Federal Nanotechnology R&D Program
2nd National Nanotechnology Advisory Panel Review

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January 8, 2008

History of PCAST and the NNI

- 1999 - PCAST supports the establishment of an NNI
- FY 2001 - NNI launched
- 2002 - NRC report “Small Wonders, Endless Frontiers” recommends that OSTP establish an independent standing advisory board.
- Feb 2003 - President tasks PCAST with reviewing NNI
- Dec 2003 - 21st Century Nanotechnology R&D Act signed, calling for the President to establish or designate a National Nanotechnology Advisory Panel
- July 2004 - President designates PCAST as the NNAP
- May 2005 - PCAST issues its first review of the NNI

NNAP responsibilities under the 21st Century Nanotechnology R&D Act

Assess:

- Trends and developments in nanotechnology.
- Progress in implementing the program.
- Need to revise the program.
- Balance among the component areas of the program, including funding levels.
- Whether program component areas, priorities, and technical goals developed by the NSET are helping to maintain US leadership.
- Management, coordination, implementation, and activities of the program.
- Whether social, ethical, legal, environmental, and workforce concerns are adequately addressed by the program.

Report and make recommendations every 2 years

Other review & planning activities

- National Academies to review & assess the NNI every 3 years (first review released September 2006)
- Interagency NSET Subcommittee to update NNI Strategic Plan every 3 years (revised update released December 2007)
- ★ Recommend that NNAP schedule for reporting be changed from every 2 years to every 3 years to be better aligned with the schedule for the National Academies review and NNI strategic planning.

Summary of 2005 NNAP Review

- U.S. is acknowledged global leader in nanotechnology R&D
  - Federal research investment is ~1/4 of total government investment
  - U.S. has the most nano-based start-up companies and produces by far the most patents and publications in nanotechnology.
- But growing public and private investment around the world is raising competitive pressure on U.S. leadership.
- U.S. Federal investment in nanotechnology R&D is robust and well-spent.
  - Effective program guidance from the NNI Strategic Plan
  - Effective management and coordination via the interagency NSET subcommittee
- The NNI is working to identify, prioritize, and address research to understand environmental and health effects of nanotechnology as well as other societal and ethical implications of nanotechnology.

Inputs to Present Review

- Expert briefings at full PCAST and Subcommittee meetings
- Ad hoc nanotechnology technical advisory group (nTAG)
- PCAST public meeting on nanotechnology (6/25/2007) on commercialization and environmental, health, and safety (EHS) issues
- Meetings, site visits, and interviews with NNI agency representatives

Structure of 2007 Review

- PROGRESS AND STATUS
  - Investment, output, management, coordination
- APPLICATIONS
  - Innovation context, challenges, and cases
- IMPLICATIONS
  - Perspective on EHS and ethics activities and needs
- RECOMMENDATIONS

NNI Participating Agencies With Budgets Dedicated to Nanotechnology R&D (13)

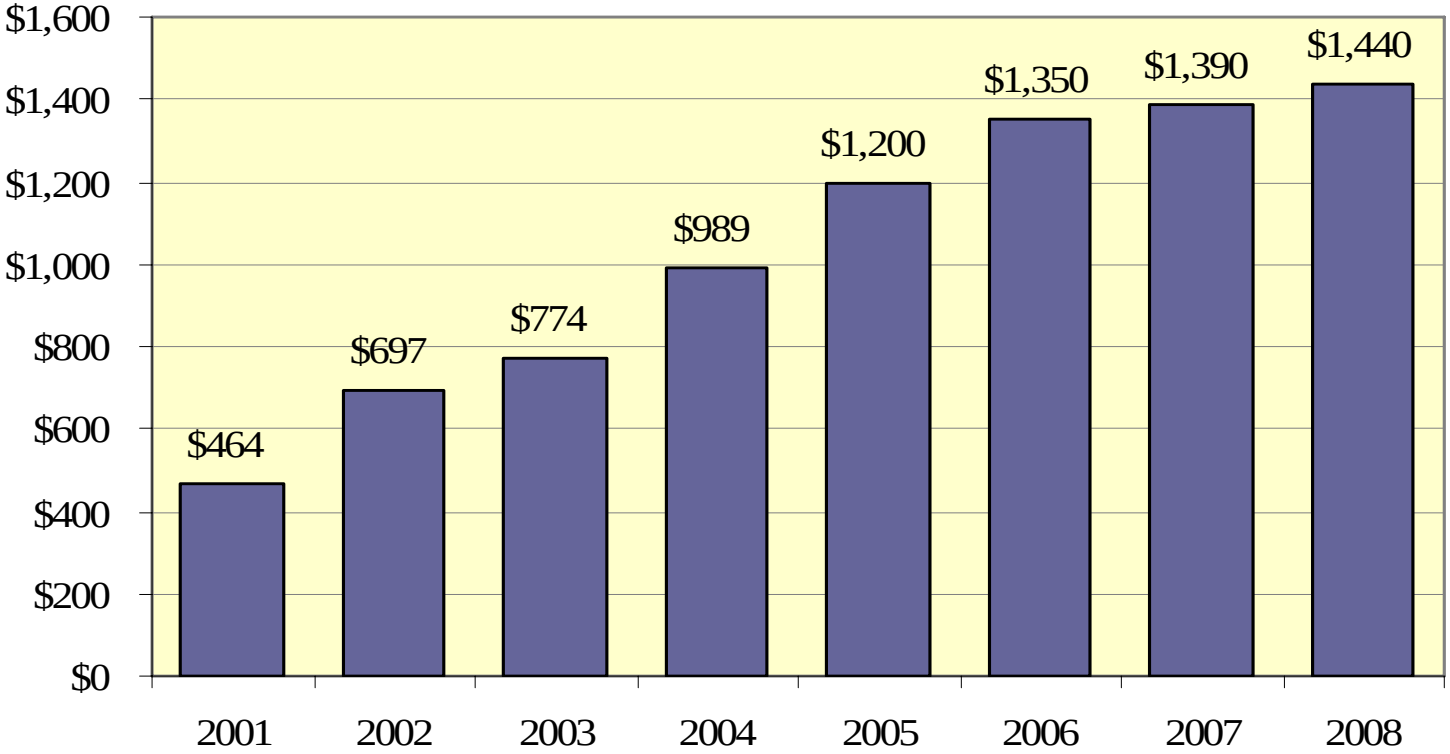
- **National Science Foundation** (NSF)
- **Department of Defense** (DOD)
- **Department of Energy** (DOE)
- **National Institutes of Health** (NIH, Department of Health & Human Services)
- **National Institute of Standards and Technology** (NIST, Department of Commerce)
- National Aeronautics and Space Administration (NASA)
- Environmental Protection Agency (EPA)
- National Institute for Occupational Safety and Health (NIOSH, DHHS)
- USDA Forest Service (FS, Department of Agriculture)
- USDA Cooperative State Research, Education, and Extension Service (CSREES, Department of Agriculture)
- Department of Homeland Security (DHS)
- Department of Justice (DOJ)
- Department of Transportation (Federal Highway Administration)

Other NNI Participating Agencies (12)

- Bureau of Industry and Security (BIS, Dept of Commerce)
- Consumer Product Safety Commission (CPSC)
- Department of Education (DOEd)
- Department of Labor (DOL)
- Department of State (DOS)
- Department of the Treasury (DOTreas)
- Food and Drug Administration (FDA, HHS)
- Intelligence Advanced Research Projects Activity (IARPA, representing the Intelligence Community)
- International Trade Commission (ITC)
- Nuclear Regulatory Commission (NRC)
- U.S. Geological Survey (USGS, Department of the Interior)
- U.S. Patent and Trademark Office (USPTO, Dept of Commerce)

PROGRESS AND STATUS

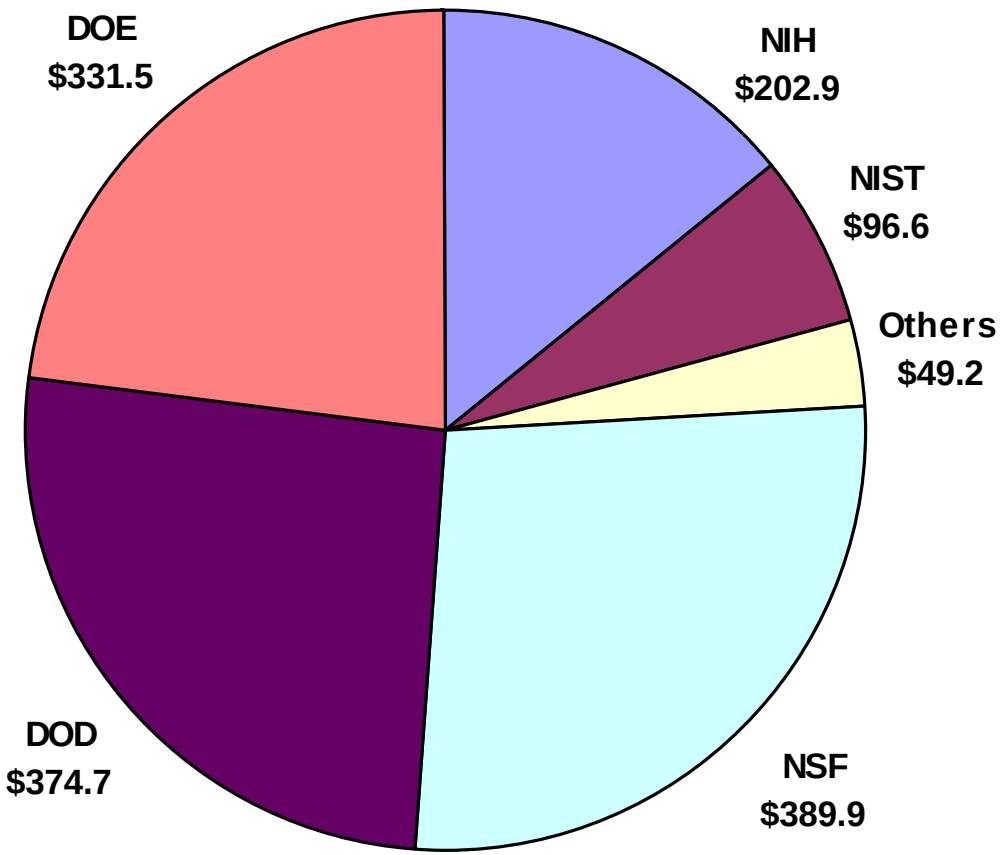
Growing investment – NNI Budgets



Collective agency funding (in $ millions) reported since NNI inception (2007 is estimated and 2008 is requested)

PROGRESS AND STATUS

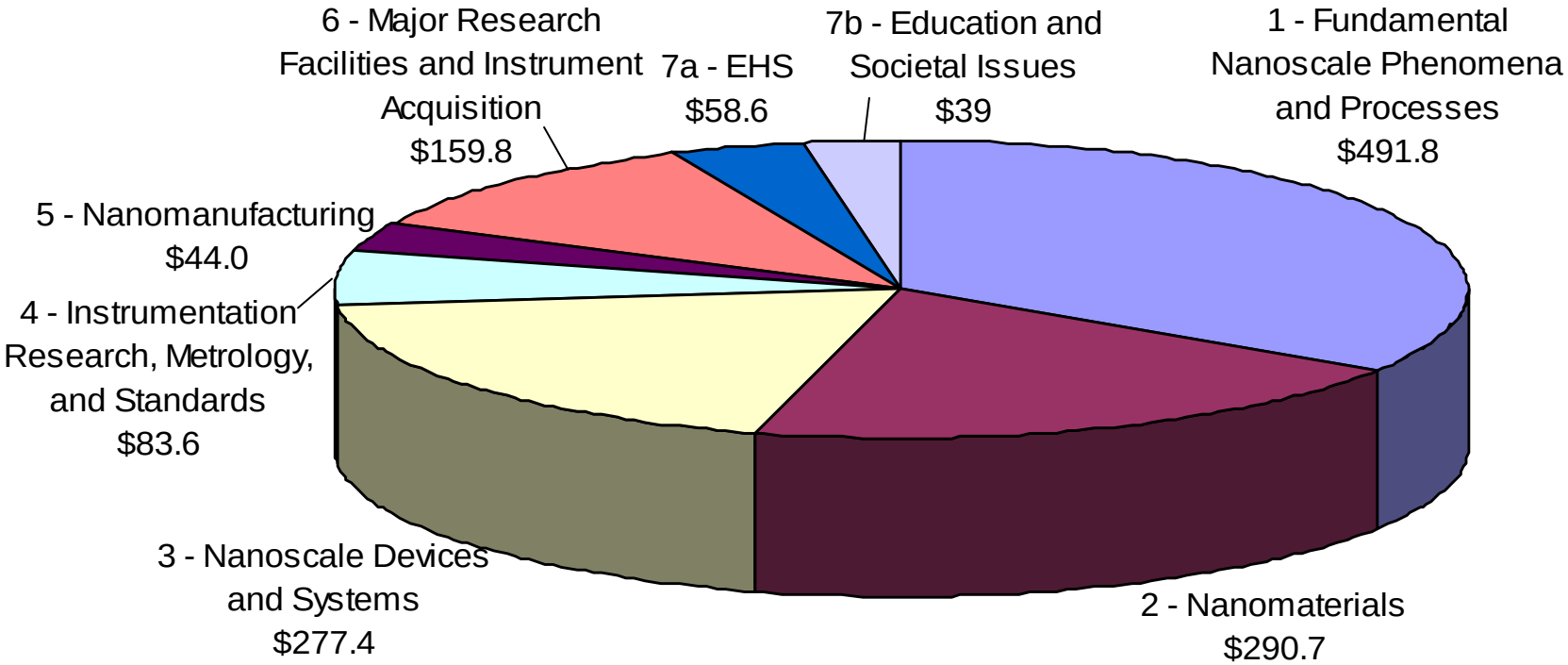
NNI FY 2008 Budget Request by Agency



$ in millions; total = $1.44 billion

PROGRESS AND STATUS

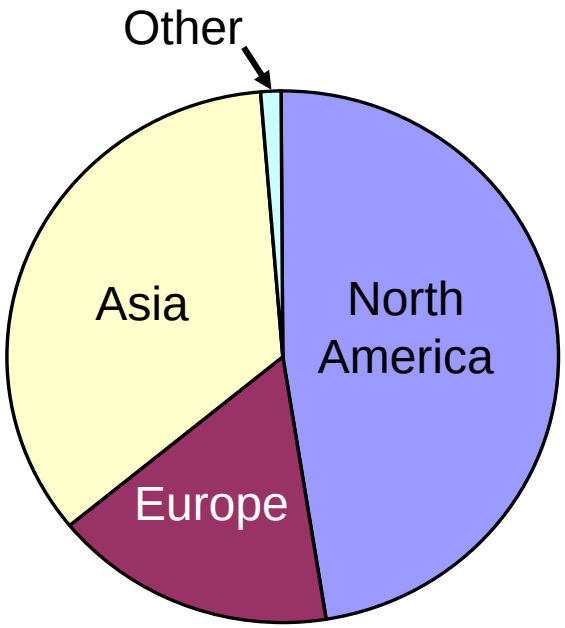
NNI FY 2008 Budget Request by PCA



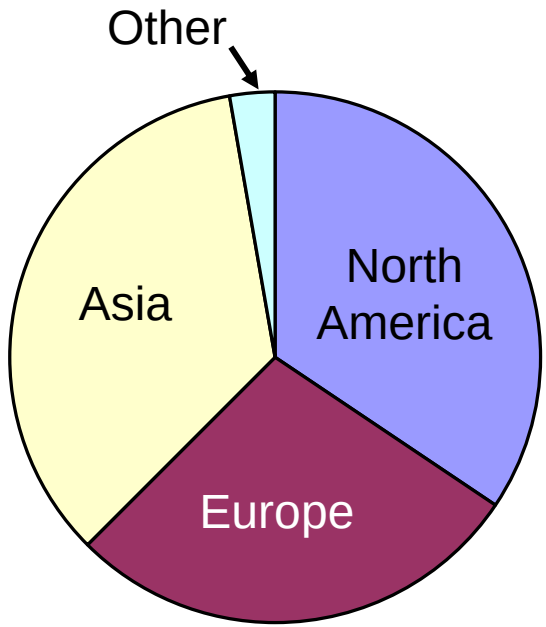
$ in millions; total = $**1.44 billion**

PROGRESS AND STATUS

Growing investment – $8.6 billion in 2004



Private (Corp. + VC)
Total = $4 billion

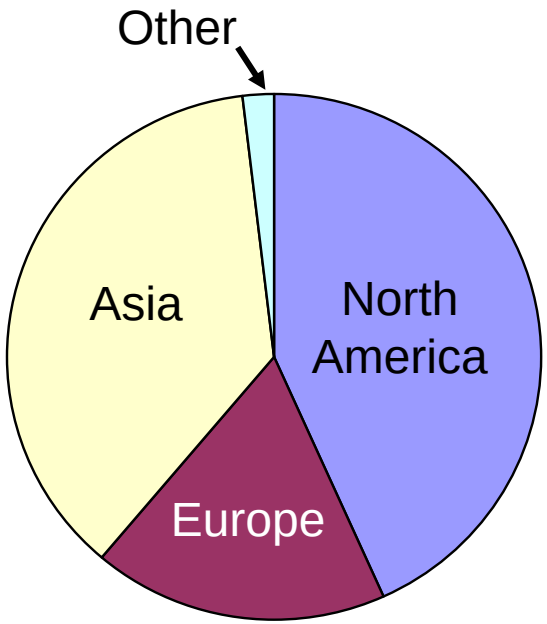


Public (National, regional, state)
Total = $4.6 billion

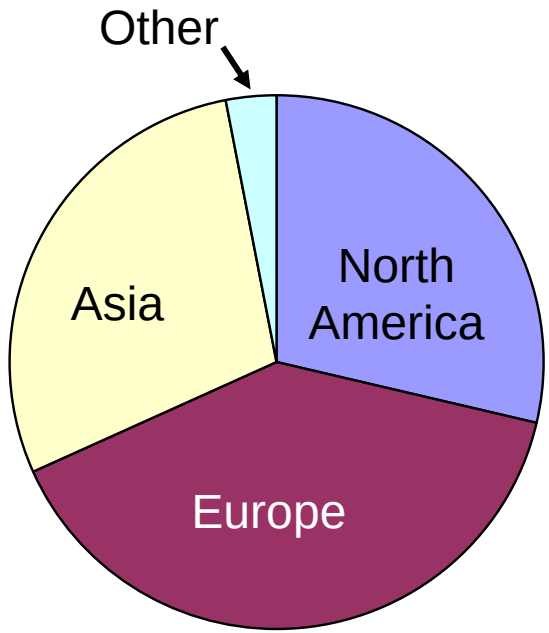
Source: Lux Research

PROGRESS AND STATUS

Growing investment - $**12.4** billion in 2006



Private (Corp. + VC)
Total = $**6** billion



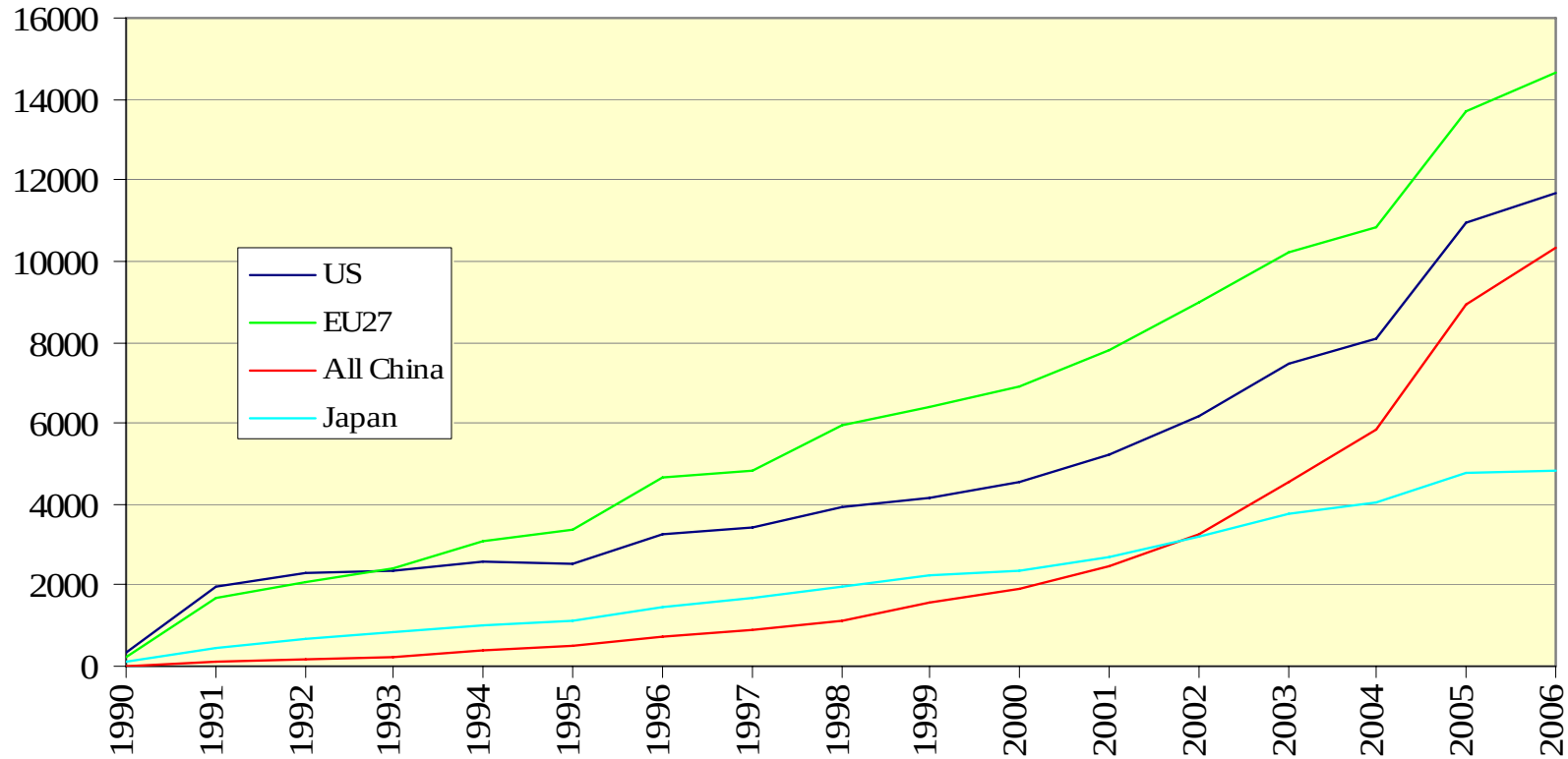
Public (National, regional, state)
Total = $**6.4** billion

Source: Lux Research

PROGRESS AND STATUS

Measuring Output – Quantity of Publications

Nanotechnology publications in the *Science Citation Index* (SCI)

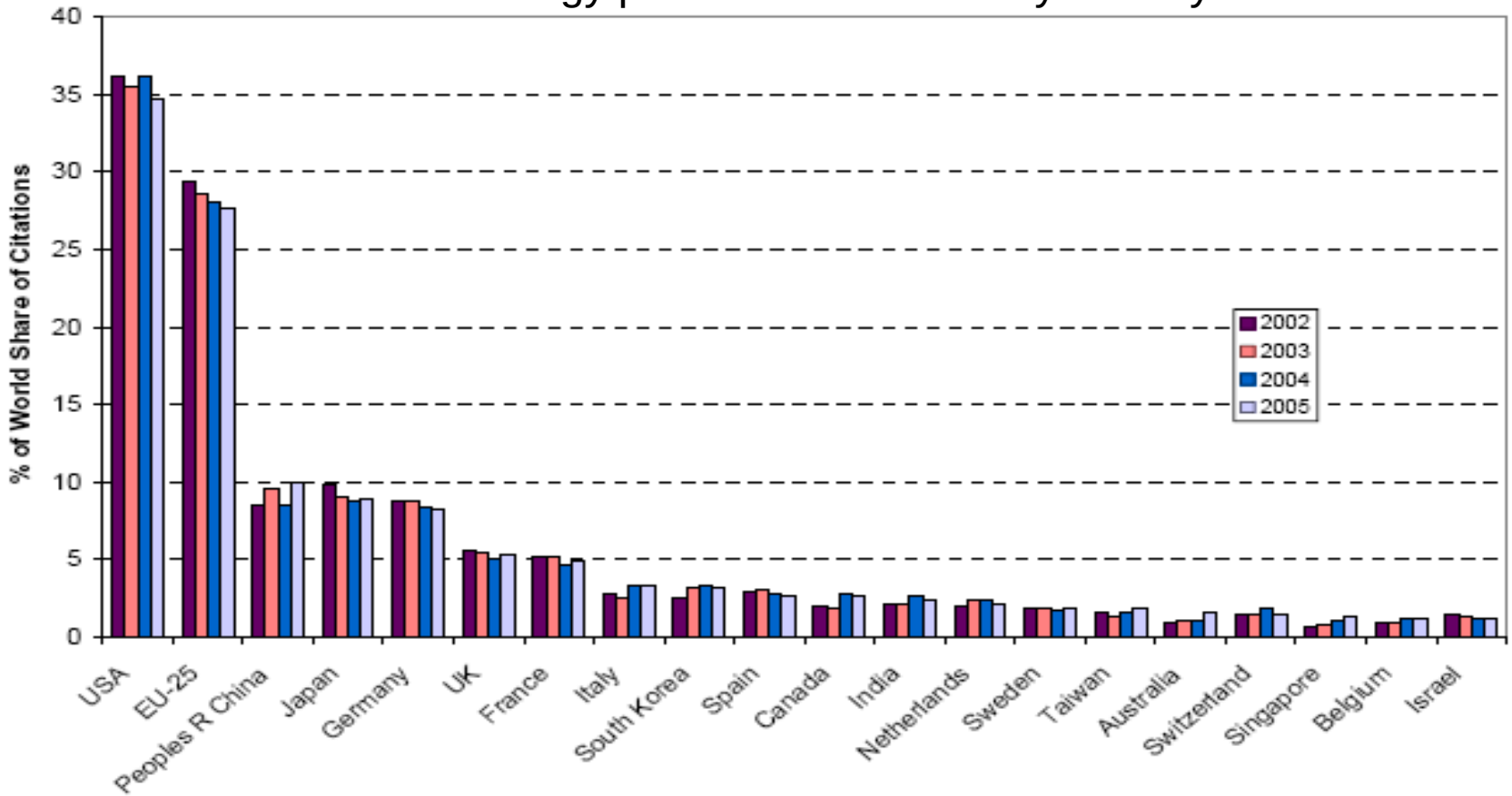


Data based on text search of the Science Citation Index as of August 2006 for nano* excluding terms of scale alone (e.g., nanosecond, nanoliter, nanogram, nanomolar, nanonewton) and including relevant terms without the nano prefix (e.g., quantum dot, quantum well, molecular device, molecular wire, fullerene, spintronic, molecular electronic or dendrimer)

PROGRESS AND STATUS

Measuring Output – Quality of Publications

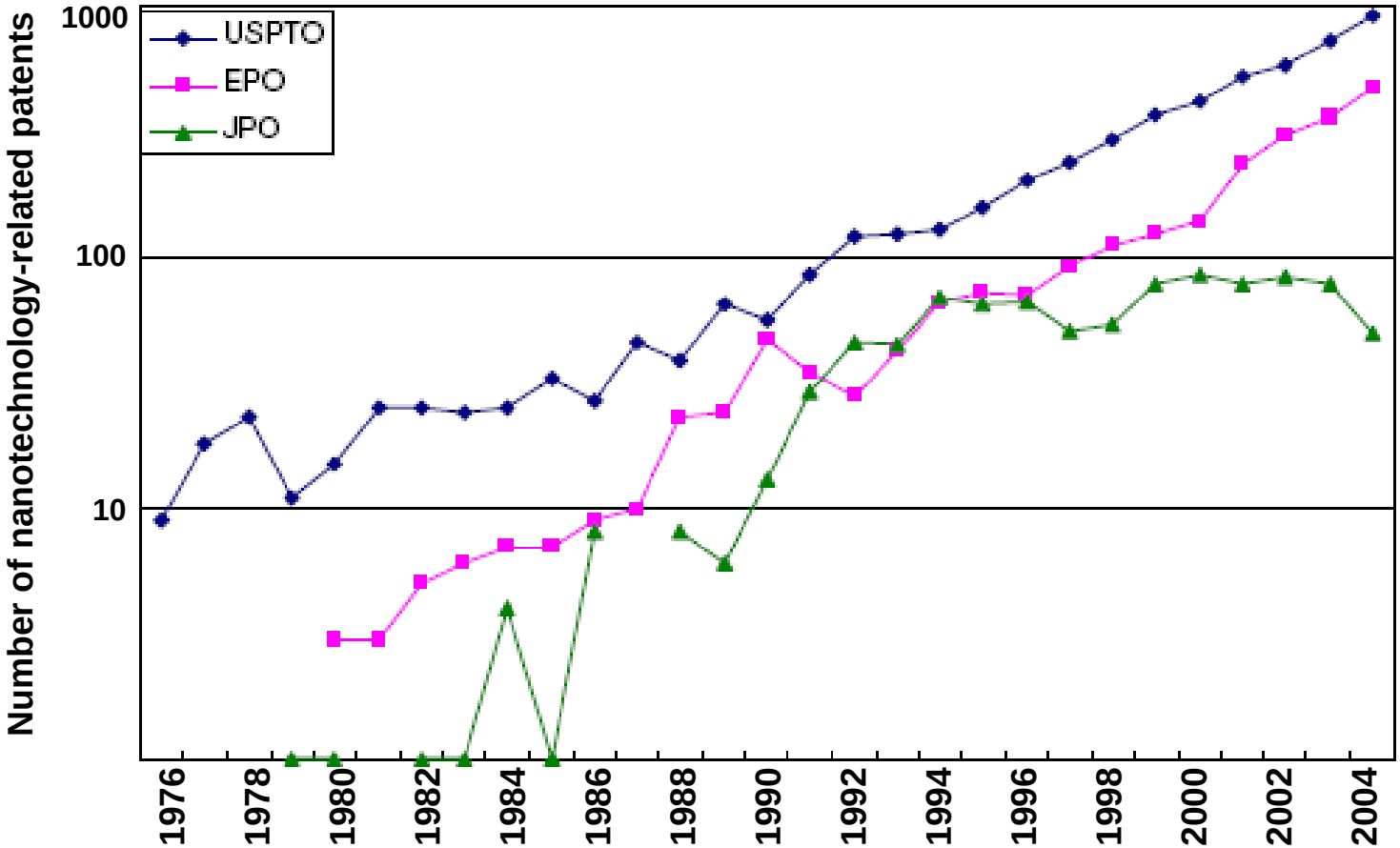
Nanotechnology publication citations by country



Source: Leydesdorff, L. and Wagner, C. (2006). "Is the United States losing ground in science? A global perspective on the world science system." (http://users.fmg.uva.nl/lleydesdorff/us_science/index.htm)

PROGRESS AND STATUS

Measuring Output – Quantity of Patents

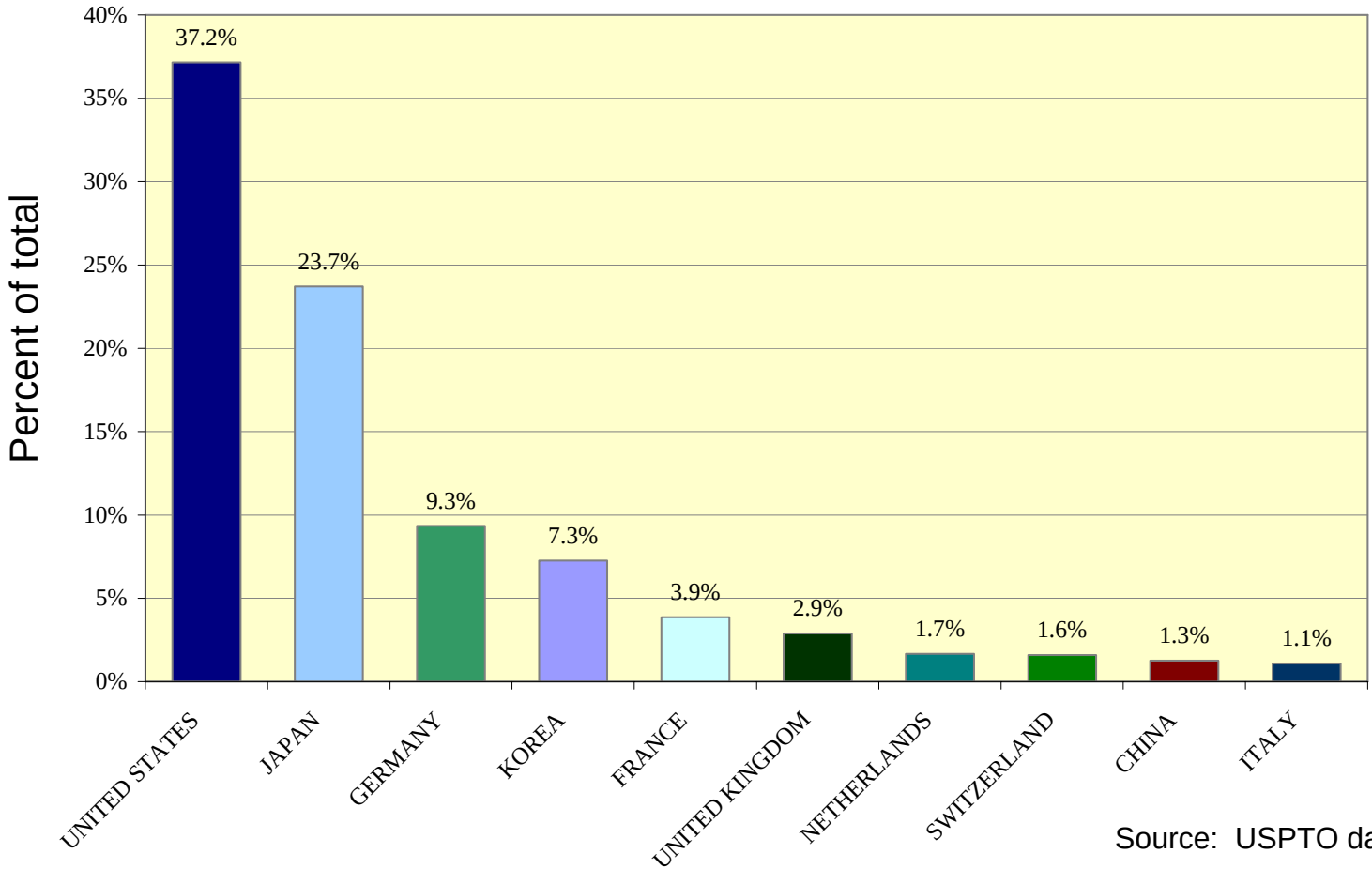


Source: Li, X., et al. (2007). "Worldwide nanotechnology development – a comparative study of USPTO, EPO, and JPO patents (1976-2004)." *Journal of Nanoparticle Research*

PROGRESS AND STATUS

Measuring Output – Quality of Patents

Three or more nanotechnology-related patent publications on same invention, by country of assignee (1985-2005)



Source: USPTO data

PROGRESS AND STATUS
NNI Infrastructure

- **Over 80 nanotechnology research centers, networks, and user facilities linked in a world-class interdisciplinary infrastructure**

- **Over 4500 active research projects in 2007 at over 500 universities, Government labs, and other research institutions in all 50 states**

Source: NNCO

APPLICATIONS
Context of Commercialization

- Growing impact of nanotechnology development remains broadly distributed
  - Spectrum of industry
  - Point on chain of innovation
  - Product composition
- Extent to which a product or process is enabled by nanotechnology or composed of nanomaterials varies substantially – challenges include:
  - Standards development
  - Market evaluation
  - Regulatory assessment

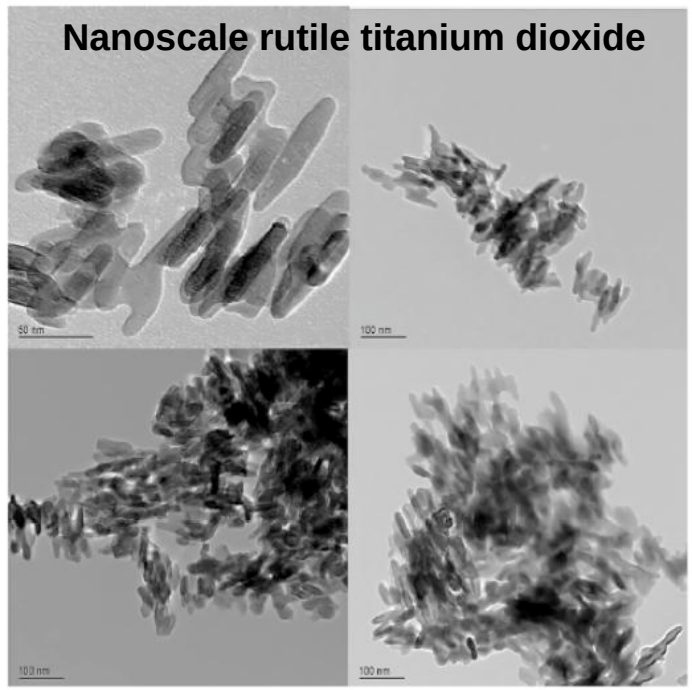
APPLICATIONS
nTAG feedback on areas of opportunity

- Many of the early applications evident today are evolutionary improvements over existing materials and products
- Nanotechnology research and development has advanced faster than expected in many areas of opportunity
  - Drug delivery devices
  - Energy conversion and storage

APPLICATIONS

Case Study – Nanotechnology and Sunscreens

- Nanoscale metal oxides (TiO_2, ZnO) are key ingredients in many sunscreens
  - Transparent instead of white
  - Adheres better when it is applied
  - Absorbs harmful UVA rays more effectively
- Though exposure and toxicology research continues, the majority of evidence to date suggests that TiO_2 nanoparticles in sunscreens do not penetrate intact skin during normal use.
- Nonetheless, many have called for product withdrawals, labeling, or a complete moratorium.



APPLICATIONS
Case Study – Nanotechnology and Sunscreens

- But when relative risks and benefits of nano-based sunscreens and those with other active ingredients are considered fully and on balance, those with nanoscale metal oxides appear to be the safest and most effective available
  - The data on TiO_2 suggests no hazard and better reduction of UV risk, whereas many other active ingredients are known hazards with less UV blocking benefit
- Conclusions:
  - Relative risks and benefits of a specific nano-based application must be set in the broader context of human health
  - Need for more accurate, effective and intentional communication from all sectors

APPLICATIONS
Other examples of commercial applications

- Wide variety of commercial products with "nanomaterials incorporated" into the structure, e.g.,
  - Films
  - Catalysts
  - High-strength fibers
  - Semi-conductor chips

APPLICATIONS
Overcoming Challenges

- Barriers to nanotechnology innovation
  - **Lack of standards**
  - Questions about EHS implications
  - Limited/restricted venture capital
  - Insufficient education and workforce preparation
- NNI's continued approaches
  - Balance of basic and application-targeted research support, based on strategic plans
  - Support of extensive infrastructure
  - Interdisciplinary education and training

IMPLICATIONS

NNI Nano EHS Research Strategy

- September 2006 – *Environmental, Health, and Safety* ***Research Needs*** *for Engineered Nanoscale Materials* report of the NEHI working group
- August 2007 – ***Prioritization*** *of Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials* interim report released for public comment, based on 1) the value of information and 2) the ability to leverage relevant research funded by other governments and the private sector
- In progress – More detailed analysis of Federal nano EHS research activity and development of an NNI EHS research strategy to address gaps/weaknesses, including transparent re-evaluation of research needs, priorities, and progress.

IMPLICATIONS
NNI Agency Nano EHS Activities

- **NIOSH** call for information in *Approaches to Safe Nanotechnology* – invites expert feedback from private industry and others
- **NIOSH** report on *Progress Toward Safe Nanotechnology in the Workplace* (June 2007)
- **EPA** White Paper summarizing anticipated approach to nanotechnology EHS research (agency research strategy to be released soon)
- **EPA** Voluntary Nanoscale Materials stewardship program
- **FDA** Nanotechnology Task Force report seeking to clarify a predictable pathway for application of existing regulatory approaches for developers of nanotechnology-enabled products under its jurisdiction.
- **NIST** work on standard reference materials for nanoscale gold and carbon nanotubes

IMPLICATIONS
NNI Nano EHS Research Support

- Total funding up from $34.8 million in 2005 to a requested $58.6 million in the President's FY 2008 nanotechnology budget
- Includes *only* research that is primarily focused on environment and health effects of nanotechnology
- Nano EHS research growth rate well above that of the whole program
- U.S. funding for nano EHS research far outweighs all others globally

IMPLICATIONS
International coordination on nano EHS

- Organization for Economic Cooperation and Development (OECD)
  - U.S. chairs the Working Party on Manufactured Nanomaterials, which is working to share EHS information and coordinate the development of information that is needed by governments and industries worldwide
- International Standardization Organization (ISO) technical committee on nanotechnologies
  - Fundamental for better understanding, communication, and oversight as well as large-scale growth of nanotechnology commercialization
  - Terminology & nomenclature, instrumentation & metrology, EHS
  - U.S. leads subgroup on EHS

IMPLICATIONS
Balanced perspective on nano EHS

- NNI is highly active in—and widely supports—nano EHS R&D and its coordination with industry and international stakeholders
- Manufacturers have a unique responsibility for product and workplace safety
  - Companies that make and use nanomaterials must also be involved in developing information about the properties of the nanomaterials in their products
- Negative public perceptions threaten our ability to obtain the full benefits of nanotechnology

IMPLICATIONS
Ethics

- Activities
  - NSF Centers for Nanotechnology and Society awarded in 2005
  - NSET convened workshop in January 2007
  - Engagement of President's Council on Bioethics

IMPLICATIONS
Communication and Outreach

- Public engagement remains part of:
  - All NSF university-based centers
  - All DOE user facilities
  - NNAP process
  - Interagency NSET Subcommittee (via its Nanotechnology Public Engagement Group)
  - NNI outreach via www.nano.gov

RECOMMENDATIONS
NNAP Review

- Overview
- 19 recommendations in 6 areas
  - Infrastructure, management, and coordination
  - Standards
  - Technology transfer and commercialization
  - EHS implications
  - Societal and ethical implications
  - Communication and outreach
- Anything that we have missed?
  - Specific area
  - Specific recommendation

RECOMMENDATIONS
Overview

- NNI remains well organized and well managed and constitutes a model program
- The eight Program Component Areas designated in the updated NNI Strategic Plan are appropriate and sufficient for program management.
- The NNAP recommends some adjustments to improve and strengthen NNI, and to maintain U.S. leadership in and benefit from nanotechnology R&D

RECOMMENDATIONS
Infrastructure, Management, and Coordination

1. Ensure continuing support from NNI member agencies and from Congress for NNI **multidisciplinary** centers, networks, and user facilities for nanoscale research.
2. Seek to improve *intra-agency* coordination.
3. Strengthen participation by DOC, DOEd, and DOL
4. Coordinate NSET Subcommittee activities with related interagency working groups (e.g., IWG on Manufacturing R&D).
5. Continue to function as the central coordination for nanotechnology R&D—including nanotechnology EHS research.

RECOMMENDATIONS
Standards

6. Participate in the development of voluntary consensus-based standards.
7. Develop material and analytical standards for nanotechnology EHS research.
8. Work towards development of minimum data sets of physical and chemical properties of nanomaterials.

RECOMMENDATIONS
Technology Transfer and Commercialization

9. Expand efforts to assess national and international innovation and commercialization activities.
10. Continue to build connections across the innovation ecosystem.
11. Educate scientists and engineers.

RECOMMENDATIONS
EHS Implications

12. Complete the strategy for nanotechnology-related EHS research.
13. Coordinate the nanotechnology EHS strategy with industry and international stakeholders.
14. Do not segregate implications research and applications research.
15. Continue developing joint programs among NNI agencies that leverage expertise and resources to conduct nanotechnology EHS research and to support agency missions.
16. Support wide distribution and availability of new nonproprietary information about the properties of nanomaterials.

RECOMMENDATIONS
Societal and Ethical Implications

17. Research on the societal and ethical aspects of nanotechnology should both be integrated with technical R&D and take place in the context of broader societal and ethical scholarship.

RECOMMENDATIONS
Communication and Outreach

18. Demonstrate more clearly the value of nanotechnology and NNI-supported research and development.
19. Enhance communications efforts within the NNCO.

RECOMMENDATIONS
Discussion

- Anything we have missed?
  - Specific area for review
  - Specific recommendation