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Nanotech 2006  
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Boston, MA



Thank you; it is good to be back at the annual NSTI Nanotech conference – now in its 9<sup>th</sup> year.

This conference does a superb job year after year of bringing together from around the world not just researchers to present their latest results, but also those who will take the research results and turn them into useful applications and products — the entrepreneurs, the companies that are expanding their activities and products through the use of nanotechnology, the start-ups and small businesses that are often the sources of innovation and new technologies, and the investors. The success of this conference is indicative of the fact that nanotechnology is “real” and not just a scientific curiosity or business news hype.

The success of this conference is also, I think, indicative of the success of the National Nanotechnology Initiative, which continues to be a major research priority of this Administration. Not only has the NNI grown since its launch in FY 2001, but spending by countries around the world has grown at a similar rate.

# Report Documentation Page

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The correlation between investment in basic research and technological leadership is a tenet of science and public policy, and is one of the pillars of American economic success since the Second World War.

While that paradigm still holds true, some significant changes have occurred. Today, research results and other types of information are electronically accessible from virtually anywhere on earth as soon as they are made public. Everyone is familiar with the fact that news now instantly moves around the world through outlets ranging from online news services to bloggers.

So too, the connectivity among scientists has accelerated progress and, in areas that are pre-competitive, has the potential to reduce the duplication of effort. Almost instant global communication has had a democratizing effect on technological discovery and is helping advance nanotechnology worldwide.



## Keeping America Competitive

Sustained scientific advancement and innovation depend on:

- o Federal investment in cutting-edge, merit-reviewed basic research
- o Favorable environment for private sector R&D
- o Education system that equips Americans with a strong foundation in technical subjects
- o Universities that provide world-class education and research opportunities
- o Immigration policies that attract the best and brightest
- o Business environment that encourages entrepreneurship and protects intellectual property.



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In the face of this more dynamic global scientific enterprise, keeping American as the most technological and competitive economy in the world requires maintaining an “innovation ecosystem.”

A critical element is strong Federal investment in R&D, along with policies that encourage private sector research spending. Competitiveness also depends on a K-12 educational system that provides students with math and science fundamentals and universities that are home to world-class learning and research. To stay competitive, we must train U.S. workers to be the best in the world and at the same time attract and retain—as we have in the past—talented and skilled individuals from around the world. And finally, in order to convert ideas and knowledge into competitive products, the business environment should encourage entrepreneurship and protect intellectual property.

Policies and investments that support each of these components of the innovation ecosystem, along with a thriving investor community that provides access to capital and is

willing to take risks, will enable the U.S. to remain not only competitive, but to continue to lead the world in science and technology.

A goal of President Bush is to make sure that the nation remains competitive by ensuring that scientific advancement and innovation can and will take place here in the United States.

To help achieve that goal, the President announced in his State of the Union address last January his American Competitiveness Initiative—or ACI—and included funding for the ACI in his proposed 2007 budget.



## American Competitiveness Initiative

- ✓ **Federal Research** – Increase critical basic research in physical sciences.
- ✓ **R&E Tax Credit** – Permanently extend and modernize the R&E tax credit.
- ✓ **Education** – Improve math and science education.
- ✓ **Immigration** – Enhance our ability to attract and retain high-skilled workers.
- ✓ **Workforce** – Expand community-based job-training grants to build workforce capacity.

★ **\$5.9B in FY2007; \$136B over 10 years**

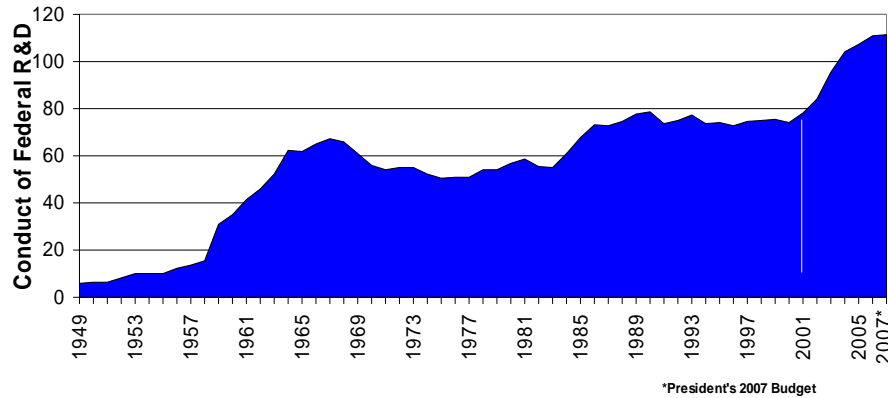
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The ACI addresses each component of the innovation ecosystem—research, both Federal and private sector-- education, and workforce.

To fund the research, education, and tax incentives, in FY 2007, the ACI commits \$5.9 billion. Over ten years, the initiative commits \$136 billion to enhancing U.S. competitiveness, including \$50 billion for Federal research alone.



### Federal R&D Spending (Outlays in billions, constant 2000 dollars)



**FY2007 Request is \$137.2 billion**

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The research funding called for by the ACI makes up a portion of the total R&D budget. Overall, the President's FY 2007 Budget increases the funding for R&D by \$3.4 billion to a new high of \$137.2 billion—51% more than the \$91.3 billion spent in FY 2001.

Analysis of Federal spending for R&D shows that the Administration's commitment to science and technology has been unprecedented since the Apollo program in the 1960's.

A significant portion of the increase in recent years has been in the life sciences with the doubling of the budget of the National Institutes for Health. During that time, the budgets for physical science research were relatively flat. Starting in 2007, the ACI seeks to restore balance in the Federal R&D portfolio.



## ACI Supports High Impact Research

- ❑ Double total funding for research within:
  - National Science Foundation
  - Dept. of Energy Office of Science
  - National Institute for Standards and Technology
  - ✓ Additional \$910M in FY07, \$50B over 10 years
- ❑ Make the research and experimentation (R&E) tax credit permanent and work with Congress to modernize it to be more effective.
  - ✓ \$4.6B in FY07, \$86.4B over 10 years

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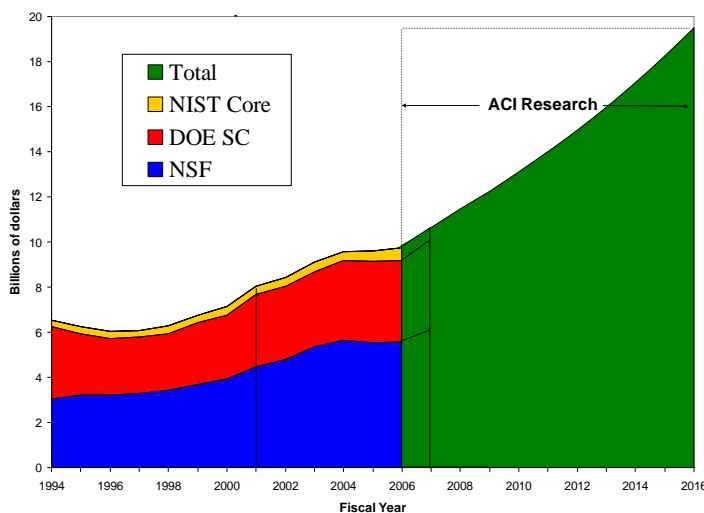
The ACI supports high impact research by both the Government and the private sector. The initiative calls for doubling the total funding for the agencies that fund basic physical science research that advances critical knowledge and innovation—the National Science Foundation, the Department of Energy (DOE) Office of Science, and the National Institute of Standards and Technology (or NIST) in the Department of Commerce.

The President's FY 2007 Budget proposes increasing the combined budget of these agencies by \$910 million. Over 10 years the ACI would increase those budgets by \$50 billion.

Although the Federal investment in R&D is substantial and growing, industry invests even greater amounts, spending roughly twice as much on R&D as the Federal government. To encourage growth in private sector research, the ACI would make permanent and modernize the Research and Experimentation Tax Credit, which expired at the end of last year. The President has budgeted \$4.6 billion in FY 2007 and \$86.4 billion over 10 years to modernize and make the credit permanent.



## ACI Research in FY2007-2016



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The Federal funding for research within agencies like NSF includes support for graduate and undergraduate students who receive training and education in the process. In addition, the ACI calls for \$380 million in FY 2007 to improve K-12 math and science education. Funds will go to enhance understanding of student learning, train math and science teachers, develop curricular materials, and improve learning.

To achieve these goals, the ACI provides \$250 million to establish math programs for elementary and middle school students that is based on a successful program to increase reading skills.

The programs will provide a range of resources to help students develop a strong foundation in mathematics and to prepare them for more rigorous coursework in middle and high school.

The ACI would increase the numbers of US student's passing Advanced Placement and International Baccalaureate programs by training 70,000 additional teachers and assisting with fees for students with financial need.

To further bolster math and science teaching, and at the same time providing students with role models, the ACI creates the Adjunct Teacher Corps. This program will enable science, mathematics and engineering professionals to earn the credentials they need to teach in local schools.

The Department of Education initiative will support partnerships between school districts and public or private organizations that encourage and prepare science, mathematics, and engineering professionals to teach high school math, science and technology courses on an adjunct basis.

The goal is to build a 30,000 member Adjunct Teacher Corps by 2015.

Education is the first step in the pipeline to developing a skilled technical workforce. However, the skills that are required for jobs today—much less those of tomorrow—do not always match the skills of the existing workforce.

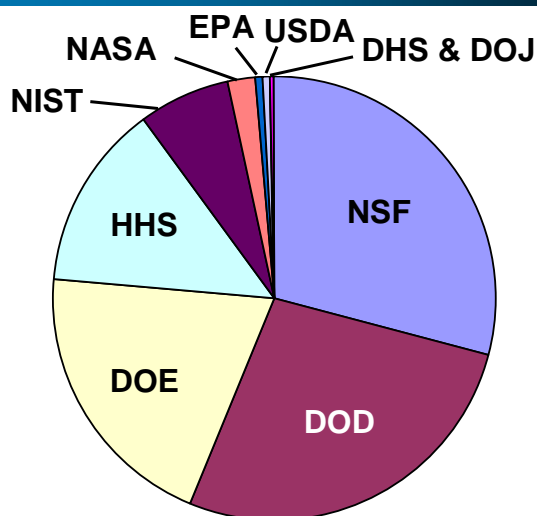
Under the ACI, the Department of Labor will expand grants to community colleges and community-based job-training centers to build workforce capacity in high-demand industries, including high-tech fields like information technology and healthcare.

In addition to providing the means to enhance our nation's well-trained workforce, the ACI seeks to strengthen our ability to attract and retain high-skilled workers from abroad while ensuring security, through existing and new visa programs.



## NNI FY 2007 Budget Request

Total = \$1.3 billion



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The provisions of the ACI directly benefit the National Nanotechnology Initiative (or NNI). The increase in funding at NSF, DOE Office of Science, and NIST under the ACI translates into greater funding for nanotechnology research at those agencies. The 2007 budget for nanotechnology research among these three agencies combined increased 14% over their estimated spending in 2006.

At NSF, the increases in 2007 will fund additional awards to individual investigators and to interdisciplinary research teams. The agency is particularly focusing on research that is aimed at using nanomaterials and processes to develop more complex structures and devices.

In 2007, the DOE Office of Science expects to have completed 4 out of 5 of its Nanoscale Science Research Centers. In fact, the official dedication of the Molecular Foundry at Lawrence Berkeley National Laboratory took place just over a month ago. I will say more about these facilities in just a minute.

NIST has established a Center for Nanoscale Science and Technology, which will bring together NIST competencies in measurement and manufacturing science at the

nanoscale. The NIST Center will provide access to the new Advanced Measurement Lab and its exceptional facilities for making high resolution measurements and experiments and state-of-the-art nanofabrication capabilities.

Precise and reliable methods of measurement, fabrication, and characterization are essential to making and using nanotechnology in commercial products and services. And NIST plays a critical role in support of the U.S. manufacturing sector in general, and the growing nanomanufacturing industry in particular.

Also of note, the EPA's budget for nanotechnology R&D is nearly doubled in FY 2007 compared to the estimate for 2006. The agency plans to develop in-house programs to complement its extramural research program. EPA's efforts continue to be focused primarily on understanding environmental and health effects.



## NNI Goals

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- *Sustain world class R&D*
- *Facilitate technology transfer*
- *Develop infrastructure: education; workforce preparation; facilities & instrumentation*
- *Support responsible development of nanotechnology*

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Together the investments across the Federal government are helping to achieve the goals of the NNI to:

- Sustain world class R&D;
- Facilitate technology transfer from the laboratory to the marketplace;
- Develop infrastructure, including materials and tools for education and workforce preparation, as well as facilities & instrumentation; and
- Support responsible development of nanotechnology.

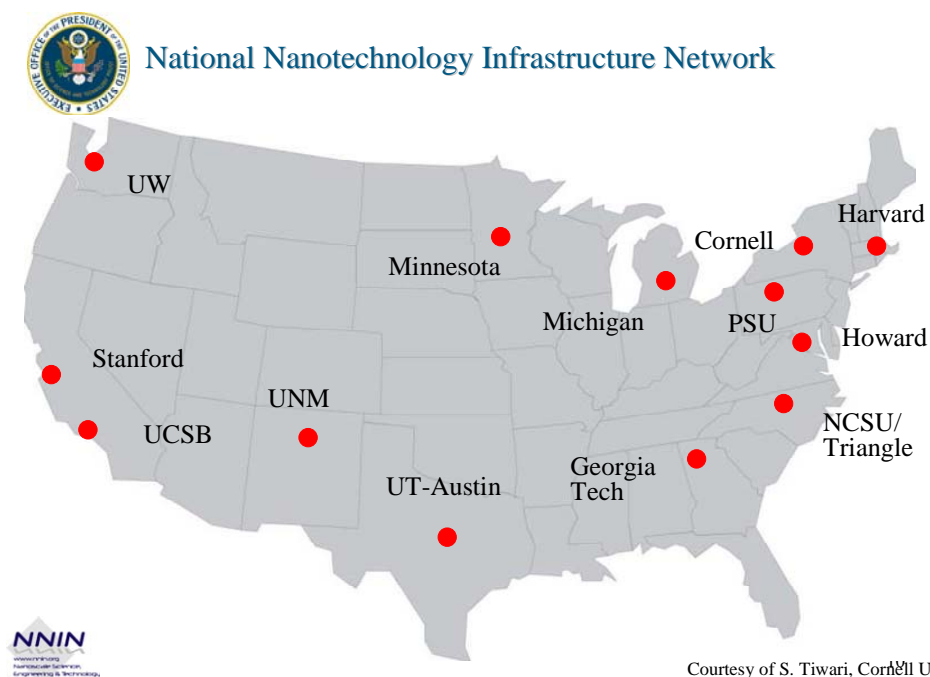
I would like to take a few minutes to elaborate on one aspect of the third goal—the infrastructure of user facilities that is in place or in the process of being completed.

The research and technology development that I have described depends, in many cases, on multidisciplinary research involving researchers from many areas working together. Frequently, it requires the use of advanced—and often costly—facilities and instrumentation.

The NNI has addressed these needs by funding a number of university-led multidisciplinary research centers and user facilities.

To date, over 50 centers and user facilities have been established, with participation by well over 100 universities and Federal laboratories across the country.

I would like to focus in particular on three groups of user facilities, which are accessible to the broad research community, not just researchers at the host institution.



The National Nanotechnology Infrastructure Network (NNIN) is a partnership of 13 universities—led by Cornell—that is funded by the National Science Foundation.

The NNIN supports nanoscale fabrication, synthesis, characterization, modeling, design, computation and hands-on training to all qualified users by providing access to both specialized equipment and expert technical staff.



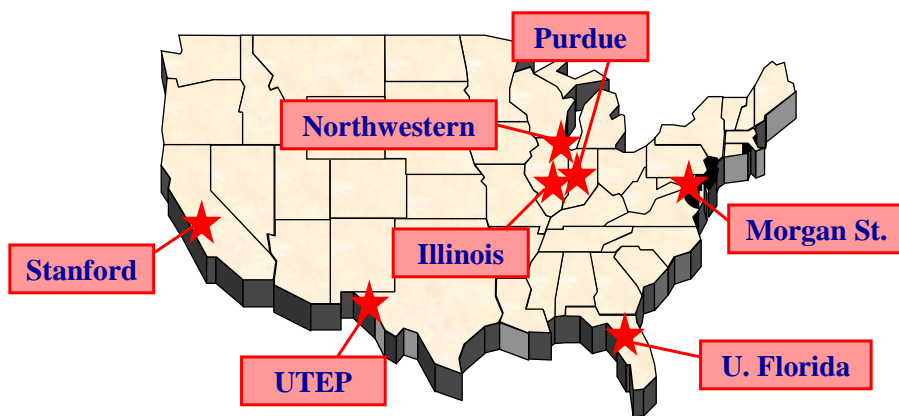
The screenshot shows the NNIN website interface. At the top, the address bar displays [http://www.nnin.org/nnin\\_reu.html](http://www.nnin.org/nnin_reu.html). The page header includes the NNIN logo and a navigation menu with the following items: HOW TO START A PROJECT (circled in red), REU, FAQ: GENERAL, TECHNICAL, MULTIMEDIA, EVENTS, ANNOUNCEMENTS, and CONTACT. Below the header is a banner image with the text "NATIONAL NANOTECHNOLOGY INFRASTRUCTURE NETWORK". The main content area features the heading "NNIN Research Experience for Undergraduates" and a sub-heading "NNIN conducts one of the largest and most successful Research Experience for Undergraduates programs in nanotechnology." The text describes the program's details, including the online application for the 2006 program, the hands-on research experience, and the national research convocation. A yellow box at the bottom of the page contains the text "The 2006 NNIN REU Program is now live!" and the URL [http://www.nnin.org/nnin\\_2006reu.html](http://www.nnin.org/nnin_2006reu.html). The browser's taskbar at the bottom shows several open applications, including Internet Explorer and various files.

The NNIN facilities house over 700 major tools, which are listed in a searchable webpage.

Getting started is as easy as clicking on “How to Start a Project” on their website at NNIN.ORG.



## User Facilities (NSF-funded): Network for Computational Nanotechnology



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The Network for Computational Nanotechnology (NCN), also funded by the National Science Foundation, is a network of 7 universities—led by Purdue University—that has a mission to connect theory, experiment, and computation to advance nanotechnology.

The screenshot shows the nanoHUB.org website interface. At the top, there is a navigation bar with "Home", "my nanoHUB", "Resources", "Contributors", "Events", "About", and "Support". Below this, a "Welcome to nanoHUB.org" banner includes a link to "Learn more about how to contribute your own content! Here's how." which is circled in red. The main content area features an "Online Simulation" section with a "Featured Tool" badge. The featured tool is "CENEMS: Electrostatics in NEMS Devices", which is also circled in red. The tool's interface shows a 2D schematic of a device with yellow dashed lines representing electric field lines. To the right of the main content, there are several sidebar sections: "What are you most interested in?" with radio buttons for various fields; "Focus Areas" with links to "Nanoelectronics", "NEMS/nano-photonics", and "Nano-bio"; "Topics" with links to "Carbon Nanotubes", "Molecular Electronics", "Nano-Transistors", "MEMS Theory", "Quantum Dots", and "MEMS"; and "Resources" with links for "K-12 Educators", "Undergraduate Educators", "Graduate Educators", "Researchers", and "Developers". The "Resources" section is also circled in red.

NCN investigators carry out research and provide on-line resources including a web-based computational user facility that makes research-grade software easily accessible. The NCN's Nanohub has links to simulation tools for nanoelectronics, nanomaterials, and semiconductor devices.

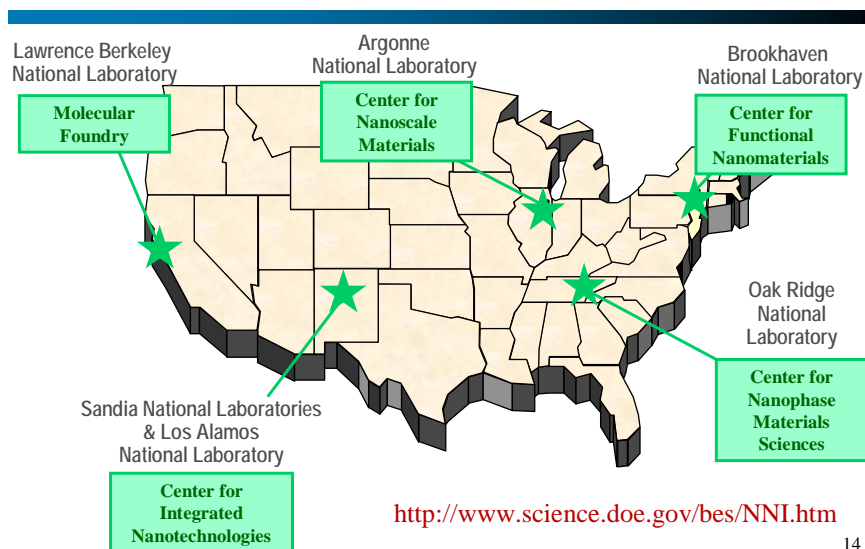
And researchers are encouraged not only to use NCN-developed software, but to share their software by making it available on the NCN website.

In addition to offering tools for researchers and developers of nanotechnology, the website has a wealth of material for educators and students from K-12 on up.



## DOE Nanoscale Science Research Centers

### State-of-the-art facilities



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In addition to the equipment and expertise that is available through the NSF university-based networks, the NNI had invested in and makes available to the broad user community, a premier set of research facilities for the synthesis, processing, and fabrication of nanoscale materials.

The DOE Office of Science is constructing five Nanoscale Science Research Centers.

The centers are collocated with existing DOE large user facilities, and provide additional equipment as well as staff expertise and support for the nation's nanoscience research enterprise.

The five centers are:

1. The Center for Nanophase Materials Science at Oak Ridge National Laboratory;
2. The Molecular Foundry at Lawrence Berkeley National Laboratory;
3. The Center for Nanoscale Materials at Argonne National Laboratory;
4. The Center for Integrated Nanotechnologies at Sandia National Laboratories (in conjunction with Los Alamos National Laboratory); and
5. The Center for Functional Nanomaterials at Brookhaven National Laboratory.

Since I spoke at the Nanotech 2005 conference, the Centers at Oak Ridge and Lawrence Berkeley National Labs have been occupied and are available for use. But even those that are not complete have "jumpstart programs" that fund collaborative work with laboratory staff using existing facilities and instrumentation.

The Centers provide specialized equipment and staff support otherwise not readily available to the research community. These centers are available to *all researchers* through a peer-reviewed process. For more on the Centers, I encourage you to visit the DOE Office of Basic Energy Sciences website.

**NANOTECHNOLOGY CHARACTERIZATION LABORATORY**

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**News & Events**

**06.01.2006**  
Next Submission Due Date for NCL Application Materials is June 2006. View submission procedures and evaluation criteria for NCL review of nanomaterials.

**01.19.2006**  
U.S. Measurement System (USMS) Workshop on Measurement and Standards Needs in Nanobiotechnology, Rice University, Houston, Texas. View details.

**Nanotechnology Characterization Lab**

Eliminating suffering and death from cancer requires an unprecedented collaborative effort that leverages resources from government, industry, and academia. Working in concert with the National Institute of Standards and Technology (NIST) and the U.S. Food and Drug Administration (FDA), the National Cancer Institute (NCI) established the Nanotechnology Characterization Laboratory to perform preclinical efficacy and toxicity testing of nanoparticles.

The NCL will serve as a national resource and knowledge base for all cancer researchers to facilitate the regulatory review of nanotechnologies intended for cancer therapies and diagnostics. By providing the critical infrastructure and characterization services to nanomaterial providers, the NCL can accelerate the transition of basic nanoscale particles and devices into clinical applications, thereby reducing suffering and death from cancer.

As part of its assay cascade, the NCL will characterize nanoparticles' physical attributes, their *in vitro* biological properties, and their *in vivo* compatibility using animal models. The time required to characterize nanomaterials from receipt through the *in vivo* phase is anticipated to be one year.

**Learn about the application process to submit materials.**

**NCL Spotlight**

**NCL Business Plan**  
Learn how the NCL, NIST and FDA are collaborating to fight cancer.

**Quick Guide to Application Process**  
View submission procedures and evaluation criteria for NCL review of nanomaterials.

**Nanotechnology WebSite**  
visit site >

Another user facility that serves the broad research community is the National Cancer Institute's Nanotechnology Characterization Lab. Working in partnership with NIST and the U.S. Food and Drug Administration, the Institute's Nanotechnology Characterization Laboratory performs preclinical efficacy and toxicity testing of nanoparticles.

The laboratory serves as a national resource and knowledge base for all cancer researchers to facilitate the regulatory review of nanotechnologies intended for cancer therapies and diagnostics. By providing the critical infrastructure and characterization services to nanomaterial providers, the laboratory can accelerate the transition of basic nanoscale particles and devices into clinical applications.

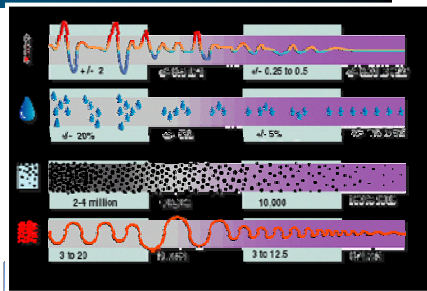
Access to the laboratory services is gained through an application & review process. The next quarterly deadline for white paper proposals is June 1<sup>st</sup>. For information about the Lab and the application process, go to [NCL.CANCER.GOV](http://NCL.CANCER.GOV).

You can also hear more about the Institute's Nanotechnology for Cancer Alliance, the Nanotechnology Characterization Lab, and the role of NIST and the FDA at the session tomorrow afternoon.



## NIST Advanced Measurement Laboratory

- Is the world's best measurements laboratory
- Will provide the standards and measurements needed for 21<sup>st</sup> century key technologies
- Establishes the *Center for Nanoscale Science and Technology* (CNST) to provide the best measurement capabilities to industry.



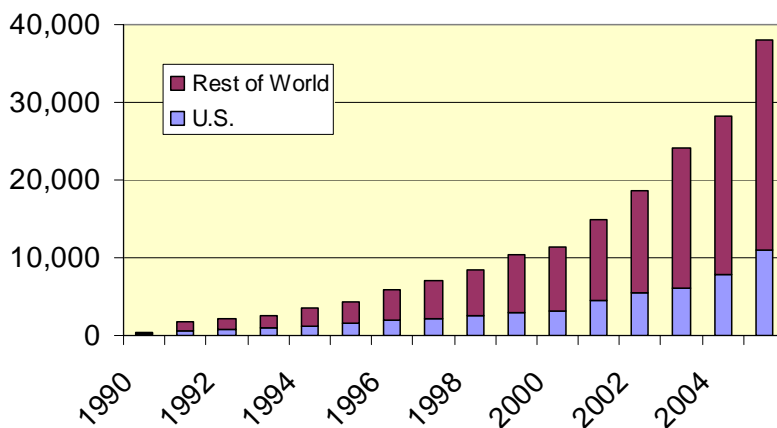
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And finally, the gold standard, if you will, of measurement facilities is the Advanced Measurement Laboratory at NIST. The AML is the centerpiece of NIST's recently announced Center for Nanoscale Science and Technology.

The Center leverages NIST's unique combination of expertise and facilities in measurement science to facilitate innovation in nanotechnology and related frontier areas of science and technology. The Center will develop and support state-of-the-art infrastructure necessary to pursue nanometrology, nanostandards, and nanomanufacturing research.



## Nanotechnology Publications



Search of ISI Web of Science using "nano\*"

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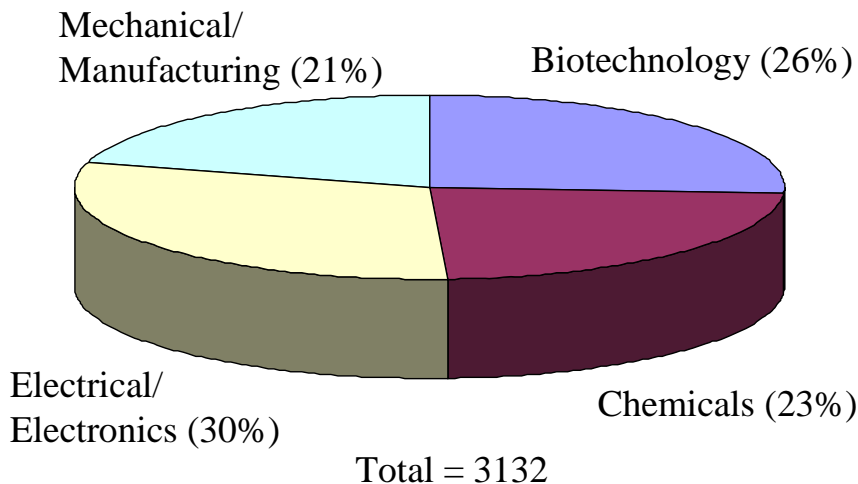
The considerable investment in infrastructure and research by the U.S. and other governments and by the private sector has resulted in a torrent of knowledge that is represented by growing attendance at meetings like this one (and at the same time, an explosion in the number of competing meetings). Likewise, there has been an exponential growth in the number of articles and even entirely new journals devoted to nanoscale science and technology. This slide plots data through 2005 provided by Dr. Jim Murday of the Naval Research Lab.

These data indicate continued growth in the number of publications, with U.S.-based authors making up between one quarter and one third overall.

This fraction is roughly equal to the fractional investment by the United States government out of the total investment by nations worldwide.



## U.S. Nanotechnology Patents & Published Patent Applications (1974-2005)



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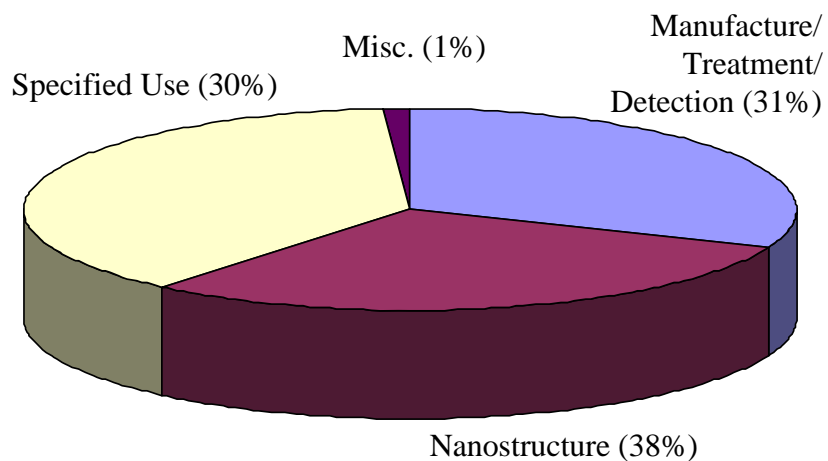
Patents are another output of research that is more closely related to innovation and eventually commercialization. Not surprisingly, the number of U.S. patents that reference nanotechnology is increasing. More telling is the distribution of these patents among the technical areas defined by the U.S. Patent and Trademark Office (PTO).

In 2004, PTO established a new cross-reference digest of patents on nanotechnology that includes patents from all of the “technical centers”. This approach recognizes that nanotechnology is an enabling technology that will be applied in many fields or industries.

As of January 2006, over 3000 patents and patent applications have been classified as relating to “nanotechnology.” These are split rather evenly among 4 major categories of inventions: biotechnology, chemicals, electrical & electronic materials & systems, and mechanical systems (including manufacturing).



## Nanotechnology Patent Subclasses



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Within the Nanotechnology Class, the PTO has a number of subclasses based on the nature of the invention. To date, roughly one third fall within each of three subclasses— nanostructures; manufacture/ treatment/ & detection; and specified use (such as biochemical detection or drug delivery).



NNI-funded basic and applied research has resulted in more than just papers and patents. There are new technologies that could have a real impact.

This slide illustrates a variety of nanotechnology-based applications, some of which are available today and others which are expected in the future.

Perhaps in no field is there as much hope as that of “Nanomedicine.” We imagine using nanotechnology to target and kill cancerous cells before symptoms even appear. To monitor and adjust blood sugar in diabetics without intervention so as to avoid the disease’s devastating affects, such as blindness, loss of extremities, and death. And in handheld tools that allow diagnosis of a host of illnesses and conditions in a doctor’s office, at home, or in a remote corner of the world far from conventional healthcare facilities.

Recently, advances have been reported in the ability to direct various nanoparticles to cancer cells and by optical or magnetic interaction, to cause heating that kills the cancer with little damage to surrounding healthy tissue.

Other approaches use nanoparticles to deliver drugs right to the tumor. Literally dozens of papers at this conference alone are reporting on research on the use of nanotechnology to detect and treat cancer. Published reports have estimated that over 150 therapies are in various stages of development worldwide.

By Nanotech 2007, we will undoubtedly see further progress toward targeted cancer therapies.

Other applications range from solid state lighting and next-generation electronics, to tougher coatings and medical imaging. A material that sometimes seems like the “poster child” for nanotechnology is the carbon nanotube (shown in a paper-like mat at the bottom center of this slide, and as a ball-and-stick model at the bottom right).

With unique physical and electrical properties, nanotubes have potential application in everything from power transmission lines to flat panel displays to super-strong structural materials.

Yet carbon nanotubes are also an example of the challenges that lie ahead. In order to be able to take advantage of their unique properties in commercial applications and products, manufacturers need to be able to obtain reliable materials at reasonable cost. Today, the price of high purity material can be several times that of gold by weight, and for many would-be purchasers, the watchword is “buyer beware.”

The obstacles to manufacturing carbon nanotubes is the subject of a session later this morning, chaired by the Director of the National Nanotechnology Coordination Office, Clayton Teague.

Through collaborations among researchers such as yourselves—from industry and academia, and from disciplines that span the fields of science and engineering—progress in scientific understanding at the nanoscale will continue, and challenges to realizing the benefits—including scaled up manufacture of carbon nanotubes—will be overcome.



“Tonight I announce an *American Competitiveness Initiative*... 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 (2006 State of the Union Address)*

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The role of nanotechnology in our Nation’s technological and economic well-being was specifically called-out in the President’s 2006 State of the Union address, in which he announced ACI and the doubling of funding for “the most critical basic research programs in the physical sciences over the next 10 years.”

The President stated:

“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.”

Looking around, I see a lot of “creative minds.” I applaud your work and I wish you a stimulating and informative conference.