**Statement of Dr. Raymond L. Orbach**
**Under Secretary for Science**
**U.S. Department of Energy**

**Before the**
**Subcommittee on Energy and Water Development**
**House Committee on Appropriations**

**Regarding FY 2009 Research**
**and Development Budget Proposal**

**March 13, 2008**

Thank you Mr. Chairman, Ranking Member Hobson, and Members of the Committee. I am pleased to appear before your Committee for what I expect to be my final budget presentation for the Department of Energy's Office of Science. I would like to thank the Committee for your strong support for the Office of Science during my tenure. This support has enabled the Office of Science to make investments in basic research and advanced research capabilities that have and will continue to improve U.S. global competitiveness, energy security, the environment, and our fundamental understanding of the universe around us.

Our Nation continues to face significant challenges in energy security and in our ability to maintain the scientific leadership and innovation that assures our continued economic security. These challenges are addressed by the President in his American Competitiveness Initiative and Advanced Energy Initiative announced in 2006. In this year's State of the Union address, the President again called our attention to the importance of harnessing the creative genius of American researchers and entrepreneurs in developing the next generation of clean energy technologies and in keeping our Nation at the forefront of basic research in the physical sciences. The budget request for FY 2009 demonstrates his forceful, continued commitment to these important initiatives. The Congress has also spoken and expressed strong, bipartisan support for an aggressive innovation and energy security agenda in passing the Energy Policy Act (EPAct) of 2005 and in following up with both the America COMPETES Act and the Energy Independence and Security Act (EISA) in 2007.

EPAct and the COMPETES Act both recognize the pivotal role of the Office of Science in securing the advantages that basic research as well as science, math, and engineering education can bring to the Nation. EISA's provisions are intended to reduce America's dependence on oil, improve efficiency, and cut emissions. Technology development proceeds fastest where there is a strong grounding in scientific understanding, but we will not meet the targets with solely incremental improvements in current technologies. We need the breakthroughs that will result only from transformational basic research.

Here are a few examples. EISA mandates the use of at least 36 billion gallons of biofuels by 2022. Without transformational breakthroughs in deriving fuels from plant cellulose materials, we reduce our chances of reaching these aggressive goals. Even though conventional approaches, such as sugar-based and corn-based ethanol, can be modestly energy positive—although this is still debated—they consume large quantities of food and feed grain. Increasing use of these feedstocks raises environmental concerns associated with land use changes and impacts on atmospheric concentrations of carbon dioxide. Biofuels derived from cellulose, and in particular feedstock crops such as switchgrass that can be grown on marginal land with minimal water and nutrient requirements, can provide the basis for a sustainable biofuels economy in the U.S. while benefiting the American farmer. Breakthroughs in science are essential for the development of more efficient and cost-effective processes for deriving fuels from cellulose and for developing dedicated feedstock crops. The approaches to cellulosic ethanol deployed in many pilot and demonstration bioethanol plants across the United States rely on niche feedstocks and conversion technologies that are not yet cost competitive. New scientific discoveries supported by the Office of Science will speed revolutionary gains in production efficiencies and cost reduction – and in some cases may be the only way to meet our goals.

The transformational basic research undertaken by the Office of Science's Bioenergy Research Centers is one way the Department is addressing the difficulties of cost-effective bioethanol production with minimal environmental footprint, by using plant and microbial genomics and other novel approaches.

EISA also mandates a national fuel economy standard of at least 35 miles per gallon by 2020—an increase in fuel economy of some 40 percent that will save billions of gallons of fuel. Automobile manufacturers will need to employ numerous conventional and advanced engine and vehicle technologies to reach this goal. Office of Science basic research will be critical in the development of cost effective advanced engine and vehicle technologies through research in areas such as high-strength, low-weight materials; electrical energy storage; hydrogen production, use, and storage; fuel cell materials; catalysts, combustion processes, and materials under extreme environments.

In FY 2009 the Office of Science will initiate Energy Frontier Research Centers. They will pursue innovative basic research to accelerate the scientific breakthroughs needed to create advanced energy technologies for the 21st century. These Centers will pursue fundamental basic research areas mentioned above as well as solar energy utilization; geosciences related to long-term storage of nuclear waste and carbon dioxide; advanced nuclear energy systems; solid state lighting; and superconductivity.

The Office of Science seeks to engage the Nation's intellectual and creative talent to address scientific grand challenges. These are the necessary transformational discoveries which will fundamentally alter our approaches to energy production and use, and they will come from the next generation of scientists, mathematicians, and engineers. If our FY 2009 request is approved, the Office of Science will be able to directly support the research of more than 4,300 graduate students – and many more who are supported by other agencies will use our world-leadership scientific research facilities in their dissertation research.

The Office of Science is accelerating the pace of discovery and innovation to address the Nation's energy needs through our multifaceted research portfolio. Your confidence in the Office of Science is based on a number of demonstrated successes in our mission areas, and your support for the Office of Science has enabled us to assess the basic research needs and engage the scientific community to respond aggressively. We routinely assess and update these research opportunities and priorities with an eye to our mission and with an ear to the research community, whether at a national laboratory, a university, or in industry. Since we build and operate large-scale, long-term, and, by necessity, cost-effective scientific research facilities, and because our mission is so important, we take these assessments seriously. We cannot afford to go in a wrong direction; we need the most complete and robust analysis of scientific opportunity, mission need, cost, and benefit.

A large part of this assessment effort in recent years has been accomplished through a series of Basic Research Needs workshops and other workshops led by our science programs in partnership with the Department's technology programs. These workshops have brought together subject experts with diverse views from the broader basic and applied research community to discuss and identify areas of focus for DOE's basic research efforts. These efforts have enabled the Office of Science to stay informed of research needs and new opportunity areas, as well as scientific and technological roadblocks, and have enabled us to create a prioritized and comprehensive research portfolio within our available funding.

While these workshops are critical to building and balancing our research portfolio, we also have a number of planning and advisory resources at our disposal to inform our long-term research portfolio planning. The National Academy of Sciences, our Federal Advisory Committees, informal and formal communication with the international scientific community, OSTP, OMB, the Congress, and our in-house Office of Science personnel all play important roles. Our programs are strong because our research portfolio and facilities are internally and externally assessed regularly and because our research and facilities are awarded through a competitive merit review process.

We have established effective processes for assessing basic research needs, and we have also developed the capacity to respond quickly with highly leveraged investments in scientific facilities and research at the national laboratories and universities. This informed, rapid response provides the world-class research results that will help solve some of our most intractable energy supply and environmental challenges, while keeping our Nation's scientific enterprise and industry at the forefront.

I think the best way to bring my statement into sharp focus is to discuss some examples of how your investments in the Office of Science have brought quick and remarkable results, and what we plan to do with the funding requested for FY 2009 to enhance the U.S. scientific and innovation enterprise and ensure the best possible return to the taxpayer.

Perhaps the best example of this aggressive and nimble approach is the response by the Office of Science to the challenge of High Performance Computing (HPC). In 2002 the Japanese announced the Earth Simulator, a high performance computer for open science which combined unprecedented performance and efficiency. Congress responded by dramatically increasing HPC funding, and making the Office of Science the lead in an effort to surpass the Earth Simulator. I am pleased to report that your confidence in us has already resulted in the U.S. attaining world leadership in open scientific computing—by the end of this year we will achieve peak capacity of one petaflop at our Leadership Computing Facility in Oak Ridge. This exceptional capability is helping us model such phenomena as turbulent flows related to combustion and to model and simulate complex climate processes that will inform decision makers on climate change, mitigation, and adaptation.

The benefits of Office of Science HPC capabilities extend well beyond DOE. We provide access to these resources to other Federal agencies, universities, laboratories, and industry. We have been involved in modeling and simulation runs as diverse as determining hurricane effects to save lives, and modeling aircraft engines and airframes to improve energy efficiency and reduce time-to-market. We use the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program to openly compete access to these world-leading HPC resources. The Office of Science created INCITE for the purpose of bringing the capabilities of terascale computing to the community in order to transform the conduct of science and bring scientific simulation through computational modeling to parity with theory and experiment as a scientific tool.  As a result, HPC modeling and simulation is now seen as a potent tool in the scientific toolbox; one that will potentially save lives, increases our energy and national security, and propels us to a competitive edge.

Another accomplishment of the past year is the successful competition and award of three Bioenergy Research Centers.  These Centers will each take different approaches to discovering fundamentally new solutions and solving critical roadblocks on the path to energy security—how will we meet the new requirement to produce 36 million gallons of biofuels by 2022 from renewable plant sources that don't compete with the food supply?  In authorizing and funding the Bioenergy Research Centers, Congress expressed its confidence in the ability of the Office of Science to tap the talent of our national laboratories and universities to tackle our fuels challenge, and these Centers are up and running well.

U.S. leadership in science and technology depends on the continued availability of the most advanced scientific tools and facilities for our researchers. The suite of research capabilities operated by the Office of Science and used annually by 20,000 researchers from industry, academia and government labs are still the envy of the world. And over the past several years, with your support, we have delivered new facilities and have achieved remarkable technical milestones with existing facilities, enabling the U.S. to work at the cutting-edge of many scientific disciplines. The Spallation Neutron Source, which came on line in 2006, is the world's forefront neutron scattering facility providing more neutrons, by a factor of ten, than any other neutron source in the world for research of materials and biological complexes. Let me give you just one example of why neutrons are so important.  Neutrons are the only way to peer inside an operating fuel cell to view water forming and moving throughout the cell. In a fuel cell, water is formed as a by-product of the reaction between hydrogen and oxygen. If the water does not drain quickly and efficiently, then fuel cells will not work properly.

The Linac Coherent Light Source currently under construction will produce x-rays 10 billion times more intense than any existing x-ray source in the world when it comes on line in FY 2010. It will have the capabilities for structural studies of nanoscale particles and single molecules and for probing chemical reactions in real time.  All five Office of Science Nanoscale Science Research Centers are now in operation, providing unparalleled resources to the scientific community for synthesis, fabrication, and analysis of nanoparticles and nanomaterials. The Tevatron at Fermilab currently remains the world's most powerful particle collider for high energy physics. New records for performance in peak luminosity were achieved in 2006, enabling the observation of the rare single top quark and bringing researchers closer to understanding the basic constituents of matter and the laws of nature at high energies.

On October 24, 2007, the international ITER Agreement went into force.  The ITER experiment will demonstrate for the first time that a reactor can create and sustain a burning plasma.  The implications of this research are far-reaching.  The world faces a series of tough choices in meeting our energy needs over the next century.  While no silver bullet may exist, fusion appears to be the closest.  Fusion energy provides the real possibility of abundant, economical, and environmentally benign energy, starting around mid-century.  Our investments today will have huge pay-offs for our children and grandchildren.  We are part of an international consortium that is sharing the cost and the risk of the project and will have full access to all experimental research data.

The Office of Science is aggressively pursuing a range of research areas that will provide answers critical to our future energy security, as the material that follows will show—and we also continue to plan for the future, seeking to identify opportunities within available resources and to update our priorities appropriately. An example of this is the *'Facilities for the Future of Science: A 20-Year Outlook'* report, which was released in November 2003 and updated last year. The Outlook contained a prioritized list of facilities to underpin our major research thrusts over the next 20 years and beyond. These facilities are designed to be world class and adaptable to evolving basic research needs to ensure that U.S. taxpayers get the most value for their money. These facilities also allow researchers access to the full array of physical and biological science large-scale resources, creating an all-important balance and 'unity' of science within the Office of Science. I ask the Members during this appropriations cycle especially to consider the lasting value of the basic energy research done in the Office of Science to our Nation's well-being and economic prowess.

The following programs are supported in the FY 2009 budget request: Basic Energy Sciences, Advanced Scientific Computing Research, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, Nuclear Physics, Workforce Development for Teachers and Scientists, Science Laboratories Infrastructure, Science Program Direction, and Safeguards and Security.

**OFFICE OF SCIENCE**
**FY 2009 PRESIDENT'S REQUEST**
**SUMMARY BY PROGRAM**

(dollars in thousands)

| | FY 2007 Approp. | FY 2008 Approp. | FY 2009 Request | FY 2009 vs. FY 2008 | |
|---|---|---|---|---|---|
| Basic Energy Sciences | 1,221,380 | 1,269,902 | 1,568,160 | +298,258 | +23.5% |
| Advanced Scientific Computing Research | 275,734 | 351,173 | 368,820 | +17,647 | +5.0% |
| Biological and Environmental Research | 480,104 | 544,397 | 568,540 | +24,143 | +4.4% |
| High Energy Physics | 732,434 | 689,331 | 804,960 | +115,629 | +16.8% |
| Nuclear Physics | 412,330 | 432,726 | 510,080 | +77,354 | +17.9% |
| Fusion Energy Sciences | 311,664 | 286,548 | 493,050 | +206,502 | +72.1% |
| Science Laboratories Infrastructure | 41,986 | 66,861 | 110,260 | +43,399 | +64.9% |
| Science Program Direction | 166,469 | 177,779 | 203,913 | +26,134 | +14.7% |
| Workforce Dev. for Teachers & Scientists | 7,952 | 8,044 | 13,583 | +5,539 | +68.9% |
| Safeguards and Security (gross) | 75,830 | 75,946 | 80,603 | +4,657 | +6.1% |
| SBIR/STTR (SC funding) | 86,936 | —— | —— | —— | —— |
| Subtotal, Office of Science | 3,812,819 | 3,902,707 | 4,721,969 | +819,262 | +21.0% |
| Adjustments[1] | 23,794 | 70,435 | —— | -70,435 | -100.0% |
| Total, Office of Science | 3,836,613 | 3,973,142 | 4,721,969 | +748,827 | +18.8% |

[1] Adjustments include SBIR/STTR funding transferred from other DOE offices ($39,319,000 in FY 2007), a charge to reimbursable customers for their share of safeguards and security costs (-$5,605,000 in each of FY 2007 and FY 2008), Congressionally-directed projects ($123,623,000 in FY 2008), a rescission of a prior year Congressionally-directed project (-$44,569,000 in FY 2008), and offsets for the use of prior year balances to fund current year activities (-$9,920,000 in FY 2007 and -$3,014,000 in FY 2008).

## BASIC AND APPLIED RESEARCH & DEVELOPMENT COORDINATION

I would also like to highlight the fact that the Office of Science continues to coordinate basic research efforts in several areas with the Department's applied technology offices through collaborative processes established over the last several years. These areas include biofuels derived from biomass, solar energy, hydrogen, solid-state lighting and other building technologies, the Advanced Fuel Cycle, Generation IV Nuclear Energy Systems, vehicle technologies, and improving efficiencies in industrial processes. The Department's July 2006 report to Congress *DOE Strategic Research Portfolio Analysis and Coordination Plan* identified 21 additional areas of opportunity for coordination that have great potential to increase mission success. The Office of Science supports basic research that underpins nearly all 21 areas; and six areas are highlighted in the FY 2009 Office of Science budget request for enhanced R&D coordination: Advanced Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment; Electrical Energy Storage; Carbon Dioxide Capture and Storage; Characterization of Radioactive Waste; Predicting High Level Waste System Performance over Extreme Time Horizons; and High Energy Density Laboratory Plasmas. The Office of Science has sponsored scientific workshops corresponding to these focus areas in collaboration with related DOE applied technology program offices. The workshop reports identified high priority basic research areas necessary for improved understanding and revolutionary breakthroughs.

*Advanced Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment*: The Advanced Scientific Computing Research (ASCR) program supports basic research in advanced mathematics for optimization of complex systems, control theory, and risk assessment. A recommendation from the workshop focused on this subject indicated additional research emphasis in advanced mathematics could benefit the optimization of fossil fuel power generation; the nuclear fuel lifecycle; and power grid control. Such research could increase the likelihood for success in DOE strategic initiatives including integrated gasification combined cycle coal-fired power plants and modernization of the electric power grid.

*Electrical Energy Storage*: About 15 percent of the Basic Energy Sciences (BES) program funding requested to support basic research in electrical energy storage (EES) is targeted for a formally coordinated program with DOE applied technology program offices. The workshop report on this focus area noted that revolutionary breakthroughs in EES have been singled out as perhaps the most crucial need for this Nation's secure energy future. The report concluded that the breakthroughs required for tomorrow's energy storage needs can be realized with fundamental research to understand the underlying processes involved in EES. The knowledge gained will in turn enable the development of novel EES concepts that incorporate revolutionary new materials and chemical processes. Such research will accelerate advances in developing novel battery concepts for hybrid and electric cars and will also help facilitate successful utilization and integration of intermittent renewable power sources such as solar, wind, and wave energy into the utility sector, making these energy sources competitive for base-load supply.

*Carbon Dioxide Capture and Storage*: BES, ASCR and the Biological and Environmental Research (BER) program support basic research in carbon dioxide capture and storage. The storage portion of this R&D coordination focus area was a subject of a BES workshop on Basic Research Needs for Geosciences in February 2007 that focused on the research challenges posed by carbon dioxide storage in deep porous saline geological formations. The workshop report noted that the chemical and geological processes involved in the storage of carbon dioxide are highly complex and would require an interdisciplinary approach strongly coupling experiments with theory, modeling, and computation bridging multiple length and time scales. The BES effort supports fundamental research to understand the underlying chemical, geochemical, and geophysical processes involved in subsurface sequestration sites. The BER research effort focuses on understanding, modeling, and predicting the processes that control the fate of carbon dioxide injected into geologic formations, subsurface carbon storage, and the role of microbes and plants in carbon sequestration in both marine and terrestrial environments. These aspects of this focus area were also the subject of additional SC workshops that identified basic research areas in carbon dioxide capture and storage that could benefit the optimization of fossil fuel power generation and the development of carbon neutral fuels. The ASCR research effort supports two Scientific Discovery through Accelerated Computing (SciDAC) partnerships with BER to advance modeling of subsurface reactive transport of contaminants; an area that has been identified as directly relevant to carbon sequestration research efforts.

*Characterization of Radioactive Waste*: BES, BER, and the Nuclear Physics (NP) program support research in radioactive waste characterization. This R&D coordination focus area was the subject of six Office of Science workshops, including three BES workshops. The workshop reports noted that the materials and chemical processes involved in radioactive waste disposal are highly complex and their characterization requires an interdisciplinary approach that strongly couples experiments with theory, modeling, and computation bridging multiple length and time scales. The BES effort will focus on research relating to the underlying physical and chemical processes that occur under the conditions of radioactive waste storage, including extremes of temperature, pressure, radiation flux, and multiple complex phases. The BER research effort addresses processes that control the mobility of radiological waste in the environment. The NP research effort is focused on characterization of radioactive waste through the advanced fuel cycle activities. The NP program areas are structured as scientific disciplines with goals to understand the nuclear cross sections important for advanced fuel cycle reprocessing. A small portion of on-going research is relevant to the issues involved with radioactive waste and related advanced fuel cycles. The knowledge gained from this research will lead to enhanced understandings of radioactive waste characterization, which would make nuclear power a far more attractive component in primary energy usage.

*Predicting High Level Waste System Performance over Extreme Time Horizons*: BES supports basic research in predicting high-level waste system performance over extreme time horizons. This R&D coordination focus area was a subject of a BES workshop on Basic Research Needs for Geosciences in February 2007, which focused on research challenges posed by geological repositories for high level waste. The workshop report identified major research priorities in the areas of computational thermodynamics of complex fluids and solids, nanoparticulate and colloid physics and chemistry, biogeochemistry in extreme and perturbed environments, highly reactive subsurface materials and environments, and simulation of complex multi-scale systems for ultra-long times.

*High Energy Density Laboratory Plasmas*: The Fusion Energy Sciences (FES) program supports basic reach in high energy density laboratory plasmas. In May 2007, Office of Science and the

National Nuclear Security Administration (NNSA) jointly sponsored a workshop to update the high energy density laboratory plasmas (HEDLP) scientific research agenda. Three scientific themes emerged from the workshop: enabling the grand challenge of fusion energy by high energy density laboratory plasmas; creating, probing, and controlling new states of high energy densities; and catching reactions in the act by ultra-fast dynamics. In FY 2009, the FES request expands existing HEDLP research in response to the research opportunities identified in the workshop.

**BASIC AND APPLIED R&D COLLABORATION FUNDING SUMMARY**

(dollars in thousands)

| | FY 2007 Approp. | FY 2008 Approp. | FY 2009 Request | FY 2009 vs. FY 2008 | |
|---|---|---|---|---|---|
| Advanced Mathematics for Optimization of Complex Systems, Control Theory, & Risk Assessment | | | | | |
| Science | | | | | |
| Advanced scientific computing research | —— | 1,900 | 2,000 | +100 | +5.3% |
| Energy Efficiency and Renewable Energy | —— | —— | 500 | +500 | —— |
| Nuclear Energy | 10,000 | 19,410 | 55,000 | +35,590 | +183.4% |
| Total, Advanced Mathematics | 10,000 | 21,310 | 57,500 | +36,190 | +169.8% |
| Electrical Energy Storage | | | | | |
| Science | | | | | |
| Basic energy sciences | —— | —— | 33,938 | +33,938 | —— |
| Energy Efficiency and Renewable Energy | —— | —— | 2,000 | +2,000 | —— |
| Electricity Delivery and Energy Reliability | —— | —— | 13,403 | +13,403 | —— |
| Total, Electric Energy Storage | —— | —— | 49,341 | +49,341 | —— |
| Carbon Dioxide Capture and Storage | | | | | |
| Science | | | | | |
| Basic energy sciences | 5,915 | 5,915 | 10,915 | +5,000 | +84.5% |
| Advanced scientific computing research | —— | 976 | 976 | —— | —— |
| Biological and environmental research | 16,841 | 16,874 | 17,374 | +500 | +3.0% |
| Total, Science | 22,756 | 23,765 | 29,265 | +5,500 | +23.1% |
| Fossil Energy | 97,228 | 118,908 | 149,132 | +30,224 | +25.4% |
| Total, Carbon Dioxide Capture and Storage | 119,984 | 142,673 | 178,397 | +35,724 | +25.0% |

| | FY 2007 Approp. | FY 2008 Approp. | FY 2009 Request | FY 2009 vs. FY 2008 | |
|---|---|---|---|---|---|
| | (dollars in thousands) | | | | |
| Characterization of Radioactive Waste | | | | | |
| Science | | | | | |
| Basic energy sciences | — | — | 8,492 | +8,492 | — |
| Biological and environmental research | — | — | 1,500 | +1,500 | — |
| Nuclear physics | 200 | 200 | 6,603 | +6,403 | +3,202% |
| Total, Science | 200 | 200 | 16,595 | +16,395 | +8,198% |
| Nuclear Energy | 37,190 | 53,722 | 59,000 | +5,278 | +9.8% |
| Environmental Management | 2,100 | 2,100 | 9,500 | +7,400 | +352.4% |
| Total, Characterization of Radioactive Waste | 39,490 | 56,022 | 85,095 | +29,073 | +51.9% |
| Predicting High Level Waste System Performance Over Extreme Time Horizons | | | | | |
| Science | | | | | |
| Basic energy sciences | — | — | 8,492 | +8,492 | — |
| Environmental Management | 500 | 500 | 1,500 | +1,000 | +200.0% |
| Total, Predicting High Level Waste System Performance | 500 | 500 | 9,992 | +9,492 | +1,898% |
| High Energy Density Laboratory Plasmas | | | | | |
| Science | | | | | |
| Fusion energy sciences | 15,459 | 15,942 | 24,636 | +8,694 | +54.5% |
| National Nuclear Security Administration | 10,000 | 12,295 | 10,147 | -2,148 | -17.5% |
| Total, High Energy Density Laboratory Plasmas | 25,459 | 28,237 | 34,783 | +6,546 | +23.2% |
| Total, Basic and Applied Research Collaborations | 195,433 | 248,742 | 415,108 | 166,366 | +66.9% |

## CONCLUSION

I want to thank you, Mr. Chairman, for providing this opportunity to discuss the Office of Science research programs and our contributions to the Nation's scientific enterprise and global competitiveness. On behalf of DOE, I am pleased to present this FY 2009 budget request for the Office of Science.

This concludes my testimony. I would be pleased to answer any questions you might have.

Dr. Raymond L. Orbach
Under Secretary for Science
U.S. Department of Energy