GLOBALIZATION OF SCIENCE AND ENGINEERING RESEARCH

A COMPANION TO SCIENCE AND ENGINEERING INDICATORS 2010

NATIONAL SCIENCE BOARD

NATIONAL SCIENCE FOUNDATION
NSB
National Science Board
Est. 1950

National Science Board

Dear Colleague:

As part of our mandate from Congress, the National Science Board oversees the collection of a very broad set of quantitative information about U.S. science, engineering and technology, and every 2 years publishes the data and trends in our *Science and Engineering Indicators* (*Indicators*) report. On occasion, the data reveal trends that raise important policy concerns that the Board believes should be brought to the attention of the President, Congress, and the public as a "companion" policy statement to the *Indicators* report.

Data presented in *Science and Engineering Indicators 2010* (NSB-10-01) illuminate trends and directions in global science and technology. The U.S. has long been a world leader in S&E research and high-technology industry, but comparative international data in *Indicators 2010* underscore the sometimes rapidly growing competitiveness of other economies in these important areas. While increased global S&E research capacity holds great promise for the advancement of scientific knowledge and collaboration in science and engineering across international borders, the U.S. government must be attentive to developments in S&E capacity around the world, and take proactive steps to maintain our nation's competitive strength. In its Companion Piece to *Indicators 2010*, *Globalization of Science and Engineering Research* (NSB-10-3), the Board examines currently available data and trends and recommends the following Federal actions:

- To ensure that the U.S. remains a world leader in S&E research, the National Science Foundation – the only non-mission-oriented Federal agency that funds S&E research – should assess its two merit review criteria for funding of S&E research to ensure that the criteria encourage the proposing and support of truly transformative research, and should modify the criteria and/or merit review process if the assessment finds modifications necessary to accomplish this goal.

- The Office of Science and Technology Policy in the Executive Office of the President, through the National Science and Technology Council mechanism, should engage all Federal agencies involved with S&E research to: (a) develop means to assess or continue to assess the quality of their agency's supported research against international activities, and (b) identify and as appropriate make adjustments necessary to ensure that their agency's research is world-leading.

- The Office of Science and Technology Policy should call for a President's Council on Innovation and Competitiveness as described in the COMPETES Act. Issues for discussion would include: (a) relationships between U.S. and foreign-supported R&D to ensure continued vitality and growth of U.S. technical strength, (b) safeguarding national interests in intellectual property, (c) ensuring that the U.S. economy benefits from R&D supported abroad, and (d) assessing critical research areas for which the U.S. should be the global R&D leader.

We urge Federal attention and action to sustain U.S. world leadership in S&E research in response to growing S&E capacity around the world. Our nation's future prosperity and security depend on strong and unwavering Federal commitment to this goal.

Sincerely,

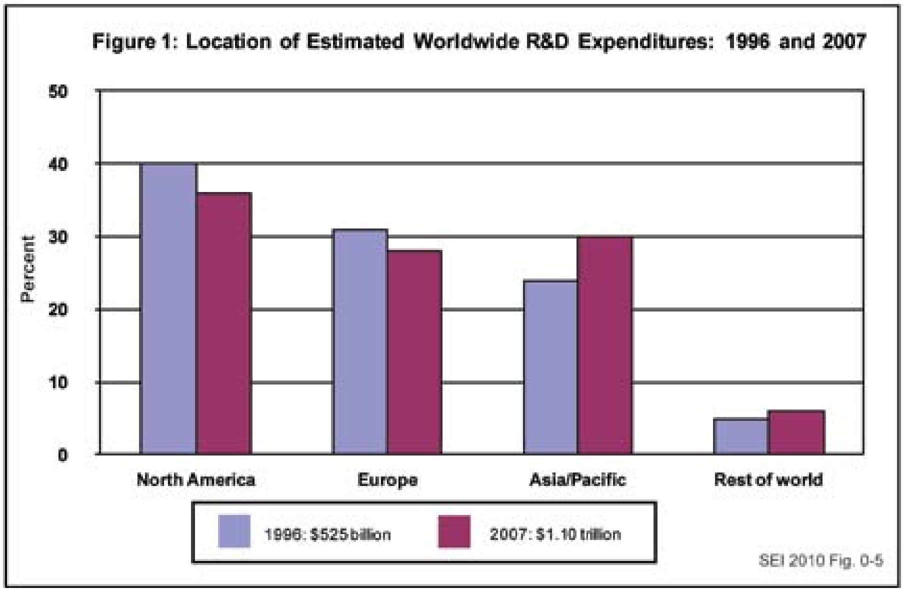
Steven C. Beering
Chairman

National Science Foundation
4201 Wilson Boulevard • Arlington, Virginia 22230 • (703) 292-7000 • http://www.nsf.gov/nsb • email: NSBoffice@nsf.gov

Globalization of Science and Engineering Research

Introduction

Science and Engineering Indicators 2010 provides clear evidence that science and engineering (S&E) research is becoming an increasingly international endeavor. S&E activities are occurring and intensifying in more regions and economies, largely in response to recognition by governments that S&E research and development (R&D) leads to economic growth, employment, and overall social well-being of their citizens. Figure 1 illustrates the changes in percentage of worldwide R&D expenditures (combined public and private) by geographical location over the last decade. While total worldwide expenditures have increased about seven percent per year on average, the percent growth in the Asia/Pacific region has out-paced this average, with most of the increase coming from China, India and other developing nations.



Overall international growth in S&E research activity is driven by increasing science and technology (S&T) capacity in economies around the world. There is widespread recognition of the need to move to a knowledge-intensive economy. Governments increasingly acknowledge the role of S&T in generating new jobs, economic prosperity, responses to national issues and/or global challenges, and global competitiveness. As a result, they are focusing on S&T as national priorities (e.g., by crafting strategic plans for S&T and integrating them in their long-range economic policies) and investing government funding in S&T infrastructure (e.g., in S&E research, education, facilities, R&D, and open markets, and frequently imposing conditions favoring their national enterprise). At the same time, the private sectors in many countries are enhancing and growing their international commercial presence as well as their research and development capabilities. The growth of S&T capacity around the world is facilitated by multinational corporate investments in R&D and new foreign direct investment in emerging markets, as well as by expanding international access to R&D knowledge, training, and facilities. There are growing international research investments by the private sectors of many countries, all enabled and enhanced through the opportunities for scientific exchange provided by revolutionary advances in information and communications technologies (ICT).

Increased global S&E capacity has been greatly facilitated by enhanced communications, enhanced freedom of travel in many nations, and striving for the efficient sharing of resources. This growing global S&E capacity and capability presents both opportunities and challenges to United States (U.S.) S&E research. On one hand, increased global S&E capacity offers great opportunities for scientific advancement and cross-border scientific cooperation. It offers a larger pool of researchers for both U.S. public and private enterprises, and a wider range of possibilities for collaborations and utilization of major foreign research facilities. On the other hand, it presents definite challenges to U.S. competitiveness in high technology areas, and to its position as a world leader in critical S&E fields.

Since the end of the Cold War, the National Science Board has discussed in a number of reports the increasing international challenge to the overall economic competitiveness of the U.S. in S&E, and strength in S&E research fields. Examples include: *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues* (NSB-92-138) (1992), *Working Paper on Government Funding of Scientific Research* (NSB-97-186) (1997), and *The Science and Engineering Workforce: Realizing America's Potential* (NSB-03-69) (2003). Additionally, the Board recently explored the value of international S&E collaboration in the public sector and, among other recommendations, encouraged the active pursuit of cross-border S&E partnerships (*International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and Our Nation's Innovation Enterprise* (NSB-08-4) (2008). The Board has also undertaken a number of studies to suggest specific NSF and Federal strategies and practices to ensure wise investment in world class research capabilities across the fields of science and engineering. These include recommendations focusing on NSF, especially *Enhancing Support of Transformative Research at the National Science Foundation* (NSB-07-32) (2007) and *Toward a More Effective NSF Role in International Science and Engineering* (NSB-00-217) (2000), and more broadly on the Federal support for research in *Federal Research Resources: A Process for Setting Priorities* (NSB-01-156) (2001).

Globalization of Private and Public Research Activities

Government support for S&E research in the U.S.

The 1945 report to President Harry S. Truman by the eminent engineer Vannevar Bush (*Science–The Endless Frontier*) solidified for the U.S. government the value of government investment in research and education in science and engineering for economic growth and improved quality of life. In the subsequent decades the Nation has invested substantial resources in building a preeminent S&E research infrastructure and providing public support for R&D activities generally. This long-term government investment includes the establishment 60 years ago of the National Science Foundation (NSF).

In more recent years, the U.S. government has actively focused on building the S&E capacity necessary for competing in a modern, knowledge-intensive global economy. In its 1997 report on government funding of scientific research, the National Science Board wrote: "In the presence of global competition, a nation should be strong in all the facets of technical innovation and should have available a continuously renewed base of knowledge to inform its decisions and those of its citizens." The Board further wrote, "A nation requires a robust high-tech industry, a scientific talent base, and a vigorous research activity to prosper over the longer term." These arguments for public support of S&E research are even more compelling a decade later as the globalization of science and engineering research continues, and even accelerates.

Impacts of the National Science Foundation and other Federal agencies on global S&E research

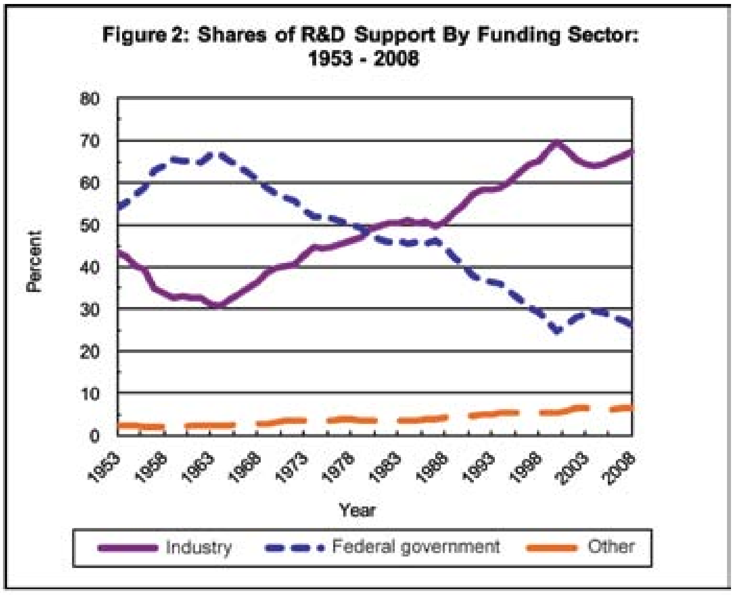
NSF has long played a pivotal role in the participation by the U.S. in the global research enterprise. The Foundation supports cutting-edge research across the global frontiers of knowledge, fostering transformational discovery that is the basis for further innovation and application. NSF supports many S&E activities, from direct research project support to sharing and providing funding for major international research facilities that bind international science and engineering research communities. These ties importantly include facilitating U.S. membership in and providing funding to the International Council for Science (ICSU).

NSF also ties university research to industry through programs such as the Small Business Innovative Research (SBIR) program and the Engineering Research Centers (ERC) program that require industry participation and investment. These ties – internationally and industrially – enable the U.S. to benefit through the participation of researchers in global science and engineering research communities.

Other Federal departments and agencies directly perform research pertaining to their missions as well as support mission-related research in other sectors (i.e., industry, academe, and non-profit organizations). Most notable are the Department of Defense (DOD), the National Institutes of Health (NIH) in the Department of Health and Human Services (HHS), the National Oceanographic and Atmospheric Administration (NOAA) and the National Institute of Science and Technology (NIST) in the Department of Commerce, the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), the U.S. Department of Agriculture (USDA), and the Department of Homeland Security (DHS), although virtually all departments and agencies support mission-related research.

The importance of industry to the U.S. research enterprise

For nearly three decades, the private industry sector has been the primary and increasingly dominant funder of U.S. R&D, with the Federal government second. The industrial share is substantially more "D" (development) than "R" (research), in contrast to the Federal share. Today, private industry funds about two-thirds of total U.S. R&D. Although continued public funding is essential to retaining U.S. global leadership in science and engineering research fields, because it provides the primary support for basic research and research performed by academic institutions, U.S. global leadership in S&E is also highly dependent on investments made by the private sector.



1. Globalization of Publicly Funded S&E Research

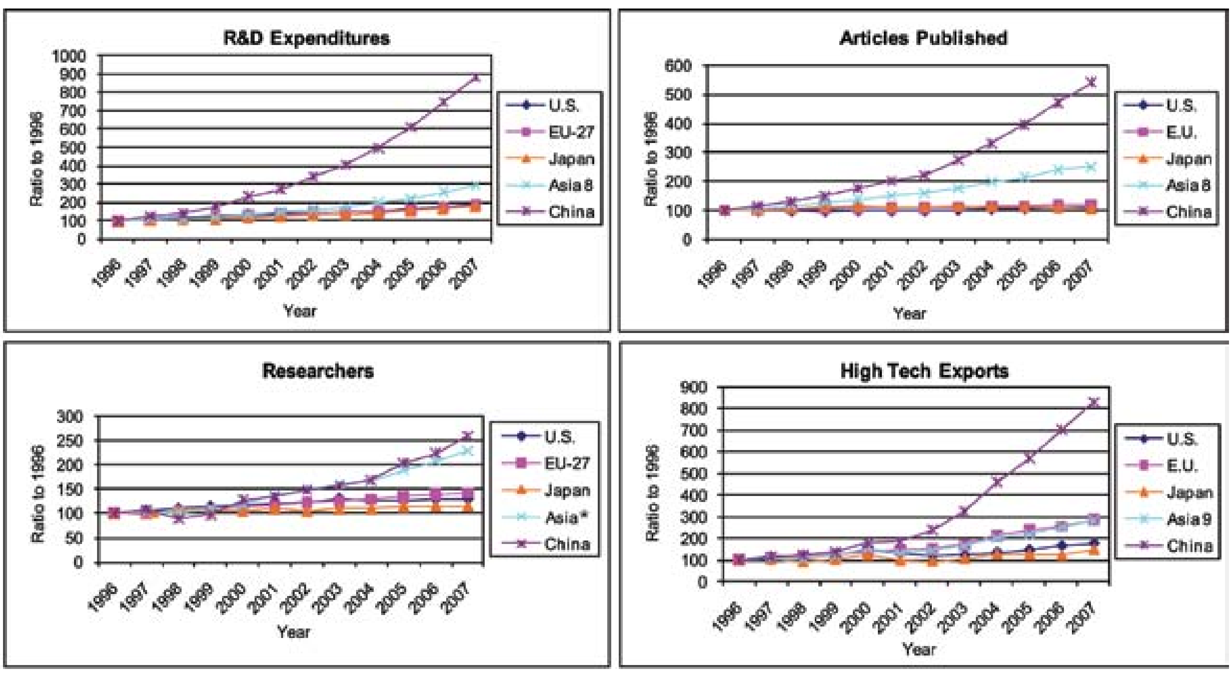
Today, governments around the world are incorporating plans for building S&T capacity into explicit national policies and strategic plans targeted at generating economic growth and competitiveness. These plans often include targeting resource allocations for specific S&E fields to drive local (national) employment and industry. The plans also usually include the creation of supportive policy frameworks to facilitate R&D activities (e.g., providing tax, direct subsidy, and other incentives for private enterprises to concentrate their R&D activities in technical areas deemed to be of national importance). However, sometimes a nation's policies can have unintended consequences of providing disincentives to R&D investments in one country over another.

Science and Engineering Indicators 2010 quantifies the increased focus nations are placing on building their S&E capacity. This increased focus is evident in essentially all measures available, including R&D expenditures, peer-reviewed S&E articles published, number of researchers, and high-tech exports from U.S., European Union (EU), China, Japan, and Asia-9 (India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam) countries. Over the past decade, the S&E capacity demonstrated by these indicators has risen steeply in the Asia-9 countries as many of them have placed a much more explicit national focus on their domestic S&E human capacity and infrastructure. Importantly, public investment in S&E (including such factors as infrastructure, workforce development, and higher education as well as research) by a national government is usually a precursor to subsequent R&D competency within private sector firms in a particular country. Some general indicators demonstrating growing global S&E capacity include:

- Increasing international participation in the peer-reviewed literature;
- International co-authorship of scientific publications and patents (e.g., between 1988 and 2007, the percentage of world S&E articles with international co-authors increased from 8 percent to 22 percent); and
- International collaborations on large S&E research facilities (e.g., the International Space Station, Antarctic Research, the Large Hadron Collider at CERN, the Gemini Telescope project, the international fusion reactor project (ITER), and the Sesame X-Ray Synchrotron).

Figure 3 below shows relative growth in four indicators of increasing S&E and high technology capabilities over the last decade for five countries or regions: R&D expenditures, articles published in peer reviewed journals, the size of the research workforce, and high technology exports.

Figure 3: Normalized Growth in S&T Globalization:
Data are indexed as a ratio to 1996 = 100



NOTE: For R&D expenditures and articles published, Asia 8 is India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand; For researchers, Asia* consists only of South Korea, Singapore, and Taiwan (no data available for remaining Asia 8); For high-tech exports, Asia 9 is Asia 8 plus Vietnam, EU exports are to non-EU nations only.

Increasing S&E capacity around the world challenges the U.S. to actively focus on maintaining its competitive strength in S&E research. As the Board has previously noted[1], science progresses in two fundamental and equally valuable ways: additive advancement in understanding, with new projects designed to build upon the results of previous studies or testing long-standing hypotheses and theories; and revolutionary advancements, through the application of radically different approaches or interpretations that result in the creation of new paradigms or new scientific fields. This second type of discovery, enabled by what the Board has defined as "transformative" research, is critical to maintaining a world-leading edge in S&E research. In response to global competitive pressures, U.S. research agencies must ensure that they provide adequate support for transformative research.

Further, U.S. research agencies should constantly assess their programs and impacts in both types of research against international S&E research activities. International benchmarking efforts will require the development of robust assessment methods to gauge impacts of S&E research funding (a challenge for science of science policy experts), but will position U.S. research agencies to support world-leading activities.

2. Globalization of Privately Funded S&E Research and Related Activities

Globalization of private sector S&E activities is marked by increased emphasis and competence in those activities by other – especially developing – countries; by the establishment of S&E-based enterprises in an increasing number of countries; and by increased funding of industrial R&D activities by multinational companies outside the borders of their home countries. The largest U.S., European, and Japanese companies have supported R&D activities in other industrialized countries for many decades. For example, German chemical and pharmaceutical firms, including some of their R&D, were established in the U.S. more than a century ago. In the 1980s, there was some concern that the build-up of the S&E capabilities of Western Europe and Japanese companies could prove detrimental to U.S. industrial strength.[2]

Increasingly within the last decade, corporations have moved aggressively to take advantage of R&D capabilities and workforces available from around the world. In particular, U.S. multinational firms that have established market presence in large, rapidly developing nations have elected to carry out some portions of their R&D work there. Concurrently, foreign-based multinational firms have also increased their R&D activities based in the U.S.

There are numerous factors that foster the internationalization of R&D activities by private multinational firms. These companies can utilize local talent and take advantage of (sometimes, but not always) lower costs while also ensuring proximity to local markets and culture. Such opportunities can benefit the firms, the markets, and the home countries involved. At the same time, this movement of corporations and their R&D activities has important implications for future U.S. competitiveness, including employment, government fiscal policies and revenue streams and sources, and for the corporations themselves. Perhaps most significantly, there have been important changes in employment patterns of R&D workers and in countries' high technology production and trade associated with globalization of R&D activities of multinational firms.

Currently, there are significant changes taking place in the employment of domestic and foreign R&D workers by U.S. and foreign multinational firms. Between 1997 and 2006, foreign multinational firms increased their employment of U.S.-resident R&D employees by about 25 percent, from 104,000 to 131,000 (data are available only every five years for employment by U.S. multinational firms in the countries in which they operate). Table 1 shows that between 1994 and 2004, U.S. firms in their majority-owned overseas affiliates consistently employed more foreign-resident R&D employees than U.S.-based affiliates of foreign firms employed U.S.-resident R&D employees.

Table 1: Employment by U.S. and Foreign Multinational Corporations of R&D Workers Abroad and in the U.S., Respectively (thousands)

Employer	Year	All	R&D	Pct
Foreign corporation in U.S.	1994	3,954.0	89.8	2.3
	1999	5,064.3	118.3	2.3
	2004	5,131.5	128.5	2.5
Change 1994-1999		28.1%	31.7%	
Change 1999-2004		1.3%	8.6%	
U.S. corporation abroad	1994	5,707.1	102.0	1.8
	1999	7,765.8	123.5	1.6
	2004	8,666.7	137.8	1.6
Change 1994-1999		36.1%	21.1%	
Change 1999-2004		11.6%	11.6%	
U.S. corporation in U.S.	1994	18,565.4	624.8	3.4
	1999	23,006.8	646.8	2.8
	2004	21,176.5	716.4	3.4
Change 1994-1999		23.9%	3.5%	
Change 1999-2004		-8.0%	10.8%	

Importantly, in the latest year for which data are available (2004), U.S. multinational firms employed about 16 percent of their R&D employees outside the U.S., up from about 14 percent in 1994. There is no reason to expect that this trend has not continued.

Figure 4 shows that the U.S. share of global high technology sales are generally high for the U.S. and have remained stable over the last few years, a trend reflected by other countries as well, except Japan and China.

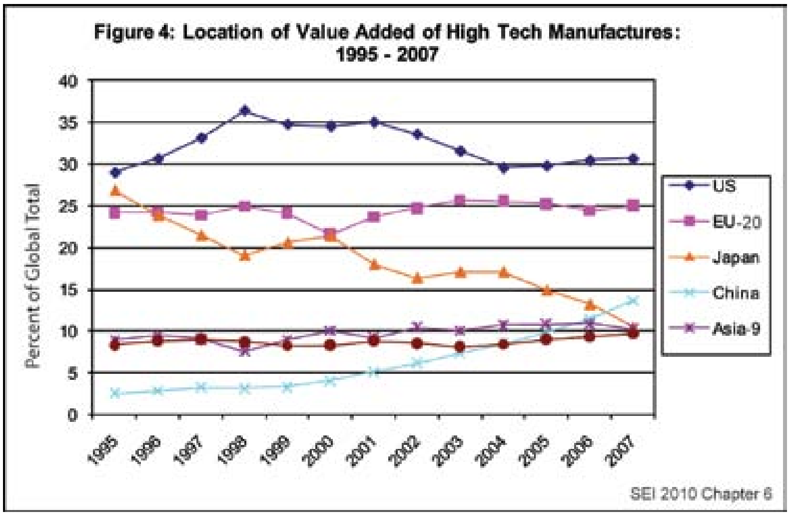
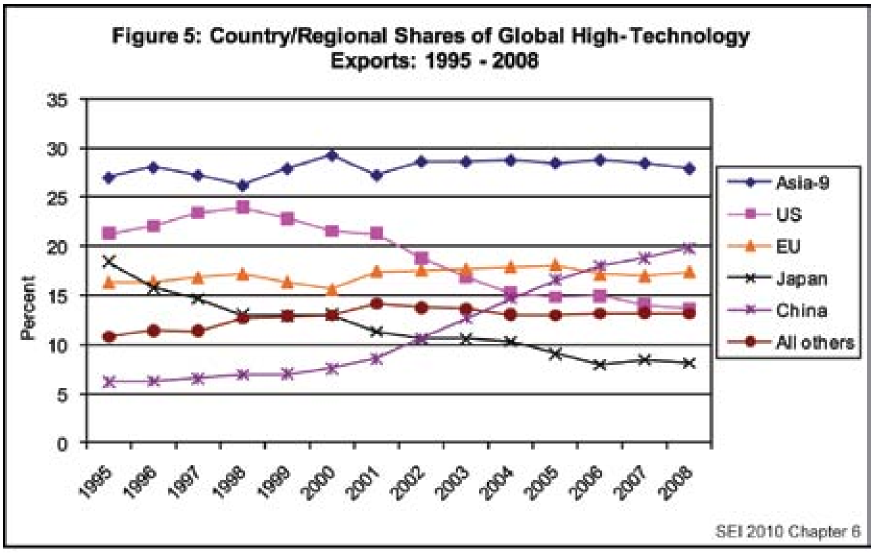


Figure 5 shows the decline in U.S. world export share (percentage) of high technology manufactured goods, driven by below average U.S. export growth in computers and communications and semiconductors (ICT) products.



Between 1995 and 2008, the U.S. share of worldwide high technology exports declined from 21 percent to 14 percent. Over the same period, Japan's export share of high technology manufactured goods declined from 18 percent to 8 percent, and the EU maintained its 16 percent to 18 percent share over the period. It is interesting to note that the U.S. share of high technology exports value added remained relatively flat (Figure 4) – though revenues increased as the global total grew – while the U.S. exports of these items declined substantially (Figure 5). One possible explanation for this is that the globalization of the manufacturing process (i.e., intellectual property creation – innovation, design, prototyping, etc.) in one country can be part of a process in which fabrication takes place in a second country and the sale to a third country. Therefore, while the documented revenue transaction is between the first and third countries, the export is from the second country to the third.

These changes, from the location of employment of R&D personnel to shifts in high technology manufacturing and knowledge-intensive services, demonstrate a worldwide restructuring phenomenon, to which U.S. corporations are responding. The location of sales and exports of high technology manufactured products have important implications for the U.S. economy, including manufacturing and high-tech employment, science and math education, and the Nation's future standard of living. The growth of R&D capabilities worldwide may have implications for U.S. leadership across a broad range of S&E fields. In any event, the U.S. will need to consider how best to capitalize on scientific advances, inventions, and R&D work performed elsewhere.

Summary and Recommendations

Investments in both public and private S&E research by nations are critical for their domestic economic growth and for overall social welfare. For the U.S., the industrial sector is the primary supporter of R&D, but relies on the Federal government to support the bulk of research on the basic end of the spectrum and in the academic sector. The complementary support by these two main players has sustained U.S. leadership across the fields of science and engineering research, and ensured the long-term growth of employment opportunities in U.S. research in academia, but even more so in the private sector. Research investments are increasing worldwide, and are growing more rapidly outside the centers that previously dominated the world R&D enterprise – North America, Europe, and Japan. Occurring in parallel with this development are increasing investments by U.S. private firms in R&D abroad, which are motivated by several dominant factors, including: proximity to customers, access to local expertise and educational institutions, ease of travel and relocation of people across borders, location of financial assets, and, often, lower cost structures for labor and facilities. This rapid evolution in worldwide R&D capabilities carries important policy issues for the Federal government as well for private firms in the U.S. The growth of global S&E research capacity raises several policy questions for the agencies in the Federal government that fund this research. These include:

- What is the role of the NSF, the only non-mission research funding agency, in guiding Federal policy in this era of increasing globalization?
- How can Federal funding agencies, individually and jointly, best respond to other countries' explicit focus on building S&E capacity?
- What are the potential lessons from other countries' S&E strategies that could benefit the Federal R&D system and the existing excellence of U.S. S&E?

The National Science Foundation, being the only non-mission-oriented agency that funds S&E research in the U.S. has often been favorably cited and even emulated by other nations. It is incumbent on the NSF to maintain its emphasis on the funding of basic, peer-reviewed research across the fields of science and engineering, with special attention to transformative S&E research in order to ensure that the U.S. remains a world research leader.

Recommendation: *The National Science Foundation should assess its two criteria for funding of S&E research to ensure that the criteria encourage the proposing and support of truly transformative research, and should modify the criteria and/or merit review process if the assessment finds modifications necessary to accomplish this goal*.

The increasing globalization of S&E has caused many developed and developing nations to establish plans and goals for specific S&E areas in which to concentrate their public research investments. The expectation is that these public investments will stimulate economic development, and both public and private employment.

Recommendation: *The Office of Science and Technology Policy in the Executive Office of the President, through the National Science and Technology Council mechanism, should engage all Federal agencies involved with S&E research to: (a) develop means to assess or continue to assess the quality of their agency's supported research against international activities, and (b) identify and as appropriate make adjustments necessary to ensure that their agency's research is world-leading.*

The continued expansion abroad of R&D activities by U.S. private firms, driven by global competitive pressures and financial incentives, poses long-term challenges for U.S. continuing domestic economic strength and the domestic employment of highly-skilled and highly-educated technical personnel. This expansion raises several policy questions for U.S. private firms and for the Nation's overall economic strength. These include:

a. What does growth in U.S. privately funded R&D abroad imply for the viability and growth of domestically based private R&D activities? What is the role of conditions that host governments and home governments may impose on private industry for technology transfers and spillovers, and what is their net effect on the long-term competitiveness of the U.S.?
b. How well do the legal systems of other countries protect intellectual property when U.S.-funded R&D activities are performed abroad, and if patents are filed, in which country are they filed?
c. How does privately funded U.S. R&D performed abroad support innovation and the economy within the U.S.?
d. Are there certain S&E research capabilities that are critical to be conducted within the Nation's borders? If yes, what are they and what are the implications for licensing and global trade?

Recommendation: *The Office of Science and Technology Policy should call for a President's Council on Innovation and Competitiveness as described in the COMPETES[3] Act. Issues for discussion would include: (a) relationships between U.S. and foreign-supported R&D to ensure continued vitality and growth of U.S. technical strength, (b) safeguarding national interests in intellectual property, (c) ensuring that the U.S. economy benefits from R&D supported abroad, and (d) assessing critical research areas for which the U.S. should be the global R&D leader.*

Conclusion

Data presented in *Science and Engineering Indicators 2010* illuminate trends and directions in global S&E research and high technology industry. The U.S. has long been a world leader in these areas, but comparative international data in *Indicators 2010* underscore the sometimes rapidly growing competitiveness of other nations and economies. While globalization of S&E research holds great promise for the advancement of scientific knowledge and for international collaboration, the U.S. government, as the primary support for U.S. basic and academic research, must respond to growing capabilities outside our borders. We urge Federal attention and action to sustain U.S. world leadership in S&E research in response to growing S&E capacity around the world. Our nation's future prosperity and security depend on strong and unwavering Federal commitment to this goal.

[1] National Science Board (NSB). 2007. *Enhancing Support of Transformative Research at the National Science Foundation* (NSB-07-32), National Science Foundation, Arlington, VA 22230

[2] NSB. 1992. *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues* (NSB-92-138), National Science Foundation, Washington, D.C.

[3] Public Law 110-69 America Competes Act (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act).

Definitions

Research and Development (R&D) Definitions[1]:

R&D, also called research and experimental development, comprises creative work undertaken on a systematic basis to increase the stock of knowledge – including knowledge of man, culture, and society – and its use to devise new applications.

Research is defined as systematic study directed toward fuller scientific knowledge or understanding of the subject studied. Research is classified as either basic or applied according to the objectives of the sponsoring agency.

Basic research is defined as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

Applied research is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

Development is defined as systematic applications of knowledge or understanding directed toward the production of useful materials, devices, and systems or methods, including design, development and improvement of prototypes and new processes to meet specific requirements.

Transformative research[2] is defined as research driven by ideas that have the potential to radically change our understanding of an important existing scientific or engineering concept or leading to the creation of a new paradigm or field of science or engineering. Such research is also characterized by its challenge to current understanding or its pathway to new frontiers.

Science and Technology (S&T) Definition[3]:

S&T and R&D are often used interchangeably, but they have very different meanings in the context of the Federal government. The Office of Management and Budget (OMB) defines R&D to include basic research, applied research, and development, which is the one overarching and official definition of R&D used by all Federal agencies. The term R&D is not fully inclusive of all S&T activities funded or performed by Federal agencies. The magnitude of civilian agency S&T activities is hard to determine, because they are not officially labeled as S&T. Specific activities that are widely believed to be R&D are instead S&T activities that fall outside the set of activities officially designated as R&D.

---

[1] Glossary, Chapter 6, *Science and Engineering Indicators 2008*, 6-56.

[2] Memorandum from Steven C. Beering, Chairman, National Science Board, *Enhancing Support of Transformative Research at the National Science Foundation* (NSB-07-32), v.

[3] National Science Board, *Federal Research Resources: A Process for Setting Priorities* (NSB-01-156), 'Defining and Detailing "R&D" and "S&T,"' Appendix E, 72-74.

References

Bush, Vannevar. 1980. *Science–The Endless Frontier* (40th Anniversary Edition). Washington, DC: National Science Foundation.

National Science Board (NSB). 1992. *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues* (NSB-92-138), Washington, DC. National Science Foundation.

NSB. 1997. *Working Paper on Government Funding of Scientific Research* (NSB-97-186), Arlington, VA. National Science Foundation. *http://www.nsf.gov/nsb/documents/1997/nsb97186/nsb97186.doc*.

NSB. 2000. *Toward a More Effective NSF Role in International Science and Engineering* (NSB-00-217). *http://www.nsf.gov/nsb/publications/pub_summ.jsp?ods_key=nsb00217*

NSB. 2001. *Federal Research Resources: A Process for Setting Priorities* (NSB-01-156). *http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsb01156*

NSB. 2003. *The Science and Engineering Workforce – Realizing America's Potential* (NSB-03-69). *http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsb0369*

NSB. 2007. *Enhancing Support of Transformative Research at the National Science Foundation* (NSB-07-32). *http://www.nsf.gov/nsb/publications/pub_summ.jsp?ods_key=nsb00217*

NSB. 2008. *Science and Engineering Indicators 2008* (NSB-08-01). *http://www.nsf.gov/statistics/seind08/*

NSB. 2008. *International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and Our Nation's Innovation Enterprise* (NSB-08-4). *http://www.nsf.gov/nsb/publications/landing/nsb0804.jsp*

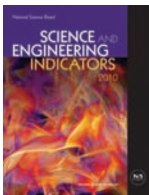
NSB. 2010. *Science and Engineering Indicators 2010* (NSB-10-01). *http://www.nsf.gov/statistics/indicators/.*

NSB. 2010. *Key Science and Engineering Indicators 2010 Digest* (NSB-10-02). *http://www.nsf.gov/statistics/digest/.*

Cover Credits

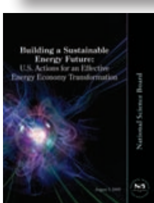
The cover design for *Globalization of Science and Engineering Research* is based on two images of turbulence. The upper image is a computer-simulated visualization of Mach 1 homogeneous turbulence, which also is the featured image on the cover of *Science and Engineering Indicators 2010*. (*Credit: Paul Woodward, Laboratory for Computational Science and Engineering, University of Minnesota.*) The lower picture is a photograph (*Credit: Patrick Cullis, NSF*) capturing the aurora borealis over the South Pole Station, a natural phenomenon also reflecting turbulence. Turbulence and plasma waves in Earth's magnetosphere produce electromagnetic structures that accelerate charged particles. These highly energized particles enter the upper atmosphere and interact with neutral gases at altitudes of approximately 100 kilometers above Earth's surface, generating rapidly changing streamers of light called the aurora. (*The cover design is by James Caras, NSF.*)

National Science Board Recent Publications



Science and Engineering Indicators 2010
(NSB-10-01)

Key Science and Engineering Indicators 2010 Digest
(NSB-10-02)



Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation (NSB-09-55)

A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System (NSB-07-114)

Enhancing Support of Transformative Research at the National Science Foundation
(NSB-07-32)

Obtaining Board Reports

This report is available electronically at: *http://www.nsf.gov/nsb/sei/*

Other Board reports are available electronically at: *http://www.nsf.gov/nsb/publications/*

Paper copies of the report can be ordered by submitting a Web-based order form at:
http://www.nsf.gov/publications/orderpub.jsp or contacting NSF Publications at: 703-292-7827.

Other options for obtaining the documents: TTY: 800-281-8749; FIRS: 800-877-8339.

For special orders or additional information, contact the National Science Board Office:
NSBOffice@nsf.gov or 703-292-7000.

NSB-10-3