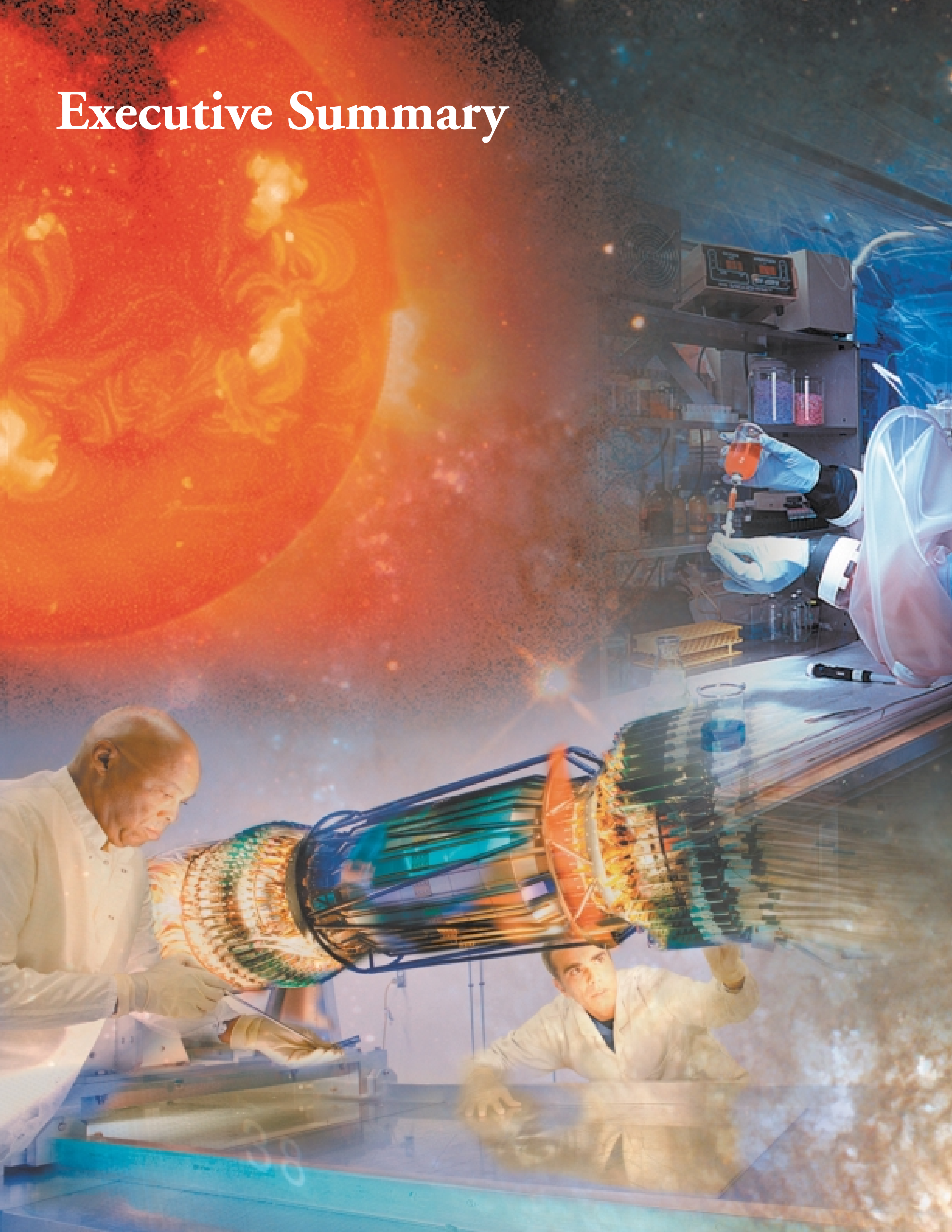
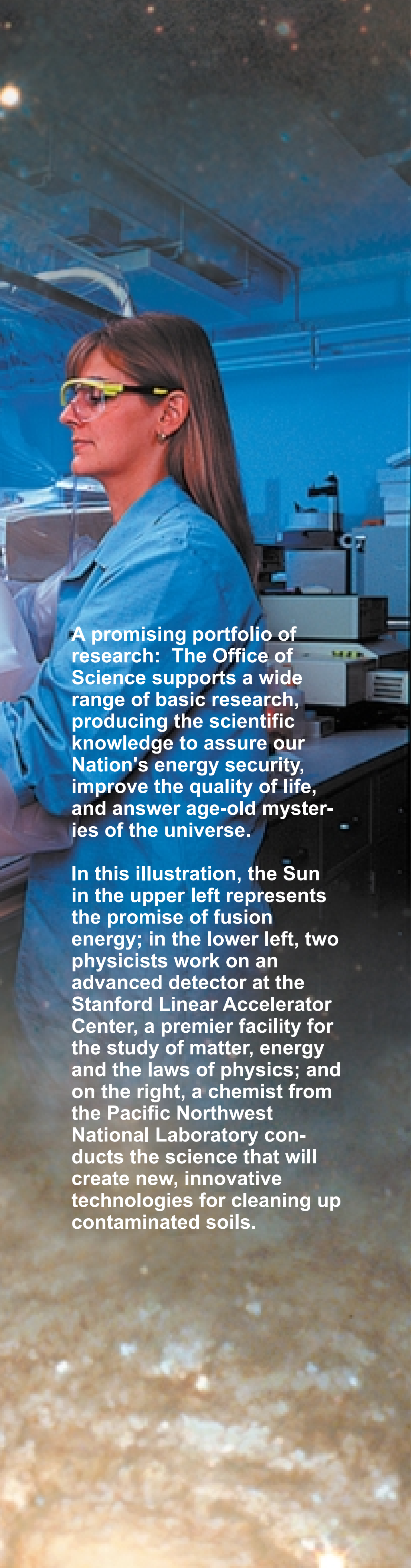
Executive Summary





A promising portfolio of research: The Office of Science supports a wide range of basic research, producing the scientific knowledge to assure our Nation's energy security, improve the quality of life, and answer age-old mysteries of the universe.

In this illustration, the Sun in the upper left represents the promise of fusion energy; in the lower left, two physicists work on an advanced detector at the Stanford Linear Accelerator Center, a premier facility for the study of matter, energy and the laws of physics; and on the right, a chemist from the Pacific Northwest National Laboratory conducts the science that will create new, innovative technologies for cleaning up contaminated soils.

Introduction…

This Strategic Plan outlines a 20-year journey filled with enormous potential for the American people. Contained within this Plan is the Office of Science's commitment to invest in some of the most exciting and daring research that humankind has ever conceived, from explorations into the origins of our universe and the constituents of life, to the scientific knowledge that will deliver new, clean, and abundant sources of energy to meet world needs for 10 billion people by the year 2050.

Over the next two decades, we will implement the goals and strategies contained in this Plan, working closely with the U.S. scientific community, Congress, the White House, and other key stakeholders. This implementation will be grounded in sound management principles and with an eye toward the highest possible return on taxpayer investments. We recognize, however, that rapid changes in science and technology, shifts in national priorities, and resources made available through the Federal budget process all create planning uncertainties and, ultimately, a highly dynamic planning environment. Accordingly, this Strategic Plan should be viewed as a living document. Frequent adjustments will be needed.

This Plan builds upon the goals and strategies found in the Department of Energy's (DOE) Strategic Plan, and it is organized around seven goals, six of which correspond to the Office of Science's primary budget categories and major science programs (see chart on page 9). The seventh goal addresses corporate management and resource issues that crosscut all of our programs, including a consolidated future outlook for our major research facilities. It also reflects our commitment to the President's Management Agenda and overall excellence in the management of science.

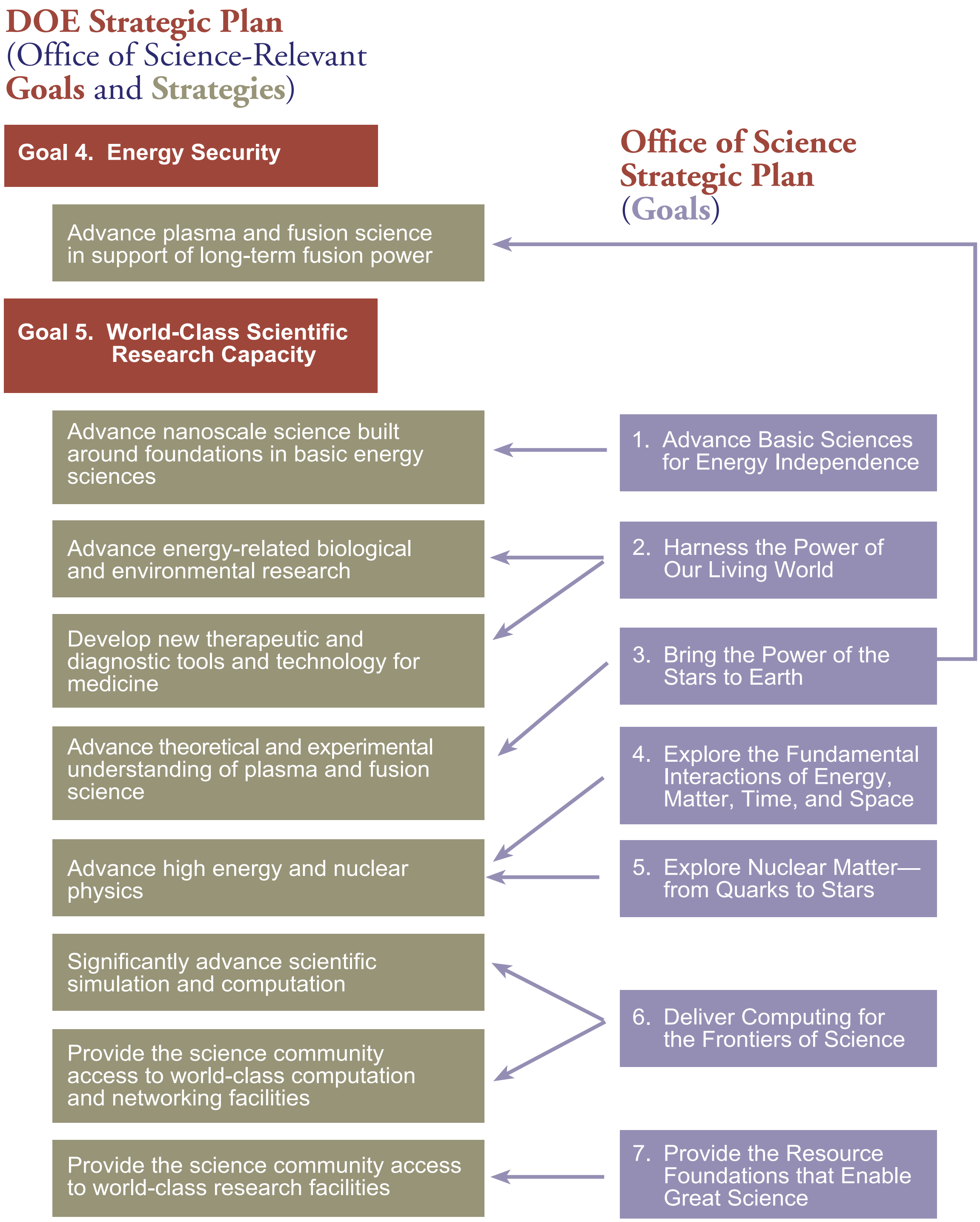
This Plan also builds on long-term measures included in the Office of Management and Budget's Program Assessment Rating Tool (PART). Extending beyond the PART measures, however, are strategic milestones contained within 20-year timelines at the end of each chapter.

The result is a Plan that provides seamless links to the main Office of Science and DOE planning, budget, and performance assessment processes and documents. Continuing in this tradition, our next step toward implementing this 20-year vision will be to develop multi-year operational plans that will bridge the gap between this Strategic Plan and our annual budget.

In developing this Plan, we pursued a highly participatory process, building on the expert advice of our Advisory Committees, vetting key decisions with the leaders of our national laboratories and principals in the university community, and exploring ideas with a large number of other interested parties (see Appendix A). We considered the range of today's most compelling national challenges and priorities—with energy and security at the top of the list—and explored the possible challenges and opportunities of tomorrow. We reviewed key testimony, policy documents, forecasts, and foresight studies. We also integrated the results of a major planning effort that identified the highest priority next-generation scientific user facilities. That report, *Facilities for the Future of Science: A Twenty-Year Outlook*, and this Plan serve as companion documents.

The Executive Summary of this Plan presents a snapshot of the main elements and provides the context, vision, and essential goals and priorities contained within the document. The individual chapters provide the detailed discussion, including strategies and the performance timelines mentioned above, that will serve as a blueprint for the Office of Science for the next two decades.

Seamless Connections: Alignment of the DOE and Office of Science Strategic Plans



Our Mission…

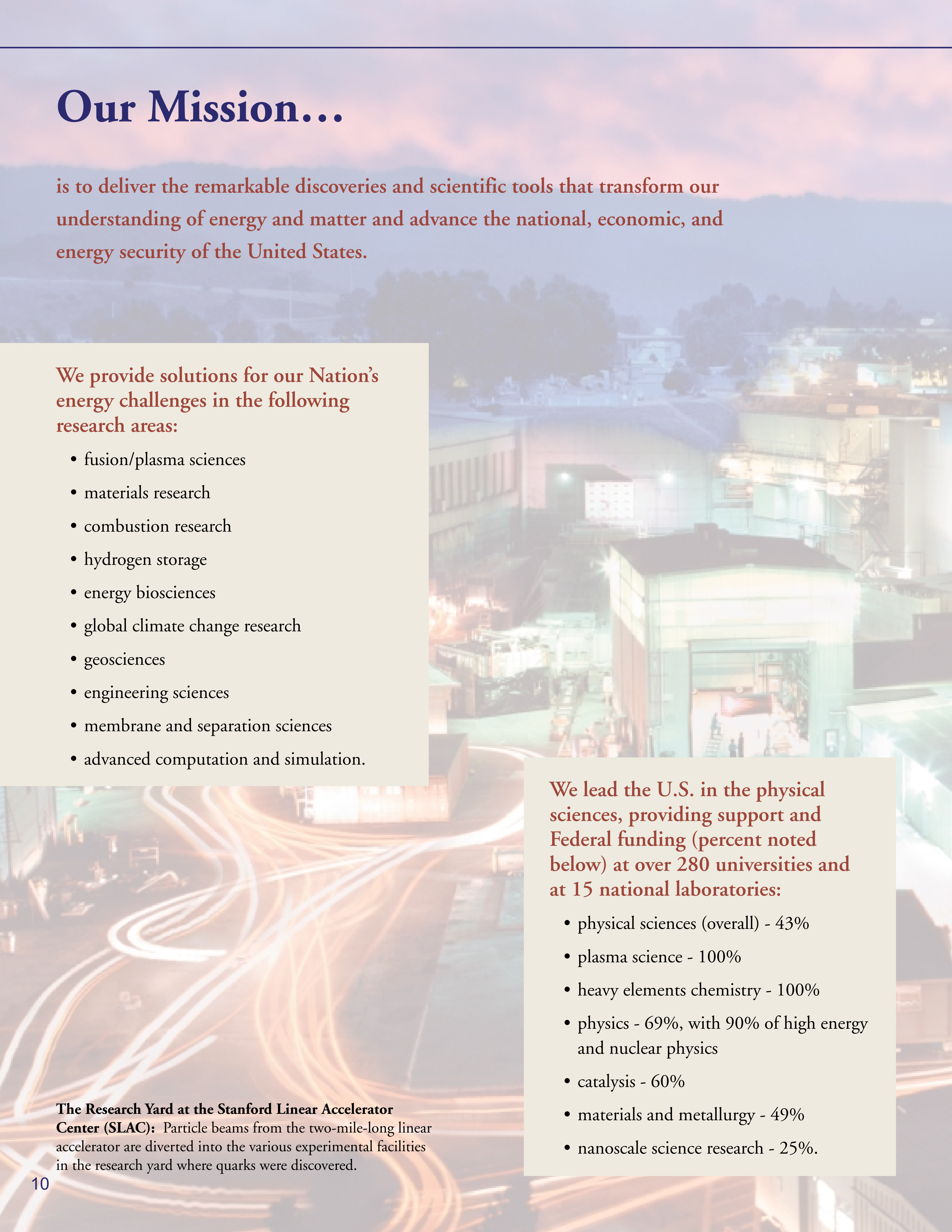
is to deliver the remarkable discoveries and scientific tools that transform our understanding of energy and matter and advance the national, economic, and energy security of the United States.

We provide solutions for our Nation's energy challenges in the following research areas:

- fusion/plasma sciences
- materials research
- combustion research
- hydrogen storage
- energy biosciences
- global climate change research
- geosciences
- engineering sciences
- membrane and separation sciences
- advanced computation and simulation.

We lead the U.S. in the physical sciences, providing support and Federal funding (percent noted below) at over 280 universities and at 15 national laboratories:

- physical sciences (overall) - 43%
- plasma science - 100%
- heavy elements chemistry - 100%
- physics - 69%, with 90% of high energy and nuclear physics
- catalysis - 60%
- materials and metallurgy - 49%
- nanoscale science research - 25%.



The Research Yard at the Stanford Linear Accelerator Center (SLAC): Particle beams from the two-mile-long linear accelerator are diverted into the various experimental facilities in the research yard where quarks were discovered.

We deliver the premier tools of science to our Nation's research enterprise:

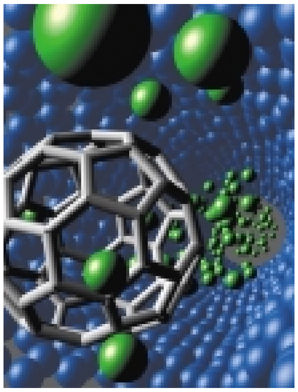
- particle accelerators and detectors
- advanced light sources
- neutron beam sources
- advanced computational and networking facilities
- plasma science facilities
- genome sequencing facilities
- nanoscale science research centers
- specialized centers and facilities for microcharacterization, combustion research, x-ray optics, molecular-level environmental sciences, atmospheric measurement, and more.

We keep the U.S. at the forefront of intellectual leadership by:

- helping to prepare the scientific and technological workforce for the 21st Century
- creating centers of research that attract the world's best scientists
- daring to take scientific risks that have enormous payoff
- sponsoring more than 2,000 graduate and postdoctoral students in research positions at our national laboratories
- constructing major scientific facilities, such as the Spallation Neutron Source, the premier research site for neutron science in the world when completed in 2006
- developing five Nanoscience Research Centers, future home to the world's most advanced nanoscale research efforts
- initiating the Human Genome Project in 1986 and the first Federal research program focused on global climate change in 1978
- discovering 10 of the 12 fundamental particles that constitute matter
- delivering a broad range of intellectual advances in applied mathematics that underpin programs in the physical, biological, and environmental sciences
- sponsoring 35 Nobel laureates since DOE's inception in 1977, and a total of 79 Nobel laureates associated with DOE and its predecessor agencies since 1934
- supporting since 1962 the basic research for 633 projects that resulted in R&D 100 Awards for promising technologies, products, or processes—among the highest number of R&D awards for any government agency or private enterprise.

Our Goals…

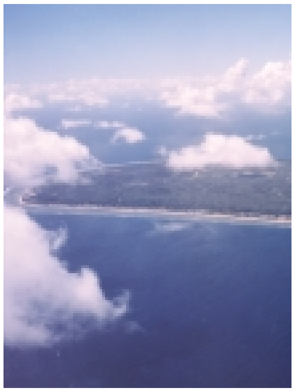
The goals and strategies contained in this Strategic Plan reflect national priorities set by the President and the Congress, our commitment to the missions of the Department of Energy, and the views of the U.S. scientific community. Our focus over the next two decades will be to ensure that the U.S. maintains scientific primacy in the key research disciplines that we support, that our science programs are relevant and useful for identified national priorities, and that we are agile enough to respond to emerging scientific challenges.



1 Advance the Basic Sciences for Energy Independence

Provide the scientific knowledge and tools to achieve energy independence, securing U.S. leadership and essential breakthroughs in basic energy sciences.

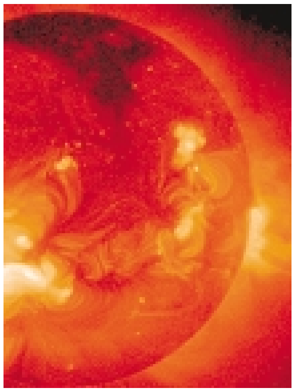
Much of our progress to reduce the energy intensity of our economy has come from advances in chemistry and materials science. We will build on this progress as we begin to design and assemble structures at the molecular level, learn to precisely predict and control chemical reactivity, and understand the behavior of complex systems. We will deliver new science that improves the reliability of our electric grid, makes our transportation system cleaner and more efficient, and enables new generation technologies, from fuel cells to hydrogen power.



2 Harness the Power of Our Living World

Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally alter the future of medical care and human health.

After two decades of research leadership in genomics, we can now search for molecular-level insights into cellular function, beginning with the characterization of multi-protein complexes. With that knowledge, we will employ the extraordinary efficiency of microbes to meet human needs and develop new approaches to medical care. In addition, through a systems-level understanding of our Earth's climate system, carbon cycle, and biogeochemistry, we will enable regional scale prediction of climate change and the design of mitigation and adaptation measures.



3 Bring the Power of the Stars to Earth

Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels a star, realizing by the middle of this century a landmark scientific achievement by bringing fusion power to the U.S. electrical grid.

We believe fusion will become a practical energy technology within three to four decades, through either magnetic confinement of plasmas or one of several inertial approaches. Over the next decade, we will resolve critical scientific uncertainties and select the most promising technical approach, including participating in an international burning plasma experiment called ITER.

4 Explore the Fundamental Interactions of Energy, Matter, Time, and Space

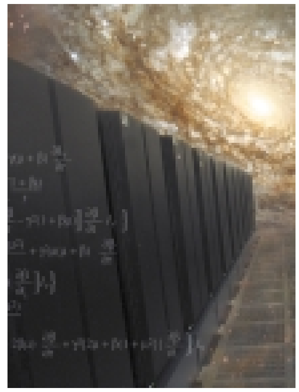
Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe, search for possible new dimensions of space, and investigate the nature of time itself.

With next-generation accelerators, we will test and extend our views of the most basic constituents of matter, and perhaps see the validation of a grand unifying theory of the fundamental forces that govern our world—the goal of particle physics for decades. On the cosmological scale, we hope to reveal the nature and behavior of the enigmatic dark matter and dark energy that we believe account for the bulk of the mass of our universe, and that are responsible for the very startling recent discovery that the expansion of our universe is accelerating.

5 Explore Nuclear Matter—from Quarks to Stars

Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks and gluons; to the elements in the universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability, possessing radically different properties from known matter.

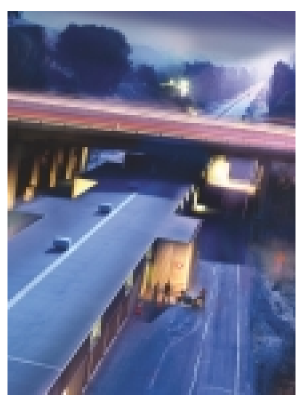
Great strides in our understanding of nuclei and nuclear reactions have led to such profound influences on society as the discovery of fission and fusion and the development of the now vast field of nuclear medicine. With technological advances in accelerators, instrumentation, and computing, we will explore new forms of nuclear structure and matter, and at last unlock the mystery of how protons and neutrons, the basic building blocks of matter, are put together. This knowledge is vital to research in energy and national security, and to understanding the stellar processes that give rise to the known elements in the universe.



6 Deliver Computing for the Frontiers of Science

Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

Each of the previous goals, and progress in many other areas of science, depends critically on advances in computational modeling and simulation. Crucial problems that we can only hope to address computationally require us to deliver orders of magnitude greater effective computing power than we can deploy today.



7 Provide the Resource Foundations that Enable Great Science

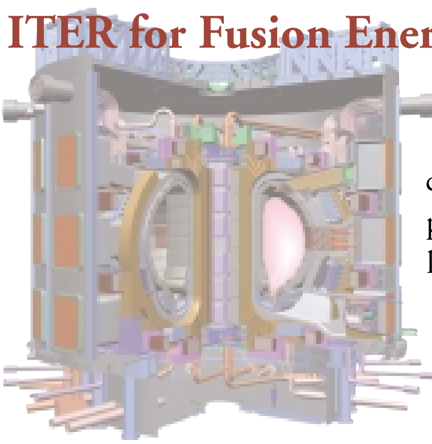
Create and sustain the discovery-class tools, 21st Century scientific and technical workforce, research partnerships, and management systems that support the foundations for a highly productive, world-class national science enterprise.

Our Nation's research enterprise depends upon a solid foundation that has been built through careful investments in people, institutions and major scientific facilities. Of particular note are the "discovery-class" scientific tools that we construct and operate. Our goal is to continue to provide leadership, stewardship, and balance of this vital combined infrastructure.

Our Priorities…

The Office of Science's research priorities flow from our long-term strategic goals and reflect our Nation's commitment to energy independence, a cleaner environment, improved health care, greater economic prosperity, and intellectual leadership. These priorities are a critically important subset of the full range of Office of Science research responsibilities that are more broadly defined by our major goals (pages 12 and 13). Pursuing these research priorities over the next 5 to 10 years and beyond will be challenging, but they hold enormous promise for the future of our Nation and the overall well-being of our citizens.

ITER for Fusion Energy

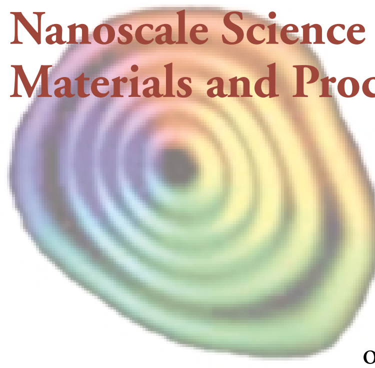


The President has made achieving commercial fusion power the highest long-term energy priority for our Nation. Our challenge is to develop a science-based solution that harnesses fusion energy to power our industries and homes. We will do this by joining an international burning plasma experiment, ITER, and exploring other promising technologies.

Scientific Discovery through Advanced Scientific Computing

Extraordinary advances in computer architecture and software design are making scientific computing a true third pillar of discovery, joining theory and experiment as a standard tool that researchers rely upon to make scientific progress. Scientific computing will enable us to model and simulate experiments that cannot be conducted in a laboratory. This means that biologists can learn the secrets of protein folding, which is essential to understanding basic life processes; and physicists can model the behavior of supernovae, which may explain how the cosmos is ordered. The Office of Science will bring 50 years of leadership in using advanced computers to a multi-agency Federal partnership with computer vendors and the academic community.

Nanoscale Science for New Materials and Processes



Nanoscale science research—the study of matter at the atomic scale—will take us into a realm where the properties of materials are dramatically different from what we have today. Structures composed of just a few atoms and molecules may be engineered to assemble themselves into useful devices such as computers that can store trillions of bits of information on a device no larger than the head of a pin or implantable in vivo diagnostic monitors the size of a cell. Large and complicated structures can be designed, one atom at a time, for desired characteristics such as super-lightweight and ultra-strong materials. The Office of Science will help lead this revolution—with nanoscale research in materials sciences, physics, chemistry, biology, and engineering—and tools that can probe and manipulate matter at the atomic scale.

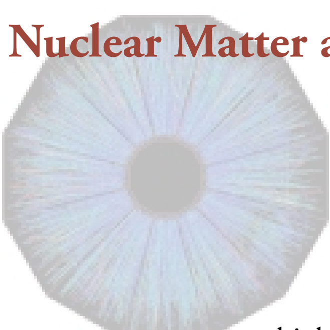
Taming the Microbial World—the Next Revolution in Genomics

Microbes are among Nature's most underappreciated resources. They thrive in extreme environments. They consider toxic waste a gourmet meal, and some are mini-factories that can produce energy supplies. Our challenge is to learn how to get microbes to work for us, to turn microbes into mighty engines of scientific progress. The Office of Science will use the knowledge and tools that we have developed over the past two decades of research into genomics to understand how microbes may be able to clean up chemical and radioactive pollutants and to produce abundant and clean energy.

Dark Energy and the Search for the Genesis

How the universe originated—its genesis—is one of the great mysteries of science. Experiments at the Office of Science's accelerators seek evidence for unification: the blending of today's diverse patterns of particles and interactions into a much simpler picture at high particle energies, like those that prevailed in the very early universe. In one experiment, a partnership with NASA will put a dedicated telescope in Earth orbit to measure the emission of light throughout supernovae explosions across the universe, providing a historical record of its acceleration in the aftermath of the Big Bang. These results are essential to understand the mysterious dark energy that dominates today's universe and drives an accelerating expansion of space.

Nuclear Matter at the Extremes



Understanding how nuclear matter is formed is critical to understanding the processes within stars and how elements are created—including possible new elements—at high-energy densities and the extreme limits of stability. Experiments with colliding gold nuclei are designed to study brief, submicroscopic samples of hot plasma of free quarks and gluons that filled the universe at the tender age of one microsecond. New accelerator studies are planned to explore the extremes of nuclear matter and the processes that form nearly all of our chemical elements in stars and supernovae.

Research Facilities for the Future of Science

The discoveries of the future will require powerful next-generation scientific tools. A list of the 28 highest priority facilities that will be needed over the next 20 years is provided below, grouped into the near-term, midterm, and far-term. These facilities support the Nation's research in areas that are traditionally the responsibility of the DOE. They are described in more detail in the companion document, *Facilities for the Future of Science: A Twenty-Year Outlook.*

Term	Priority	Program	Facility
Near-Term	1	FES	ITER
Near-Term	2	ASCR	UltraScale Scientific Computing Capability
Near-Term	Tie for 3	HEP	Joint Dark Energy Mission
		BES	Linac Coherent Light Source
		BER	Protein Production and Tags
		NP	Rare Isotope Accelerator
Near-Term	Tie for 7	BER	Characterization and Imaging
		NP	CEBAF Upgrade
		ASCR	Esnet Upgrade
		ASCR	NERSC Upgrade
		BES	Transmission Electron Achromatic Microscope
Mid-Term	12	HEP	BTeV
Mid-Term	13	HEP	Linear Collider
Mid-Term	Tie for 14	BER	Analysis and Modeling of Cellular Systems
		BES	SNS 2-4 MW Upgrade
		BES	SNS Second Target Station
		BER	Whole Proteome Analysis
Mid-Term	Tie for 18	NP/HEP	Double Beta Decay Underground Detector
		FES	Next-Step Spherical Torus
		NP	RHIC II
Far-Term	Tie for 21	BES	National Synchrotron Light Source Upgrade
		HEP	Super Neutrino Beam
Far-Term	Tie for 23	BES	Advanced Light Source Upgrade
		BES	Advanced Photon Source Upgrade
		NP	eRHIC
		FES	Fusion Energy Contingency
		BES	HFIR Second Cold Source and Guide Hall
		FES	Integrated Beam Experiment

Near-term
Mid-term
Far-term

Programs:
ASCR = Advanced Scientific Computing Research
BES = Basic Energy Sciences
BER = Biological and Environmental Research
FES = Fusion Energy Sciences
HEP = High Energy Physics
NP = Nuclear Physics

Our Vision…

We envision a future where our contributions to the physical, biological, and environmental sciences have transformed the world as we know it. Our discoveries have changed forever how we provide for life's most basic needs—and how we view our own existence within a complex, ever-changing universe.

By 2023, our science will have helped us achieve a large measure of energy independence. The energy intensity of our economy decreases, and energy sources are now more plentiful and clean. There is a new, more competitive menu of renewable energy sources, a safer generation of nuclear power, a hydrogen-based energy storage utilization infrastructure, and an efficient energy distribution network that is greatly enhanced by breakthroughs in nano-designed materials, computation, and other relevant fields of science. Having completed key experiments, the promise of fusion power—clean, almost limitless energy—is closer than ever.

We see a world where our science provides enduring solutions to the environmental challenges posed by growing world populations and energy use. New, cost-effective approaches, some based on the use of engineered microbes, enable us to tackle some of our most intractable cleanup problems. On a global scale, we have a clearer picture of the complex process of climate change, and we have solutions in hand made possible through the biological and environmental sciences, and in particular, through genomics.

Through 2023, our science will sustain critical growth and strength in the U.S. economy. During this period, entirely new industries will be created, and virtually all industries will benefit through the enormously broad reach of breakthroughs in energy and the physical sciences. Our mastery of catalysis, nano-assembly, self-replicating, and complex systems will not only increase our industrial efficiency, but it will create entirely new opportunities for harnessing the power of our material world.

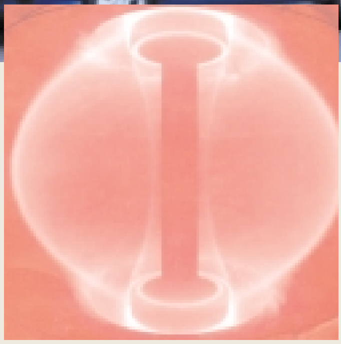
Science fiction will give way to science fact as medical miracles unfold and a new set of promises arises to fill the void. DOE will continue to capitalize on its strengths at the nexus of the physical and life sciences, delivering the nanoscience, biology, precision engineering, and advanced computation that will "close the deal" in these developments and secure our valued contributing role in medical science. Restoring sight to the blind with micro-assembled retinal implants will start the journey, with the next stop, hope for those with spinal cord injuries.

As the future unfolds, not only do our citizens enjoy an improved quality of life, but they are more secure. Our Nation is more secure. DOE science will have provided the science behind innovations in monitors, sensors, computational analysis, structures, materials, and countless areas that help to provide early threat detection and protect those that we serve.

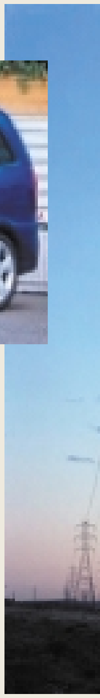
In the not-too-distant future, our universe will seem more familiar to us, and the mysterious properties of matter and energy less complex. Our pursuit of answers to some of the most persistent questions of science will have revealed important secrets and assured U.S. intellectual leadership in key areas of science and mathematics.

At the end of the day, we envision a future where our discoveries have resulted in improved benefits to mankind, whether it was to light the night, heat a home, transport food, cure an illness, or to see and understand the beginning of time itself.

Hydrogen Production and Storage



Fusion Power Generation



Energy

Nanoscale science, materials catalysis, and genomics are just some of the fertile areas of basic research that will open the doors to more efficient and competitive renewable energy, the promise of fusion power, transition to a hydrogen economy, a vastly improved electrical distribution system, and gains in demand-side efficiency.

Economy

The ability to create materials atom-by-atom, to precisely control chemical reactions, to make microelectromechanical (MEM) devices the size of a human blood cell—all foretell the scientific breakthroughs that will fuel the U.S. economy in the decades to come.

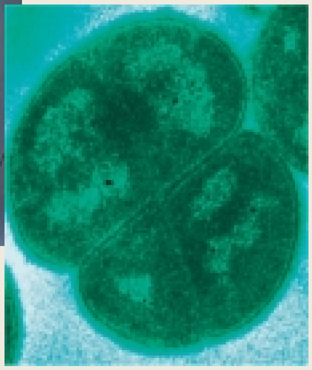

Efficient Electrical Power Distribution

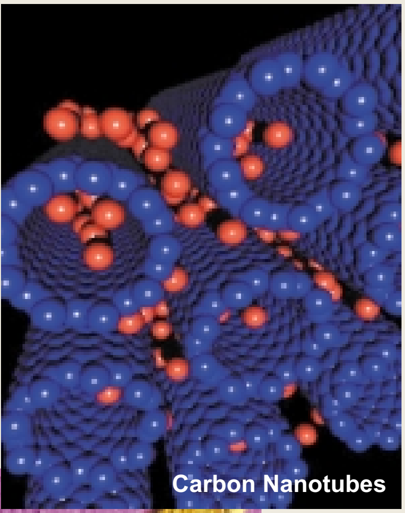
Global Environmental Monitoring

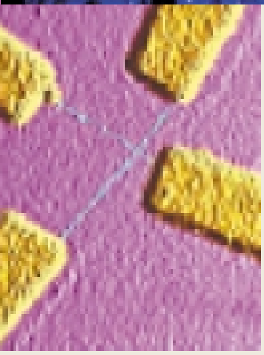
Environment and Health

Understanding and protecting our global environment, harnessing the ability of microbes to do work, and advancing such medical technologies as Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) will occur through effective integration of the physical, computational, life, and engineering sciences.


Medical Imaging

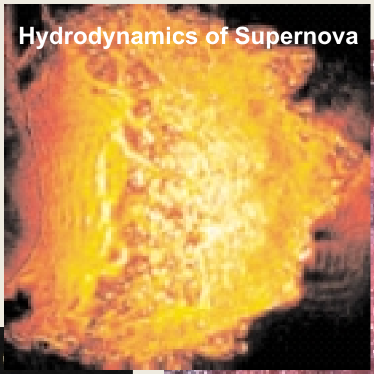

Microbe "Workers"

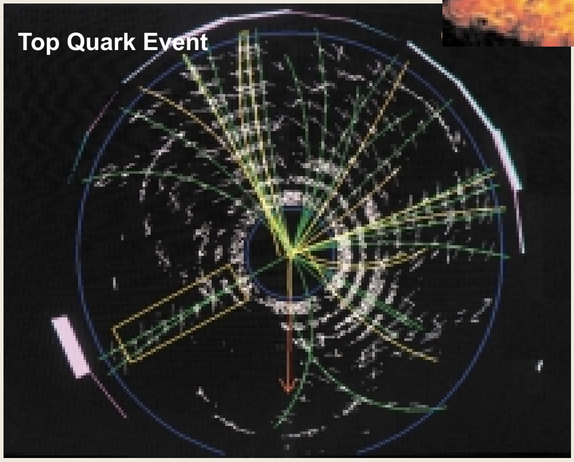

Carbon Nanotubes


Nanoscale Electronics

Intellectual Leadership

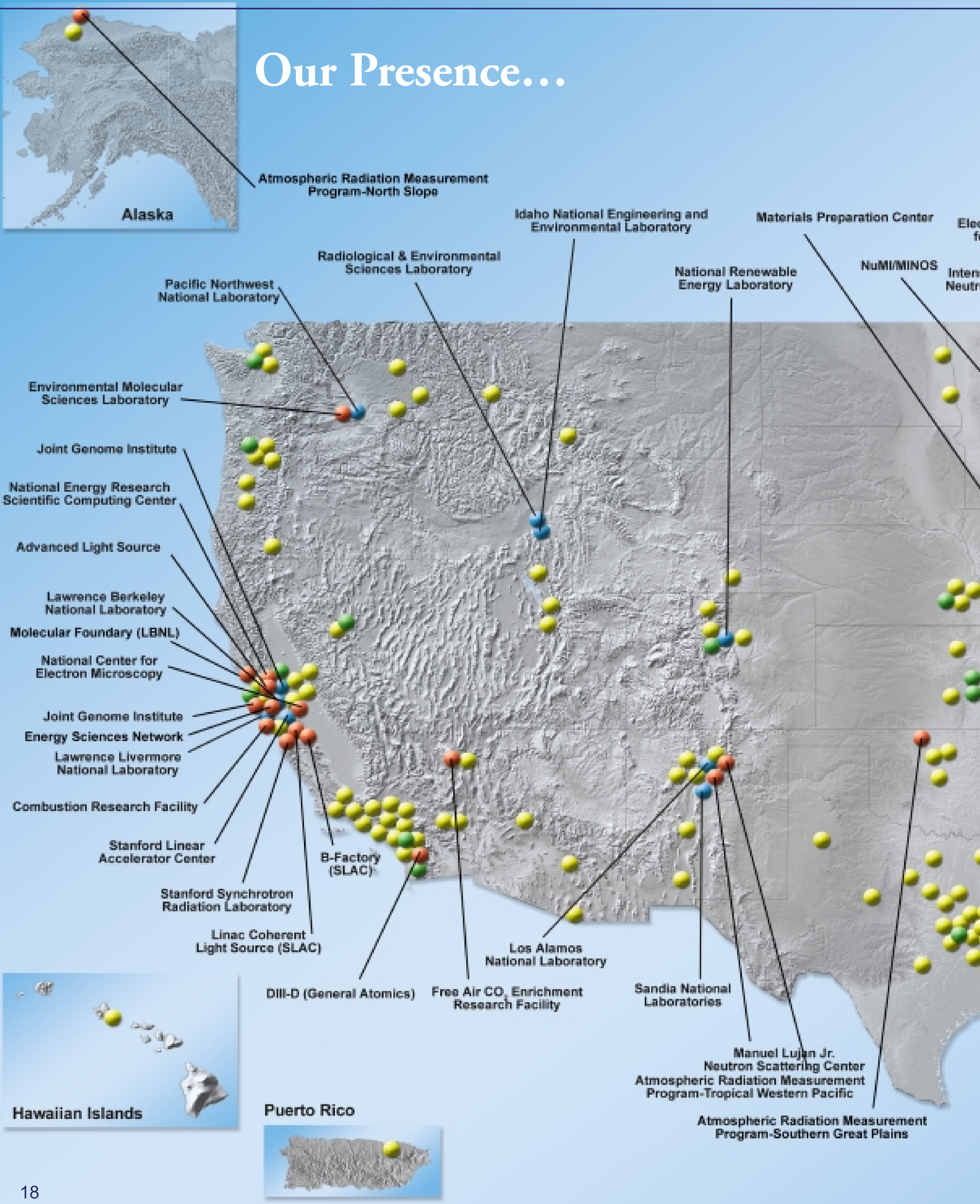
Exploration of such challenging scientific areas as high-energy physics and astrophysics, the essence of nuclear matter, and the hydrodynamics of a supernovae, will extend the frontiers of knowledge and scientific capability.


Hydrodynamics of Supernova


Top Quark Event


High Energy Physics and Astrophysics

Our Presence…




Booster Neutrino (Fermilab)
New Brunswick Laboratory
ctron Microscopy Center
or Materials Research
Tevatron Collider (Fermilab)
Argonne National Laboratory
se Pulsed
on Source
Main Injector
(Fermilab)
Fermi National
Accelerator Laboratory
Argonne Tandem Linac Accelerator System
Advanced Photon Source
Center for Microanalysis
of Materials
National Energy
Technology Laboratory
Pulse Radiolysis
Facility
BTeV (FNAL)
Relativistic Heavy
Ion Collider (BNL)
Knolls Atomic
Power Laboratory
Bates Linear
Accelerator Center (MIT)
Alcator C-Mod
Tokamak Facility (MIT)
National Synchrotron
Light Source
Center for Functional
Nanomaterials (BNL)
Brookhaven National Laboratory
Accelerator Test Facility (BNL)
Environmental Measurements
Laboratory
Princeton Plasma
Physics Laboratory
Bettis Atomic
Power Laboratory
National Spherical
Torus Experiment
Continuous Electron Beam
Accelerator Facility (TJNAF)
Thomas Jefferson
National Accelerator Facility
Center for Nanophase Materials (ORNL)
Oak Ridge National Laboratory
Atmospheric Radiation Measurement Program Archive
Holifield Radioactive Ion
Beam Facility (ORNL)
Savannah River Technology Center
High Flux
Isotope Reactor
Center for
Neutron Scattering
Ames Laboratory
Center for Nanoscale
Materials (ANL)
DOE National Laboratories
Office of Science User Facilities
Office of Science University-Based Research
Office of Science University Research User Facilities*
*See Appendix B for the complete list of University-Based
Research and University Research User Facilities