboratory in 1993 and the Advanced Photon Source at Argonne National Laboratory in 1996 more than doubled the capacity of the light sources. The growth in users was additionally spurred by the influx of new users, notably those who studied macromolecular crystallography. Finally, it is interesting to note that the total number of users reached a maximum in FY 2006. This is largely due to funding limitations during FY 2006 through FY 2008.

The charts below show the numbers of users at the BES synchrotron radiation light sources each year as a function of facility (Chart 1); user discipline (Chart 2); and user home institution (Chart 3). In Chart 1, APS is the Advanced Photon Source at Argonne National Laboratory; ALS is the Advanced Light Source at Lawrence Berkeley National Laboratory; SSRL is the Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center; and NSLS is the National Synchrotron Light Source at Brookhaven National Laboratory.

In all of the charts below, there is a standard definition of "user." A user is a researcher who proposes and conducts peer-reviewed experiments at a scientific facility or conducts experiments at the facility remotely. A user does not include individuals who only send samples to be analyzed, pay to have services performed, or visit the facility for tours or educational purposes. The term user also does not include researchers who collaborate on the proposal or subsequent research paper but do not conduct experiments at the facility. For annual totals, an individual is counted as one user at a particular facility no matter how often or how long the researcher conducts experiments at the facility during the year.







Several years ago the BES program reevaluated the metrics used to assess effective operation and utilization of the synchrotron light source facilities, looking potentially to broaden the metrics from those used previously in annual reports to Congress: hours of operation of the accelerator complex and numbers of users who annually visit the facilities. With the cooperation of the facilities, new measures were devised that provided quantitative assessments of instrument capability, instrument capacity, and staffing levels. These measures were piloted in FY 2005 and FY 2006, and data were collected for FY 2007 and FY 2008 as well. These pilot studies show that overall effectiveness of operation and utilization of the synchrotron light sources could be improved but that usually such improvements would require additional operations costs, although some improvements could be gained from enhanced strategic planning within and across facilities. These studies supported enhanced funding requests for the facilities in FY 2007 and FY 2008; however, the proposed increases were not funded in the appropriations for those years. Increases have been requested again in FY 2009.

Future Directions
The BES program supports a broad portfolio of work, and planning for the future is an ongoing activity. The first set of *Basic Research Needs* workshops and the report *Directing Matter and Energy: Five Challenges for Science and the Imagination* are complete. Together they describe a continuum of research from the most fundamental questions of how nature works to the “show-stopper” questions in the applied research programs supported by the DOE technology offices. The BES programs’ portfolios have been reassessed and restructured as necessary to reflect the results of these workshops. In addition to the work identified in these workshops, other BES priority areas include general support for ultrafast science, chemical imaging, and mid-scale instrumentation. Funding for all of these activities was requested in FY 2007 – FY 2009; however, the FY 2007 and FY 2008 appropriations were not sufficient to support many of the new directions.

Planning for the facilities sponsored by the BES program is also an ongoing activity. The BES program has a long tradition of planning, constructing, and operating facilities well. During the past 10 years, the BES program has delivered nearly $2 billion of facilities and upgrades on schedule and within budget. Among others, this includes the Spallation Neutron Source, the complete reconstruction of the Stanford Synchrotron Radiation Laboratory, five Nanoscale Science Research Centers, and numerous instrument fabrication projects for the major scientific user facilities.

The 2003 Office of Science report, *Facilities for the Future of Science: A Twenty-Year Outlook*, describes the long-range plan for the Office of Science facilities. As high priorities, the report includes construction of the Linac Coherent Light Source, which is nearing completion and will begin operations in FY 2009, and the Transmission Electron Aberration-corrected Microscope, which already has delivered an early prototype.

Mid-term priorities include upgrades to the Spallation Neutron Source, which was commissioned in FY 2006. The upgrades consist of an energy upgrade to the linac and the construction of a second target station; the former will undergo cost and schedule baselining this year, and the later is preparing for Critical Decision 0, Approval of Mission Need. Another mid-term priority is the construction of the National Synchrotron Light Source-II. This project moved up in priority owing to elimination of technical impediments, and it is scheduled to begin construction in FY 2009.

Far-term priorities include upgrades to the Advanced Photon Source and the Advanced Light Source. These activities as well as the consideration of next-generation light sources are now under consideration by the BES program. Recently, the Basic Energy Sciences Advisory Committee has been charged to sponsor a Photon Workshop to consider the science drivers for new photon sources. The workshop will identify new grand energy and scientific opportunities in materials, chemistry, biology, medicine, environment, and physics that can be addressed with diffraction, excitation, and imaging by photons. The primary outputs of the workshop will be (1) the evaluation of the impact of each new opportunity in advancing the frontier of science or enabling new approaches to energy challenges, and (2) the definition of the photon attributes required to realize each opportunity. The photon attributes include coherence length, time structure, energy, energy resolution, brightness, intensity, spatial resolution, and polarization. It is expected that this workshop will help set the course for photon science facilities for the next decade.

Five-year BES program planning is consistent with funding profiles proposed by the America COMPETES Act of 2007 (P.L. 110–69), which would lead to a doubling of funding in the Office of Science in seven years.

Concluding Remarks

Thank you, Mr. Chairman, for providing this opportunity to discuss the Basic Energy Sciences program. This concludes my testimony, and I would be pleased to answer any questions you might have.