The Synchrotron and Neutron Users’ Group (SNUG) represents:

- 5 Photon Light Sources
- 4 High-Flux Neutron Sources
- Including two under construction
Who We Are

The Synchrotron and Neutron Users’ Group (SNUG) represents over 9,000 faculty, student, industrial and government scientists. Their research is critical to every sector of the economy:

- Materials Chemistry and Nanotechnology
- Electronic Materials and Devices
- Energy Production, Storage and Conversion
- National Security
- New Medicines and Disease Treatments
- Environmental Sciences
- Human and Molecular Biology

Approximately 600 scientists from over 160 companies representing technology, manufacturing, energy, chemical, and bio-pharmaceutical industries use the synchrotron and neutron facilities.

E.I. duPont de Nemours & Co
ExxonMobil Research
Dow Chemical Company
Lucent Technologies
IBM Research Division
Bristol-Myers Squibb
Pfizer Global R&D
SmithKline Beecham
Bruker AXS Inc.
UOP
Merck & Co., Inc.
Abbott Laboratories
PPG Industries, Inc
Eli Lilly & Co.
Pharmacia & Upjohn, Inc.
Glaxo research Institute
Biogen Inc.
Bechtel Nevada
Monsanto/Searle
Emerald BioStructures, Inc.
Adelphi Technology, Inc.
Proctor & Gamble
Roche Biosciences

Applied Materials
Berlex Biosciences
Wyeth Research
Cytokinetics Inc.
The EXFAS Co.
Indoff/K&M
Komag Co.
Photon Imaging Inc.
Canmet
AMGEN
Chiron Corp.
Tularik Inc.
Aracor
Genetics Institute
Burnham Institute
Intel Corporation
Hoffmann-LaRoche
IBM Corp.
Motorola
Genentech
Hewlett Packard
Eastman Kodak Co.

Advanced Micro Devices
Gladstone Laboratory
STI Optronics, Inc.
Northrop Grumman ATDC
Scientific Manu. Techno. Inc.
Edge Analytical, Inc.
National Semiconductor
Ovoncic Synthetic Materials Co.
New Century Pharmaceuticals
Area Detector Systems Corp.
Hughes Space & Comm.
Walschon Fire Protection
William Hassenzahl Consulting
Daimler Chrysler AG
BASF Bio-Research Corporation
Kraft Foods Technology Center
SFA, Inc.
Corning, Inc.
BASF
Orthologics
Alpha Braze, Inc.
Anticancer, Inc.
Aventis Gencell
Chevron
Conductus Inc.
Crystal Logic Inc.
Exelixis
Genomics Institute
GETOM Corp.
Lumileds Lighting
Pyro Fusion
Xradia
Veeco-Ion Tech
Pratt & Whitney
Spectra-Tech Inc
MVA, Inc.
Landauer Inc.
Neocera Inc.
SAIC Corp.
Spectragen, Inc.
Rigaku Corporation
Attelexis
Bruker Optics Inc
Panametrics, Inc
Photons Unlimited
Varian Vacuum Products
BioSpace Int'l. Inc
Millennium Chemicals Inc
Dow Corning Corp.
Merrc Electronic Materials
Aventis Pharma
Bell Laboratories
NEC Research Institute
Osrarn Sylvania, Inc.
Princeton Gamma-Tech
Wyeth-Ayerst Research
Advanced Fuel Research
Akzo Nobel Chemicals
General Electric
Pall Corp
Bicron NE
Eveready Battery Co.
Ford Motor
Aerospace Corp.
Attelexis
Hinds Instruments, Inc.
Air Products Chemical Inc.
Rohn & Hass Co.
St. Jude Children's Res. Hosp.
Molecular Structure Corp.
Texas Instruments
Physical Sciences, Inc.
Boeing Co.
Balazs
Xencor, Inc.
Innovene
INOES Technologies
GE Global Research
Palo Alto Research Corp.
Infinon Technologies
Evergreen Solar
Schott Solar
BP Solar
MER Corporation
Micell Technologies
Microt Technologies
WHY Are These Machines So Valuable?

Synchrotrons:
– produce ultra-high intensity light over a wide range of energies from infra-red to visible light to ultraviolet to X-rays.
– the energy of this light can be precisely tuned allowing many different kinds of element-specific investigations, such as:
  » determining atomic scale and nanoscale STRUCTURE in proteins, semiconductors, and nanoparticles;
  » determining the MECHANISM by which superconductors work, cells respire, diseases infect, and catalysts operate; or
  » ANALYZING and IDENTIFYING trace quantities of harmful substances in lakes, oceans, air, soils, or human tissues.

Neutrons:
– are uncharged, so they can penetrate deep into materials to give precise information about positions and motions of atoms in the interior of a sample.
– are particularly well-suited to study the magnetic structure and properties of materials.
– are especially sensitive to the presence of light elements such as hydrogen, carbon, and oxygen which are found in many biological molecules.

Only the federal government can design, build and operate facilities large and sophisticated enough to be of continuing use to thousands of individual industry and government researchers.
Competition for Synchrotron and Neutron Sources

- The synchrotrons and neutron sources were invented out of fundamental physics at U.S. laboratories.

- The U.S. now has 7 major facilities. The FY 2007 budget will augment current U.S. capacity with 2 additional facilities and another major upgrade.

- While the U.S. invented these machines, in recent years other nations of the world have hastened to build their own
  - 10 synchrotrons worldwide in 1980
  - >50 synchrotrons worldwide today, with more under construction
  - Major construction of neutron sources underway in Europe and Japan

Considering only beam ports on 3rd generation synchrotrons worldwide, by 2009 the U.S. will be outnumbered by the rest of the world 7:1
Research at User Facilities has Increased Significantly even though operating budgets have remained near flat.

Scientists use the DOE synchrotron and neutron facilities in ever-increasing numbers.

Operating resources as proposed in the FY 2007 budget will restore more efficient use of this national investment, and greatly increase support for peer-reviewed research into energy efficiency and supply, toxic waste clean up, bioterrorism and disease detection, electronics, telecommunications, and manufacturing.
Last year two experiments detailing how synchrotrons helped to reveal ancient secrets received significant media coverage: **Beethoven’s lead poisoning and deciphering Archimedes’ text.**

![X-ray Fluorescence Intensity from Pb in Hair](image)

Intensity of Pb x-ray fluorescence from a standard hair (SN-1) with 6 ppm of lead compared to that of a hair from Beethoven (LVB) as determined at APS.

A distant relative of Beethoven sent bone fragments to the **Pfeiffer Treatment Center** who worked with APS scientists to **confirm massive amounts of lead** as the cause of the composer’s chronic illness.

![A photograph of one page of the Archimedes Palimpsest. Visible and UV light cannot see Archimedes’ text under the gold painting done by a 20th Century forger.](image)

Funded by an anonymous collector, scientists from the Walters Art Museum, Stanford University and SSRL used x-ray fluorescence to **decipher the Archimedes Palimpsest**, covered over by a 20th Century forgery, the only source for at least two previously unknown treatises by the Greek scholar.
Improved computational power comes from squeezing more and ever smaller transistors onto microprocessors. Extreme Ultraviolet (EUV) Lithography is the likely next generation technology to do that. Synchrotron radiation has driven this technology forward toward commercialization.

Current technology will allow manufacturers to print circuits as small as 0.1 micron in width (1/1,000th of a human hair). EUV lithography will extend this down to 30 nm or less (.03 microns), making processors 8 times more powerful than they are today.
Improved Data Storage: Liquid Crystal-Like States in Colossal Magnetoresistance Materials

In recent years, a great deal of attention has been paid to a new class of materials that exhibit huge changes in their electrical resistivity when a magnetic field is applied.

The interest in these colossal magnetoresistance (CMR) materials stems from the fact that the unusually strong coupling between the magnetism and electron transport in these materials could be used in technological applications like data storage or magnetic sensors.

This technology could improve data storage by 1000%.

Work funded by DOE

Neutron scattering in a CMR material (left panel) revealed that the charge order in the insulating state is formed by linear spin chains that are weakly coupled (top right panel). Eventually these chains lock in a two-dimensional structure (bottom right panel).

Scientists have developed a new organic polymer that can be laid down using **simple printing techniques** rather than the expensive and elaborate methods used to process silicon, **6 times faster** than previous organic polymers. Now just as fast as silicon plus much cheaper, **this inexpensive organic conductor could be used in areas where silicon struggles to compete, eventually slashing the cost of transistors, PDA’s, flat panel screens and bringing electronic paper into common use.**

Research team includes Merck Chemicals (UK), Palo Alto Research Center (California), Stanford University, and SSRL

*Science (311)*, March 2006.

**Crystal Power.** New semiconducting plastics form large crystals that help whisk electrical charges at higher speeds than ever before.
Crystal Structures of Real Materials

The data from synchrotrons - 200-500,000x better than from laboratory sources – enables the precise delineation of complex crystal structures of which most materials are comprised.

This new understanding improves the performance of many industrial materials, ranging from common expectorants in decongestants on the drugstore shelf to components in efficient refrigerators with no moving parts.

Funded by BP/Innovene
In Alzheimer’s Disease (AD), the brain contains a buildup of a misfolded protein, called “plaque,” that is believed to kill brain cells. It is thought that normal metal ions in the brain play a role in plaque formation. At the NSLS and APS, scientists showed that copper and zinc ions accumulate in AD plaques, suggesting that metal ions may impact plaque formation.

These findings can be used for developing drugs to prevent this process.

Funded by National Institutes of Health

Eli Lilly is in the process of starting a collaboration to extend this work

L. Miller et al., J. Structural Biology in press.
Scientists are analyzing sensors in human cells that detect viruses, bacteria, fungi and parasites.

This will be important for pharmaceutical companies when designing viral and bacterial immunizations that can quickly counter specific threats due to bioterrorism and/or diseases such as avian flu.

Funded by the National Institutes of Health

Researchers have found that water (red and yellow) confined in a nanotube (orange) behaves like a liquid, even below freezing temperatures.

An understanding of this phenomenon could provide insights into biological systems that utilize water at sub-freezing temperatures. It may also shed light on fast hydrogen ion transport, a critical mechanism throughout biology. Water and hydrogen-ion transport across the cell membrane are responsible for maintaining the integrity of living cells. Without the "proton pump," cells would be unable to maintain constituents at their physiological concentrations.

Work funded by DOE

Industrial partner: Materials and Electrochemical Research (MER) Corporation

Scientists, environmental officials, and the waste-water management industry are anxious to improve the great potential of carbon dioxide (CO₂) as a cleaning agent for many environmentally important missions.

Research at HFIR has led to new and more efficient options for removal of proteins and heavy metals through the use of Carbon Dioxide.

Processes based on this research have been commercialized for the dry cleaning industry by Micell Technologies.


Improved Catalysts Increase Gasoline Production

About half the gasoline used in the U.S. is produced in Fluid Catalytic Cracking (FCC) units in refineries.

Experiments at NSLS show how to formulate catalysts that perform best at the extreme temperatures at which refineries operate, and thus improve the yield of gasoline from each barrel of crude oil by up to 20%.

Work funded by Amoco/BP
Scientists at the IPNS have confirmed the existence of a unique new compound, platinum oxo complex, which mimics the bonding of oxygen to platinum present in a catalytic converter. This new knowledge may increase efficiencies and reduce unburned hydrocarbons in automotive exhaust that contribute to "greenhouse" effects and global warming.

Funded by DOE and NSF
Collaboration with Emory University

The efficiency of solar cells depends on their purity. Ultrahigh-purity silicon is expensive and difficult to produce.

Previous research efforts have concentrated on ways to decrease contaminants in solar cells. Now scientists have discovered an alternative: “corral” the contaminants into one area, rather than trying to get rid of them altogether.

This "defect engineering" is much easier and much more cost-effective than producing ultrapure silicon. Studies show that solar cells with defects confined to smaller areas outperform up to 4 times solar cells with the same total number of defects spread over a larger area.

Material performance and size and spatial distributions of metal defects (insets). The material with microdefects in lower spatial densities (orange) clearly outperforms materials with smaller nanodefects in higher spatial densities (blue), even though all materials contain the same total amount of metals.


Work supported by the National Renewable Energy Laboratory, GE Energy, Evergreen Solar, Schott Solar, BP Solar
Discovering Hydrogen Storage Materials

Aiming at using hydrogen as an alternative fuel, GE is working with DOE to develop onboard hydrogen storage materials for automotive applications. Li$_2$Mg(NH)$_2$, which contains 5.6% hydrogen and has reversible storage capability, has been the recent research focus. GE is using both synchrotron x-rays and neutrons to study the reaction pathways and crystal structures in unprecedented detail.

Following the decomposition (left) and hydrogen release (right) in real-time during dehydrogenation of a lithium and magnesium amide-imide system, by using synchrotron x-rays and mass spectrometry.

Funded by DOE and GE Global Research
Steps Toward Hydrogen Vehicles

Synchrotron research has shown that **carbon nanotubes**, 50,000 times more narrow than a human hair, are a promising material for **storing hydrogen safely, efficiently and compactly**.

The **DOE Freedom CAR program** has set the goal of a material that can hold 6% of the total weight in hydrogen by the year 2010. Theoretical calculations indicate they may exceed these goals substantially.

**Funded by DOE, NSF and Global Climate and Energy Project** (alliance of scientific researchers and leading companies in the private sector, including ExxonMobil, General Electric and Schlumberger)

Scientists at NSLS are studying nanoparticles made of the compound ceria that could **improve the ability of catalytic converters to lead to more efficient ways to generate hydrogen fuel because it is clean and renewable**.

**Funded by DOE and NSF**
But … Are We Losing Our Edge?

The U.S. still leads the world in scientific innovation. But years of declining investment and fresh competition from abroad threaten to end our supremacy.

Broad science programs essential for U.S. future competitiveness
Constrained Funding for 30 years has Slowed U.S. Progress


Source: American Association for the Advancement of Science (AAAS)


* - Other includes research not classified (includes basic research and applied research; excludes development and R&D facilities)
Underfunding Erodes U.S. Position


- **US**
- Fastest Growing Economies
- Established Economies: Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, U.K.

**Established Economies:**
China, Hong Kong, India, Ireland, Israel, Singapore, S. Korea, Taiwan

- **1988**
  - Western Europe: 31%
  - US: 38%
  - Asia: 11%
- **2001**
  - Western Europe: 36%
  - US: 31%
  - Asia: 17%

**S&E Articles: US Already passed by Western Europe with Asia rapidly closing**

- United States
- Western Europe
- Asia

Sources:
- National Science Foundation, Science and Engineering Indicators 2004, Appendix Table 6-11
- Compiled by the APS Office of Public Affairs
The Nation Needs to Keep Basic Research Moving Forward!

Congress in the past few years has worked within fiscal limits to restore science, math and education funding. It has taken several important initiatives this year.

The President has joined the effort in a major way for FY 2007:

“We must continue to lead the world in human talent and creativity. Our greatest advantage in the world has always been our educated, hardworking, ambitious people – and we're going to keep that edge. Tonight I announce an American Competitiveness Initiative, to encourage innovation throughout our economy, and to give our nation's children a firm grounding in math and science.”

“I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years. This funding will support the work of America’s most creative minds as they explore promising areas such as nanotechnology, supercomputing, and alternative energy sources.”

President George W. Bush
State of the Union Address
January 31, 2006
The U.S. needs to optimize knowledge-based resources, particularly in science and technology.

Scientific progress and competitive position of U.S. depends on how wisely we invest in research capability.

User research has broad applications of national interest, including:
- energy efficiency and supply
- toxic waste cleanup
- bioterrorism and disease detection
- electronics, telecommunications and manufacturing

After several decades of constrained spending, support for the American Competitiveness Initiative is essential in FY 2007 to reinvigorate the U.S. science base, including efficient maintenance and use of the large U.S. investment in synchrotron facilities and neutron facilities.
BACKUP SLIDES FOLLOW
Nature has devised biological syringes (right) that function exactly as they look to mainline toxins or virulent proteins into a host cell. The workings of these syringes is of enormous interest to public health, pharmaceutical designers and other scientists, who can now use this information to thwart these mechanisms.

Researchers have uncovered the needle complex found in bacteria such as *Salmonella* and *E.Coli* and used by the bacteria to deploy diseases ranging from food poisoning, bubonic plaque, and whooping cough.

---

**Funded by the Howard Hughes Medical Institute and the National Institutes of Health**

*Ribbon and surface representation of the modeled 24-subunit ring which makes up the base of the needle*

*Nature 435, 702 (2005)*
Data from xylose isomerase recorded 181,797 reflections allowing researchers to map hydrogen.

Xylose isomerase helps convert sucrose to fructose in the body.

*Human insulin* data using PCS user-friendly display (left) and a schematic of PCS (below)
Dew drops roll off lily pads because their surfaces are hydrophobic (“water fearing”)

An air layer has been long-suspected under such a drop

Removal of dissolved gases reduced the layer thickness; aeration increased it

**Hydrophobic forces govern protein folding, lipid aggregation, and hence life itself**

Dhaval A. Doshi, Erik B. Watkins, Jaroslaw Majewski, Jacob Israelachvili, *PNAS*

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**Neutron Reflectivity Reveals Suspected Air Layer under Water Drops on Lily Pads**

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[Image of a lily pad with a water drop]
Cleaning Up Radioactive Waste

Cleaning up high-level radioactive waste is a top priority of U.S. Department of Energy’s Environmental Management Program.

Scientists from Westinghouse Savannah River Co., Savannah River National Lab, and MVA, Inc. have used the NSLS to study the molecular structure of Monosodium Titanate (MST). MST is a promising “sponge” to concentrate and sequester radioactive strontium and uranium.

These findings will help to scale up methods to deal with the 30,000,000 gallons of high level waste at the Savannah River site.

Funded by DOE

Improved Catalysts Reduce CO\textsubscript{2} Emissions

Acrylonitrile-based acrylic fibers are used to make many things, for example clothing, carpeting, blankets and rubber for hoses and gaskets.

About 5,000,000 tons of acrylonitrile are made each year, with CO\textsubscript{2} as an undesirable byproduct. Neutron powder diffraction analyses have been critical to the development of manufacturing catalysts that perform best at the high reaction temperatures, therefore reducing CO\textsubscript{2} by as much as 33% compared to previous catalysts.

Work funded by Innovene
A Lighter Filling in Earth’s Core

The outer core of the Earth, whose composition until now has been a mystery, may consist of an alloy of iron and magnesium.

Researchers in the laboratory created high pressures to make new alloys of iron and magnesium with the same sound propagation properties as the earth’s core.

- This is a major step toward predicting earthquakes.
- This research will also be significant for high pressure alloy manufacturing techniques.

Funded by DOE BES & National Nuclear Security Administration (Carnegie/DOE Alliance Center), NSF, the State of Illinois, and the W. M. Keck Foundation

N. Dubrovinskaia et al., Phys. Rev. Lett. 95, 245502 (9 December 2005)
Funded by DFG, Swedish Research Council (VR), and the Swedish Foundation for Strategic Research (SSF)

The Density of States of Iron at high temperatures (red curve) is shifted toward lower energies, indicating a softening of the lattice, which decreases the velocity of compression waves.
GE scientists analyze residual stresses, which contribute to understanding of life and performance of gas and steam turbines and aircraft engines.

GE is developing novel classes of ceramics with improved performance for lighting, medical imaging and homeland security applications.

Non-destructive analysis of residual stress distribution below surface with high-energy x-rays

Accurate determination of atomic positions in a doped Lu and Al based perovskite crystal using neutron diffraction

Funded by GE Global Research
Permanent magnetic materials play **central roles in the conversion of mechanical energy to electricity in alternators, generators** and many other products and technologies.

Researchers at APS have developed promising ways to enhance magnets, opening **new performance possibilities in energy conservation, miniaturization of magnetic devices, and other applications.**

Funded by DOE


Unit cell of Nd$_2$Fe$_{14}$B indicating the location of the two unequal Nd crystal sites that are the focus of this study.
Capturing Atomic Processes

Preliminary experiments at the SSRL using electron bunches only quadrillionths of a second long have illuminated the motions of atoms, including the atoms of a microchip.

These experiments point toward the enormous possibilities opened up in 2008, the start target for the Linac Coherent Light Source, a machine that will generate light so bright and fast that it will:

-- Discover and probe new states of matter
-- Understand chemical reactions and biological processes in real time
-- Image biological materials at the atomic level
-- Image chemicals and material structure on the nanoscale


Funded by DOE and in collaboration with several universities and national laboratories
## Major U.S. Investment in User Facilities

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<tr>
<td>ALS</td>
<td>$99,700</td>
<td>1993</td>
<td>$300,342</td>
<td>$44,800</td>
<td>5,344</td>
<td>2,003</td>
<td>$49,802</td>
<td>5,600</td>
<td>2,100</td>
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<tr>
<td>APS</td>
<td>$811,900</td>
<td>1996</td>
<td>$1,240,800</td>
<td>$100,500</td>
<td>4,931</td>
<td>3,215</td>
<td>$108,604</td>
<td>5,000</td>
<td>3,300</td>
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<tr>
<td>NSLS</td>
<td>$339,139</td>
<td>1980</td>
<td>$539,100</td>
<td>$36,750</td>
<td>5,313</td>
<td>2,256</td>
<td>$40,763</td>
<td>5,400</td>
<td>2,300</td>
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<tr>
<td>NSLS II Upgrade (approved 2006, est. cost $800,000)</td>
<td>$25,000</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>SSRL</td>
<td>n/a</td>
<td>1972+</td>
<td>$410,000</td>
<td>$32,388</td>
<td>3,527</td>
<td>1,007</td>
<td>$35,836</td>
<td>5,000</td>
<td>1,200</td>
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<tr>
<td>LCLS (under construction, est. cost $379,000)</td>
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<td></td>
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<tr>
<td>HFIR</td>
<td>$14,750</td>
<td>1965+</td>
<td>$1,100,000</td>
<td>$46,900</td>
<td>2,613</td>
<td>96</td>
<td>$51,598</td>
<td>4,500</td>
<td>220</td>
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<tr>
<td>IPNS</td>
<td>$60,000</td>
<td>1979+</td>
<td>$187,000</td>
<td>$16,800</td>
<td>3,462</td>
<td>244</td>
<td>$18,531</td>
<td>3,600</td>
<td>240</td>
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<td>Lujan</td>
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<td>1972+</td>
<td>n/a</td>
<td>$9,588</td>
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<td>221</td>
<td>$10,582</td>
<td>3,600</td>
<td>300</td>
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<td>SNS</td>
<td>$1,400,000</td>
<td>2006</td>
<td>n/a</td>
<td>$37,600</td>
<td>-</td>
<td>-</td>
<td>$171,409</td>
<td>n/a</td>
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$ in thousands
Figure 1: ACI Research Funding, 2007-2016.

American Competitiveness Initiative Research: FY 2007 - FY 2016

<table>
<thead>
<tr>
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<th>FY 2006 Funding</th>
<th>ACI Research FY 2007</th>
<th>ACI Research FY 2016</th>
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<tr>
<td></td>
<td>(billions of dollars)</td>
<td>(billions of dollars)</td>
<td>% increase</td>
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<td>NSF</td>
<td>$5.58</td>
<td>$6.02</td>
<td>7.8</td>
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<td>DoE SC</td>
<td>$3.60</td>
<td>$4.10</td>
<td>14.0</td>
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<tr>
<td>NIST Core$^2$</td>
<td>$0.57$</td>
<td>$0.54</td>
<td>-5.8$</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$9.75</td>
<td>$10.66</td>
<td>9.3</td>
</tr>
</tbody>
</table>

1 ACI doubles total research fund; individual agency allocations remain to be determined.
2 NIST core consists of NIST lab research and construction accounts.
3 The 2006 enacted level for NIST core includes $137 million in earmarks.
4 Represents a 24 percent increase after accounting for earmarks.