CRITICAL CHOICES: SCIENCE, ENERGY, AND SECURITY

Final Report of the Secretary of Energy Advisory Board's Task Force on the Future of Science Programs at the Department of Energy

October 13, 2003

Secretary of Energy Advisory Board
U.S. Department of Energy

CRITICAL CHOICES: SCIENCE, ENERGY, AND SECURITY

Final Report of the
Secretary of Energy Advisory Board's
Task Force on the Future of Science Programs
at the Department of Energy

October 13, 2003

Secretary of Energy Advisory Board
U.S. Department of Energy

Secretary of Energy Advisory Board
Task Force on the Future of Science Programs
at the Department of Energy

Members

Dr. Charles M. Vest, Chairman
President
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dr. John Baldeschweiler
Johnson Professor & Professor Emeritus
Chemistry Department
California Institute of Technology
Pasadena, California

Mr. Alfred R. Berkeley III
Former President and Vice Chairman
Nasdaq Stock Market Inc.
Washington, D.C.

Dr. Robert Birgeneau
President
University of Toronto
Toronto, Ontario
Canada

Dr. James Duderstadt
University of Michigan
Ann Arbor, Michigan

Dr. M.R.C. Greenwood
Chancellor
University of California, Santa Cruz
Santa Cruz, California

Dr. Ray Irani
Chairman
Occidental Petroleum
Los Angeles, California

Dr. Steve Koonin
Provost
Professor of Theoretical Physics
California Institute of Technology
Pasadena, California

Dr. Leon Lederman
Resident Scholar
Illinois Math & Science Academy
Aurora, Illinois

Honorable William F. Martin
Chairman
Washington Policy and Analysis, Inc.

Honorable Peter McPherson
President
Michigan State University
East Lansing, Michigan

Dr. Modesto A. Maidique
President
Florida International University
Miami, Florida

Mr. Steven Papermaster
CEO, Powershift
Austin, Texas

Ms. Deborah Wince-Smith
President
Council on Competitiveness
Washington, D.C

(This Page Intentionally Left Blank)

Table of Contents

Preface

Task Force on the Future of Science Programs at the Department of Energy

The Secretary of Energy Advisory Board (SEAB) at its Thirty-First Plenary Meeting on May 8, 2002 decided to appoint the Task Force on the Future of Science Programs at the Department of Energy, a subcommittee of the SEAB. The objective of this subcommittee was to provide the Board and the Secretary of Energy with appraisals and recommendations regarding the content and structure of science programs at DOE with an eye to identifying current and future opportunities to advance DOE's mission through coordinated and focused scientific research. This subcommittee of the SEAB was chartered to address questions regarding strategies for positioning the Department's science program to meet future critical needs in terms of scientific opportunities in the 21st Century. The subcommittee was also chartered to assess the Department's performance in coordinating science efforts within DOE and focusing them on the research needed to develop or advance technologies that support its energy and national security missions.

This report by the Task Force on the Future of Science Programs at the Department of Energy is the culmination of a series of five meetings of the task force over a period of eight months. In addition the task force worked in subgroups from time to time, and commissioned a large number of confidential interviews with senior staff members across the Administration, Federal agencies, Congress, and the scientific user community.

SUMMARY

The Department of Energy has a paramount responsibility for keeping American science preeminent in the 21st century. It administers 40 percent of the federal investment in physical science and engineering research. It maintains large, complex, unique and essential scientific and computational infrastructure for the nation through its 17 laboratories and other facilities.

Our future economy, security, health and quality of life fundamentally depend on continuing advances in science and technology. Frontier research will determine whether we can produce, store and distribute secure, sustainable, clean and affordable energy, and whether we can develop and produce the new materials, devices, systems and processes that will enable our industries to win in the competitive, knowledge-based, global economy.

The Department of Energy must lead our nation effectively through its stewardship and development of critical areas of scientific research and advanced technology by:

- Appointing an Under Secretary for Science;

- Developing and sustaining an increased level of R&D funding;

- Administering its programs using modern management tools and merit-based decisions;

- Establishing critically important and inspirational new scientific programs addressing:
    - Energy production, storage, distribution, or conservation,
    - Advanced computation for basic science, and
    - Frontier, internationally-leading, research facilities for fundamental science;

- Improving its congressional, intergovernmental, and public relations and communications; and

- Inspiring, attracting, educating and training the best and brightest as scientists and engineers for careers in DOE-related fields.

(This Page Intentionally Left Blank)

INTRODUCTION

"A serious commitment to national security and energy security means a serious commitment to science."
Spencer Abraham, Secretary of Energy

The U. S. Department of Energy serves our nation through three essential missions – Energy, Security, and Science.

The Department of Energy (DOE) is responsible for:

- Developing and promoting policies, programs and technologies to assure that the Nation will have secure, sustainable, clean and affordable sources and distribution of energy;

- Contributing to our national defense and homeland security by maintaining our nuclear capability and by developing and operating unique research programs and infrastructure to support this mission;

- Developing and operating programs and infrastructure to maintain U.S. leadership in two domains: science and advanced technology that directly support the Department's energy and security missions, and areas of fundamental scientific research for which it has stewardship; and

- Protecting the environment by providing a responsible resolution to the environmental legacy of the Cold War and providing for the permanent disposal of the Nation's high-level radioactive waste.

In this report, we respectfully propose organizational, programmatic, and budgetary changes that we believe will enhance the Department's effectiveness in accomplishing its missions in energy, security and science.

REPORT OF THE TASK FORCE ON THE FUTURE OF SCIENCE PROGRAMS AT THE DEPARTMENT OF ENERGY

THE DEPARTMENT OF ENERGY: ITS ORIGINS, MISSIONS AND STRATEGIC GOALS

In order to assess the Department of Energy's science programs and assess current and future opportunities to advance the Department's missions through coordinated and focused scientific research, it is first necessary to understand the rich and diverse missions of the Department and the resources supporting these missions. The introductory paragraph of the Department of Energy's most recent Strategic Plan[1] states that:

The Department of Energy contributes to the future of the Nation by ensuring energy security, maintaining the safety and reliability of the nuclear stockpile, cleaning up the environment from the legacy of the Cold War, and developing innovations in science and technology. After 25 years in existence, the Department now operates 24 preeminent research laboratories and facilities and four power marketing administrations, and manages the environmental cleanup from 50 years of nuclear defense activities that impacted two million acres in communities across the country. The Department has an annual budget of about $23 billion and employs about 14,500 federal and 100,000 contractor employees.

As stated in the Department's Strategic Plan, *The Department of Energy is principally a national security agency and all of its missions flow from this core mission to support national security. ….. The Department has shifted its emphasis and focus as the needs of the Nation have changed. During the late 1970s, the Department emphasized energy development and regulation. In the 1980s, nuclear weapons research, development, and production took a priority. Since the end of the Cold War, the Department has focused on environmental cleanup of the nuclear weapons complex, nuclear nonproliferation and nuclear weapons stewardship, energy efficiency and conservation, and technology transfer. …. Science and technology are the Department's principal tools in the pursuit of its national security mission.*

[1] U.S. Department of Energy Strategic Plan: Protecting National, Energy, and Economic Security with Advanced Science and Technology and Ensuring Environmental Cleanup, dated September 30, 2003.

The Task Force on the Future of Science Programs at the Department of Energy conducted its assessment in the context of the Department of Energy's Strategic Plan and its four Strategic Goals:

1. *Defense Strategic Goal: To protect our national security by applying advanced science and nuclear technology to the Nation's defense*
2. *Energy Strategic Goal: To protect our national and economic security by promoting a diverse supply of reliable, affordable, and environmentally sound energy*
3. *Science Strategic Goal: To protect our national and economic security by providing world-class scientific research capacity and advancing scientific knowledge*
4. *Environmental Strategic Goal: To protect the environment by providing responsible resolution to the environmental legacy of the Cold War and by providing for the permanent disposal of the Nation's high-level radioactive waste.*

TASK FORCE FINDINGS: ENERGY, SCIENCE, SECURITY AND OUR NATION'S FUTURE

In assessing the Department of Energy's science programs the Task Force acknowledges many strengths within the Department of Energy's science programs which are noted throughout this section. In addition, the Task Force reaffirms the critical role that the Department of Energy and its science programs play in advancing and indeed underpinning the national security, economic security, and energy security of the United States. In an effort to be brief and to the point, the Task Force has chosen to focus on those areas where specific recommendations can have the greatest impact on the Department of Energy's achievement of its missions and strategic goals.

America cannot retain its freedom, way of life, or standard of living in the 21st century without secure, sustainable, clean, and affordable sources of energy.

America is facing its most serious energy shortage since the oil embargoes of the 1970s. As demonstrated clearly and unequivocally in President Bush's National Energy Policy, our projected energy consumption will rapidly outpace our projected energy production as projected at 1999-2000 growth rates. This policy statement challenges the nation to promote energy conservation, modernize our energy infrastructure, and increase our supplies in ways that protect and improve the environment.

The Task Force concurs with this challenge, but fears that our nation as a whole has not grasped the seriousness and systemic nature of the problem we face. Energy is fundamental to virtually every human activity in an advanced society – heat, light, climate control, transportation, communication, education, manufacturing, health care, and security. If demand for energy continues to outpace its production, our economy will suffer, the geopolitical situation will become even less stable, our national and economic security will be threatened and our quality of life will degenerate. Furthermore, there will be growing temptations to increase energy production in ways that do not protect the quality of our environment, that increase the gap between the affluent and the poor, or that diminish the hard-earned safety of our energy systems.

The Department of Energy has the primary federal role in providing policy, scientific and technological leadership, vision, and accomplishment to meet this challenge head on. In our view, no other federal agency has a mission of more fundamental importance to the future of our nation and planet. It is imperative that the DOE's priorities and budgets reflect a sense of urgency commensurate with the seriousness of the increased threat.

America can be free, secure and economically strong in the 21st century only if we continue to excel in science and advanced technology.

A vibrant society in the 21st century must be based on the broad development and wise use of scientific and technological knowledge. The economies of the future will literally be knowledge-based. Those nations that excel in discovering, synthesizing, and applying scientific and technical knowledge can prosper and provide security, opportunity, and health for their peoples. Many nations around the globe realize this and are investing and building their scientific and educational infrastructures with a great sense of urgency. The U.S. must not be complacent.

It is, therefore, imperative that we improve education at all levels, paying particular attention to the quality, attractiveness, and effectiveness of science, mathematics, and engineering education. Young people in virtually every walk of life will need better quantitative and computer skills, a better understanding of the physical, biological, and economic world, and an ability and opportunity to learn continuously throughout their lives.

It is especially important that we inspire and educate the next generation in advanced science and engineering. This is essential to the work of the Department of Energy, and the Department must contribute boldly and substantially to the broad national need for educating the next generation in science and engineering.

America can meet its energy needs if and only if we make a strong and sustained investment in research in physical science, engineering, and applicable areas of life science, and if we translate advancing scientific knowledge into practice.

The nation is underinvesting in research in the physical sciences and engineering. This neglect is especially detrimental to our energy future.

Our energy future and environmental stewardship cannot be assured by tinkering around the edges of the existing situation. The current mix of energy sources is not sustainable in the long run. Energy conservation and the efficiency and reliability of distribution must be improved. We need to move aggressively now to reevaluate the role of nuclear energy, to understand the complete systems that could comprise a hydrogen economy, and to explore the possibilities of nanotechnology and biological engineering for energy production and storage. All of this requires the generation and careful application of new scientific and technological knowledge.

In other words, research and development, especially aimed at radically improving our ability to efficiently produce, store, and deliver energy, are central and indeed indispensable to the Department of Energy's ability to carry out its mission.

Our Task Force believes that organizational and budgetary changes must be made to maintain and strengthen the Department's research programs and to ensure that the DOE applications branches access and use the best available scientific knowledge and expertise.

The Department of Energy is a major science agency. It is responsible for 40 percent of the federal investment in physical science, as well as 14 percent of federal basic research investments in mathematics and computing, environmental sciences, and engineering. Approximately 37 percent of the Department's budget is allocated to R&D. It has an excellent record of scientific accomplishment.

The public and many in the federal government immediately recognize that the National Science Foundation and the National Institutes of Health are science agencies, and that NASA and the Department of Defense have technology-based missions. But they frequently appear to be unaware that the Department of Energy has the largest responsibility in the federal government for maintaining and advancing the nation's capabilities in the physical sciences.

Overall, approximately 37 percent of the Department's FY03 budget of $22 billion is allocated to scientific research and development (R&D). The remaining 63 percent supports a wide variety of programs focused on the four strategic goals identified in the Department's Strategic Plan. R&D accounts for 94 percent of the Office of Science's budget, and 45 percent of the National Nuclear Security Administration (NNSA) budget.

Many of the nation's Nobel Prize winners in the physical sciences worked in, or were supported by, the Department of Energy. Scientific and technological advances abound in DOE's history: 1) fundamental work in atomic and quantum physics that has made much of contemporary technology possible, 2) launching the sequencing of the human genome, 3) nuclear energy reactors to power the US nuclear submarine fleet, 4) development of sophisticated computer codes to ensure the safety and reliability of America's nuclear stockpile without resorting to nuclear testing, 5) command and control systems and instrumentation of the Predator Unmanned Aerial Vehicle (UAV), used so successfully in recent military victories. Fundamental work is ongoing in areas such as solar energy conversion and hydrogen energy. These are only a small sample of advances made or sponsored by the Department of Energy and its laboratory system.

Science Accomplishments of the DOE

Department of Energy research investments in science have yielded a wealth of dividends, including significant technological innovations, medical and health advances, new intellectual capital, enhanced economic competitiveness, and improved quality of life for the American people.

Research supported by the Office of Science has made major contributions to development of the Internet; magnetic resonance imaging (MRI) and medical isotopes; composite materials used in military hardware and motor vehicles; and x-ray diagnostics of computer chips and other high-tech materials. The NNSA's Stockpile Stewardship Program has invested in research that has lead to breakthroughs in treatment planning for radiation therapy for cancer patients; the ability to predict the properties and behavior of materials from simulations at the atomic scale; and revolutionary new laser technologies that have driven advances in inertial confinement fusion research as well as opened the regime of relativistic plasma physics to exploration in the laboratory for the first time.

Office of Science research investments also have led to such innovations as the Nobel Prize-winning discovery of new forms of carbon, non-invasive detection of cancers and other diseases, improved computer models for understanding global climate change, and new insights on the fundamental nature of matter and energy. A total of 77 Nobel Laureates have been affiliated with the Department over its rich history of service to the Nation. A more complete listing of awards and accomplishments may be found at http://www.sc.doe.gov/sub/accomplishments/overview.htm

The Department of Energy has primary federal responsibility for crucial fields of science that investigate the fundamental properties of matter and underpin virtually all modern technology.

Most of the experimental and theoretical research to understand the fundamental nature of matter and energy in our universe has been assigned by Congress to the Department of Energy. Indeed, the Department provides 90 percent of the federal government's overall investment in high-energy and nuclear physics. The work in these areas is essential to the needs of an advanced society to understand its world.

Top Five Government Research Organizations for:

Physical Sciences	Mathematics & Computing	Life Sciences	Environmental Sciences
1 Energy (1,938)	1 Energy (862)	1 HHS (18,216)	1 NASA (1113)
2 NASA (1,158)	2 DOD (861)	2 USDA (1,342)	2 NSF (515)
3 HHS (798)	3 NSF (515)	3 DOD (616)	3 DOI (353)
4 NSF (593)	4 HHS (181)	4 NSF (500)	4 DOD (301)
5 DOD (364)	5 DOC (78)	5 Energy (267)	5 Energy (298)

Ranking Based on FY 2002 appropriated funds (in millions). Source: NSF Preliminary Federal obligations for research by agency, field of science and engineering: fiscal year 2002

Work in the nuclear and subnuclear domains continues to provide profound insights into the structure and workings of nature. It drives advances in myriad areas of engineering and advanced technology that are likely to find numerous applications to society's needs, including those associated with energy. The strength of our industries and the economic future of our Nation will likely depend on advances in fundamental science, just as it has during the last fifty years.

Other areas for which the DOE has major stewardship include catalysis, magnetic and inertial confinement fusion, heavy element chemistry, and life sciences for selected applications. Each is critical to the future of energy production and storage. DOE also has a very large role in guiding and supporting research in nuclear medicine and in aspects of climate change research.

The Department of Energy has both a mission and an exceptional capability to launch and manage complex scientific research projects and infrastructure on a very large scale.

Because of its long history in the nuclear weapons program and in nuclear and particle physics, the Department has gained nearly unique experience and expertise in the design, construction, and operation of very large and complex projects.

Many other fields of science rely on the Department of Energy's stewardship of large-scale physical science infrastructure, including intense photon, neutron, electron, and ion beam sources, supercomputers, airborne instrumentation, and large environmental installations. The fields served by these capabilities include those most likely to contribute to our future energy, environmental, and national security needs.

The Department of Energy's primary responsibilities for the nation's nuclear deterrent and its support for global nonproliferation and homeland security also demand world class leadership in physical and engineering science as well as access to the most advanced and large-scale computational and experimental tools and infrastructure.

This capacity to deal well with both the scale and complexity of these efforts is especially important in today's rapidly changing world. As we continue to gain the ability to work at very small scales and to probe the dynamic, three-dimensional structure of molecules, the interface between physical science and life science is of critical importance. Work at the interface of frontier disciplines like bioinformatics, genomics, proteomics, and nanotechnology is greatly enhanced by DOE's capacity in large-scale computation and research tools based upon physical science.

The Department of Energy is responsible for a number of national laboratories – critical national resources and unique research facilities of a scale, expense, and focus that are not appropriate for either the industrial sector or universities.

The Department is responsible for nine major multi-program laboratories and eight single-program laboratories and numerous facilities throughout the Nation.

DOE Multi-Program and Single Program Laboratories

Major Multi-program Laboratories	Single Program Laboratories
Argonne National Laboratory*	Ames Laboratory*
Brookhaven National Laboratory*	Fermi National Accelerator Laboratory*
Idaho National Engineering and Environmental Laboratory	National Energy Technology Laboratory
	National Renewable Energy Laboratory
Lawrence Berkeley National Laboratory*	Princeton Plasma Physics Laboratory*
Lawrence Livermore National Laboratory	Savannah River Technology Center
Los Alamos National Laboratory	Stanford Linear Accelerator Center*
Oak Ridge National Laboratory*	Thomas Jefferson National Accelerator Facility*
Pacific Northwest National Laboratory*	
Sandia National Laboratories	

* Laboratories Managed by the Office of Science

Three of the nine multi-program laboratories, specifically Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories, are primarily national security laboratories responsible for the Defense Strategic Goal of protecting our national security by applying advanced science and nuclear technology to our Nation's defense. They are managed through the National Nuclear Security Administration (NNSA), which comprises approximately one-third of DOE on a budget basis. The remaining six multi-program laboratories contribute to multiple DOE missions. Five of these six multi-program laboratories are managed through the Office of Science. It should be noted that while DOE is responsible for the overall structure and direction of its National Laboratories, their operations are generally managed by universities and/or industrial organizations.

Five of the eight single-program laboratories are managed through the Office of Science and are devoted to the conduct of fundamental science and serve users from universities, industry and research institutes throughout the nation and around the world. They provide the nation’s primary infrastructure for particle accelerators, light sources, and neutron beams. These unique facilities are important in basic physics, in materials science, and in their next generation will become centrally important to life science. The National Energy Technology Laboratory is managed through the Office of Fossil Energy and is focused on coal, oil and natural gas research. The National Renewable Energy

Laboratory is managed through the Office of Energy Efficiency and Renewable Energy and is focused on renewable energy technologies. The Savannah River Technology Center, the former Savannah River Laboratory, is managed through the Office of Environmental Management and serves both the national security and environmental strategic goals.

DOE, primarily in support of its weapons laboratories, has commissioned and operates the largest and fastest computers in the United States. Through programs such as the Advanced Scientific Computing Initiative in NNSA's Stockpile Stewardship Program, as well as through the Office of Science's National Energy Research Scientific Computing Center and the Energy Sciences Network, DOE has established leadership in advanced computer simulation and modeling of physical phenomena, a field that is likely to gain broad scientific and engineering importance in the next several years. Indeed, we believe that advanced scientific computing is emerging as an indispensable capability for the conduct of science.

The federal government alone cannot provide America's energy or meet its energy-related R&D needs. The Department of Energy does have the mandate, the relationships, the scale and the persistence to partner with universities, industry, and other federal agencies.

Each sector – government, industry, and academia – has a role to play in ensuring America's energy future. Industry is the actual provider of energy through a competitive, market-based system. It has neither the resources nor an incentive to do much of the high cost, high risk research with moderate to long time horizons that is necessary to meet our long-term energy needs. The federal government, through the Department of Energy, develops important national policy and conducts or supports the high risk long time horizon research and development that is necessary if we are to have secure sources of clean, affordable energy in the future. Universities are our primary source of the basic research, innovation, and the human capital needed to secure our energy future.

It is necessary to maximize the quality of work produced by all three sectors, and to take advantage of synergies through partnerships when it is necessary or attractive to meeting our energy goals.

The Department of Energy's primary responsibility for the nation's nuclear deterrent and its support of national nonproliferation and homeland security goals demand world leadership in the physical and engineering sciences. To achieve this the Department must have access to the most advanced computational and

experimental tools, a world class research and development infrastructure, and the specialized talent needed to meet these goals.

Since the Manhattan Project, the Department of Energy and its predecessor organizations have been charged with developing and maintaining our nation's nuclear weapons design capability, production complex, and stockpile readiness. DOE annually certifies to the President the viability of the nuclear stockpile. The end of the Cold War brought new treaty obligations to reduce and dismantle nuclear weapon systems. This has reduced some of the nuclear danger, but has not stopped global proliferation. With the 1992 decision to cease underground nuclear testing of weapons, the stewardship responsibilities of the Department of Energy were radically transformed.

At no time in its history has DOE's national security mission been more dependent upon advances in science and technology, rapid development of new computational tools, modernization of obsolete infrastructure, and establishment of the next generation of experimental facilities. In addition, DOE is faced with an aging population of weapons scientists and technicians. DOE also has a new set of security challenges brought on by the global war on terrorism and the imperative for homeland defense.

The Department's science-based Nuclear Stockpile Stewardship Program has pushed the frontiers of the physical and engineering sciences, and helped keep the United States at the forefront of high-performance computing, modeling and simulation, and visualization. The emerging fields of MEMS (Micro-Electro-Mechanical Systems), nanotechnology, and bioinformatics also have been impacted by this program. These capabilities support the new Department of Homeland Security and its long-term missions to protect the homeland, assure critical national infrastructures, and help defeat global terrorism.

TASK FORCE FINDINGS: SYSTEMIC WEAKNESSES AND CHALLENGES

The importance of DOE science and facilities to our national, economic and energy security are not well understood by the American public, Congress, or the Executive Branch.

Science and technology planners, authorizers, appropriators, and agencies within the government all need to work closely together to ensure that the Nation's research investment encompasses all the fields of research and facilities needed to deliver the technologies upon which the freedom and standard of living of our children and grandchildren will depend. Yet there has been a lack of the close integration and clear communications needed to build understanding and support for Department of Energy and its research and development programs.

The mission of the Department of Energy is widely misunderstood and considered to be unclear and unstable. Outside the research community itself, science is rarely recognized as an essential component of the DOE mission.

Like each of the proverbial blind beggars feeling an individual part of an elephant, the public and many federal officials hear about nuclear security, energy security, alternative energy sources, the human genome, environmental cleanup, national laboratories, big computers, and nuclear waste disposal. They are left with no sense of an urgent, much less coherent mission, or a sense of integration or synergy. When DOE science is recognized, it is often viewed as strong, but it is nonetheless viewed as somehow separate from any basic Departmental mission.

In order to assess the effectiveness of the Department of Energy's science program, and to identify issues impacting its future, the task force commissioned a large number of confidential interviews with senior staff members across the Administration, Federal agencies, Congress, and the scientific user community. The Task Force found the depth of criticism and concern shocking, consistent, and extremely important to address. Most problems identified have to do with process, communication, and interaction. They can and must be corrected.

The conduct of DOE's public relations and congressional and intergovernmental affairs was widely considered to be lacking. Unfavorable comparisons with the public relations and congressional affairs activities of other agencies were frequently made. Among those interviewed, there is a desire to be supportive of the basic DOE mission and of DOE science, but, as one observer said, this support "must be earned." The Department needs to redouble its efforts to improve the clarity, quality and responsiveness of its communications.

The DOE national laboratories, both multi-user facilities and nuclear weapons facilities, are frequently viewed as powerful independent actors whose association with the DOE is sometimes not recognized. Unfortunately, there is no strong perception that these DOE facilities collectively comprise a remarkable national infrastructure for science.

The federal investment in physical science and engineering has been stagnant for over thirty years. During this same period, the Department's national laboratories have suffered from decay and deferred maintenance, and U.S. industry has largely phased out its basic research programs and organizations. As a result, the U.S. is no longer the clear leader in some important areas of science.

During the last 30 years, the federal investment in research in the physical sciences and engineering has been nearly stagnant, having grown less than 25 percent in constant dollars. The corresponding investment in life science research has grown over 300 percent. Specifically, in 1970 physical science, engineering, and life science each were funded at an annual level of approximately $5 billion in 2002 dollars. Today, physical science and engineering research are funded at approximately $5 billion and $7.5 billion, respectively. The current funding for life science is about $22 billion.

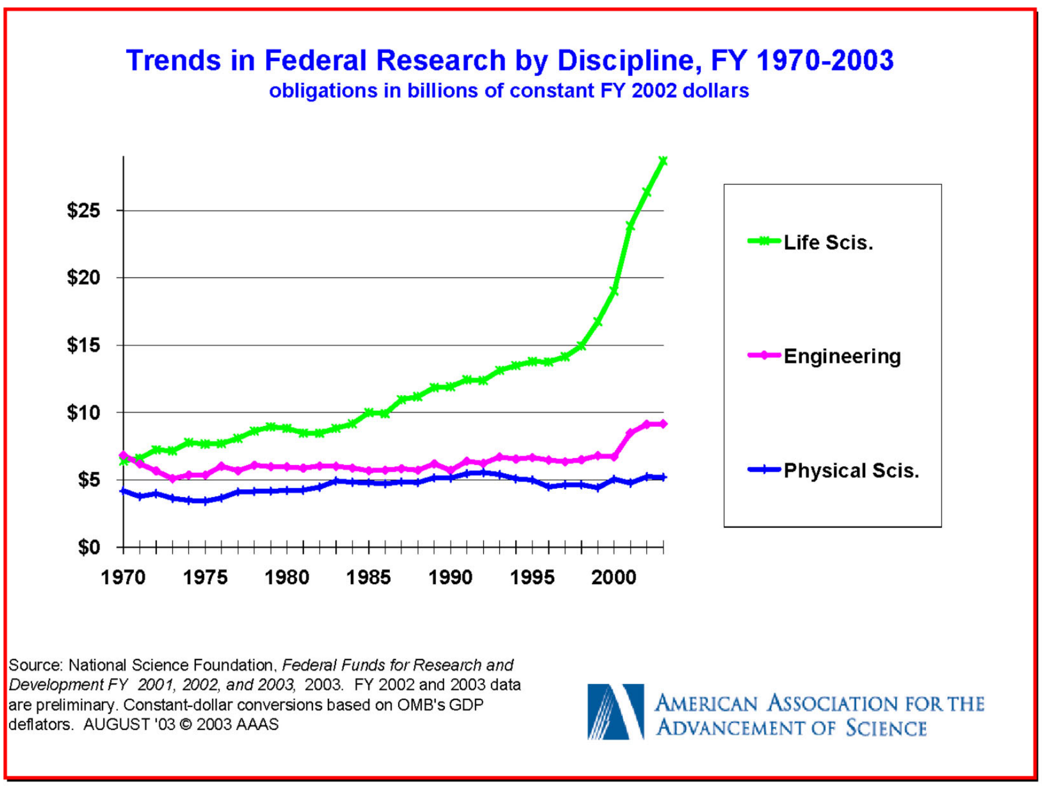

Figure1: Trends in Federal Research by Discipline 1970 - 2003. This figure has been used with the permission of the AAAS.

Stagnant federal funding of physical science and engineering research is far more damaging than it might appear because of the following externalities:

- These are the fields needed to power the search for both near-term and long-term sources of secure, sustainable, clean, and affordable energy as well as means for their storage and distribution
- American industry has pulled back almost entirely from research with moderate to long time horizons, leaving the federal government as essentially the sole source of support, and universities as nearly the sole performer of such research
- The number of public and private universities capable of doing excellent research and advanced education in science and engineering has grown substantially
- The complexity and sophistication of most research endeavors have caused their real cost to grow more rapidly than traditional measures of inflation
- Finally, the development and application of physically based technologies and methods is needed to advance the life sciences and medicine.

The underfunding of physical science and engineering research has put U.S. leadership at risk in certain important areas. Examples of critically important fields of science in which we are no longer clearly preeminent are high-energy physics and neutron sources for materials science and biology.

When the United States decided to stop construction of the Superconducting Supercollider (SSC) and the European Union moved ahead with construction of the Large Hadron Collider (LHC), U.S. preeminence was diminished in the international effort to explore the boundaries of high-energy physics. If our young scientists want to work at the leading edge of this field, many must now do so in Europe. Many of our universities have, in fact, lost outstanding young faculty members who have emigrated to where the action is. If not addressed through actions like establishing the Next Linear Collider in the United States, our capability to design and develop the most advanced tools in this field will also diminish over time.

For many years, reaching back to the 1950s, U.S. leadership in neutron diagnostics not only advanced our fundamental science but also gave us a great advantage in developing new industries and products dependent upon a deep understanding of materials. The most obvious example is today's semiconductor industry. Today the most advanced tools are in Europe. This will be corrected to some extent when the Spallation Neutron Source successfully comes on line. But this loss of leadership remains a deep concern because it is important to cutting edge biology and biochemistry, and to the next frontiers of condensed matter physics and materials science and engineering. These are areas of great importance to both industrial and academic user communities.

The budgets of DOE science suffer from the Department's historically poor reputation as badly managed, excessively fragmented, and politically unresponsive. DOE science budgets have not received the priority merited by their importance to our Nation's future energy, security, and economy.

Whether or not this reputation is deserved, this perception exists and needs to be addressed. The Department of Energy is a very large and complex organization, but we believe that the coherence of its programs and communications can and must be improved. Furthermore, we believe that science should be an important integrator of the Department around its central mission.

Knowledgeable observers understand that throughout its existence the Department of Energy has hosted and conducted extraordinarily good science and technological research. Nobel Prizes have been won, and generations of outstanding scientists have completed graduate degrees and developed their careers with the support of DOE funding and facilities. Entire fields of science, especially those based on nuclear physics and on the use of radiation sources or accelerators, have been established and driven by the Department. Personnel of the Office of Science generally get good marks from the scientific community. The DOE has served the nation's defense through the design, production, and stewardship of our nuclear weapons.

Nonetheless, there is extensive fragmentation of effort and lack of integration and communication across elements of the Department that are unacceptable as we enter the 21st century facing a historically unparalleled need to develop new means for the production, storage, and distribution of clean energy, to enable better energy conservation, and to deal with many important aspects of both homeland security and international security. These are problems whose solutions require the ability to work across disciplinary boundaries, especially given the promise of emerging applications of life science to engineering and the advent of radical new tools of nanoscale science and technology. A forward-looking DOE science program must be better integrated across fields, facilities and organizations. In general, the best available science and advanced technologies are not readily making their way into the DOE's application areas.

To the extent that such perceptions are justified, weak linkages and interactions with other federal agencies such as the Department of Defense should be recognized and addressed. It is widely perceived that this insularity stems from neglect of explicit interagency bridge building. Cross-agency scientific cooperation by and with DOE, while generally effective, is widely viewed as crisis-driven rather than proactive.

The current organization of the Department is not appropriate to the magnitude and centrality of scientific and advanced technological research in the DOE. It does not ensure that the Department's mission offices responsible for energy, environmental and national security programs benefit from the best available scientific and advanced technological knowledge.

The Department of Energy is a major science agency, but this fact is not obviously reflected in its organizational structure. The Department currently has two Under Secretaries – one for the Nuclear Security mission programs and one for Energy, Science, and the Environment programs. The Office of Science reports to the latter Under Secretary, despite the central role of science, and despite the need for science to extend across energy, environment and the work of the National Nuclear Security Administration (NNSA). Good people and good will usually have made this workable, but the Task Force considers it a serious flaw that must be repaired.

In fact, nearly half of the NNSA's budget is allocated to R&D, and the Office of Science's laboratories receive about 13 percent of their operating budget from the NNSA. It is also instructive to note that while environmental quality, i.e. programs dealing with nuclear waste and cleanup matters, account for 36 percent of the Department's budget only 4 percent of DOE's R&D portfolio is assigned to that critically important matter. This despite the fact that it is imperative that these operations be well informed by the most up-to-date science available.

We also note that advanced computing and computational infrastructure are essential to DOE's mission. The National Laboratories contain the nation's most advanced large-scale computers and a wealth of computational expertise. But in part due to their primary use for national security applications, many of these machines are not widely accessible to the user community (whether inside or beyond the Department). The time has come for DOE to be organized and funded to provide major elements of the Nation's cyberinfrastructure for science.

The Department's national laboratories increasingly suffer from decay and deferred maintenance, unpredictable program funding, poorly understood missions, perception of them as independent actors, and the burden of some highly publicized security lapses. The strong political independence of some of the laboratories, coupled with multiple directives from DOE and Congress, is a mixed blessing.

The DOE laboratories, both those directed at national nuclear security and the multi-user scientific facilities, are proud and essential elements of our nation's and world's scientific infrastructure. But they have operated for many years on essentially flat budgets, even as new scientific and technological opportunities and responsibilities have soared. An inevitable consequence of this situation is an unacceptable level of deferred maintenance and decay that is reaching the crisis stage. The situation is more daunting still when the cleanup of former nuclear facilities at some of the labs is considered.

The deferred maintenance and attendant issues of safety and laboratory working environment have reached the stage where laboratory directors are cutting already inadequate operating budgets to solve the worst of the problems. The Task Force reviewed various schemes for attracting third party financing of maintenance and construction that, while valiant, strike us as unreasonably complex and inefficient in the long run. It would be better to meet the Department's responsibilities head on.

The lines of accountability for many of the Laboratories are unclear due to the organizational structure of DOE, especially the position of the Office of Science, and oversight by multiple Congressional committees. These factors lead to creep, ambiguity, and fluctuation of mission and leave the Laboratory directors sensing that they have "many masters with conflicting views."

Currently about 15 percent of DOE research is performed by universities (exclusive of support at user facilities), while the rest is done at the DOE laboratories. Expanding the use of objective merit review across the DOE, including in the NNSA national security laboratories, should be considered to ensure that the proportion of research performed by university researchers is appropriate and justified. This is particularly true for a number of emerging, frontier areas, like nanoscale science and technology and life science, where university researchers are not only at the forefront of discovery, but where the economies of scale achieved at national laboratories are not necessary for research performance and success.

The Task Force believes that rigorous merit review of proposed programs and performers, coupled with legitimate institutional concerns, is an important element for generating great science. Many programs in the DOE weapons laboratories are not subjected to such review - either internally or in competition with other potential performers. The merit review processes in the Office of Science are generally viewed as strong. Systematic use of objective merit review should be adopted for the research investments made by other mission programs across the DOE. This would strengthen the quality of the research portfolios and better ensure strong outcomes for the mission needs.

From political and public perspectives, the larger DOE laboratories are viewed as having considerable independence. Frequently, the image and voice of the individual laboratories far outweighs that of the Department of Energy. Although this has some positive aspects, over the years it has led to various Congressional mandates and has not enhanced the sense of the Department's integration and clarity of mission.

Finally, we note that the politically explosive issues of real and perceived security lapses is being addressed by the Department of Energy through other avenues but nonetheless has had a real and tangible adverse impact on the Department's reputation which must be rectified.

TASK FORCE RECOMMENDATIONS

To recognize the centrality of science to its mission, the Department of Energy should have an Under Secretary for Science. Attendant organizational changes should be made to better accomplish that scientific mission.

The organizing and organizational role of science in the DOE should be elevated and expanded in order to clarify that DOE is science agency, better conduct cutting edge research, better conform to the Department's mission, improve DOE application areas' access to and use of the best available scientific knowledge, and better integrate scientific work and knowledge across the Department and across federal agencies. A major step in accomplishing this goal is to establish the position of Under Secretary for Science.

The Under Secretary for Science would have both Department-wide and line responsibilities. He or she should serve as the chief science officer for the Department as a whole, overseeing the science officers within Department's missions. As chief science officer, the new Under Secretary will require a cross-cutting department-wide forum to coordinate and integrate science across the entire Department. The Department of Energy should consider emulating cross-cutting management structures used by other federal agencies to assist their chief scientists or chief engineers to coordinate and integrate department-wide. The Under Secretary for Science would also have line responsibility for the Office of Science, which might report to him or her through an Assistant Secretary.

We recognize that this change cannot stand alone, but would require other organizational and cultural adjustments. Our discussions suggest that the Department might profitably adopt a structure with three Under Secretaries – one for Energy and Environment, one for Science, and one for National Security.

The Under Secretary for Science should articulate a clear and compelling mission to steward basic research at DOE and to assure that the DOE application areas devoted to our energy future and national security are well informed by the best available knowledge in science and advanced technology.

The new Under Secretary should craft a clear and compelling mission statement. This statement should then be used to define and establish a consistent basis for priority setting, communication and integration across the Department, establishing appropriate planning parameters and performance metrics, communicating more effectively at the Cabinet, Congressional and public levels, and in promulgating an understanding of the centrality of DOE science to the Department and to the nation's future.

The Under Secretary for Science would be responsible for coordinating matters of research and application of science and advanced technology across the Department of Energy. A particularly important responsibility would be to improve the flow of the best available scientific knowledge into those parts of the DOE responsible for applications and policy and to facilitate its effective use.

The Under Secretary for Science should have a high-level Science Advisory Board, drawn from academia and industry, to help ensure that the Under Secretary's mission is accomplished.

Appointing a high-level Science Advisory Board would enhance the effectiveness and provide the proposed Under Secretary for Science with an independent advisory body to provide advice in response to taskings by the Under Secretary on cross-cutting science issues. This board should be established to have a stature equivalent to that of the National Science Board or the Defense Science Board. It should include an appropriate mix of leaders with expertise and perspective from business, academia, and the science and engineering communities. Some members should have had major governmental responsibilities in the past.

Science at the Department of Energy must have a clear and effective public and political voice, and effective interactions with Congress, other federal agencies, and the Executive Office of the President.

It is essential that the Under Secretary for Science, and the Department as a whole, refine and enhance their Congressional relations, public communications, and linkages with the Executive Office of the President and with other federal agencies. The Secretary of Energy and the Under Secretary for Science should promote a more unified view of science in the DOE as a whole, and attenuate the cacophony of messages about individual laboratories and offices.

There should be no ambiguity about the threat to our economy, security, health, and way of life associated with the growing imbalance between energy demand and production. The DOE must promulgate a vision and a sustainable path to reliable, efficient, clean, and affordable sources and distribution of energy for the nation. It must also be made clear that without sufficient federal investment in science and advanced technological research, we will not achieve this goal. It should also be clear that the DOE has a strong and important mission to sustain U.S. leadership in areas of science for which it has stewardship independent of direct application to energy and security.

Each Department of Energy research and development initiative should have a regular review to assess whether it is consistent with the Department's 20-year strategy to produce secure, sustainable, clean, and affordable sources of energy, to enhance our national security, and/or to maintain U.S. scientific leadership in areas stewarded by the DOE.

The Secretary of Energy should direct the Under Secretary for Science and the other Under Secretaries to develop a 20-year strategy for their respective mission/strategic goal areas, including scientific leadership. Each Under Secretary should be directed to conduct a regular R&D Portfolio Analysis review of R&D projects and underlying basic science initiatives to assure their continued relevance and contributions to the larger 20-year strategies. This initiative should be adequately funded and staffed. Differences in spending in basic science and in specific areas should be reported to the Secretary for consideration in the budgets. The 20-year facilities study should be part of this process.

Program and technology roadmapping should be included in the portfolio analysis as a planning and decision tool to develop and execute a balanced R&D portfolio in future years. The roadmaps should derive from the needs of DOE programs and from the need to sustain national leadership in appropriate areas of science. They would help define what is known and what future R&D and technology programs are needed to accomplish specific program objectives. They would clarify technological needs and better communicate expectations between users of scientific knowledge and new technology and the research community. The roadmaps thus become central planning and decision tools in the development of the R&D portfolios.

The Task Force believes that rigorous merit review of proposed programs and performers is an important element for generating great science. More DOE programs in the Laboratories should be subjected to such review in competition with other potential performers.

We believe that the 20-year vision of future scientific facilities currently being developed in the Office of Science is outstanding and could have a far-reaching, positive effect on the nation's leadership in science. It should be an integral component of the Department's strategic plan.

The Department should enhance the quality of research through greater use of merit-based competition, seek the best balance of national laboratory, university, and industrial research, and form partnerships with industry and academia to drive innovation in its mission areas.

This Task Force believes that competition and merit review are indispensable if we are to produce the highest quality science to further our national energy needs and scientific leadership. We believe that a critical assessment of the balance between Laboratory and university research must be a key component of strategic planning for DOE and its national laboratories. Indeed, we believe that the Department and its Laboratories must be challenged to increase the use of competitive, peer-reviewed programs in order to enhance creative research and innovation.

We note that a strong base of university research is essential to our future. This is our nation's primary mechanism for conducting fundamental scientific and advanced engineering research. It inspires, enables, and financially supports the next generation of scientists, engineers, and leaders of related business and industry. This is of critical importance as the intellectual underpinnings of technology are changing rapidly, especially if the government intends to strengthen the federal investment in physical science and engineering.

Despite the differences in basic roles and responsibilities of the three sectors – industry, government, and academia – we will improve our ability to meet our long-term energy goals by forming effective partnerships across these sectors. The synergies that come from mutual understanding of policy, business, and science improve our ability to innovate and to create the strategies and systems to produce reliable, sustainable, and affordable energy sources in the future.

Such partnerships have been common in the conduct of DOE basic science in the multi-program laboratories and many program-dedicated laboratories. Partnerships will be even more important as the DOE increasingly provides national facilities for advanced scientific computation and modeling, and provides infrastructure for work cutting across the boundaries of physical and life science.

The Department should establish and sustain a program for renewing its laboratories, facilities and infrastructure. It should transfer the funds necessary to achieve this objective from other, non-science accounts.

The amount expended annually on maintenance and renewal of DOE laboratory facilities is approximately 0.7 percent of replacement value. By industry standards, this should be on the order of 2-4 percent. The deferred maintenance and the "ticking time bomb" of cleanup of former nuclear facilities at some of the laboratories must be addressed. The Task Force believes that the cost of doing so should not come from the existing operating budgets that have been essentially flat for some years. Either it should be transferred from other DOE accounts or an increment to funding should be requested from Congress.

The Department should embark on three major, highly visible research initiatives in order to promote and meet its mission of leadership in energy, security, and science. One should directly address a basic issue in energy production, storage, distribution, or conservation; one should establish world leadership in the application of advanced computation and simulation to basic scientific problems; and one should provide a frontier research facility for the pursuit of basic science.

U.S. leadership in the world community in areas of science that are relevant to the mission of the Department of Energy is important to our future and important to attracting the best and brightest into their pursuit. We recommend that DOE undertake three highly visible, critically important and inspirational new scientific programs.

The first should directly address a grand challenge associated with the production, storage, distribution, or conservation of energy. This will functionally and visibly tie cutting edge science to the crisis facing the nation because of the growing gap between the demand for and production of energy. It should address aspects of this issue in a way that provides for explicit good stewardship of our environment.

The second should clearly sustain and leverage U.S. leadership in advanced scientific computation and simulation. Computational modeling and simulation are rapidly becoming indispensable to basic scientific research and advanced technological development. The application of extremely large-scale computation to problems like the climate, the dynamics of biological molecules, combustion processes, and the behavior of complex systems and materials is essential for technological progress. The DOE has much of the nation's expertise and machinery in this area, but it has mostly been developed for the nuclear weapons program and is segregated from use by much of the scientific community. DOE should lead in this area with wide-spread collaboration and access to the scientific and advanced engineering communities in academia and industrial R&D.

The third should put America in the lead of a next-generation international program in basic physical science that is relevant to the Department's mission. Scientific, technological, and industrial opportunities arise from the international community that conducts frontier basic science, but there is a clear advantage to the country that hosts the core facilities.

These important initiatives should be a highest priority for the Secretary of Energy and the proposed Under Secretary for Science. They should be shaped with the advice and approval of the proposed Science Advisory Board. Analysis and planning should begin immediately, but to the extent possible, their establishment should be informed by the strategic plans and portfolio analysis recommended in this report.

The Department should strengthen the federal investment in the physical sciences and advanced engineering research.

The federal investment across all major agencies that invest in physical science and engineering research in support of their missions – DOE, DOD, NASA, and NSF – has been stagnant for over thirty years. During this same period, the federal investment in life science research, especially through the National Institutes of Health (NIH), has strengthened considerably.

Just as NIH is the lead agency for most areas of biomedical research, and NASA is the lead agency for most space science, the Department of Energy is the lead agency for many areas of physical science and engineering. It therefore should assume a leadership role in elevating understanding of their importance and in establishing stronger federal investment in research and research infrastructure in these fields. The growing crises in energy and environmental quality, and the need to proactively advance U.S. leadership in basic science, must be clearly and effectively addressed by the Department of Energy.

The Department of Energy should actively and effectively build support within the Administration and Congress for higher priorities for science and increased budget authorization and appropriations for physical science and advanced engineering research. The DOE's own internal budgets should also reflect a strengthened investment in these areas.

The Department should be more proactive in leading interagency initiatives that require expertise in energy, environment, physical science and advanced scientific computation, as well as conducting and sponsoring strong research within its own mission. The organizational changes we recommend will facilitate such a leadership role.

The Department should dramatically enhance its role in educating and training future scientists and engineers, drawn from America's diverse population, for careers in DOE-related fields. The Department should establish strong programs of undergraduate, graduate, and postdoctoral fellowships or traineeships in the physical sciences and engineering and should strengthen its outreach at the K-12 level.

The DOE must continue and enhance its crucial role in advanced education of scientists and engineers through sponsorship of research grants and contracts in our nation's universities. These grants and contracts support graduate students and postdoctoral researchers as research assistants. The DOE also plays a unique role in the advanced education of science and engineering students who conduct research in DOE Laboratories and user facilities, thereby utilizing equipment and facilities with capabilities of a scale and scope rarely found in universities. This enables them to train while being part of large-scale, cutting-edge scientific exploration.

We recommend that the Department also explicitly and boldly address the declining numbers of young Americans pursuing careers in advanced science and technology relevant to the DOE's mission by establishing strong programs of undergraduate, graduate and postdoctoral fellowships. These should carry tuition and stipend levels that allow students to select the best schools for their interests. If one looks back to the grand fellowship programs of the 1960s, and traces from them much of our scientific leadership during the 1980s and 1990s, a compelling case is made to once again inspire, motivate and enable our young men and women to extend our national leadership in the future.

We further recommend that training grants be established in areas required to advance DOE's mission in the future, but for which the U.S. is not producing scientists and engineers. Some of these should be in traditional areas essentially unique to DOE such as nuclear engineering and nuclear science. Others will be especially useful in emerging areas like nanotechnology and biological engineering that must grow at the intersections of traditional disciplines.

Education is not explicitly in the charter of the Department of Energy. Nonetheless, we believe that just as NASA inspires school children with the excitement and beauty of space sciences, just as NIH similarly reaches out to schools to explain the frontiers and the benefits of the life sciences, so should DOE use its vast frontier technological facilities and the collaboration of scientists from all over the world to inspire students and teachers with the rich frontiers of the molecular, atomic, nuclear and sub-nuclear worlds. The Department's Laboratories and university programs offer unique resources for mounting aggressive programs to support the nation's students and teachers in science, mathematics and engineering. Such programs should be well informed by current cognitive research and by studies such as "A Nation at Risk" (1983), the National Research Council's National Education Standards published in 1996, and several recent reviews of "best practice."

Page Intentionally Left Blank