



National Science Board

RESEARCH AND DEVELOPMENT: ESSENTIAL  
FOUNDATION FOR U.S. COMPETITIVENESS  
IN A GLOBAL ECONOMY

A Companion to Science and  
Engineering Indicators - 2008

NATIONAL SCIENCE FOUNDATION



# National Science Board

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# National Science Board

Dear Colleague:

As part of our mandate from Congress, the National Science Board (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 in the form of a “companion” policy statement to the *Indicators* report.

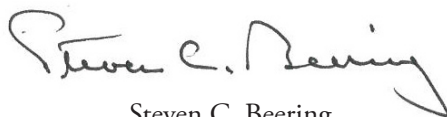
The 2008 volume of *Indicators* reinforces the Board’s concern with declining support for U.S. research and development (R&D), especially basic research, by U.S. industry and the Federal Government. The confluence of a range of indicators raises important questions about future U.S. high technology industry’s competitiveness in international markets and implications for highly skilled jobs at home. The importance of understanding the implications of these indicators underscores the need for new metrics to guide Federal Government investment strategies for R&D to more effectively enhance international competitiveness of the U.S. in high technology.

This Board Companion Piece, *Research and Development: Essential Foundation for U.S. Competitiveness in a Global Economy (NSB-08-3)*, examines currently available data and recommends the following.

- The Federal Government should take action to enhance the level of funding for, and the transformational nature of, basic research.
- Industry, government, the academic sector, and professional organizations should take action to encourage greater intellectual interchange between industry and academia, with industry researchers encouraged to also participate as authors and reviewers for articles in open, peer-reviewed publications.
- New data are critically needed, and this need should be addressed expeditiously by relevant Federal agencies, to track the implications for the U.S. economy of the globalization of manufacturing and services in high technology industry.

We urge all Americans to support sustaining our Nation’s long-term commitment to basic research and to a strong U.S. R&D enterprise, coupling the advantages of our world leading academic research institutions with our strength in industrial science and technology. Our continued commitment is essential to our Nation’s future prosperity and security.

Sincerely,



Steven C. Beering  
Chairman  
National Science Board

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National Science Foundation

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# Research and Development: Essential Foundation for U.S. Competitiveness in a Global Economy

*Our hope is that there will be full employment, and that the production of goods and services will serve to raise our standard of living... Surely we will not get there by standing still, merely by making the same things we made before and selling them at the same or higher prices. We will not get ahead in international trade unless we offer new and more attractive and cheaper products... There must be a stream of new scientific knowledge to turn the wheels of private and public enterprise. (Vannevar Bush, 1945)<sup>1</sup>*

## *U.S. Basic Research: A Need for Serious National Attention*

U.S. industry and the Federal Government are the primary pillars of financial support for the U.S. research and development (R&D)<sup>2</sup> enterprise. The National Science Board (Board) observes with concern the indicators of stagnation, and even decline in some discipline areas, in support for U.S. R&D, and especially basic research, by these two essential patrons and participants. A decline in publications by industry authors in peer reviewed journals suggests a de-emphasis by U.S. industry on expanding the foundations of basic scientific knowledge. More specifically, research contributions by U.S. industry authors in the physical and biomedical sciences through publications in peer reviewed journals have decreased substantially over the last decade. In addition, in this century the industry share of support for basic research in universities and colleges, the primary performers of U.S. basic research, has also been declining. Likewise, Federal Government support for academic R&D<sup>3</sup> began falling in 2005 for the first time in a quarter century, while Federal and industry support for their own basic research has stagnated over the last several years. These trends are especially alarming in light of the growing importance of knowledge-based industries in the global economy.

The confluence of these indicators raises important questions about implications for the future of U.S. competitiveness in international markets and for the future existence of highly skilled jobs at home. The net economic and workforce effects on the Nation and on industry of these negative changes are complex, and the Board finds that requisite data for an adequate analysis of current conditions and future trends do not presently exist. Nevertheless, the Nation must be acutely aware of the current trends as future resource allocations for basic research are debated and decided in industry and by the Federal Government.

## *Global Competition in Science and Technology: A Strong National Response Required*

Innovation is a key to economic competitiveness and the technological breakthroughs that improve our lives. Basic research fuels technological innovations and is critical in fostering the vitality of the U.S. science and technology enterprise and the growth of highly-skilled jobs. The scientific and technological advances that have led to our Nation's remarkable ability to create new industries and jobs, improve the standard of living for people, and provide sophisticated technology that ensures our national security can be traced back to the outcomes of basic research.

Although industry funds two-thirds of U.S. R&D, the majority of basic research is conducted by research universities, and the U.S. Government has long recognized the importance of public support for these institutions. The Federal Government established the basis for the Nation's land grant institutions through the Morrill Acts<sup>4</sup> in the second half of the 19th century. During World War II, the wartime success of the partnership between universities and the Federal Government through the Office of Scientific Research and Development (OSRD) led to a proposal – requested by the President – from the head of OSRD for public funding for research, specifically basic research, in academic institutions and research institutes. Such funding would encourage the creation of knowledge and employ science and engineering (S&E) for discovery and innovation—and thereby expand national economic growth, increase employment, and improve the quality of life. This proposal ultimately led to the creation of the National Science Foundation (NSF).

*The conduct of basic research is international in character and, in today's global environment, its benefits are widely shared by all nations. At the same time, America's economic competitiveness relies on the ability to exploit scientific and technological advances. The country in which a discovery is made has an enormous initial advantage in exploiting such advances in understanding. Furthermore, by maintaining strength in a variety of basic research fields, we will be positioned to benefit from the breakthroughs made by investigators in other parts of the world.*

— National Science Board, 1993<sup>7</sup>

Through its support of entities that fund basic research, the U.S. Government helps underwrite our national infrastructure for science and engineering R&D and thereby the global preeminence of the U.S. in S&E innovation. Over time, the Federal Government support for R&D, and the related important efforts of industry, have grown into a complex and changing web. Given the impacts on the national innovation infrastructure of changes in investment patterns, it is imperative that patterns and trends of R&D investments be monitored.

Extending beyond U.S. borders, dramatic changes have occurred that have led to a new global economy operating in ways not envisioned even several decades ago. As with our own Nation, innovation and its hand maiden, R&D, is driving the global economy, and we are seeing more nations recognize this by creating their own version of U.S. research institutions and infrastructure. U.S. businesses are taking advantage of the global markets and resources, and are increasing their support for research and R&D infrastructure outside the U.S. At the same time, industry support for its own U.S. basic research has been fairly stagnant in this century,<sup>5</sup> and its support to academic basic research in the U.S. has remained at most flat, and declined in share of support for academic R&D to a level not seen in more than 2 decades.<sup>6</sup> The rapid changes taking place internationally increase the urgency of understanding and monitoring where our Nation stands in its R&D competitiveness, the direction of trends related to competitiveness in high technology, and what critical information may be lacking that would provide more accurate assessments of the Nation's standing and outlook.

### ***Basic Research: A Declining National Commitment***

In 2006 the total expenditure for R&D conducted in the U.S. was about \$340B in current dollars. Of this total, basic research accounts for about 18% (\$62B), applied research about 22% (\$75B), and development about 60% (\$204B).<sup>8</sup> Over the past decades the U.S. institutions contributing to the output of basic research have shifted dramatically.<sup>9</sup> Although industrial contributions to national R&D now far outpace Federal R&D support, only about 3.8% of industry-performed R&D can be classified as 'basic', with the remainder devoted to applied R&D. For industry-funded and performed R&D, the basic percentage is about the same for 2006, 3.7%. This percentage of basic research performed by industry has hovered slightly below 4% of all industry-performed R&D for most years since the late 1990s.<sup>10</sup> In 2006, industry funded 17% of U.S. basic research, and performed 15% of it.

The Federal Government is the second largest source of R&D funding (28%) following industry. Federal expenditures vary greatly from agency to agency in terms of amounts, directions, and objectives, depending upon the mission of the particular agency.<sup>11</sup> Federal funding is the primary source of basic research support in the U.S. (over 59% in 2006<sup>12</sup>), of which about 56% is carried out by academic institutions. U.S. basic research is also funded by foundations (about 10%), universities and colleges (about 10%), and state and local governments (about 3.5% through funding of academic basic research).<sup>13</sup> Federal obligations for academic research (both basic and applied) and especially in the current support for National Institutes of Health (NIH) (whose budget had previously doubled between the years 1998 to 2003) declined in real terms between 2004 and 2005 and are expected to decline further in 2006 and 2007. This is the first multiyear decline in Federal obligations for academic

research since 1982.<sup>14</sup> The intent of Federal policy is to increase support for physical sciences research in future years.<sup>15</sup>

## *International Competitiveness of the U.S. in Science and Technology*

The relative increase in R&D and basic research of foreign nations as compared to the U.S. can (in some ways) work to the advantage of U.S. industry. Domestic industries can learn and profit from the R&D that is carried out in other countries and reported in the literature. Basic research that is published can be used freely by all nations, and the benefits do not necessarily accrue to the industries or nations that fund the research. However, as the Board stated in 1993,<sup>17</sup> there are enormous advantages to those industries and nations who are first with discoveries.

A review of quantitative indicators of the state of U.S. science and engineering in the new *Science and Engineering Indicators 2008* provides some measure of U.S. international standing in R&D. The total 2006 R&D in the U.S. (about \$340B) comprised about 2.6% of the Nation's gross domestic product (GDP). The ratio of R&D to GDP is a widely used measure of an economy's R&D intensity. From a high of about 2.9% of GDP in the early 1960s (after the Sputnik "scare"), the Nation's R&D expenditures have hovered around 2.5% of GDP in the last decades. With 2.6% of its GDP devoted to R&D, the U.S. ranks seventh among OECD<sup>18</sup> countries, and second among G-7<sup>19</sup> countries (as it has for the last more than a decade at least). U.S. funding for R&D has exceeded 50% of the total G-7 nations' R&D since 1997. In 2002 (the latest global data available), the U.S. expenditures for R&D were one third of the world-wide total R&D (over \$800B in current dollars).

Countries can be compared over time with respect to contributions to knowledge and innovation using two indicators of research outcomes: (1) patents, as a measure of a nation's inventiveness and (2) publications by authors from the respective nations in peer reviewed journals, as a measure of cutting edge S&E capabilities.

### *Patents*

The share of patent applications in the U.S. patent office filed by inventors<sup>20</sup> residing in the U.S. dropped from 55% in 1996 to 53% in 2005. The percentage drop was largely caused by the increasing filings by Asian inventors. Inventions for which patent protection is sought in the world's three largest markets – the U.S., the EU,<sup>21</sup> Japan – are called "triadic patent families." The U.S. has been the leading source of triadic filings (about 37% of the world share) since 1989, when it surpassed the EU, and its share has continued to increase. The U.S. position in patent filings and in triadic patents suggests sustained U.S. leadership for inventions.

Companies that innovate might not always choose to secure every innovation through patenting. Some innovations can be retained as trade secrets. Growing, maintaining and defending a patent portfolio involves costs, so that companies must evaluate the marginal benefits of individual patent filings. On the other hand, cross-licensing of patents can be competitively beneficial for companies, as can the revenue received from licensing or sale of patents. Thus, motivations for patent filings, and therefore the significance of declines in the share of U.S. filings, are not well understood.

*Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost – and the difficulty of recovering a lead once lost, if indeed it can be regained at all.*

— The National Academies, 2007<sup>16</sup>

## *Publications*

Basic research articles published in peer-reviewed journals by authors from U.S. private industry peaked in 1995 and declined by 30% between 1995 and 2005<sup>22</sup> as industry research, and therefore publications, tended to shift away from basic research. Five broad fields – biological science, geosciences, chemistry, physics, and medical sciences – account for 95% of the industry basic research literature. The drop in physics publications was particularly dramatic: decreasing from nearly 1,000 publications in 1988 to 300 in 2005.<sup>23</sup>

The decline in physics publications by U.S. industry is likely reflected in the observed drop in share of highly influential<sup>24</sup> S&E articles published by U.S. authors in peer reviewed journals: The U.S. has now dropped from first to second rank in physics over the 12-year period from 1992 to 2003. The U.S. retained the first rank in all other major fields in 2003, but overall lost share of highly influential articles, dropping from 63% to 58%. Other fields where the U.S. declined to near parity with the EU-15<sup>25</sup> in recent years are biology and chemistry, also traditional focus areas for industrial basic research publications. This most likely reflects, in part, the decline in U.S. industry authors' publications, and flat (or decreasing as in the case of physics) industry support for its own basic research. In the field of engineering/technology, although the U.S. lost share while the EU-15 gained, the decline in U.S. share more importantly reflects the rapid rise in share by the East Asia-4 (comprising China, South Korea, Singapore, and Taiwan). U.S. annual growth in all S&E article publications in peer reviewed journals also slowed from 3.8% over the period from 1988 to 1992 to 0.6% from 1992 to 2003. Although the rate of growth also declined for the EU-15 and other S&E publishing centers, all exceeded the U.S. growth rate during both periods.<sup>26</sup>

## *Intellectual Property and Industrial Innovation*

Patents and publications do not necessarily equate to innovation and thus do not reflect the totality of industrial innovation. In global, competitive, high technology industries, some innovations might be more cost effectively protected by means other than patenting. In addition, research and/or commercial priorities might direct limited resources towards further advances in research or to addressing how to apply the results of the innovation rather than publishing articles. As a result, any basic research that may have contributed to such processes is unknown to (and unrecorded in) the wider community. Further, under these conditions the wider community cannot be alerted to possible basic research directions that might be productive for achieving new breakthroughs.

The growing competitiveness in the global environment is resulting in new business models such that the impact of innovations might not be captured in current international trade metrics. Companies might innovate and create intellectual capital in one country that is then utilized in designing and developing products, services, applications, etc. in that country or another. The actual fabrication might occur in yet another country. The complete process from creation of intellectual capital and high-tech design through to fabrication and distribution of products, services and applications can be performed across many countries in a global supply chain that can result in cost-effective products for consumers. Although the transfer of a physical product across a border may be recorded in such a process, if no intellectual property licensing occurs, the value of the intellectual capital may not be captured by the current global trade metrics. Furthermore, some international commercial transactions (sale, payment, product delivery) in such an environment are not simply bilateral exchanges between two countries. Instead, such transactions may involve multiple flows of information, components, products/services/applications, and payments that are not easily correlated. In parallel with new metrics to capture this type of innovation, the traditional Federal Government investment strategies for basic research may need to be adapted to the emerging environment of discovery, innovation, and deployment in order to more effectively support the web of connections between R&D investments and U.S. competitiveness.

## *Competitiveness of U.S. Industry*

Another measure of competitiveness is the U.S. international trading position in high technology industries. The U.S. trading position in technology-oriented services remains strong as evidenced by the continued surplus in trade of computer software and manufacturing know-how.<sup>27</sup> By current measures, the U.S. trade balance across all high technology sectors significantly declined over the last decade. This could translate into the loss of manufacturing jobs<sup>28</sup> in high technology industries, although the data are insufficient to measure the impact on employment over time.



Of the five high technology manufacturing industries identified by the OECD, only that for aerospace had a large positive balance of trade in 2005. The scientific instruments industry is relatively balanced with regard to trade, and the other three high technology manufacturing categories are negative. The total U.S. trade balance in high technology shifted from surplus to deficit in the late 1990s, with a deficit of \$32B in 2000, increasing to \$135B in 2005. This increase primarily reflects increases in the deficits with Asia.

In contrast to the manufacturing category, the U.S. trade balance in royalties and fees for intellectual property between affiliated and non-affiliated companies has continued a sustained surplus over the years.<sup>29</sup> Licensing fees and royalties largely reflect past innovations, sometimes quite distant past, and are not good measures of the current state of research or accurate predictors of future intellectual property revenues from the research.

## *Global Investment by Industry in Innovation*

U.S. industries are establishing R&D facilities and manufacturing facilities in nations in which they have markets and in which they wish to grow market share. Such facilities can also contribute to more cost-effective manufacturing capabilities to the benefit of consumers in the U.S. and elsewhere. Off-shore facilities for engineering design are also being established by U.S. industry, especially in China and India. Such R&D can benefit U.S. industry's products, profitability, and over-all competitiveness, as well as provide some limited domestic job growth. However, critical data on these trends in off-shoring R&D by U.S. industry are presently lacking, as is the net effect of such trends on industrial competitiveness and domestic job growth.

Foreign nations continue to establish R&D centers in the U.S., as well as manufacturing facilities in some industries. Foreign companies also support some academic R&D, including endowed professorships. There are limited data on these trends, as well as on the net economic effects on the U.S. of the "out-sourcing" of R&D by U.S. companies and of the "in-sourcing" of R&D funded by foreign companies. However, Indicators data on R&D by multinational corporations are instructive. These data show that affiliates of foreign companies located in the U.S. made \$29.9B in R&D expenditures in 2004, little changed from 2003. Between 1999 and 2004, R&D by these affiliates increased faster than overall U.S. industrial R&D (2.1% on an annual average rate basis after adjusting for inflation, compared with 0.2% for U.S. industry overall).

On the other hand, foreign affiliates of U.S. multinational corporations performed \$27.5B in R&D abroad in 2004, a rise of \$4.7B from 2003, the largest annual increase since a 22% rise in 1999. This amount nearly equals the R&D by affiliates of foreign countries in the U.S. (\$29.9B).<sup>30</sup> Affiliates located in Europe represented slightly more than two-thirds of the 2004 increase.

## *The Road Ahead: Conclusions and Recommendations*

The stagnation in industry support for its own basic research in this century, together with the current decrease in support of academic R&D and basic research by the Federal Government could over time have severe implications for U.S. competitiveness in international markets and for highly skilled and manufacturing jobs at home. However, the net economic effects on the Nation and on industry of the off-shoring of manufacturing capabilities are complex, and appropriate data do not exist for adequate analysis of present situations and future trends.

For more than a quarter century U.S. industry has dominated the funding of U.S. R&D. The Federal Government continues to dominate research funding to the academic sector. The recent three-year decline in Federal obligations for academic research, the first since 1982, and the decrease of support by industry for basic research could pose significant problems in that academic researchers, primarily supported by Federal funds, are now likely to have less available funding and to be considerably less aware than previously of the major research challenges that face U.S. industry and industrial competitiveness. Further, with fewer industry researchers focusing on basic research, a company may be unable to readily tap into the expertise and facilities of the university community.

*To keep America competitive, one commitment is necessary above all: We must continue to lead the world in human talent and creativity ... With more research in both the public and private sectors, we will improve our quality of life – and ensure that America will lead the world in opportunity and innovation for decades to come.*

— President George W. Bush, 2006<sup>31</sup>

1. Based on past experience, basic research can be expected to be a major driver in the future for innovations that result in new industries and new jobs, and that will enhance the Nation’s global competitiveness.

**Recommendation:** *The Federal Government should take action to enhance the level of funding for, and the transformational nature of, basic research.*

2. The decrease in industrial-based basic research may result in a decreasing level of interactions between industry and academic research and teaching. In addition, changes in some industry’s policies related to the management of patent portfolios and to publishing peer-reviewed journal articles are likely limiting public awareness of some innovation. It is unknown how much, if any, basic research in industry results in innovations that remain company-proprietary, or that could beneficially influence the directions of any basic research.

**Recommendation:** *Industry, government, the academic sector, and professional organizations should take action to encourage greater intellectual interchange between industry and academia. Industry researchers should also be encouraged to participate as authors and reviewers for articles in open, peer-reviewed publications.*

3. In the area of high technology manufacturing of products and services, globalization has often resulted in “value flows” across several nations before the end user acquires the device or service. Current trade measurements monitor the flow of components and products, but do not track at present all of these value flows. New metrics would be valuable in order to accurately attribute where value is added and, therefore, where intellectual capital is created and skilled labor is employed. Basic research is crucial to advancing science and engineering and creating intellectual capital in the United States, and for the U.S. to continue to add value and to provide leadership in the global marketplace.

**Recommendation:** *New data are critically needed to track the implications for the U.S. economy of the globalization of manufacturing and services in high technology industries, and this need should be addressed expeditiously by relevant Federal agencies.*

Industry and the Federal Government bear special responsibility for the health of U.S. science and technology in the emerging global economy. Several indicators, described earlier, imply a reduced commitment to the U.S. enterprise by both the Federal and industry sectors—especially to academic and basic research—over the last several years, in spite of the growing importance of knowledge-based industries in international trade. The potential impacts of persistent negative trends in R&D support, and especially support for basic research, on the U.S. economy and jobs are indeed troubling. As a Nation we must renew our strong commitment to R&D to ensure our continued preeminence in global science and technology. New metrics are required to guide national R&D investments in all sectors to ensure that we respond to the research needs in a rapidly changing global economy.

# Endnotes

1. Vannevar Bush. *Science—The Endless Frontier*. National Science Foundation, Washington, DC, 1980: 18.
2. **Research and Development Definitions:**

**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 application 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.
3. Federal obligations for R&D controlling for inflation.
4. Morrill Acts of 1862 and 1890, [http://www.higher-ed.org/resources/morrill\\_acts.htm](http://www.higher-ed.org/resources/morrill_acts.htm). Accessed 27 October 2007.
5. National Science Board (NSB). 2008. *Science and Engineering Indicators 2008* (SEI 2008), Arlington, VA: National Science Foundation. Appendix table 4-8.
6. NSB. 2008. Appendix table 5-2.
7. NSB. 1993. *In Support of Basic Research* (NSB-93-127). <http://www.nsf.gov/nsb/documents/1993/nsb93127/nsb93127.htm>. Accessed 27 October 2007.
8. NSB. 2008. Chapter 4.
9. Contributions to basic research are indicated by publications in science and engineering peer-reviewed journals.
10. NSB. 2008. Appendix table 4-8. In 2003, basic research exceeded 4% of industrial R&D, reaching 4.2%.
11. **Primary Federal R&D funding agencies:**

Department of Defense: the largest Federal R&D funding agency devotes about 89% of its estimated FY2007 expenditures of \$56B to development.

Health and Human Services (primarily NIH): about 55% of the R&D budget of \$29B in FY2007 is devoted to basic research.

National Aeronautics and Space Administration: about 55% of the total R&D FY2007 budget of \$8B is basic and applied research.

Department of Energy: about 67% of a FY2007 R&D budget of \$8B is spent in Federally Funded R&D Centers (FFRDCs).

National Science Foundation: about 91% of the FY2007 of \$6B is devoted to basic research.

U.S. Department of Agriculture: about 69% of the \$2B FY2007 R&D budget is intramural funding.
12. NSB. 2008. Appendix table 4-9.
13. National Science Foundation, Division of Science Resources Statistics. 2007. *National Patterns of R&D Resources: 2006 Data Update*. NSF 07-331. Brandon Shackelford and John E. Jankowski, project officers. Arlington, VA, Table 6.
14. Consistent with this trend, reported Federal expenditures for academic R&D declined between 2005 and 2006. A decline in real terms in Federal expenditures for academic R&D had not previously occurred in the last quarter century.
15. America COMPETES Act. (H.R. 2272)
16. National Academies. 2007. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future*, National Academies Press. [http://books.nap.edu/openbook.php?record\\_id=11463&page=3](http://books.nap.edu/openbook.php?record_id=11463&page=3)
17. National Science Board, op. cit. Accessed 27 October 2007.
18. Organisation for Economic Co-operation and Development, <http://www.oecd.org/home>. Accessed 27 October 2007.
19. **G-7:** The United States, Japan, Germany, France, United Kingdom, Italy and Canada. G-7 finance ministers meet several times a year to discuss economic policy. [http://www.hm-treasury.gov.uk/otherhmtsites/g7/g7\\_members.cfm](http://www.hm-treasury.gov.uk/otherhmtsites/g7/g7_members.cfm). Accessed October 27, 2007.
20. Inventors can be individuals or organizations. Most are organizations.
21. **EU:** European Union, comprising 27 countries.
22. NSB. 2008. Appendix table 6-28.
23. NSB. 2008. "S&E Articles in Peer Reviewed Journals/Articles in Basic Research Journals" in chapter 6.
24. "Highly influential" defined by citations by other authors.
25. **EU-15:** Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the UK.
26. Derek Hill, Alan I. Rapoport, Rolf F. Lehming and Robert K. Bell. 2007. *Changing U.S. Output of Scientific Articles: 1988-2003*. Arlington, VA: National Science Foundation.
27. Manufacturing "know-how" is defined as industrial processes used in the production of goods, sold as intellectual property. See SEI 2006: 6-23.
28. The nature of jobs associated with "manufacturing" in high-technology industries varies greatly. They may include basic research, applied research, systems engineering, planning, design, development, fabrication, sales, distribution, customer support, etc. Trade statistics often reflect the value flows due to the fabrication and the distribution of products, services and applications to a customer destination. In practice, value flows due to other job functions may not be reflected in trade statistics. This could be significant in considering current employment and trade statistics as indicators of national competitiveness.
29. "Affiliate" is defined as "A company or business enterprise located in one country but owned or controlled (10% or more voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated. See SEI 2008, 6-45.
30. NSB. 2008. Chapter 4: Highlights, 4-52.
31. George W. Bush. 2006. State of the Union Address. <http://www.whitehouse.gov/stateoftheunion/2006/index.html>. Accessed 3 December 2007.

**Cover Credits:** The cover for *Research and Development: Essential Foundation for U. S. Competitiveness in a Global Economy* celebrates the 2007–09 International Polar Year with a montage including photographic images from the polar regions. At the center is an ice cave at Loudwater Cove, on Anvers Island. Arcing above it and to the left are smaller images showing (counterclockwise): a team of seal researchers in Antarctica by the light of research vessel Laurence M. Gould; the elevated station and flags of the original 12 Antarctic Treaty signatory nations at Amundsen-Scott South Pole Station. A sundog, caused by diffraction of ice crystals, can also be seen; an aurora borealis, and a sunset at Cape Hallett. (Credit, ice cave: Zenobia Evans, National Science Foundation (NSF); Credits for images counter clockwise: Steve Trumble, NSF; Scott Smith, NSF; Patrick Smith, Ken Ryan, NSF.)

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