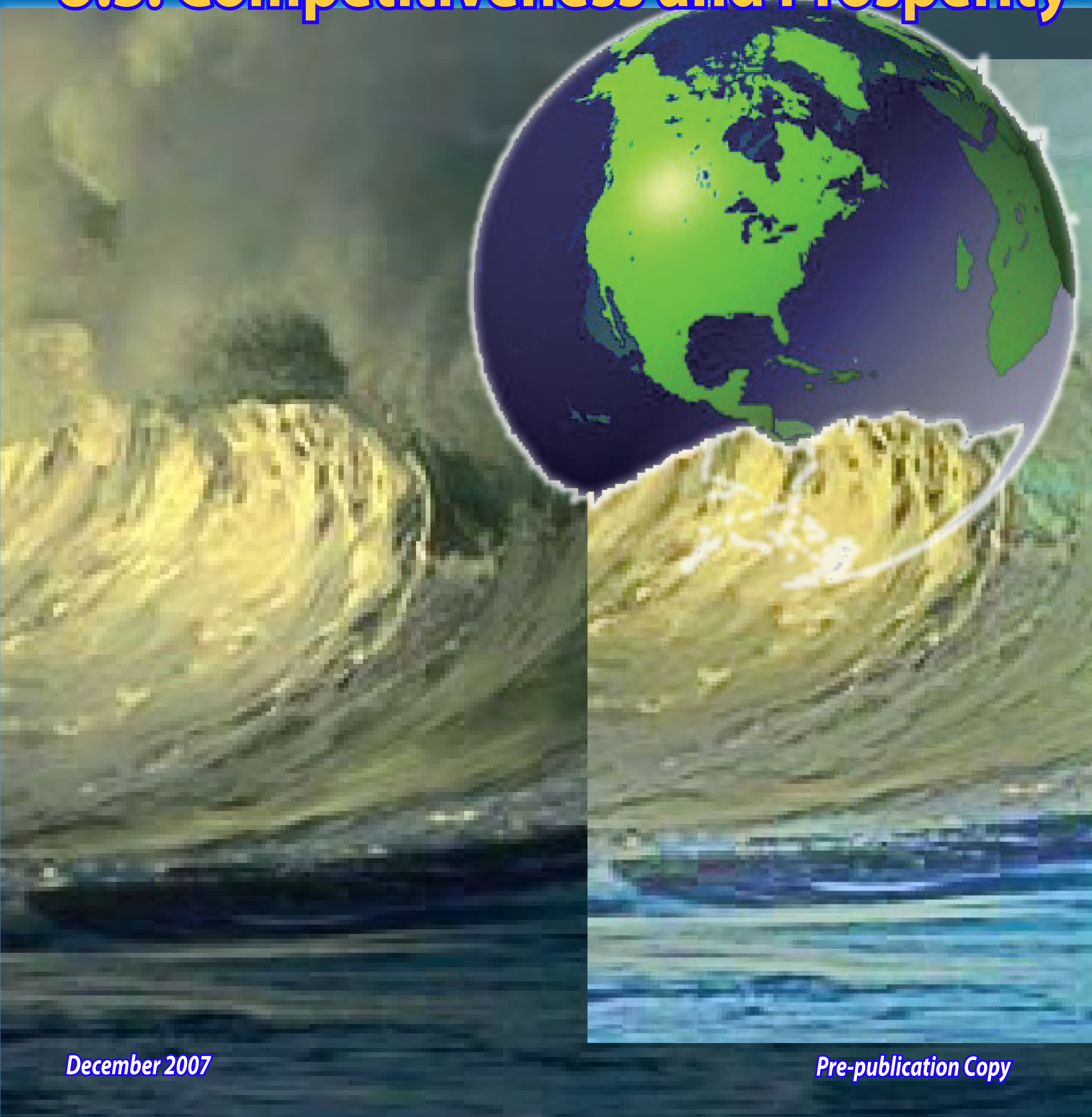
ASTRA's 14-Point Action Agenda for our Innovation Future ...

Riding the Rising Tide:

A 21st Century Strategy for U.S. Competitiveness and Prosperity



December 2007

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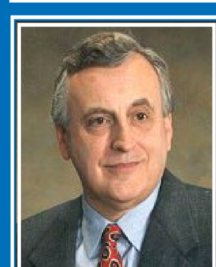

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In A Nutshell: ASTRA's 14-Point Action Program

December 11, 2007 Press Briefing for launch of *Riding the Rising Tide: A 21st Century Strategy for U.S. Competitiveness and Prosperity* in the House Science & Technology Committee Hearing Room on Capitol Hill. From right: Rep. Bart Gordon (D-TN), Chairman of the House Committee on Science & Technology commends ASTRA's multi-year efforts while Rep. Phil Gingrey (R-GA), Ranking Member of the Committees's Subcommittee on Technology & Innovation and ASTRA Board Members listen.

R&D ENTERPRISE

- Balance defense/civilian share of Federal R&D Portfolio
- Increase Federal funding for physical sciences and engineering R&D
- Focus R&D on the leading edge of science and technology
- Increase focus on interdisciplinary and multi-disciplinary research, new forms of collaboration, and nurturing capacity in new geographic regions.
- Provide incentives to capture benefits of public R&D within U.S.

PRO-INNOVATION BUSINESS CLIMATE

- Review U.S. laws, regulations and policies to determine impact on innovation; address inhibitors.
- Develop innovation indicators and metrics for knowledge-based economy; use indicators to drive policy and strategy.
- Create and provide support for better government analysis of U.S. and foreign innovation systems.

INNOVATION WORKFORCE

- Examine adequacy of skills for innovation economy; educate for non-rule based, judgment-oriented problems
- Improve statistical and career information for STEM workers; companies should articulate skill needs to educators and students
- Improve higher education for scientists and engineers by focusing on global and cultural awareness, communications, business and management skills
- Strengthen efforts to attract and retain top foreign students and STEM professionals

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Riding the Rising Tide:

A 21st Century Strategy for U.S. Competitiveness and Prosperity

December 2007

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To: Colleagues, the Science and Technology Communities, and Policy Makers Interested in the Technology Competitiveness of the United States

The Alliance for Science and Technology Research in America (ASTRA) was organized several years ago to advocate for, and educate about, Federal funding for research in engineering, and the physical and mathematical sciences. These fundamental disciplines are the foundation for technical progress in the non-medical industries in the United States and elsewhere, and they provide significant support to the medical-related industries, particularly in instrumentation, data analysis, and diagnostic systems. Thus, the health of these disciplines, including a highly qualified workforce, is a necessary component in any competitiveness policy of the country.

Federal funding in these disciplines provides crucial support for the fundamental science and technology base used by the business community to create new products and processes, and for the university activities that provide both new knowledge and a research-trained workforce in these fields. However, annual Federal R&D funding for these fields has stagnated or declined in constant dollars over the past several years.

In response to these troublesome funding trends, the members of ASTRA—including corporate, academic, and professional society representatives—have worked with policy makers to move research funding for engineering, and the physical and mathematical sciences to a national priority. The need for increased funding in these fields has been reinforced by the realization that the U.S. position of leadership in science and technology is being challenged by developing countries, especially China and India, who see their competitive position in a “flat world” dependent on aggressive growth of their technical capability.

Several studies have assessed the U.S. position and recommended significant increases in Federal funding for research and incentives for innovation. Reports that have had significant impact are *Innovate America* from the Council of Competitiveness, and the National Academies’ report, *Rising Above the Gathering Storm*. These were followed by Congressional passage of the *America COMPETES Act*, which authorizes increased funding for the National Science Foundation, the Office of Science at the U.S. Department of Energy, and the National Institute of Standards and Technology. At this time, the appropriations to fulfill the promise of the *America COMPETES Act* have not been passed by Congress.

All of the recent U.S. competitiveness studies make it clear that <u>innovation</u> is key to the competitiveness and future prosperity of the United States. Research and development are major components of an innovation strategy, but there are other elements essential to a nation’s ability to innovate. This report provides a snapshot in time of where the United States stands in the global competitiveness race in which innovation is key. The roles of R&D and talent development are highlighted, along with other factors that enable innovation to flourish.

We also make recommendations to Federal policy makers on the dramatic changes in America’s approach to innovation that will be required to strengthen U.S. research and development assets, develop a world-class workforce, and create a business environment that supports entrepreneurship, innovation and competitiveness.

We hope that this report and our recommendations will further inform and galvanize policy leaders to move aggressively toward strengthening the U.S. environment for innovation by significantly increasing funding for the R&D community, both federal funding for fundamental research and targeted, applied R&D that is vital to the industrial sector.

Mary L. Good
Chair,
ASTRA, The Alliance for Science & Technology Research in America
December 11, 2007

Acknowledgements

Acknowledgements:

1. The Honorable Kelly H. Carnes, President and CEO, TechVision21 (former Assistant Secretary for Technology Policy, U.S. Department of Commerce), and Carol Ann Meares, Vice President, TechVision21 (former Senior Policy Analyst, Office of Technology Policy, U.S. Department of Commerce) prepared this report under ASTRA direction.

2. ASTRA member organizations now number more than 100 national, state and local organizations, companies, universities, trade and professional societies, coalitions and individuals. A listing of these organizations is found on **page 50** of this report. We are grateful for their support and guidance.

3. ASTRA is only one voice in the national conversation on innovation. We have been particularly grateful to be an integral, supporting partner in seven key coalitions which advance the needs of specific federal agencies or disciplines since our founding in 2000. ASTRA-supported coalitions (with related Web Sites) include:

ASTRA Supported Coalitions:

CNSF (Coalition for National Science Funding) — supports National Science Foundation funding and programs
www.cnsfweb.org

CNSR (Coalition for National Security Research) — primary focus is Department of Defense R&D Funding
www.cnsronline.org

Coalition for NIST Funding — mission is preservation and expansion of funding for the National Institute of Standards & Technology (NIST) as well as education about NIST's Advanced Technology Program (ATP) and its successor program, the Technology Innovation Program or "TIP."
www.aboutastra.org

ESC (Energy Sciences Coalition) — primary concern is the Department of Energy's Office of Science budget and programs and funding
www.aps.org/policy/tools/coalitions/esc

SETWG (Science-Engineering-Technology Working Group — organizes the Annual Congressional Visits Day and other events throughout the year
www.setcvd.org/cvd2008/index.html

STEM Ed Coalition — (coordinates Science, Technology, Engineering and Mathematics policy development and funding) www.stemedcoalition.org/

Task Force on the Future of American Innovation — spin-off of ASTRA's Media Task Force in 2004, focuses on public relations about innovation and competitiveness topics, has issued two "benchmark" reports and some media ads
www.futureofinnovation.org

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ASTRA's 14-Point INNOVATION ACTION AGENDA

(Not ranked According to Priority)

FEDERAL FUNDING: STRENGTHEN U.S. R&D ENTERPRISE

1. **BALANCE DEFENSE/CIVILIAN SHARE OF FEDERAL R&D PORTFOLIO**

2. **INCREASE FEDERAL FUNDING FOR PHYSICAL SCIENCES AND ENGINEERING RESEARCH**

   The Congress and the Administration should fulfill the physical sciences and engineering R&D commitments made in the American Competitiveness Initiative (ACI). However, to ensure that funding expands beyond increases in inflation, the timetable for these investments should be accelerated. In addition, investment should be increased beyond the ACI recipient agencies.

3. **INCREASE AND STABILIZE FUNDING FOR APPLIED RESEARCH**

   The Federal government should increase and stabilize funding for applied research and advancing promising, high-risk technologies with substantial economic potential to bring them to a stage of maturity that is attractive for private sector investment. This includes funding for the new Technology Innovation Program (TIP) and other programs that meet this objective. In addition, the approach to SBIR funding should be reviewed to determine how this program could maximize its ability to contribute to the U.S. innovation base.

4. **FOCUS R&D ON LEADING EDGE OF SCIENCE AND TECHNOLOGY**

   A large share of Federal R&D investment should focus on the leading edge of science and technology, especially in fields expected to have revolutionary impacts, such as nanotechnology, biotechnology, and high-performance computing.

5. **INCREASE R&D TO SUPPORT GROWING SERVICES SECTOR**

   The Federal government should increase R&D to support the U.S. service economy, including support for services innovation, productivity, efficiency, competitiveness, and technical workforce development.

6. **INCREASE FOCUS ON INTERDISCIPLINARY AND MULTI-DISCIPLINARY RESEARCH, NEW FORMS OF COLLABORATION, AND NURTURING INNOVATIVE CAPACITY IN GEOGRAPHIC REGIONS WHERE INNOVATIVE CAPACITY EXISTS BUT IS UNDER-USED**

   While investigator-driven research remains the cornerstone of Federally-supported academic R&D, the Federal government should increase attention to emerging opportunities for interdisciplinary and multidisciplinary research, including a focus on centers of research excellence where rapid development of innovations requires this type of collaboration. This includes reaching out to academic institutions in geographic regions in which the potential for innovative capacity exists—such as high quality research and researchers—but needs further nurturing.

7. **PROVIDE INCENTIVES FOR BENEFITS OF FEDERAL R&D TO BE CAPTURED WITHIN THE U.S.**

To ensure that the US. reaps the benefits of Federal R&D investments, the Federal government should examine what incentives can be put in place to enable adequate returns from public R&D to be captured domestically For example, the U.S. should consider devoting a small part of the Federal research portfolio to investments in applied research, technology prototyping, demonstration, testing, pilot-scale production and other pre-competitive activities to increase the likelihood of eventual commercialization on our shores.

WORKFORCE & STEM* EDUCATION: DEVELOP A WORLD-CLASS WORKFORCE FOR THE INNOVATION ECONOMY

8. **EXAMINE ADEQUACY OF U.S. SKILLS FOR INNOVATION ECONOMY**

The U.S. needs to examine whether prevailing skill levels are adequate for an innovation-based economy, and for our success in the growing global "trade in tasks" in which routine knowledge work is easy to ship offshore.

9. **IMPROVE STATISTICAL AND CAREER INFORMATION ABOUT THE U.S. SCIENCE, TECHNOLOGY AND ENGINEERING WORKFORCE**

The U.S. should provide better and more detailed information on the nation's need for scientists, engineers and information technology workers. The National Science Foundation should: encourage employers to better articulate their current and prospective STEM workforce needs, and the types of skills and disciplines needed; ensure students and workers understand what these specific skills and disciplines are; as well as encourage a significant shortening of the feedback loop between employers and their needs, and the responses by education and training institutions. This includes providing career information and nurturing to groups underrepresented in STEM—such as minorities and women—to increase their knowledge of opportunities in STEM education and careers.

10. **IMPROVE HIGHER EDUCATION FOR SCIENTISTS AND ENGINEERS BY FOCUSING ON GLOBAL AND CULTURAL AWARENESS, COMMUNICATIONS, BUSINESS AND MANAGEMENT SKILLS**

The Federal government should encourage university educators to broaden the skill sets of U.S. scientists, engineers and information technology workers. University educators should ensure that scientists, engineers and IT professionals have: global and cultural awareness; knowledge that helps them understand business, markets, marketing and customers; the ability to work as a member of and communicate effectively in teams of diverse disciplines; some understanding of business finance such as cost-benefit and return on investment concerns; as well as project management abilities.

11. **STRENGTHEN EFFORTS TO ATTRACT TOP FOREIGN STUDENTS AND STEM PROFESSIONALS TO THE U.S.; REMOVE BARRIERS TO IMMIGRATION OF TALENT**

The U.S. should strengthen efforts to attract top foreign students and PH.D.-level professionals in science, engineering and technology. This includes developing a national strategic plan for recruiting top international students, scientists, engineers and technologists, and evaluating the U.S. immigration system to remove barriers to these talented individuals migrating to the U.S.

CREATE A BUSINESS ENVIRONMENT TO SUPPORT INNOVATION AND COMPETITIVENESS

12. **PERFORM WHITE HOUSE REVIEW OF LAWS, REGULATIONS AND POLICIES; ADDRESS INHIBITORS TO INNOVATION**

The next President should launch a White House level initiative to perform a comprehensive review of U.S. laws and regulations relating to the business climate for innovation. This would include regulations promoting human health and safety, standards for environmental protection, as well as tax, trade and antitrust policies, to determine whether changes are needed to meet the nation's public policy goals while, at the same time, promoting innovation and competitiveness.

13. **DEVELOP A MEANINGFUL SET OF INNOVATION INDICATORS TO GUIDE U.S. INNOVATION POLICY AND STRATEGY**

The Federal government should lead efforts to determine where the priorities are, and to begin the process of developing some high level indicators around the key drivers of innovation that are known and recognized.

14. **CREATE, AND PROVIDE ADEQUATE SUPPORT FOR, BETTER GOVERNMENT ANALYSIS OF U.S. AND FOREIGN INNOVATION SYSTEMS**

The U.S. must create—and provide meaningful financial resources to—institutions within the Federal government capable of performing high quality analysis of U.S. and foreign innovation systems, and formulating a Federal innovation policy and investment agenda commensurate with the new economic realities and 21st century competitiveness challenges.

Executive Summary

The United States confronts a global competitive landscape that has radically transformed in the past decade. Fueled by global deployment of advanced telecommunications, trade liberalization, and economic reforms in many countries, globalization and integration of the world's national economies have accelerated, and emerging economies represent a growing share of global business commerce. While these changes spread increased growth and economic opportunity around the world, the competitive arena is more crowed than ever before.

The United States must now compete against many other nations to attract and retain the R&D investment and business activities that drive our economy, and an increasing number of Americans at all skill levels find themselves in direct competition with foreign workers. High wage advanced economies will find it more difficult to compete in the global marketplace to perform many routine tasks, routine manufacturing and routine service delivery. In this environment, U.S. competitiveness will depend on our ability to develop and deliver "first to the world" products and services. Ensuring America remains the world's leader in science, technology and innovation will be key to meeting this challenge.

This report examines the powerful forces driving this global economic transformation, and outlines an action agenda for policy makers to begin making the dramatic changes in support for innovation that will be necessary to ensure U.S. leadership in innovation in the 21st century.

A Transformed Competitive Landscape

Some of the key factors driving today's global economic competition include:

- **China and India are becoming powerful actors on the global stage.** China's economic growth—averaging 10% since 2003—owes much to the extraordinary share of GDP devoted to capital investment. China is attracting substantial foreign direct investment, a significant portion of which is accounted for by non-Chinese producers locating manufacturing facilities there. Given its size and rapid growth, China's economic transformation will have a large impact on the global marketplace.

  Services are driving economic growth in India, accounting for more than half of India's output. The Indian economy has posted an average growth rate of more than 7% since 1996. India is capitalizing on its large numbers of well-educated English-speaking people to become a major exporter of software services, IT workers, and IT-enabled services.

- **Business enterprise has become increasingly global.** The digitization of work processes and the slicing of these processes into value chains of separable activities, coupled with high-speed telecommunications, have dramatically reduced the costs of coordinating production and supply chains among globally distributed suppliers. This has expanded the scope of tradable products and service tasks to IT, accounting, customer service, product design, R&D, and more. Multinational corporations increasingly employ global sourcing and delivery strategies. They develop products and services, and serve overseas customers through foreign affiliates, partners, and foreign business ventures.

  While the digital infrastructure and globalization of supply chains have improved productivity in the United States—a key to improved living standards—and increased economic growth and opportunity around the world, they also present new competitive challenges for the United States.

- **A global "trade in tasks" has arisen and created new competitive challenges.** Billions of people from emerging economies have entered the global free market system. Many workers in these nations are educated, skilled, and ready for work. As a result, a growing number of American workers at every skill level are in direct competition with workers around the globe.

- **Competition in high technology industries has grown more important.** High technology industries are vitally important to the U.S. economy, and are driving economic growth around the world. High technology industries report about 30% more value-added than other manufacturing industries, they generally pay higher wages, and they are major performers of R&D.

  Competition in high technology industries is expanding. South Korea and Taiwan are increasing their global presence in high technology manufacturing. National policies that combine government measures and corporate investments have spurred growth in high technology industries in places such as Ireland and China, exports by Asia's high technology manufacturing industries have grown especially rapidly.

New Challenges to America's Historic Strengths in Science and Technology

The United States remains the world's leader in science and technology. However, in many measures of science and technology leadership—domestic R&D investment, patents, scientific publications, scientific researchers, and science and engineering degree production—the U.S. share of global output has fallen.

Nations around the world recognize the vital role science and technology play in global competitiveness, innovation, economic growth and job creation. Many of these nations are increasing their investments in research and technology development, high technology infrastructure, and in producing science, engineering, and technology talent. As other nations increase their science and technology capabilities, they will become more attractive for global business investment and the location of R&D.

Some key developments include:

- **China is rapidly becoming an R&D leader.** China's rapid advance on the leading R&D-performing countries and regions is unprecedented in recent history. According to OECD data, Chinese R&D spending was expected to reach $136 billion in 2006, up from $12.4 billion in 1991, in part, reflecting the growth of R&D performed by foreign-owned firms based in China. This would make China the world's second highest investor in R&D, behind only the United States.

  This rapid growth in R&D investment is complemented by the growth of China's research workforce. The number of researchers increased 77% between 1995 and 2004, and the country now ranks second worldwide with 926,000 researchers, just behind the United States (more than 1.3 million).

- **U.S. competitors are building their science and technology talent bases.** For the past three decades, science and engineering degrees have constituted about one-third of U.S. bachelor's degrees. In several countries/economies around the world, the proportion of first degrees in science and engineering fields is higher than in the United States—in Japan (64%), China (57%), and South Korea (47%).

  The EU graduated one-third of the new science and engineering doctorates worldwide. One-third of the engineering doctorates were awarded in Asia (where numbers are understated because of incomplete reporting). While the United States produced 15% of the world's engineering doctorates in 2002, students on temporary visas earned more than half of these degrees.

- **Emerging economies show rapid increases in science and technology accomplishment.** Dramatic increases in patenting and scientific publication outside of the traditional leading science and technology countries over the past several years demonstrate the ever-widening global competition in science and technology, and increased technological sophistication in other parts of the world. Between 1990-2003, U.S. patent applications from China and the Asia-8 rose by 800% and, by 2003, constituted nearly one-fifth of all foreign-resident inventor filings. In recent years, Taiwan and South Korea have displaced Canada and France in the top five foreign country recipients of U.S. patents.

  Rapid development of scientific expertise outside the United States, the EU, and Japan is also demonstrated by research articles published in the world's major peer-reviewed scientific and technical journals. From 1988 to 2003, the combined share of research articles published held by the United States, Japan, and the EU15 declined slightly from 75% to 70% of the total.

- **Global competitors are focused on physical science and engineering research.** Competitors are focused on improving capabilities in physical sciences and engineering, disciplines that play a vital role in fueling innovation-based economies. For example, China is beginning to show leading-edge capabilities in important fields such as materials science and supercomputing. While the United States, Japan, Germany, and South Korea remain leaders in nanotechnology, China is moving into the top tier. Chinese government spending on nanotechnology is ranked second globally, behind only the United States on a purchasing power parity basis.

An Action Agenda to Maintain U.S. Leadership in Innovation In a Radically Changed Global Economy

Rising concerns about America's future leadership in science and technology, and our ability to innovate and compete have spurred national efforts to examine America's competitive strengths and weaknesses, and improve the U.S. position. Recent actions by the President, the Congress, and the nation's governors—culminating most recently in passage of the *America COMPETES Act*—are vital first steps in bolstering the nation's ability to innovate and compete. However, increasing investment in fundamental research, and improving math and science education are insufficient to ensure U.S. innovation leadership in the 21st century.

Increasingly, the competitiveness of the United States will be defined by its ability to generate, absorb, and commercialize knowledge, and compete in areas of business and work that the developing world cannot perform. This requires an emphasis on cutting edge R&D; the development of groundbreaking products, services, and business models; highly creative design and marketing; and world-class supply chain management.

A dramatic change in our approach to innovation is required, if the United States is to sustain its competitive advantage. Doing so will require a transition to an innovation-driven economy capable of routinely developing and commercializing "new-to-the-world" technologies, products, and services.

Following is ASTRA's recommended action agenda to maintain America's leadership in innovation by strengthening U.S. research and development assets, developing a world-class workforce for the innovation economy, and creating a business environment that supports entrepreneurship, innovation, and competitiveness. ASTRA hopes that preparing the United States for sustained leadership in innovation will take center stage as the nation's next President and Congressional leaders take office in January 2009.

Strengthen U.S. Research and Development Assets

1. The Federal government should restore balance to the defense/civilian share of the Federal R&D investment portfolio.

Given the ongoing private sector focus on R&D investment that supports product and services development and deployment, the public investment in basic and applied research is more important than ever to ensure U.S. leadership in science and technology.

Civilian R&D's share of the Federal research portfolio has declined substantially since 2001, when civilian R&D accounted for 56% of the Federal research investment. Of the 42% of Federal R&D investment allocated for civilian research today, half is invested in health-related R&D. As a result, about 80% of Federal R&D investments are devoted to either defense (primarily weapons systems development and testing) or health. While defense and health research remain vitally important to the nation, it is essential that investment in the leading edge civilian technologies that underpin the U.S. economy be increased, and that a balanced investment portfolio be created.

2. As a crucial step in achieving a balanced Federal R&D portfolio, the Federal government should substantially increase Federal investments in physical sciences and engineering R&D.

Despite their critical importance to the nation's security, economy and industrial base, physical sciences and engineering have taken a back seat to weapons systems development and health in the U.S. public research portfolio. Federal investments in the physical sciences have remained flat for nearly two decades, and investment in engineering research has seen only modest growth.

To address the need for more physical sciences and engineering R&D, President Bush made investment in this area the centerpiece of his American Competitiveness Initiative (ACI). The ACI would double funding at key Federal agencies that support physical sciences and engineering research, $50 billion in new investment over ten years.

The Congress and the Administration should fulfill the physical sciences and engineering R&D commitments made in the ACI. However, to ensure that funding expands beyond increases in inflation, the timetable for these investments should be accelerated. In addition, investment should be increased beyond the ACI recipient agencies.

3. The Federal government should increase and stabilize funding for applied research and advancing promising, high-risk technologies with substantial economic potential to bring them to a stage of maturity that is attractive for private sector investment. This includes funding for the new Technology Innovation Program and other programs that meet this objective. In addition, the approach to SBIR funding should be reviewed to determine how this program could maximize its ability to contribute to the U.S. innovation base.

Many results emerging from basic research, and early-stage technologies are not sufficiently developed and, thus, too risky to attract investment from individual companies, financial institutions, venture capitalists, or angel investors. As a result, promising technologies may be ignored or developed too slowly to compete in rapidly changing world markets, or these technologies may be commercialized outside the United States if market incentives for pre-commercialization activities are lacking here.

The Federal government has made some investments to further the development of high-risk and generic technologies to bring them to a stage of maturity at which the private sector is able to invest to bring them to market, including funding for the Advanced Technology Program at the National Institute for Standards and Technology (NIST)[1] and other programs that meet this objective, such as the Small Business Innovation Research Program (SBIR). However, funding for this type of investment has been uncertain. In addition, the formulaic approach to SBIR funding does not consider how to optimize the overall SBIR investment portfolio's potential to contribute to innovation and private sector commercialization. The current approach to SBIR funding should be reviewed to determine how this program could maximize its ability to contribute to the U.S. innovation base.

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1 The *America COMPETES Act* eliminates ATP and establishes a new program—the Technology Innovation Program—with similar objectives.

4. A large share of Federal R&D investment should focus on the leading edge of science and technology, especially in fields expected to have revolutionary impacts such as nanotechnology, biotechnology, and high-performance computing.

Because science and technology flow around the world, there is growing concern about the potential for migration of U.S.-based research assets to other countries. However, new knowledge and technology are not well codified and, thus, more difficult to transfer. As a result, the geographic source of new knowledge and technology can serve as a powerful magnet for attracting business activity, scientific and technical talent, and capital investment focused on commercializing new innovations. Creating more and maintaining leading edge R&D in the United States would help preserve and attract these competitive assets domestically.

5. The Federal government should increase R&D to support the U.S. service economy, including support for services innovation, productivity, efficiency, competitiveness, and technical workforce development.

Historically, most research has been geared to support manufacturing. However, the U.S. services sector had emerged as a set of dynamic, technology-intensive industries with major impact on the U.S. economy, accounting for 78% of U.S. GDP, and 78% of U.S. employment. More frequently, service industries rely on science

and technology in their operations, and technology also is changing service functions and products in manufacturing companies. As a result, service industries will increasingly benefit from scientists, engineers, and information technology workers who are trained to apply science, technology, and engineering to service sector innovations and operations.

More R&D is needed to support services innovation, productivity, efficiency, competitiveness, and technical workforce development. An R&D agenda, informed by the needs of the service industries, would bring together disciplines such as computer science, operations research, computational research, industrial engineering, business modeling, management sciences, and social and cognitive sciences in inter- and multidisciplinary research.

6. While investigator-driven research remains the cornerstone of Federally supported academic R&D, the Federal government should increase attention to emerging opportunities for interdisciplinary and multidisciplinary research, including a focus on centers of research excellence where rapid development of innovations requires this type of collaboration. This includes reaching out to academic institutions in geographic regions in which the potential for innovative capacity exists—such as high quality research and researchers—but needs further nurturing.

Some Federal R&D investments should reflect the complex and multi-disciplinary nature of innovation today. Increasingly, innovations arise at the intersection of disciplines or require the integration of several disciplines, particularly in fields expected to have revolutionary impacts such as nanotechnology, biotechnology, and high-performance computing. In recognition of this important and growing aspect of innovation, some Federal R&D investments should encourage cross-fertilization and the integration of knowledge from different disciplines.

Multidisciplinary centers of cooperative research offer the opportunity to integrate a broader spectrum of research and technical skills capable of focusing on problems of a scope or complexity requiring the advantages of scale, synergy, and interdisciplinary interaction. In addition, because a critical mass of research is taking place in a single location, such a research center can serve as a powerful magnet for attracting business investment.

Most academic R&D is concentrated in relatively few of the 3,600 U.S. institutions of higher education. About 100 institutions account for 80% of academic R&D, and the top 200 institutions account for about 95%. Maintaining America's leadership in science and technology will require not only nurturing our existing base of university research, but also looking to create new centers of excellence in geographic regions in which innovative capacity exists.

7. To ensure the United States reaps the benefits of Federal R&D investments, the Federal government should examine what incentives can be put in place to enable adequate returns from public R&D to be captured domestically. For example, the United States should consider devoting a small part of the Federal research portfolio to investments in applied research, technology prototyping, demonstration, testing, pilot-scale production, and other pre-competitive activities to increase the likelihood of eventual commercialization on our shores.

The U.S. public investment in R&D is substantial, and predicated on the belief that this investment will generate economic and social returns to the nation. However, for the most part, these returns cannot be realized without substantial private sector investment in commercialization. But, today, many companies are global in nature, and seek to locate some R&D and manufacturing in the markets they serve. Also, because the cost of manufacturing is relatively higher in the United States than in many other nations, firms can be attracted to low cost offshore manufacturing.

The United States should take steps to increase the likelihood of establishing and retaining on its shores higher-end manufacturing operations with high-skill and sophisticated technical requirements. This would increase opportunities for the United States to capture fuller benefits from its public R&D investments, and increase the return on investment to U.S. taxpayers.

Develop a World-class Workforce for the Innovation Economy

8. The United States needs to examine whether prevailing skill levels are adequate for an innovation-based economy, and our success in a growing global "trade in tasks" in which routine knowledge work is easy to ship offshore.

Research indicates that the skill mix in the United States is moving upscale. A recent study showed that jobs that require higher order skills—such as complex communications and expert thinking—are growing, while jobs that require routine and non-routine manual skills, and routine cognitive skills are on the decline.

It is widely accepted that students need to be taught problem-solving skills. However, if a problem can be solved by rules, it can also be programmed for computer processing, or written down in a set of rules that can instruct lower-wage workers overseas what to do. As a result, routine problem solving has diminishing value in the labor markets of advanced nations. Solving new problems cannot be programmed in this way, and it is difficult to capture high end thinking in rules, including activities such as formulating and solving new problems, exercising good judgment in the face of uncertainty, creating new products and services, and recognizing what needs to be done and what rules may apply. These are skill sets needed in the innovation economy.

9. The United States should provide better and more detailed information on the nation's need for scientists, engineers, and information technology workers.

The science, technology, engineering, and mathematics (STEM) labor market changes in response to scientific and technological developments, and business needs. Demand in certain STEM disciplines may increase while, during the same time period, demand in other disciplines wanes. Moreover, technological advancements can significantly affect the STEM labor market, making some skills obsolete, and creating high demand for other skills. The education system, as well as current and prospective STEM workers, must be prepared to move quickly in response to technical and market change, and new jobs and careers as they emerge. Recruiting domestic science and engineering talent depends on students' perceptions of the careers awaiting them.

The National Science Foundation should: encourage employers to better articulate their current and prospective STEM workforce needs, and the types of skills and disciplines needed; ensure students and workers understand what these specific skills and disciplines are; as well as encourage a significant shortening of the feedback loop between employers and their needs, and the responses by education and training institutions. This includes providing career information and nurturing to groups underrepresented in STEM—such as minorities and women—to increase their knowledge of the opportunities in STEM education and careers.

10. The Federal government should encourage university educators to broaden the skill sets of U.S. scientists, engineers, and information technology workers. University educators should ensure that scientists, engineers, and IT professionals have: global and cultural awareness; knowledge that helps them understand business, markets, marketing, and customers; the ability to work as a member of and communicate effectively in teams of diverse disciplines; some understanding of business finance such as cost-benefit and return on investment concerns; as well as project management abilities.

Science and technology have become ever more central to core business functions in a wide range of companies and industries. U.S. scientists, engineers, and IT professionals need to possess the multi-dimensional skill set that employers need, and that can underpin—not just the creation of new knowledge—but innovation in its many manifestations.

11. The United States should strengthen efforts to attract top foreign students and Ph.D.-level professionals in science, engineering, and technology. This includes developing a national strategic plan for recruiting top international students, scientists, engineers, and technologists, and evaluating the U.S. immigration system to remove barriers to these talented individuals migrating to the United States.

The most advanced levels of science and technology work remain an activity vital for continued U.S. science and technology leadership. The highest expression of scientific and technical work—for example, groundbreaking research, research program design, the education and training of future scientists and engineers, or research and engineering project management—is often the responsibility of an individual who has obtained a Ph.D. degree.

The United States must develop, attract, and retain highly skilled Ph.D. degree holders to ensure that a large share of the world's most advanced work in science and technology is performed within the United States. However, three factors may undermine the U.S. ability to do so: foreign students comprise a large share of those receiving Ph.D. degrees awarded by U.S. universities in key science and engineering fields and, increasingly, these Ph.D. degree holders have opportunities to perform R&D in their home countries; global competition for highly skilled technical talent is increasing; and U.S. immigration policies can inhibit U.S. attraction and retention of foreign scientists and engineers.

To compete with countries that are rapidly expanding their scientific and technological capabilities, the United States needs to bring to the country those whose skills will benefit society and enable us to compete in a high-value innovation economy. We need an integrated, strategic approach to recruiting and retaining international students and STEM professionals. This approach should include incentives to attract leading foreign-born scientists, engineers, and technologists, including public funding for their research if they migrate to and carry out that research in the United States.

Create a Business Environment that Supports Innovation and U.S. Competitiveness

12. The next President should launch a White House initiative to perform a comprehensive review of U.S. laws and regulations relating to the business climate for innovation. This would include regulations promoting human health and safety, standards and environmental protection, as well as tax, trade and antitrust policies, to determine whether changes are needed to meet the nation's public policy goals while, at the same time, promoting innovation and competitiveness.

While investment in R&D, and development of world-class scientific and engineering talent are necessary foundations of an innovation economy, investment in these assets alone is insufficient to ensure America remains the world's leading innovation economy. There are many factors that drive the transformation of knowledge into useful products and services, and value for society. Innovating enterprises interact with an innovation "ecosystem" that includes: capital resources; industry codes and standards; government regulatory, tax, and trade policies; state and regional technology initiatives; entrepreneurial culture; telecommunications and social networks; and organizational, management, and business practices.

Government regulatory, tax and trade policies can create a business environment that either encourages and rewards or serves as a barrier to innovation. The costs of doing business—including the costs of regulatory compliance—affect a firm's financial ability to invest in innovation, as well as its decisions about where to locate business activity and manufacturing. In addition, some times regulatory approaches can discourage the creation and deployment of more innovative technologies.

To ensure U.S. technological leadership in today's global economy, the United States will need to attract leading edge R&D and business investment from around the world, and creating a welcoming pro-innovation business climate is an essential ingredient in attracting that investment. Because most U.S. tax, trade and regulatory policy was developed without innovation in mind, a comprehensive review of these regimes would be beneficial to ensure that other priority U.S. goals—such as ensuring human health and safety—are accomplished while, at the same time, promoting U.S. innovation leadership.

Create an Institutional Capability to Support Sound Policy Making to Promote Innovation and Competitiveness

13. The United States needs to develop a meaningful set of innovation indicators to help guide policy and strategy. The Federal government should lead an effort to determine where the priorities are, and begin the process of developing some high level indicators around the key drivers of innovation that are known and recognized.

Knowledge and innovation are vitally important to the U.S. economy. Yet, many elements of our measurement systems were designed to measure an economy dominated by manufacturing and physical goods production. The United States needs to develop a strong analytical capability and a system of metrics to better understand the unfolding innovation economy, and the relative position of the United States and U.S.-based firms' competitiveness in the global economy.

The purpose of a system to measure "innovation vital signs" would be to provide policy makers a tool to evaluate the nation's innovation capabilities and performance, and to better assess policy choices and potential impacts. This system should take a multi-dimensional and comprehensive view that recognizes the complexity of the innovation process and the context in which innovation takes place.

14. The United States must create—and provide meaningful financial resources to—institutions within the Federal government capable of performing high quality analysis of U.S. and foreign innovation systems, and formulating a Federal innovation policy and investment agenda commensurate with new economic realities and 21st century competitiveness challenges.

The Federal government lacks adequate capacity and resources devoted to innovation-related policy analysis and development. Over the past two decades, competitor nations have dramatically increased the level of national attention and resources devoted to research and analysis regarding the global economy, national systems of innovation, and development of strategies to promote technology development and commercialization. In contrast, the United States has downsized its innovation-related analytical and policy making infrastructure, including the elimination of the Congressional Office of Technology Assessment in the mid-1990s, and the Technology Administration within the U.S. Department of Commerce in 2007.

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U.S. Innovation, Productivity, and Prosperity

Introduction

By almost any measure, the United States remains the most competitive and innovative country in the world. Among larger countries (those with 20 million or more people), the United States is the world leader in productivity and efficiency—in overall productivity measured as GDP per person employed, in industrial productivity, and in services productivity. This strong performance is due, in no small measure, to America's ability to manage its science and technology resources, and apply its business assets to new economic opportunities.[2]

At the firm level, the American business culture rewards nimbleness and innovation. The U.S. science and technology enterprise remains the world's strongest and most technically diverse. And America's culture of entrepreneurship and risk taking, flexible capital markets, and innovation skills have helped make the U.S. economy particularly strong in terms of new product and services commercialization. The World Economic Forum's 2006 competitiveness rankings cite U.S. market efficiency, the sophistication of U.S. businesses, and our science and technology enterprise as making the United States a highly competitive economy.

Despite our strength, new competitive realities are creating a host of challenges that require the United States to take steps and make new investments to ensure our continued leadership in innovation.

> *Civilization is on the brink of a new industrial world order. The big winners in the increasingly fierce global scramble for supremacy will not be those who simply make commodities faster and cheaper than the competition. They will be those who develop talent, techniques, and tools so advanced that there is no competition. That means securing unquestioned superiority in nanotechnology, biotechnology, and information science and engineering.*
>
> *—President's Council of Advisors for Science and Technology*[3]

2 World Competitiveness Center.

3 Sustaining the Nation's Innovation Ecosystems: Information Technology Manufacturing and Competitiveness, PCAST, January 2004.

1. A Transformed Competitive Landscape

The United States confronts a global competitive landscape that has radically transformed in the past decade. The effects of these changes are colossal in scale, larger and more profound than the challenges to U.S. economic leadership brought about by competition from Japan, severe losses in U.S. manufacturing, and slow productivity growth twenty years ago.

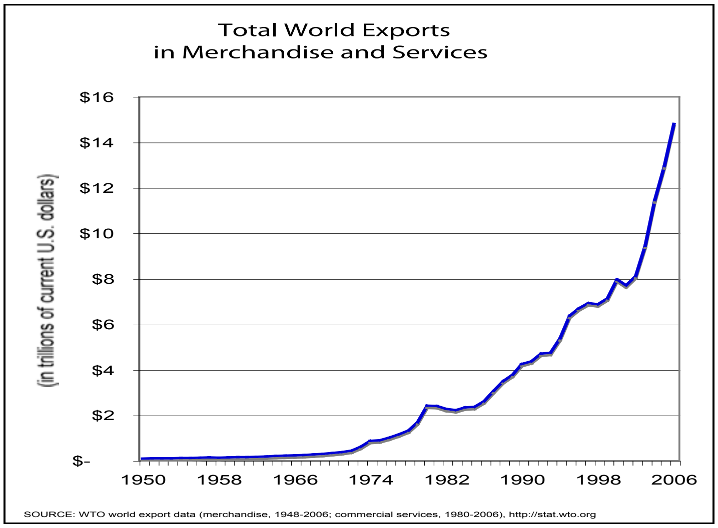
New Competitive Realities

- **Unprecedented levels of global competition among nations.**
- **Global competition to acquire business investment, R&D facilities, and outsourced work.**
- **Competitors strengthening market positions in high tech industries vital to the U.S.**
- **More American workers in direct competition with workers abroad.**
- **China and India developing rapidly into powerful actors on global stage.**

1.1 Global Integration is Raising Economic Competition Among Nations to Unprecedented Levels

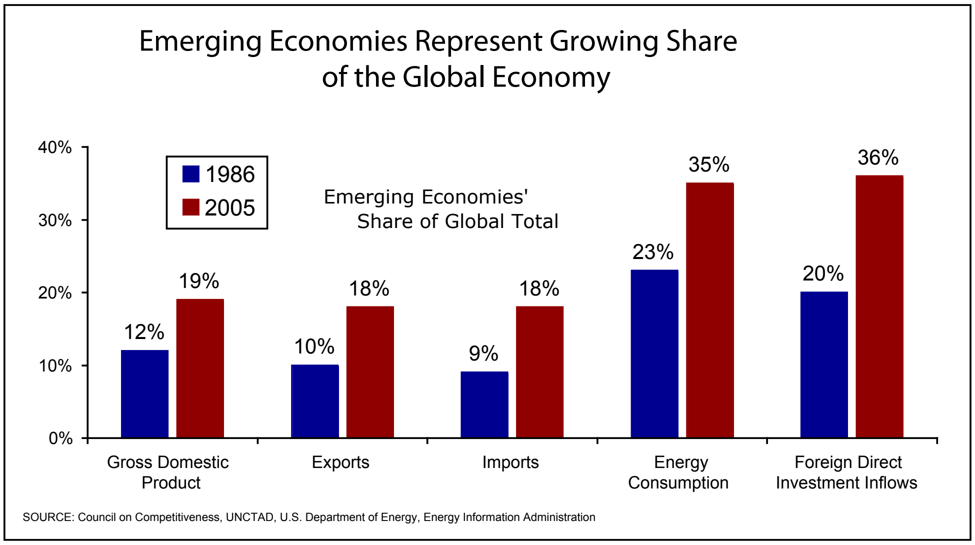
Fueled by global deployment of advanced telecommunications, trade liberalization, and economic reforms in many countries, globalization and the integration of the world's national economies has accelerated. To participate in global free markets, many countries, including developing nations, have made reforms to their laws to open trade and business investment, and they have built the infrastructure required to support modern commerce.

Many of these nations are working hard to attract global business operations and investment, including offering a range of incentives to lure global companies. Emerging economies are connecting to advanced countries, their markets, and businesses, and represent a growing share of global business commerce. As a result, the competitive arena is more crowed than ever before. The scale and pace of the current global economic integration is unprecedented.



For example, in recent years, global merchandise exports have been above 20% of world GDP, compared with less than 15% as recently as 1990, and international financial flows have expanded even more quickly. But these data understate the magnitude of change we are now experiencing. The emergence of China, India, and the former communist-bloc countries implies that the greater part of the earth's population is now engaged, at least potentially, in the global economy.

There are no historical antecedents for this development. Columbus's voyage to the New World ultimately led to enormous economic change, but the full integration of the New and the Old Worlds took centuries. In contrast, the economic opening of China, which began less than three decades ago, is proceeding rapidly.[4] China's real growth in GDP has accelerated at a breakneck pace, averaging about 10% annually since 2003, and gross domestic investment per capita has more than tripled since 1995. China's investment-to-GDP ratio exceeded 40% percent of GDP in 2005.[5] India's and Russia's GDP doubled from 1995 to 2006. Russia's GDP has been growing more than twice the rate of the United States, and India's GDP has been growing three times as fast.[6]



In addition, global cross-border capital flows have reached a record $6 trillion, more than double the level of 2002. While 80% of the capital flows are between the United States, the UK, and the EU, capital flows to emerging markets are growing rapidly. This may signal increasing integration into a single global market for capital.[7]

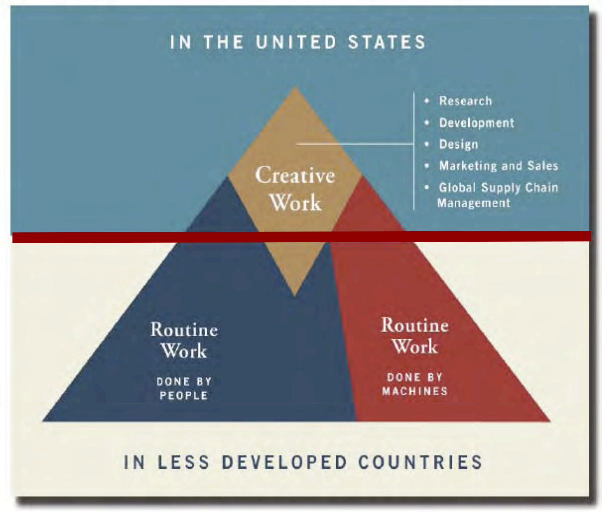
1.2 Multinational Corporations Are Globalizing Value Chains, Creating High Levels of Global Competition for Business Investment, R&D Facilities, and Outsourced Work

The geographical extension of production processes is far more advanced and pervasive than ever before, and much more responsive to relative labor costs around the world.[8] Increasingly, multinationals locate production and service facilities overseas to be near the markets they serve. In addition, production processes are becoming more distributed geographically. Rather

4 Global Economic Integration: What's New and What's Not, Remarks by Ben Bernanke, Chairman Federal Reserve Board, August 25, 2006.
5 World Economic Outlook 2007, International Monetary Fund.
6 International Monetary Fund.
7 Mapping the Global Capital Markets Third Annual Report, McKinsey and Company, January 2007.
8 Global Economic Integration: What's New and What's Not, Remarks by Ben Bernanke, Chairman Federal Reserve Board, August 25, 2006.

than producing goods in a single process in a single location, firms can break the production process into discrete steps and perform these steps in locations that are favorable in terms such as availability of talent, cost of production, and market proximity. For example, the U.S. chip producer AMD locates most of its research and development in California; produces in Texas, Germany, and Japan; does final processing and testing in Thailand, Singapore, Malaysia, and China; and then sells to markets around the globe. In another example, IBM's team for a complex utility project includes research scientists in New York and Texas, software developers in India, engineering equipment and quality specialists in Florida and New York, and utility experts and software designers from Pennsylvania, California, Illinois, and North Carolina.[9]

Profile of Successful U.S. Firms in the Future



Source: *Tough Choices or Tough Times, The Report of the New Commission on the Skills of the American Workforce, National Center on Education and the Economy*

The digitization of work processes and the slicing of these processes into value chains of separable activities, coupled with high-speed telecommunications, have dramatically reduced the costs of coordinating production and supply chains among globally distributed suppliers. The digital infrastructure and globalization of supply chains have improved productivity in the United States—a key to improved living standards—and increased economic growth and opportunity around the world. However, a growing global "trade in tasks" enabled by digitization presents new competitive challenges for the United States.

Enabled by the digitization of work and advanced telecommunications, multinational corporations frequently employ global sourcing and delivery strategies. While these companies continue to participate in cross-border trade, U.S. multinationals are developing products and services, and serving overseas customers through foreign affiliates, partners and foreign business ventures. For example, sales from foreign affiliates of U.S. companies are more than three times greater than all U.S. exports of goods and services. With the emergence of highly integrated, digitally enabled global enterprises, the lines between domestic and foreign business operations are disappearing.

Nevertheless, U.S. multinationals face challenges in these overseas operations, especially in the developing world. These include geopolitical risk, problems with data security and confidentiality, reliability of telecommunications and other infrastructure, unwanted knowledge transfers, and risk to intellectual property. In addition, companies may face a range of management challenges in areas such as inadequate management skills of foreign partners, cultural differences and communications, difficult knowledge transfers, and different work schedules.

1.3 American Workers Face Expanding Global Competition for Work and Jobs

At the same time that "trade in tasks" is growing, over the past 20 years, the globally available labor force has risen fourfold. Billions of people from emerging economies—such as China, India, and the former states of the Soviet Union—have entered the global free market system, opening large and lucrative new markets, and labor pools of unprecedented size.

9 At IBM, a Smarter Way to Outsource, New York Times, July 5, 2007.

Many workers in these nations are educated, skilled, and ready for work. The supply of workers with higher education available globally has increased by about 50 percent in the past25 years.[10] Many of these workers in emerging economies are enthusiastic, growing in their sophistication, and hungry for success. As a result, a growing number of American workers at every skill level are in direct competition with workers around the globe.

High-wage, advanced economies will find it more difficult to compete in the global marketplace to perform many routine tasks, routine manufacturing, and routine service delivery. For example, while total hourly compensation costs for manufacturing workers increased more rapidly in China than in the United States between 2002 and 2004, hourly compensation per employee in China continued to be 3% of the U.S. level.[11]

As competitive pressures rise, routine work that can be codified into a set of rules and transmitted via high-speed telecommunications will increasingly be performed in the developing world, or even by machines. This is likely to require adjustments for more and more of the workforce—in the way we work, and the way we educate our people—since the United States will need to focus on high-value knowledge and creative work; high value-added, leading-edge products and services; and high levels of customer service and service options to differentiate its offerings in the global marketplace.

1.4 Competition Rising in High Tech Industries Vital to the United States

High technology industries are driving economic growth around the world. For example, during 1980-2003, the production of high technology goods grew nearly 6.4% annually, compared with 2.4% for other manufactured goods.[12] Growth in high technology production was especially strong during the late 1990s, growing at more than four times the rate of growth for all other manufacturing industries. High technology industries are R&D intensive. R&D leads to innovation, and firms that innovate tend to gain market share, create new product markets, and use resources more productively. High technology industries are important to the U.S. economy:

- During the 1980s, manufacturing output in the United States and other high-wage countries shifted to the production of higher value-added, technology-intensive goods. In 1980, high technology manufactures accounted for about 11% of total U.S. domestic production. By 1990, this figure had increased to 13.5% and, due to the demand for communication and computer equipment, grew to more than 27% by 2000. By 2003, high technology manufactures were estimated to be 34% of domestic manufacturing output in the United States.[13]

- In the United States, high technology industries reported about 30% more value added than other manufacturing industries[14].

- High technology industries generally pay higher wages than other manufacturing industries. In a U.S. Bureau of Labor Statistics analysis of 44 high technology industries, all had median earnings greater than the median for all industries in May 2004. In five of the high technology industries,

10 World Economic Outlook 2007, International Monetary Fund.

11 Labor Costs of Manufacturing Employees in China: An Update to 2003-2004, Monthly Labor Review, Bureau of Labor Statistics, U.S. Department of Labor, November 2006. These statistics do not consider other benefits Chinese workers may receive in lieu of wages, such as room and board.

12 Analysis from Global Insight World Industry Service database.

13 Science and Engineering Indicators 2006, National Science Foundation.

14 Science and Engineering Indicators 2006, National Science Foundation.

wages were at least twice the median for all industries. In 21 more high technology industries, wages exceeded the median for all industries by 50-99 percent.[15]

- The industrial R&D performed by high technology industries benefits other commercial sectors by developing new products, machinery, and processes they use to increase their productivity and expand business activity.

South Korea and Taiwan typify the growth of R&D-intensive industries in newly industrialized economies. In 1980, high technology manufactures accounted for 9.6% of South Korea's total domestic manufacturing output. This share increased to 14.8% in 1990, and reached an estimated 21.5% in 2003. The transformation of Taiwan's manufacturing base is even greater. High technology manufacturing in Taiwan accounted for 9.7% of total domestic output in 1980, 15.9% in 1990, and jumped to an estimated 28.5% by 2003.[16]

Directed national policies that combine government measures and corporate investments have spurred growth in high technology industries in places such as Ireland and China. For example, Ireland's high technology manufacturing industries accounted for 12.4% of total domestic output in 1980, 26.4% in 1990, but for more than half its total domestic production since 1999.[17] China's high technology manufacturing accounted for just 4.8% of total domestic output in 1980, 6.2% in 1990, but an estimated 19.0% in 2003. The value of China's domestic high technology production in 2003 is estimated to be twice that of Germany, nearly identical to production in Japan, and nearly five times that of Ireland.[18]

Exports by Asia's high-technology manufacturing industries have grown especially rapidly since 1990. In 2003, Asia accounted for 43% of world high technology exports, up from 33% in 1990.[19] High technology manufacturing exports from China and the Asia-8 economies rose at the expense of the United States and Japan. The U.S. share of global exports declined from 23% to 16% from 1990 to 2003. The Japanese share dropped from 17% to 9%. China's rise in high technology exports, from $23 billion in 1990 to $224 billion in 2003—a remarkable ten-fold increase in a little more than a decade—moved its share of world high-technology exports to 12%.[20]

Multinational corporations have contributed to the development of high technology manufacturing in the emerging world. When foreign investments and foreign corporations represent major portions of a developing country's manufacturing base, it is likely that the foreign corporations are transferring technological and manufacturing know-how to the host country. For example, electrical engineering and electronics, and chemicals are among the industries in which R&D is most global.

The primary knowledge base in these industries is codified and, therefore, the transfer of knowledge and R&D can be easier. The R&D in sectors that rely on more complex knowledge—such as pharmaceuticals, healthcare, industrial manufacturing, energy, and consumer goods—is less globally diverse because it is more difficult to move.[21] This suggests that the United States should seek to

15 High-technology Employment: A NAICS-based Update, Monthly Labor Review, Bureau of Labor Statistics, U.S. Department of Labor, July 2005.

16 Science and Engineering Indicators 2006, National Science Foundation.

17 Science and Engineering Indicators 2006, National Science Foundation.

18 Science and Engineering Indicators 2006, National Science Foundation.

19 Asia's Rising Science and Technology Strength, Comparative Indicators for Asia, the EU, and the United States, National Science Foundation, May 2007.

20 Science and Engineering Indicators 2006, National Science Foundation.

21 Innovation: Is Global the Way Forward, A Joint Study by Booz-Allen Hamilton and INSEAD, 2006.

develop, attract, and retain industries and business operations that rely on complex knowledge, as well as those that generate new knowledge, which is harder to move because it has not been codified.

1.5 China and India Developing into Powerful Actors on the Global Stage

Given its size and rapid development, China's economic transformation will have a large impact on the global marketplace. China's economic growth—averaging 10% since 2003—owes much to the extraordinary share of GDP that is devoted to investment in new capital, such as factories, equipment, and office buildings. For example, from 1990 to 2001, fixed investment as a share of GDP in China averaged about 33% but rose to about 40% of GDP between 2001 and 2005.[22] Between 1978—when the Open Door policy reforms began, and 1989, output per employed person in China grew vigorously, at an estimated average rate of about 6.5% per year. However, from 1990 to 2005, productivity grew at an even more impressive rate of 9% per year.[23]

A central component of China's economic development has been its openness to trade and capital inflows.[24] For example, the value of goods exports and imports currently equals about two-thirds of China's GDP, a high level for a country of China's size. China's accession to the World Trade Organization (WTO) stimulated trade significantly; since joining the WTO in 2001, China has seen the dollar value of its exports grow at an average rate of about 30% per year, compared with annual growth of about 12.5% over the five years before gaining WTO membership.

China has also proved successful in attracting capital inflows, particularly foreign direct investment (FDI). The flow of FDI into China increased from about $2 billion in 1986 to $72 billion in 2005, making the country the third largest recipient of FDI in the world, after the United Kingdom and the United States.[25] A significant portion of Chinese manufacturing output exported to foreign markets is accounted for by non-Chinese producers who have located manufacturing facilities there. For example, of the 120 chemical plants being build around the world, one is in the United States and 50 are in China.[26] FDI benefits China's development by bringing with it new technologies, products, and business methods.

Services are driving economic growth in India, accounting for more than half of India's output with less than one third of its labor force. The Indian economy has posted an average growth rate of more than 7% in the decade since 1996, and India achieved 8.5% GDP growth in 2006.[27] India is capitalizing on its large numbers of well-educated people skilled in the English language to become a major exporter of software services, software workers, and IT-enabled services.

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22 The Chinese Economy: Progress and Challenges, Remarks By Ben S. Bernanke, Chairman of the Federal Reserve Board, before the Chinese Academy of Social Sciences, December 15, 2006.

23 The Chinese Economy: Progress and Challenges, Remarks By Ben S. Bernanke, Chairman of the Federal Reserve Board, before the Chinese Academy of Social Sciences, December 15, 2006.

24 The Chinese Economy: Progress and Challenges, Remarks By Ben S. Bernanke, Chairman of the Federal Reserve Board, before the Chinese Academy of Social Sciences, December 15, 2006.

25 The Chinese Economy: Progress and Challenges, Remarks By Ben S. Bernanke, Chairman of the Federal Reserve Board, before the Chinese Academy of Social Sciences, December 15, 2006.

26 How Long Will American Lead the World, Newsweek, June 12, 2006.

27 World Factbook, CIA.

In summary, while globalization and the accelerating integration of the world's economies creates positive benefits for the United States, countries and people worldwide, these forces create a competitive environment more challenging than ever before for Americans. The number of capable competitors is growing, and China's advancement is especially rapid due, in part, to high levels of foreign direct investment.

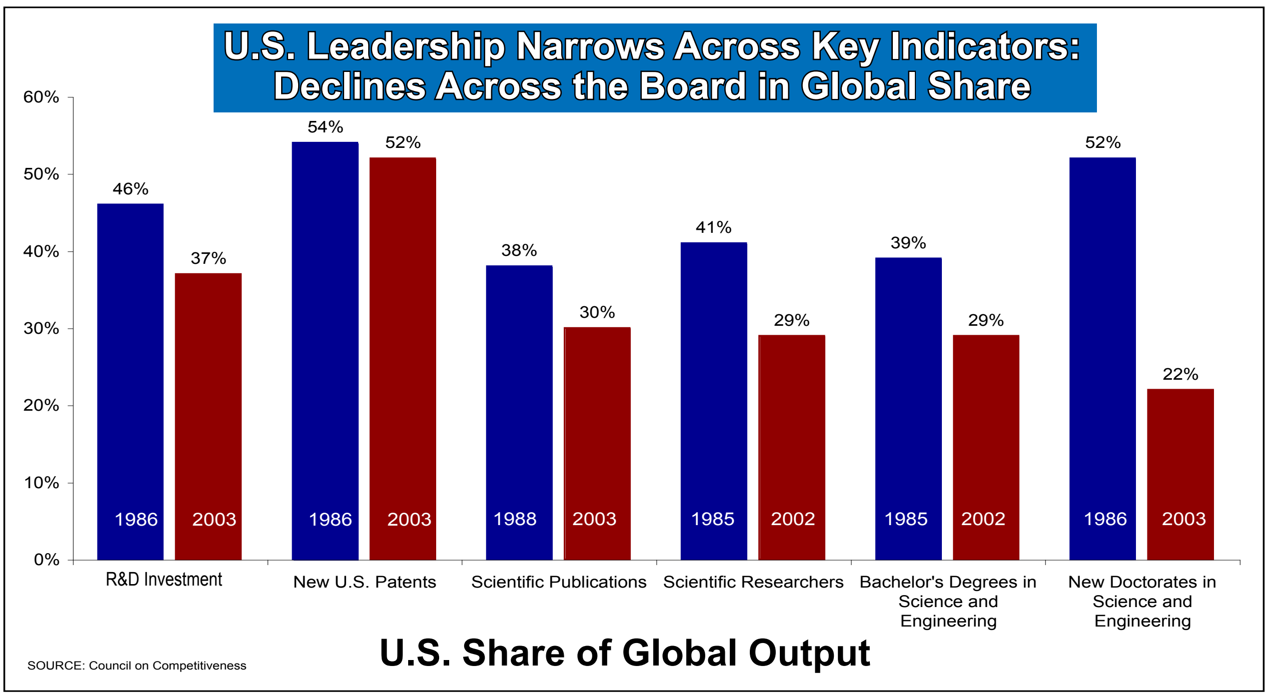
Many of these competitors are developing strengths in high technology products and service markets that are important to the United States. There is also greater competition globally to acquire business investment, R&D facilities, and outsourced work. In addition, more American workers in a greater diversity of industries and occupational classes are in direct competition with workers abroad.

2. New Challenges to America's Historic Strengths in Science and Technology

The United States remains the world's leader in science and technology. However, in many measures of science and technology leadership—domestic R&D investment, patents, scientific publications, scientific researchers, and science and engineering degree production—the U.S. share of global output has fallen.[28]

New Global Players in Science and Technology

- **Many nations strengthening science and technology capabilities.**
- **China rapidly becoming an R&D leader.**
- **Competitors building talent base to compete in science and technology.**
- **Emerging economies show rapid increases in science and technology accomplishment.**
- **Global competitors focused on physical science and engineering research.**



28 In addition, some of these indicators—such as R&D investment—may overstate the U.S. position. For example, the U.S. public research portfolio is dominated by defense investments—primarily development and testing of large weapons systems—while the public investments of competitor nations are heavily tilted toward commercially relevant R&D, making comparisons of these investments more difficult.

2.1 Many Nations Strengthening Science and Technology Capabilities

Nations around the world recognize the vital role science and technology play in global competitiveness, economic growth, and job creation. Many of these nations are increasing their investments in research and technology development, high technology infrastructure, and in producing science, engineering, and technology talent.

For example, in December of 2006, the European Union established its 7th Framework Program for research and technology development. The program is committed to invest more than $70 billion in research and technology development activities from 2007-2013, in areas such as health, biotechnology, information and communication technologies, nanotechnology, energy, and aeronautics.[29] This is the largest funding allocation for any EU framework program, and represents a 63% increase in funding over the 6th Framework. The program is aimed at helping meet one of the main EU goals—increasing the potential for economic growth and strengthening European competitiveness by investing in knowledge, innovation and human capital.

EU member states also committed to raising research spending from 2% to 3% of GDP by 2010. For example, Germany recently announced a new high-tech strategy in which the government will spend $19 billion in the next three years to boost technology research, technology-based enterprises, and national R&D investment to 3% of GDP by 2010. The investment will be spread over 17 innovative fields including information and communications technologies, health, optical technologies, environmental technologies, aeronautics, transport, nanotechnology, and biotechnology. The German initiative will focus on getting innovative products to market through strategic partnerships between government and industry, and on supporting small and medium-sized enterprises.[30]

Over the past decade, South Korea and Taiwan have advanced their technological capacity, and more often challenge U.S. prominence in many technology areas and product markets. More recently, China, Finland, India, and Ireland have begun to distinguish themselves as producers of world-class science and technology.

Based on the science and technology-driven economic growth strategies in other nations, it is not surprising that the U.S. share of global science and technology outputs would decline. However, the United States cannot be complacent. As other nations rapidly increase their science and technology capabilities, they will become more attractive for global business investment and the location of R&D. This is especially true of the rising science and technology capabilities in developing countries, where the cost of science, engineering, and technology talent is low compared to that in the United States. As characterized by the new Commission on the Skills of the American Workforce:

> *Indian engineers make $7,500 a year compared to $45,000 for a similarly qualified American engineer. Why would global businesses pay more than they have to pay the Indians to do work? They would be willing to do that, only if the United States can offer capabilities that engineers in places such as India and China cannot.*[31]

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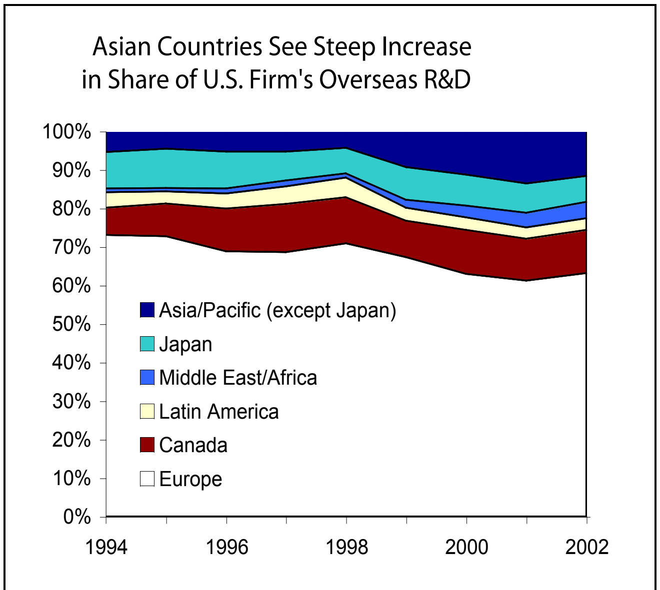
29 Press Release, Council Approves EU Research Programme for 2007-2013, Council of the European Union, December 18, 2006. Unlike in the U.S., where budgeting requires annual appropriations, these funds already have been appropriated through 2013.

30 Germany Launches a High-Tech Initiative, Science, September 8, 2008; Backing Innovation with 15 Billion Euros, German Embassy, August 30, 2006.

31 Tough Choices, Tough Times, The Report of the new Commission on the Skills of the American Workforce, National Center on Education and the Economy, 2007

Given the rise of science and technology capability globally, companies are looking beyond the United States and other advanced nations for locating research, development, and innovation-related activities. The R&D activities of global companies have become more international and are likely to become more so in the years ahead. The share of multinational companies' foreign R&D sites has increased from 45% in 1975 to 66% in 2004.[32]

R&D spending by U.S.-owned companies abroad rose from about $12 billion in 1994 to $21 billion in 2002. Asia is an increasingly attractive location for R&D spending by U.S.-based multinationals, with investment growing from about $1.5 billion during 1994-97, to $3.6 billion in 2002. Growth has been fastest among the developing Asian economies. The share of Asian economies other than Japan rose from 3.4% to 10%, with investments in these countries growing more than 400% from $408 million in 1994 to $2.1 billion in 2002. While Europe remains the single largest location for overseas R&D spending by U.S. companies, accounting for about 60% of the total, its share has slipped by more than 12 percentage points since 1994.[33]



SOURCE: 2006 Science and Engineering Indicators, National Science Foundation

The United States also has benefited from the global flow of R&D investment. R&D spending by U.S. affiliates of foreign companies grew substantially in the late 1990s. In 2002, R&D performed by U.S. affiliates of foreign companies reached $27.5 billion, an inflation adjusted increase of 2.3% over 2001, and accounted for 14.2% of total U.S. industrial R&D in 2002 compared with just above 13% from 1998 to 2001.[34]

R&D globalization is also reflected in the rising number of companies' international alliances devoted to joint R&D or technology development. Industrial innovation more often involves external partners to complement internal capabilities, share costs, spread market risk, expedite projects, and increase sensitivities to geographic variations in product markets. As a result, companies have resorted to a variety of technology alliances that often cross national boundaries. The number of new international alliances rose from under 100 in 1980 to 342 early in the new century. Historically, U.S. companies have been involved in 75%-86% of these alliances. Maintaining the United States as a dominant partner in these international research and technology alliances requires that we continue to offer the world's most advanced science and technology. This globalizing innovation footprint is partially driven by the potential to access new markets, as well as the increase in scientific and technical capabilities worldwide. Global businesses increasingly locate at least some R&D near the markets they serve, and the developing world represents much of the market growth for the future. By 2020, 80% of middle class consumers will reside outside of the current industrialized world.[35]

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32 Innovation: Is Global the Way Forward? A Joint Study by Booz-Allen Hamilton, and INSEAD, 2006.

33 Table 8. Research and development performed abroad by majority-owned foreign affiliates of U.S. multinational corporations, by host region and country/economy: 1994-2002, Asia's Rising Science and Technology Strength, Comparative Indicators for Asia, the European Union, and the United States, National Science Foundation, May 2007.

34 Science and Engineering Indicators 2006, National Science Foundation.

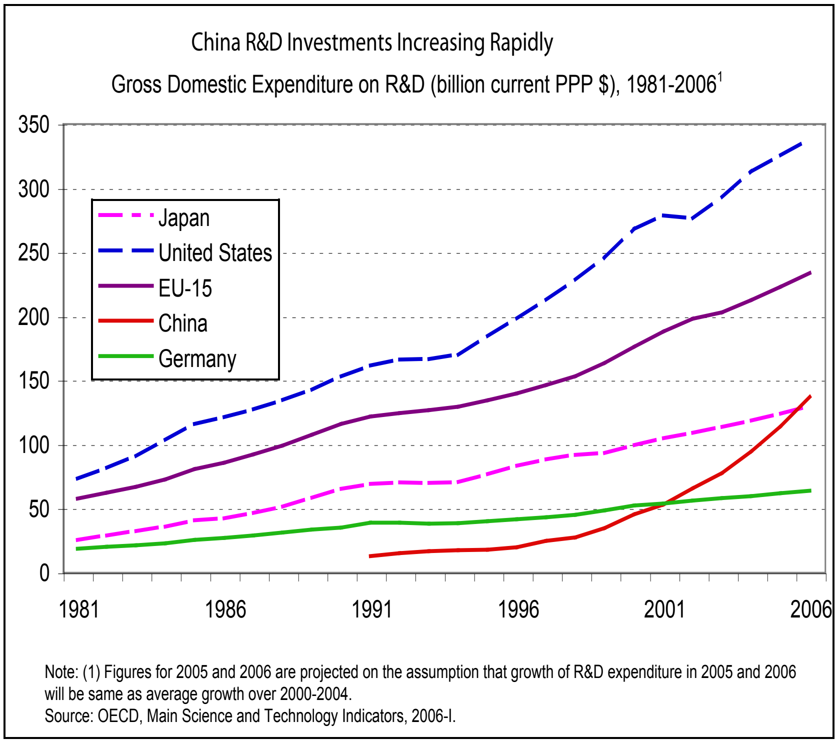
35 Paul A. Laudicina, World Out of Balance: Navigating Global Risks to Seize Competitive Advantage, McGraw-Hill, 2005.

2. New Challenges to America's Historic Strengths in Science and Technology

2.2 China Rapidly Becoming an R&D Leader

China's rapid advance on the leading R&D-performing countries and regions is unprecedented in recent history. According to data compiled by OECD, Chinese R&D spending was expected to reach $136 billion in 2006, up from $12.4 billion in 1991[36], in part, reflecting the growth of R&D performed by foreign-owned firms based in China. Although a question remains about the precise international comparability of the data, *this would make China the world's second highest investor in R&D*, behind only the United States, and ahead of Japan and Germany. Following the pattern set by Japan and the Asian tigers, China's R&D investment emphasizes applied research and development aimed at boosting its competitive capabilities.

Growth rates in Chinese R&D investment far outpace rates in the United States and other key R&D-performing nations. Compound annual growth rates in R&D investment over the 1991-2006 period ranged from 4% to 5% for the United States, EU-15, Germany and Japan. These contrasted significantly with China's 17.4% compound annual growth rate. The Chinese rate of increase in R&D investment is accelerating; between 2000 and 2004, China's R&D investments have shown a 20.4% compound annual growth rate.[37]



From 1995 to 2004, China's spending on R&D as a percentage of GDP—known as R&D intensity and an indicator of the relative importance of R&D to an economy—has more than doubled from 0.6% to 1.2%, compared with about 2.7% for the United States.[38]

This rapid growth in R&D investment is complemented by the growth of China's research workforce. In China, the number of researchers increased by 77% between 1995 and 2004, and the country now ranks second worldwide with 926,000 researchers, just behind the United States (more than 1.3 million).[39]

With respect to R&D, multinational corporations are increasing their focus on China. In a recent survey, companies indicated that almost all planned growth in foreign R&D over the next three years would be in China and India, with most growth accounted for by increasing the size of

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36 China Will Become World's Second Highest Investor in R&D by the End of 2006 Finds OECD, Organization for Economic Cooperation and Development, April 12, 2006.

37 OECD, Main Science and Technology Indicators, 2005.

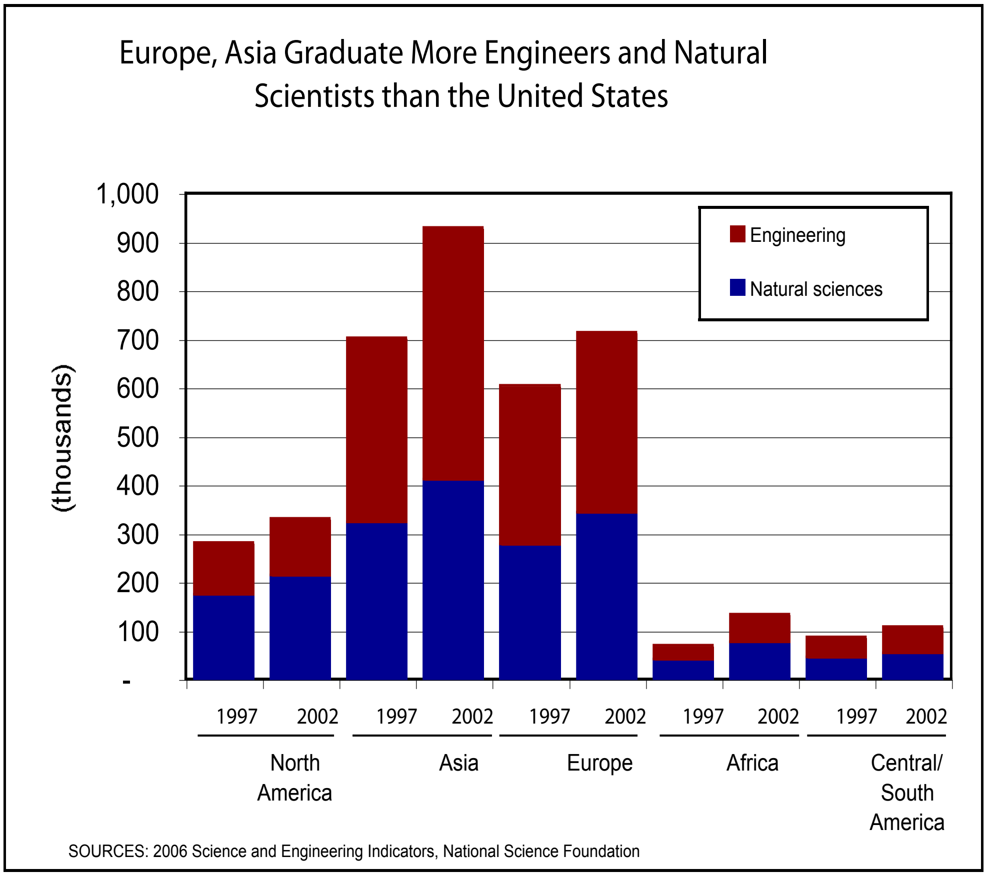
38 OECD, China Will Become World's Second Highest Investor in R&D by the End of 2006 Finds OECD, and Main Science and Technology Indicators 2005.

39 China Will Become World's Second Highest Investor in R&D by the End of 2006 Finds OECD, Organization for Economic Cooperation and Development, April 12, 2006.

R&D staff in these countries. The survey suggests that, by the end of 2007, China and India will account for nearly one-third of global R&D staff, up from 19% in 2004.[40] In the same survey, when asked where they would open up new or scale up existing R&D if they could, China and India were also the favored locations. In another survey, more than half of corporate respondents (who identify the United States as their home country) reported that they have either recently expanded or planned to locate R&D facilities in China and India.[41]

Companies point to many different factors driving their decisions about future R&D sites. Accessing markets and proximity to production facilities are important. But the most cited reason was access to qualified staff. R&D site location decisions are often based on the assets and capabilities offered in a given country. For example, low cost labor and market access are important reasons for locating in China. In India, companies are attracted to the country's low cost labor and high quality staff. In the United States and other advanced countries, access to markets are important, *but access to technology, and research capabilities and institutions are more important than in other countries*.[42]

With its world-leading science and technology enterprise, the United States is an attractive venue for foreign companies seeking to conduct R&D. From 1990 to 2002, R&D expenditures in the United States by majority-owned affiliates of foreign-based multi-nationals rose from 8% to 14% of total U.S. industrial R&D performance. The United States must continue to support leading edge science and technology to continue to attract these investments.

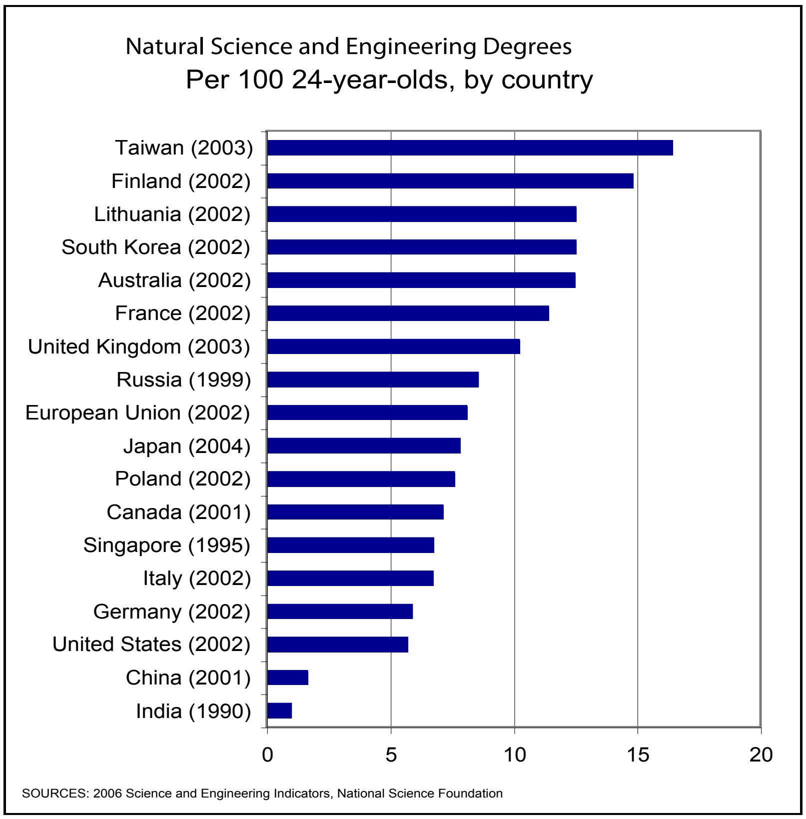


40 Innovation: Is Global the Way Forward, A Joint Study by Booz-Allen Hamilton and INSEAD, 2006.
41 A Survey of Factors in Multinational R&D Locations, Kauffman Foundation, 2007.
42 Innovation: Is Global the Way Forward, A Joint Study by Booz-Allen Hamilton and INSEAD, 2006.

2.3 Competitors Building the Talent Base Needed to Compete in Science and Technology

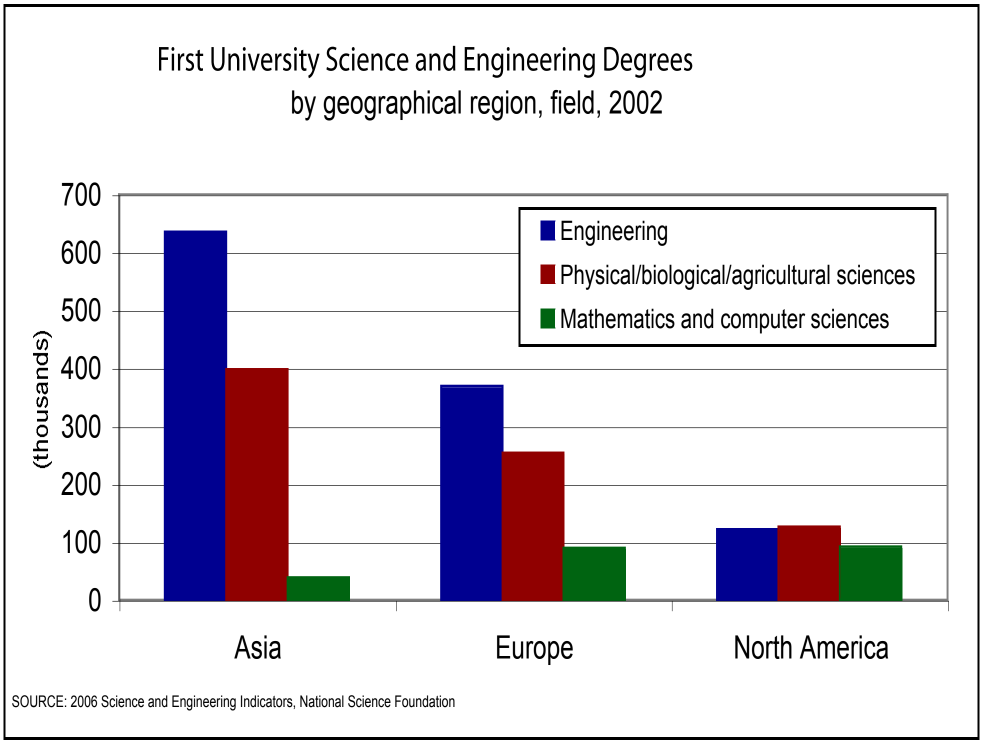
The number of first university degrees awarded around the world is rising rapidly, from 6.4 million in 1997 to 8.7 million in 2002. Strong increases occurred in Asia and Europe, with large numbers and strong gains in engineering and the natural sciences. In 2002, engineering degrees awarded in Asia were more than four times the amount of those awarded in North America, and the number of natural science degrees was nearly double. Europe graduated three times as many engineers as North America in 2002. However, the quality of science and engineering higher education varies among countries.

To bolster their participation in knowledge-intensive industries and markets, the education of young people in natural sciences and engineering has become more important for many governments. For example, first university degrees in the natural sciences and engineering range from about 16 per 100 24-year-olds in Taiwan to 12–13 in Australia and South Korea, and 10 in the United Kingdom. The United States ranks 32nd out of 90 countries for which such data are available at just under 6 per 100.

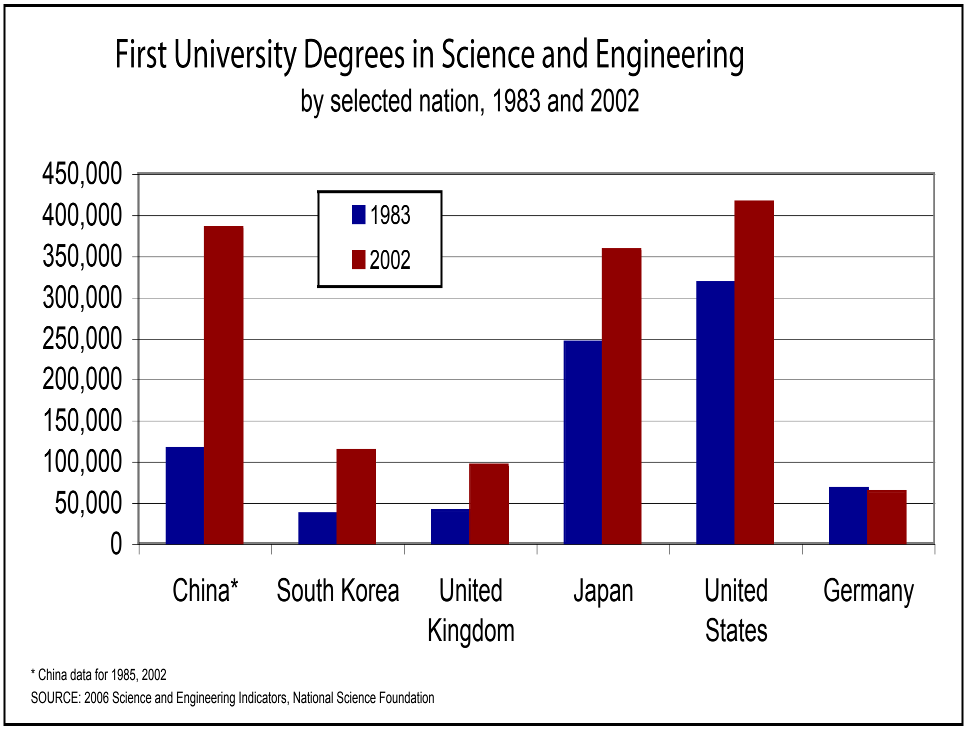


At this time, China and India have low ratios of first university degrees in natural sciences and engineering (1.6 and 1.0, respectively). This reflects low overall rates of access to higher education in those countries, but this trend may now be changing. For example, science and engineering degree production in China doubled and engineering degrees tripled over the past two decades.

In 1998, China began an effort to consolidate institutions, increase funding, and reorganize its educational system, resulting in more efficient administration, reduction of competing programs, a more flexible curriculum, and rapid expansion of enrollment.[43] As a result of this effort, natural sciences and engineering enrollment in Chinese universities grew from roughly 1.8 million students in 1995 to 5.8 million in 2003. More than half of all undergraduate students were enrolled in these fields in 2003.



Asian universities accounted for almost 1.5 million of the world's science and engineering degrees in 2002, more than 600,000 of them in engineering. Students across Europe (including Eastern Europe and Russia) earned about 930,000 science and engineering degrees in 2002, and students in North and Central America earned almost 600,000.

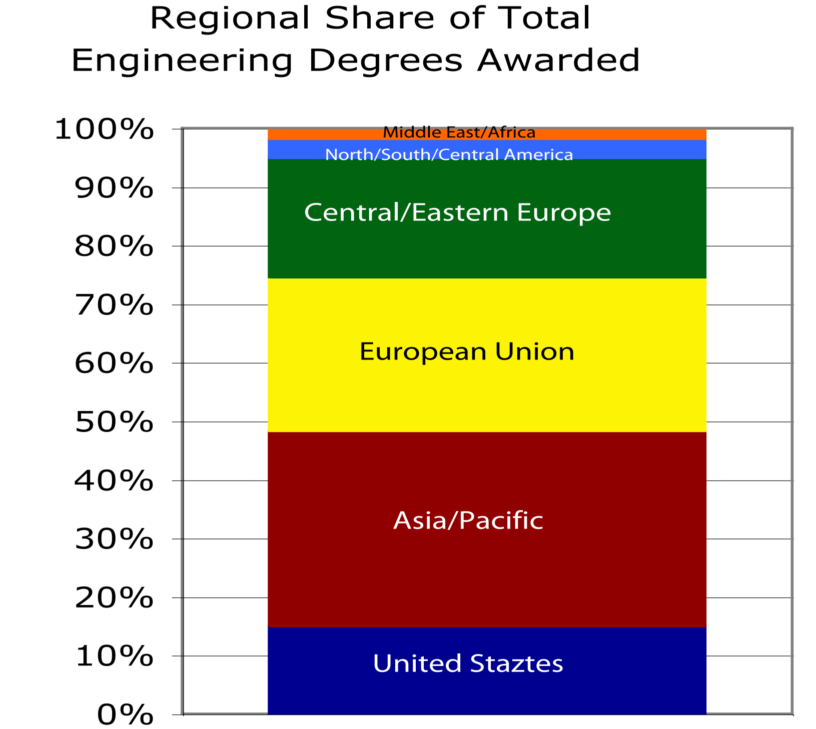


43 China's Science and Technology System: Challenge and Change: Report for the Environment, Science, Technology and Health Section. U.S. Embassy, China: Forthcoming.

For the past three decades, science and engineering degrees have constituted about one-third of U.S. bachelor's degrees but, in several countries/economies around the world, the proportion of first degrees in science and engineering fields is higher than in the United States. In recent data, the corresponding figures in Japan (64%), China (57%), and South Korea (47%) were much higher. Over the past two decades, the number of first university science and engineering degrees awarded in China, South Korea, and the United Kingdom more than doubled, and those in the United States and Japan generally increased.

International production of science and engineering doctorate holders—key talent for the R&D enterprise—has also accelerated. In recent years, most of these degrees (78% in 2002) have been granted outside of the United States.

The EU graduated one-third of the new science and engineering doctorates worldwide, and also one-third of those with doctorates in the natural sciences. One-third of the engineering doctorates were awarded in Asia (where numbers are understated because of incomplete reporting.) While the United States produced 15% of the world's engineering doctorates in 2002, students on temporary visas earned more than half of these degrees. The numbers of natural sciences and engineering doctoral degrees awarded in China, South Korea, and Japan have continued to rise, while doctoral degree production has leveled off or declined in the United States, the United Kingdom, and Germany.



SOURCE: 2006 Science and Engineering Indicators, National Science Foundation

Asian growth is even more pronounced in engineering bachelor's degrees. While the United States output of students with engineering bachelor's degrees fell by 6.3 percent between 1990 and 2002, China's tripled, Taiwan's grew more than fourfold, South Korea's more than doubled, and Japan's grew by 20.9 percent. EU-15 also ramped up its output of engineering bachelors degrees, more than doubling.

In addition to the indigenous development of science and engineering personnel, national governments and private businesses have increased their efforts to recruit the best talent on a global basis. For example, the EU has issued a directive instructing member countries to establish fast-track procedures for admitting non-EU researchers. Germany, the EU's largest investor in R&D, has implemented the law. France, the EU's second largest R&D spender, is in the process of implementing the directive. Researchers granted visas would work on par with EU nationals in terms of social security, working conditions, and the freedom to move within the EU to carry out their research. The EU's aim is to profit from becoming attractive for foreign scientists.[44]

44 Patchy Start to New EU Science Visa Law, The Scientist, April 4, 2007.

India's Infosys Seeks U.S. Talent

Infosys, one of India's largest IT services providers, has gone global in its search for top talent, and the United States is its big target for recruitment. Infosys has established the InStep program, a global internship program for students from the best academic institutions around the globe. InStep interns mainly work in the corporate headquarters of Infosys in Bangalore, India. Interns are provided a monthly student trainee allowance for living costs, and those who work in India receive airfare, accommodations, food, and transportation within the city.

Infosys is recruiting at about three dozen top U.S. universities, including many Ivy league campuses; top business and management schools such as Harvard, Fuqua, Stanford, Haas, Tuck, Darden, Sloan, and Wharton; and top technical schools such as Cal Tech, Carnegie Mellon, Georgia Tech, Harvey Mudd, and MIT.

In May 2006, it was reported that 100 new U.S. graduates were to start as full-time engineers at Infosys, and 200 more were expected to arrive in Bangalore by the end of the year.

Source: www.infosys.com; "Americans Make Reverse Commute—to India," MSNBC.com, May 11, 2006.

In another example, thousands of Japanese engineers and other professionals are migrating to other Asian countries such as Taiwan, South Korea, and China. These countries are offering attractive employment opportunities to acquire Japanese engineering know-how.[45]

Cutting-edge research and technologies create unique sets of skills and knowledge that can be transferred through the physical movement of people. The United States has benefited, and continues to benefit, from the international flow of knowledge and personnel in science and technology. However, competition for skilled personnel continues to increase. Many countries have increased their research investments, improved science and technology-related infrastructure, and also made high-skill migration an important part of national economic strategies, raising the level of global competition for technical talent. As a result, the United States is becoming less dominant as a destination for migrating scientists and engineers.

The number of individuals with higher education degrees who lived outside their home countries grew by 9.5 million from 1990 to 2000. Individuals from Eastern Europe, Central and South America, and smaller Asian countries accounted for most of the increase, followed by Western Europe, China, India, and Africa. The number of expatriates from China, India, and Africa more than doubled. In 1990, 1 in 6 of these highly educated individuals resided abroad. However, by 2000, that number had dropped to 1 in 9, indicating that much of the world had developed an infrastructure capable of using these highly educated people productively.

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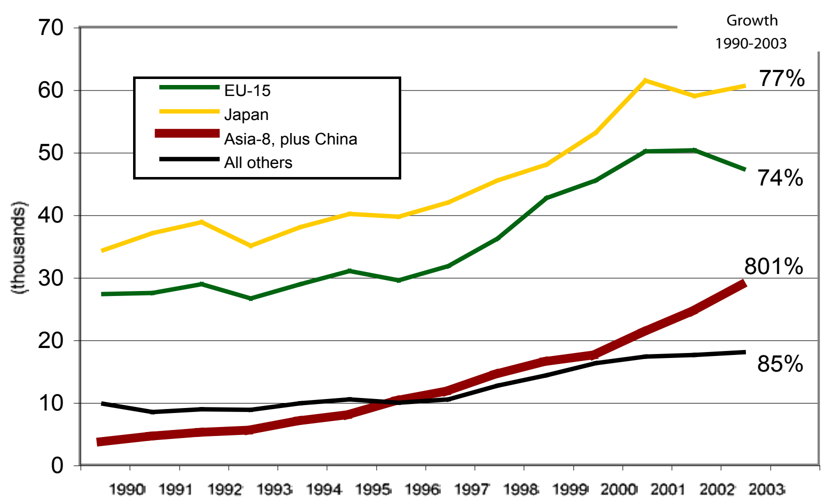
45 A Japanese Export: Talent—Technologists See Brighter Prospects in Other Parts of Asia, New York Times, May 24, 2007.

2.4 Emerging Economies Show Rapid Increases in Science and Technology Accomplishment

Large increases in R&D activities in newly industrializing and developing economies are translating into rapid increases in science and technology accomplishment. Strong growth in U.S. patenting by foreign-resident inventors, particularly from Asia, attests to the increase in technological sophistication in other parts of the world. Between 1990-2003, U.S. patent applications from China and the Asia-8 rose by 800% and, by 2003, constituted nearly one-fifth of all foreign-resident inventor filings.

For example, between 1963 (the year data first became available) and 1990, Taiwan received just 2,341 U.S. patents. During the subsequent 13 years, inventors from Taiwan were awarded more than 38,000 U.S. patents. Before 1990, South Korean inventors received just 599 U.S. patents; since then, they have been awarded nearly 29,000 new patents.[46] In recent years, Taiwan and South Korea have displaced Canada and France in the top five foreign country recipients of U.S. patents.[47] Data suggest that the rising trend in U.S. patents granted to residents of these two Asian economies is likely to continue.

U.S. Patent Application Growth Rate of "Asia-8 Plus China" Vastly Outstrips Other Regions



NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.
SOURCE: 2006 Science and Engineering Indicators, National Science Foundation

- As recently as 1980, Taiwan's U.S. patent activity was concentrated in the area of toys and other amusement devices. But, data from 2005 show that Taiwan's inventors also added semiconductor device manufacturing, solid-state electronics, electrical systems, liquid crystal cells, computer graphics processing and visual display systems to their technology portfolio.

- U.S. patenting by South Korean inventors also reflects that country's rapid technological development. The 2005 data show that South Korean inventors are currently patenting heavily in semiconductor device manufacturing, solid state electronics, and a broad array of computer technologies that include liquid crystal cells, devices for dynamic and static information storage, computer graphics, and digital communications.[48]

- Inventors from Israel, Finland, India, and China have also increased their U.S. patenting. In 2003, inventors from Israel filed more than 2,500 U.S. patent applications, up from about 600 in 1990; inventors from Finland filed more than 1,900 U.S. patent applications, up from about 600 in 1990; inventors from India filed for nearly 1,200 U.S. patent applications, up from 58 in 1990; and inventors from China filed for 1,034 U.S. patent applications, up from 111 in 1990.

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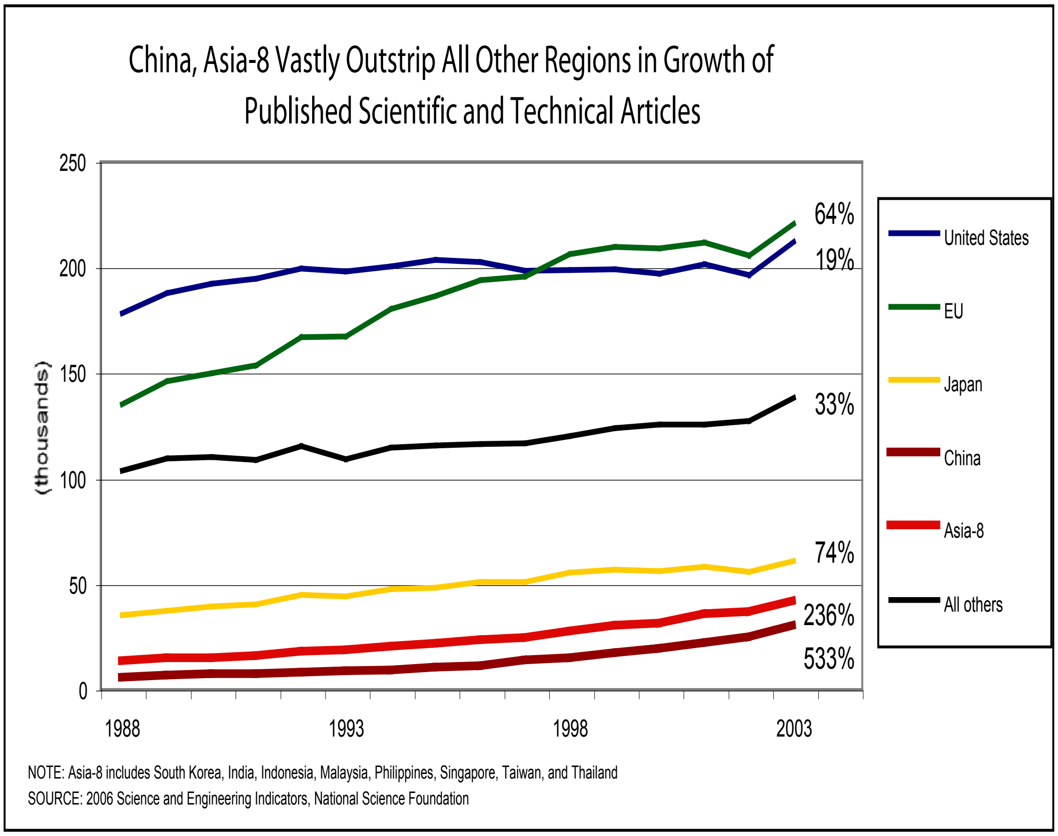
46 Science and Engineering Indicators 2006, National Science Foundation

47 In 2006, the top five countries in U.S. patenting were Japan, Germany, Taiwan, South Korea, and the U.K.

48 Patenting by Geographic Region, Breakout by Technology, U.S. Patent and Trademark Office.

Rapid development of scientific expertise outside the established scientific centers of the United States, the EU, and Japan is also demonstrated by research articles published in the world's major peer-reviewed scientific and technical journals.



The total number of articles rose from 466,000 in 1988 to 699,000 in 2003. Over that period, the combined share of the United States, Japan, and the EU-15 declined slightly from 75% to 70% of the total. However, the U.S. share dropped from 38% to 30%, while the EU-15 and Japanese share rose. Output from China and the Asia-8 expanded rapidly over the period, by 533% and 236%, respectively, boosting their combined share of the world total from less than 4% in 1988 to 10% in 2003.

These dramatic increases in patenting and scientific publication outside of the traditional leading science and technology countries over the past several years demonstrate the ever-widening competition in global technology development and diffusion.

2.5 Global Competitors are Focused on Physical Science and Engineering Research—Key Foundations of Innovation

Physical and mathematical sciences, information technology, and engineering R&D play a vital role in fueling technology and innovation-based economies. They are a key underpinning for U.S. economic leadership in the future.

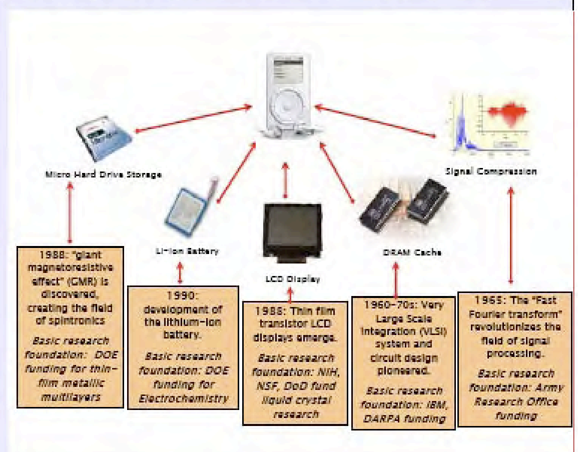
These fields include vital areas of research that advance knowledge, and lead to technologies and tools that are used in nearly every field of science and technology. This research has been essential to advance nascent ideas and technologies to a stage of maturity and risk sufficient for the private sector to invest in their development to create a marketable product or service.

For example, past research in these disciplines has enabled the technologies for personal computers, the Internet, fiber optics, medical imaging, global positioning systems, and satellite telecommunications. Today, basic techniques for the imaging, manipulation, and simulation of matter at the atomic scale are important for applications in many fields, and vital for advancing nanotechnology, a technology expected to have revolutionary impacts with enormous economic potential. Advancements in biotechnology depend on the physical sciences, information technology, and engineering to create new tools for decoding the building blocks of life.

In addition to their role in fueling new knowledge generation and advancements in a wide range of other technical fields, research in physical sciences, information technology, and engineering contribute significantly to the strength of high technology manufacturers from advanced materials producers and aerospace, to chemicals and digital technologies. Research in physics, mathematics, computer sciences, and engineering is also the basis for advancements in military technology and the transformation of military capabilities.

The value of high-technology industries has led to intense competition among nations and localities to attract, nurture, and retain them. Given their reliance on R&D, these industries depend on, and are likely to be attracted to, world-class physical science and engineering research capabilities. These fields will produce the new sciences and technologies—such as nanotechnology, multifunctional materials, and process design— vital to these industries' global success.

IMPACT OF BASIC RESEARCH ON INNOVATION



The development of MP3 technologies illustrates the unexpected benefits of basic research. In 1965, a hand-sized storage and playback device that would hold 15,000 recorded songs was the stuff of science fiction. Even simple hand-held calculators were rare and expensive at that time. Research funded by the Department of Defense, the National Science Foundation, the National Institutes of Health, the Department of Energy, and the National Institute of Standards and Technology contributed to the breakthrough technologies of magnetic storage drives, lithium-ion batteries, and the liquid crystal display, which came together in the development of MP3 devices. The device itself is innovative, but it built upon a broad platform of component technologies, each derived from fundamental studies in physical science, mathematics, and engineering.

Competitors are focused on improving capabilities in physical sciences, information technology, and engineering. For example, while China's government aims to strengthen the country's science and technology capabilities broadly, China is beginning to show leading-edge capabilities in important fields such as, materials science and supercomputing.[49] While the United States, Japan, Germany, and South Korea remain leaders in nanotechnology, China is moving into the top tier.

49 Is China the next R&D superpower? EDN.com, July 1, 2005.

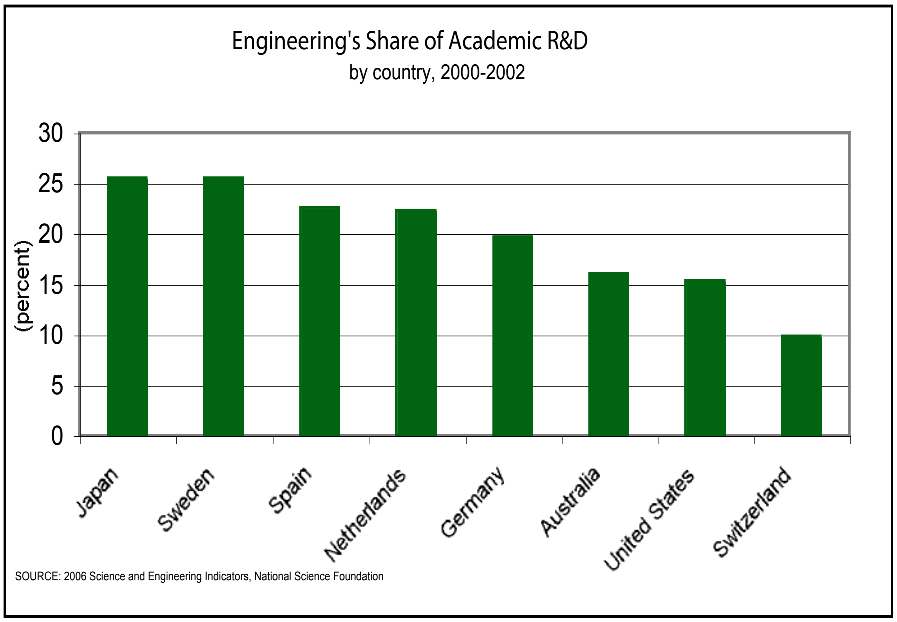
Chinese government spending on nanotechnology is ranked second globally, behind only the United States on a purchasing power parity basis.[50] All of these fields rely on physical sciences and engineering R&D.

A recent biblio-metric analysis of the scientific literature shows that China emphasizes the hard sciences that underpin defense and commercial needs, and it is among the leaders in nanotechnology and energetic materials. The United States emphasizes research focused on medical, psychological, and social science areas that underpin improvement of individual health and comfort. There are even research areas where China leads the United States in absolute numbers of research articles published.[51] However, in recent years, the United States has increased its focus on nanotechnology and high-performance computing. For example, the Federal govern-ment manages significant investments in these areas—$1. 3 billion in nanotechnology and $3 billion in high-performance computing—through cross-agency White House-level initiatives.

Japan has closed the gap in several areas of U.S. science and technology strength. Japan is a world leader in high performance computing, and Japanese companies are investing in basic research in areas such as medical imaging, materials sciences, and robotics—all fields that rely on physical sciences and engineering R&D.

The scientific portfolios of the East Asian-4 suggest a relatively greater emphasis on physical sciences and engineering than in the EU and United States. Among developing countries, the portfolios of countries in the Near East and North Africa (excluding Israel), Eastern Europe, and the former Union of Soviet Socialist Republics (USSR) are similar to those of the East Asia-4.
In 2003, more than half of China's publications focused on the physical sciences and nearly another fifth on engineering. In comparison with the rest of the world, the life sciences and social sciences constituted a very small share. The sum of eight other Asian publication portfolios showed a similar pattern.[52]

Most countries supporting a substantial level of academic R&D[53] devote a larger proportion of their R&D to engineering than does the United States. Conversely, U.S. academic R&D emphasizes the medical sciences and natural sciences relatively more than do many other OECD countries. This emphasis is consistent with the priority the United States places on health and the biosciences, and the concomitant public R&D investment in these areas.



50 Top Nations in Nanotech See Their Lead Erode, U.S., Japan, Germany, and South Korea Remain Leading Countries, but China India, and Russia Begin to Close the Gap, Lux Research, March 8, 2007.

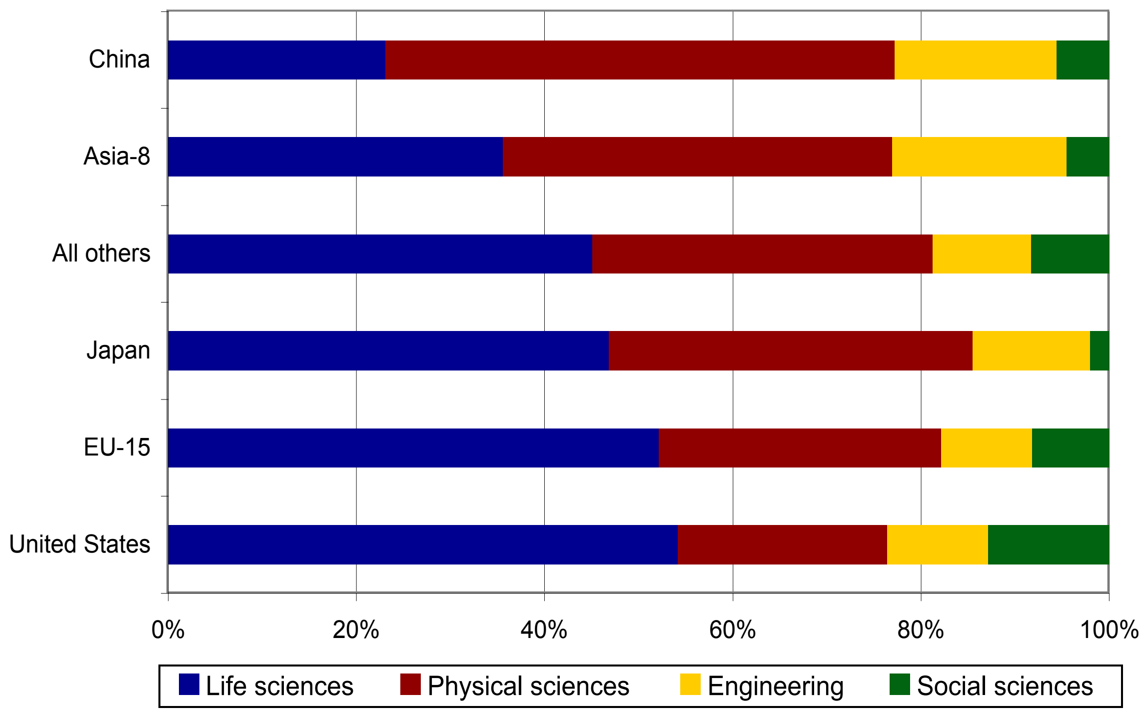
51 The Structure and Infrastructure of Chinese Science and Technology, Office of Naval Research, 2006.

52 Science and Engineering Indicators 2006, National Science Foundation

53 at least $1 billion PPPs in 1999

Not surprisingly, the literature from both the United States and the EU-15 show a fairly heavy emphasis on the life sciences (45%–54%) and a relatively lighter share in engineering (10%–13%) and the physical sciences (22%–39%). These portfolio patterns have changed little since the mid-1990s.

US, EU Scientific and Technical Articles Weighted Heavily to Life Sciences; China, Asia-8 to Physical Sciences, Engineering



NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand
SOURCE: 2006 Science and Engineering Indicators, National Science Foundation

Materials research is an important component of both physical sciences and engineering research. A recent study warned that competition from new materials R&D centers worldwide could weaken the U.S. position in this field.[54] The Chair of the report's research committee stated, "With the globalization of research and development in materials science and engineering, cutting edge work is expected to emerge from countries that historically have not been centers of materials innovations, such as China, India, Singapore, Taiwan, and South Korea. The United States can no longer assume that the most important innovations in materials science and engineering will take place domestically.

54 Globalization of Materials R&D: Time for a National Strategy, National Research Council, National Academies of Science, 2005.

3. Maintaining Leadership in Innovation In a Radically Changed Global Economy

Increasingly, the competitiveness of the United States will be defined by its ability to generate, absorb, and commercialize knowledge, and compete in areas of business and work that the developing world cannot perform. This requires an emphasis on cutting edge R&D; the development of groundbreaking products, services, and business models; highly creative design and marketing; and world-class supply chain management. In other words, the United States must focus on the endeavors that produce innovation in all of its forms.

> ***Civilization is on the brink of a new industrial world order. The big winners in the increasingly fierce global scramble for supremacy will not be those who simply make commodities faster and cheaper than the competition. They will be those who develop talent, techniques, and tools so advanced that there is no competition. That means securing unquestioned superiority in nanotechnology, biotechnology, and information science and engineering.***
>
> *— President's Council of Advisors for Science and Technology*[55]

3.1 A New Competitiveness Movement

Recognition of the dramatic changes in the global economy, and rising concerns about future U.S. leadership in science and technology and America's ability to innovate and compete have spurred national efforts to examine America's competitive strengths and weaknesses, and to develop recommendations to strengthen the U.S. position. These changes and concerns have also created political momentum to act through legislative and executive branch initiatives that form a new national competitiveness agenda. For example:

- The Council on Competitiveness National Innovation Initiative released its "Innovate America" national innovation policy agenda for the United States in December 2004. This policy agenda outlines what the United States must do to create an "innovation eco-system" that supports the development and commercialization of high-value innovations in the United States. In addition, ASTRA has spent several years promoting the important role physical sciences and engineering play in U.S. innovation, and advocating for greater Federal investment in these fields.

- The National Academies of Sciences report "*Rising Above the Gathering Storm*," Thomas Friedman's best-selling book "*The World is Flat*," and the U.S. Council on Competitiveness's *2006 Competitiveness Index* all chronicle the dramatic changes that have taken place in the competitive landscape in the past decade due to globalization, the entry of emerging economies into global commerce, and the globalization of science and technology. They also identify potential threats to U.S. leadership in science and technology.

55 Sustaining the Nation's Innovation Ecosystems: Information Technology Manufacturing and Competitiveness, PCAST, January 2004.

- The Congress and the President have responded to these calls for strengthening U.S. innovation and competitiveness. The America COMPETES Act,[56] signed into law by President Bush in August 2007, is a broad legislative initiative based on recommendations set forth in these studies and others. Among other actions, the legislation elevates competitiveness and innovation to a White House-level concern, increases investment in research and innovation development, establishes programs to boost math and science teaching and education, and creates a new agency (ARPA-E) within the Department of Energy for energy-related technology development. Speaker of the House Pelosi also is leading an Innovation Agenda for the 110th Congress, which also includes increased investment in research, and math and science education, as well as efforts to spur affordable access to broadband technology and to develop emerging clean energy technologies.

- To address the need for more physical sciences and engineering R&D, President Bush made investment in this area the centerpiece of the American Competitiveness Initiative (ACI), introduced in his 2006 State of the Union Address. The ACI would double, over 10 years, funding at the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology laboratories.

- The nation's governors have also adopted an innovation agenda. The National Governors Association Chair's Innovation America Initiative focuses on improving math and science education, developing high-growth centers of innovation in U.S. states, and raising awareness of the need to embrace innovation.

3.2 Building on the Momentum to Strengthen U.S. Competitiveness and Innovation

The actions of the President, the Congress, and the nation's governors are vital first steps in bolstering America's ability to innovate and compete. However, increasing investment in fundamental research, and improving math and science education—the key priorities established in these initiatives—are insufficient to ensuring U.S. innovation leadership in the 21st century.

A dramatic change in the approach to innovation is required, if the United States is to sustain its competitive advantage. Doing so will require a transition to an innovation-driven economy capable of routinely developing and commercializing "new-to-the-world" technologies. This new growth opportunity cannot be realized using only traditional methods such as increasing R&D inputs.

Our view of innovation has to be broadened to include new business models and value creation as main drivers of innovation, and we must pay greater attention to the contextual conditions in which innovation operates and flourishes. We must recognize that there is a fundamental change in innovation practices, from the previously closed, static, linear and individualistic perspectives, to today's multidimensional, dynamic approaches that are capable of keeping pace with the demands of a global economy. ***Riding the Rising TIde: A 21st Century Strategy for U.S. Competitiveness and Prosperity*** builds on the current competitiveness and innovation initiatives by recommending vitally important next steps in the national innovation agenda.

56 The *America COMPETES* or *Creating Opportunity to Meaningfully Promote Excellence in Technology, Education and Science Act* authorizes billions in spending for R&D, and science, technology, engineering and mathematics education. However, these funds have not, to date, been appropriated.

4. Strengthening U.S. R&D Assets to Maintain Leadership in Innovation

Domestic R&D performance is a prime indicator of a nation's innovative capacity. It is a key condition that businesses consider in their decisions about locating investments and business operations. Domestic R&D performance also supports productivity and the competitiveness of U.S.-based businesses.

Strengthening U.S. R&D is a vital step we can take to improve our ability to innovate, compete, and stimulate economic growth. For example, a recent analysis on capitalizing R&D by the U.S. Department of Commerce and the National Science Foundation showed that, between 1959 and 2004, R&D investment accounted for 5% of real GDP growth. Between 1995 and 2004, R&D's contribution to real GDP growth rose to 7%.[57]

Strengthening U.S. R&D Assets to Maintain Leadership in Innovation

- **Balance the Federal R&D portfolio.**
- **Increase Federal investments in physical sciences and engineering R&D.**
- **Invest in R&D that supports the U.S. service economy.**
- **Invest in the leading edge of science and technology, especially revolutionary technologies.**
- **Give greater focus to R&D investments with the emerging inter- and multi-disciplinary nature of innovation.**
- **Ensure adequate returns from Federal R&D investments.**

4.1 The United States Needs a Balanced Federal R&D Investment Portfolio

The United States has seen significant increases in R&D investments in the past decade and a half. U.S. R&D grew to more than $300 billion in 2004, a doubling of the U.S. investment since 1990. The private sector has been responsible for most of this growth and, today, accounts for about two-thirds of U.S. R&D investment (about $200 billion).[58]

However, most of the growth in private R&D investment has been devoted to product and services development, rather than basic and applied research. This suggests that the public investment in basic and applied research is more important than ever to ensure the future competitiveness of U.S. high technology industries, the future stream of innovative products and services, and the attractiveness of the United States as a place in which American and foreign researchers want to work.

57 Research and Development Satellite Account, 2007 Satellite Account Underscores Importance of R&D, News Release, U.S. Department of Commerce, Bureau of Economic Analysis, September 28, 2007.

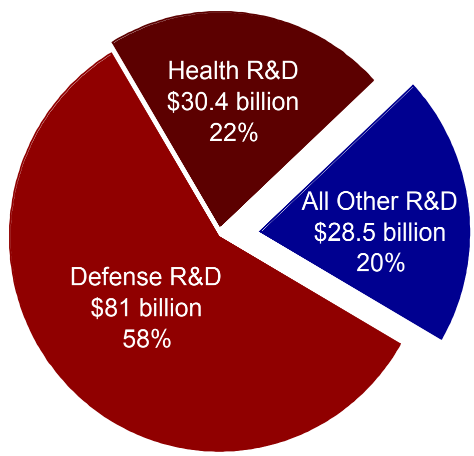
58 National Science Foundation.

The Federal government has increased significantly its investments in research and development, which have grown from $93 billion (in constant dollars) in 1990 to $140 billion in 2007. However, 58% of the Federal investment is allocated for defense, and the vast majority of this defense investment (81%) is devoted to the development and testing of weapons systems. Although defense-related R&D does result in spillovers that produce social benefits, non-defense R&D is more focused on national scientific progress, standard-of-living improvements, economic competitiveness, and commercialization of research results.

The "Federal Science and Technology" (FS&T) budget highlights the creation of new knowledge and technologies more consistently and accurately than does the overall Federal R&D data. The FS&T budget emphasizes research, and does not count funding for defense development, testing, and evaluation. In 2007, the FS&T budget was $61 billion, compared to the $140 billion Federal R&D investment count that included defense development, testing, and evaluation.[59]

The Federal government should restore balance to the defense/civilian share of the Federal R&D investment portfolio

Defense, Health R&D Account for 80% of Total U.S. Government R&D Investments



SOURCE: American Association for the Advancement of Science, FY 2007

Civilian R&D's share of the Federal research portfolio has declined substantially since 2001, when civilian R&D accounted for 56% of Federal research investment. Of the 42% of Federal R&D investment allocated for civilian research today, half is invested in health-related R&D. As a result, about 80% of Federal R&D investments are devoted to either defense (primarily weapons systems development and testing) or health.

The large share of Federal R&D investment devoted to health is partially the result of a five-year effort beginning in the late 1990s to double the R&D budget of the National Institutes of Health. This investment is bringing significant benefits to the country, and underpins U.S. world leadership in bio-medical science and innovation. However, the NIH budget has not kept pace with inflation. It is vitally important for the Federal government to reverse the erosion of the NIH budget, and return the budget to a growth path to ensure continued U.S. global biomedical leadership.

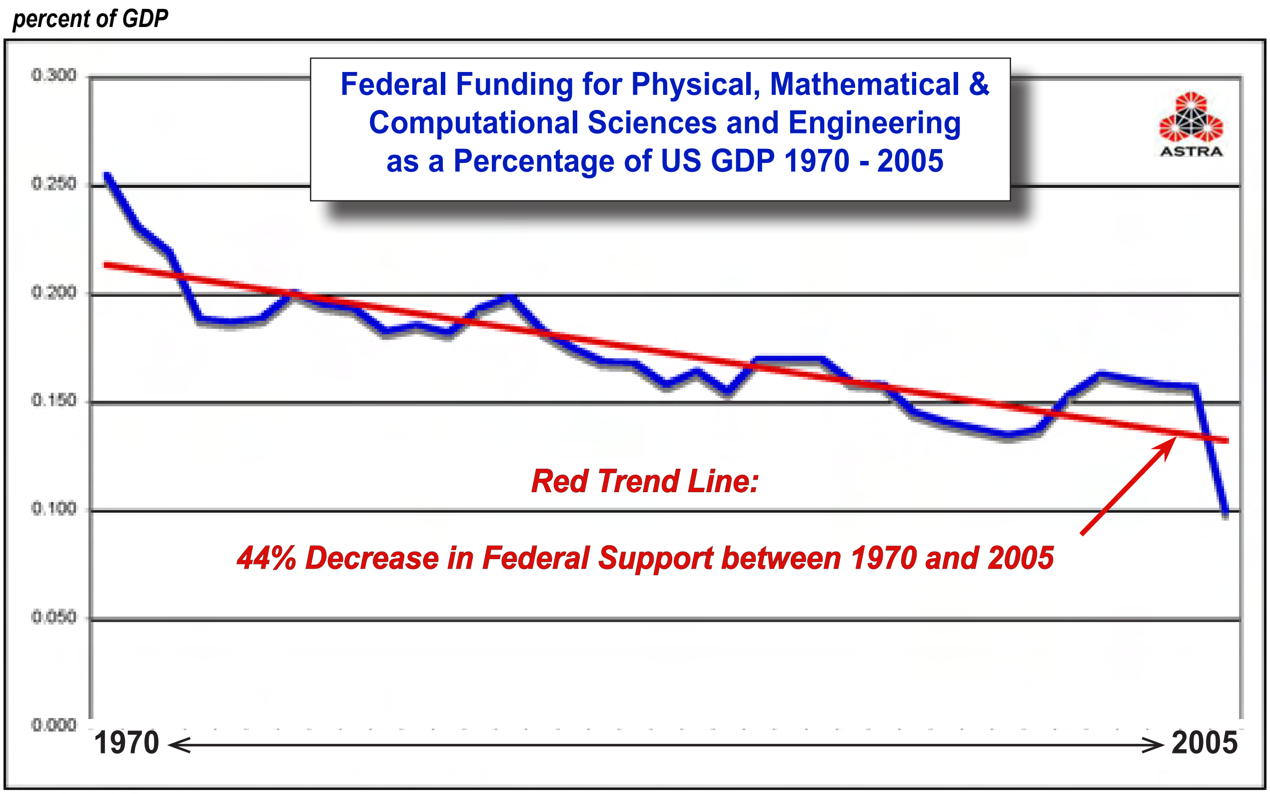
59 Analytical Perspectives, Budget of the United States Government, Fiscal Year 2008, Office of Management and Budget.

4.2 The United States Needs to Increase its Federal Investments in Physical Sciences and Engineering R&D

The vast majority of the U.S. industrial base depends on physical sciences and engineering for technologies, materials, tools, and processes. In addition, scientists in nearly every field also depend on the results of physical sciences, information technology, and engineering R&D.

Federal investment in physical sciences and engineering R&D generates significant benefits to the nation. For example, a recent study reported that for every billion dollars the Federal government invests in chemical sciences research, there was $5 billion in additional and follow-up chemical industry R&D. Together, these investments generated $10 billion in chemical industry operating income, 600,000 jobs, and $40 billion in GNP.[60]

Yet, despite their critical importance to the nation's security, economy and industrial base, physical sciences and engineering have taken a back seat to defense weapons systems developmentand health in the U.S. public research portfolio, accounting for a small part of the Federal R&D investment. Investments in the physical sciences have remained flat for nearly two decades, and have declined as a share of GDP. Federal investment in engineering research has seen only modest growth. For example, U.S. government spending on R&D in the physical sciences, mathematics, and engineering slipped from 0.25% of GDP in 1970 to less than 0.10% in 2005.[61]



Sources: Compiled by ASTRA from National Science Foundation, *Federal Funds for Research and Development* series; GDP data from the Bureau of Economic Statistics, U.S. Dept. of Commerce. R&D Figures are for Basic and Applied Research only. Development and R&D facilities are not classified by discipline. © 2007 ASTRA, The Alliance for Science & Technology Research in America.

60 Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine, Council for Chemical Research, February 2006.

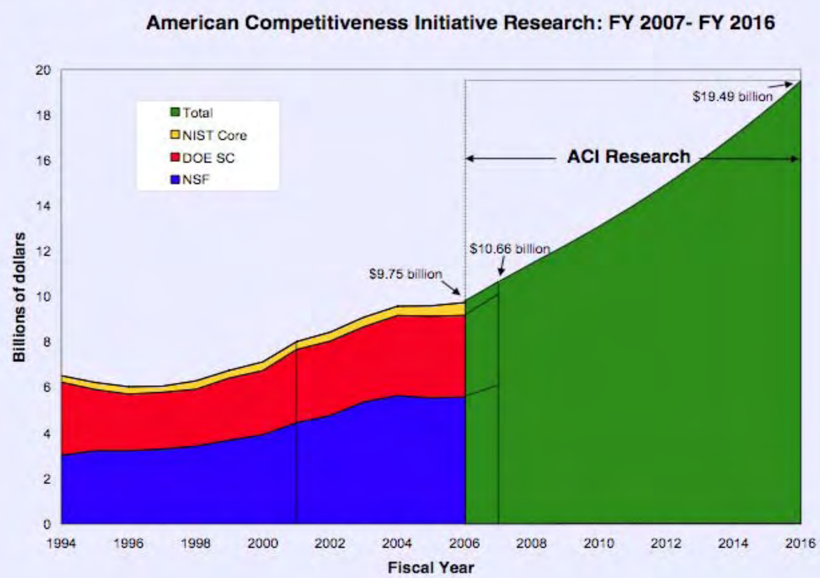
61 Alliance for Science and Technology Research in America.

To address the need for more physical sciences and engineering R&D, President Bush made investment in this area the centerpiece of the American Competitiveness Initiative (ACI), introduced in his 2006 State of the Union Address. The ACI would double, over 10 years, funding at key Federal agencies that support physical sciences and engineering research—the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology. This would represent a total of $50 billion in new investment over ten years.

This investment could result in advances in a wide range of areas such as advanced materials, nanofabrication and nanomanufacturing, high-end computing, renewable energy, cyber security, sensors, and detection technologies. These advancements would impact nearly every sector of commerce including telecommunications, computing, electronics, health care, energy, manufacturing, and pharmaceuticals. They are also vital to continuing the substantial advantage the Armed Forces of the United States employ on the battlefield.

The President, in his annual budget request, and Congressional budget appropriators have given their support to this increased level and time-table for growth of investment in physical sciences and engineering R&D.

Figure 1: ACI Research Funding, 2007-2016.



	FY 2006 Funding	ACI Research FY 2007		ACI Research FY 2016	
	(billions of dollars)	(billions of dollars)	% increase	(billions of dollars)	% increase over FY06
NSF	$5.58	$6.02	7.8	$11.16[1]	100.0
DoE SC	$3.60	$4.10	14.0	$7.19[1]	100.0
NIST Core[2]	$0.57[3]	$0.54	-5.8[4]	$1.14[1]	100.0
TOTAL	$9.75	$10.66	9.3	$19.49	100.0

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

Source: American Competitiveness Initiative: Leading the World in Innovation, Domestic Policy Council/Office of Science and Technology Policy, The White House, February 2006

As a crucial step in achieving a balanced Federal R&D portfolio, the Federal government should substantially increase Federal investments in physical sciences and engineering R&D. The Congress and the Administration should fulfill the physical sciences and engineering R&D commitments made in the ACI. However, to ensure that funding expands beyond increases in inflation, the timetable for these investments should be accelerated. In addition, investment should be increased beyond the ACI recipient agencies.

The Department of Defense is a major supporter of physical sciences and engineering research. But, while investment in military R&D has reached record highs with dramatic increases in weapons development, these increases contrast with sharp cuts proposed for FY 2008 in the defense investment devoted to basic and applied research, and technology development. These investments are vital to ensuring U.S. armed forces' superiority in the future, as new materials, information and communications technologies, new sources of power supply, and other advancements are needed to provide new capabilities for a shifting military battlescape. In addition, some of these developments will spin-off for application in commercial markets.

The President's FY 2008 budget cuts military basic and applied research, and technology development (6.1, 6.2, and 6.3) by more than 20 percent, down to $10 billion from $13.6 in FY 07.[62] This should be reversed.

The National Aeronautics and Space Administration is a large supporter of physical sciences and engineering research, and its research is essential for advancements in aeronautics. For example, NASA accounts for nearly a quarter of Federal support for engineering research, and nearly all Federal support for astronautical and aeronautical engineering. It also plays an important role in environmental sciences, and is the second largest Federal supporter of physical sciences. However, for FY 08, NASA aeronautics research would be cut by 20 percent following similar cuts in previous years. In real terms, the aeronautics research portfolio of FY 08 would be half the size of four years ago. This aeronautics research portfolio plays an important role in national defense.

NASA life and physical sciences research has sustained significant cuts from 2005-2007; in 2007 alone, this account was cut by 60 percent. This should be reversed.

4.3 Federal Government Support for Applied R&D

The Federal government primarily supports basic research and R&D in direct support of its missions. Most business R&D is aimed at incremental improvements, developing new and improved goods, services, and processes to capture faster returns to companies and shareholders. However, some results emerging from basic research, as well as early-stage technologies are not sufficiently developed and, thus, too risky to attract investment from individual companies. In addition, few financial institutions, venture capitalists, and angel investors fund unproven, early stage technologies.

62 The Bush Administration has concluded that most of these decreases are accounted for by the proposed elimination of House and Senate directed appropriations or so-called "earmarks."

As a result, promising technologies may be ignored or developed too slowly to compete in rapidly changing world markets. The Federal government has made some investments to further the development of high-risk as well as generic technologies to bring them to a stage of maturity at which the private sector is able to invest to bring them to market. These investments have been carried out in programs such as the Commerce Department's Advanced Technology Program (ATP), the research agency-wide Small Business Innovation Research program (SBIR), and the investments of the Department of Energy in developing alternative energy technologies. However, for over a decade, funding for ATP has been uncertain.[63] Meanwhile competitor nations have moved aggressively to develop programs supporting applied R&D, many modeled after U.S. programs.

In addition, among the goals of the SBIR program are stimulating technological innovation, and increasing private sector commercialization of innovations derived from Federal R&D. Yet, SBIR funding government-wide is allocated as a formulaic percentage of individual agency R&D budgets, and SBIR funds are awarded across government, with little regard for optimizing the overall SBIR investment portfolio's potential to contribute to technological innovation and private sector commercialization.

The Federal government should increase and stabilize funding for applied research and advancing promising, high-risk technologies with substantial economic potential to bring them to a state of maturity that is attractive for private sector investment. This includes funding for the new Technology Innovation Program, and other programs that meet this objective. In addition, the approach to SBIR funding should be reviewed to determine how this program could maximize its ability to contribute to the U.S. innovation base.

4.4 The United States Needs to Stay on the Leading Edge of Key Technologies

There is growing concern about the potential for the migration of U.S.-based research assets to other countries, especially emerging economies where companies are attracted to rapid market growth. This concern arises from the increasing trend of companies locating manufacturing, services, and some R&D or technical services in close proximity to their markets. This concern also arises from the fact that science and technology flow easily around the world. However, new knowledge and technology are not well codified and, thus, more difficult to transfer.

Successful transfer and application can require physical proximity, and intense interactions between scientific, technical, manufacturing, and business personnel. Thus, the geographic source of new knowledge and technology—as well as leading edge research facilities—can serve as a powerful magnet for attracting business activity, scientific and technical talent, and capital investment focused on commercializing new innovations. Creating more and maintaining leading edge R&D in the United States would help preserve and attract these competitive assets domestically.

A large share of the Federal R&D investment should focus on the leading edge of science and technology, especially in fields expected to have revolutionary impacts, such as nanotechnology, biotechnology, and high-performance computing.

63 The *America COMPETES Act* eliminates ATP and authorizes a new Technology Innovation Program (TIP) at NIST in place of ATP. Many features of TIP are new; however, it retains the focus on investment in high-risk, high-payoff technologies offering substantial economic benefits for the nation.

4.5 R&D Needs to Support the U.S. Service Economy

Historically, most research has been geared to support and assist manufacturing, once the dominant force in the U.S. economy. However, U.S. services have emerged as a set of dynamic, technologically intensive industries with major impact on the U.S. economy. Services now account for 78% of U.S. GDP, and service-producing industries account for 78% of U.S. employment. Service industries account for only one-quarter of private R&D investment despite the dominant role they play in the economy.

The rise of high-value services enabled by digital technologies is changing the way service companies organize their operations and do business. Some companies are even beginning to employ science to better understanding customer behavior, and in the design of service provision. New technology is also changing service functions within manufacturing companies, and many manufactured products are higher value added because they are linked to a complementary service. As a result, service industries will increasingly benefit from scientists, engineers, and information technology workers who are trained to apply science, technology, and engineering to service sector innovations and operations.

The Federal government should increase R&D spending to support the U.S. service economy, including support for services innovation, productivity, efficiency, competitiveness, and technical workforce development.

An R&D agenda, informed by the needs of the service industries, would bring together disciplines such as computer science, operations research, computational research, industrial engineering, business modeling, management sciences, and social and cognitive sciences in inter- and multidisciplinary research.[64]

4.6 The Federal R&D Investment Should Respond to the Complex and Multi-disciplinary Nature of Technology and Innovation Today

While investigator-driven research remains the cornerstone of federally supported academic R&D, innovations increasingly arise at the intersection of disciplines or require the integration of several disciplines. In recognition of this growing aspect of innovation, some Federal R&D investments should encourage cross-fertilization and the integration of knowledge from different disciplines.

Multidisciplinary centers of cooperative research offer the opportunity to integrate a broader spectrum of research and technical skills capable of focusing on problems of a scope or complexity requiring the advantages of scale, synergy, and interdisciplinary interaction. They permit longer-term commitments on several themes, and the sustained efforts needed to advance the state-of-the-art in critical areas of science and technology. These centers also can integrate research capabilities from multiple academic institutions.

These centers can perform missions in research and education, but also foster cooperation with industry to stimulate knowledge exchange between university-based researchers and those concerned with the application and implementation of research in industry. Centers can participate in joint research programs, and develop shared experimental facilities for use by companies and others.

64 Section 1005 of the *America COMPETES Act* calls for a study and report to Congress on how the Federal government should support through research, education, and training the emerging management and learning discipline known as service science.

that could not afford to develop them on their own. Visiting researcher programs can enhance knowledge transfer between the performers and users of research, as can joint seminars, colloquia and workshops.

In addition, because a critical mass of research is taking place in a single location, such a research center can serve as a powerful magnet for: attracting businesses that could benefit from the research, investment for commercializing innovations emanating from the research, and scientific and technical personnel who are attracted to a center's research agenda. The United States has seen the clustering of companies, venture capital, and associated business services around geographic areas that have a strong R&D asset base.

Most academic R&D is concentrated in relatively few of the 3,600 U.S. institutions of higher education. About 100 institutions account for 80 percent of academic R&D, and the top 200 institutions account for about 95%. The Federal government continues to provide nearly two-thirds of the funding for academic R&D.[65]

Many universities are experimenting with new modes of interacting with industry and philanthropic organizations. Universities prefer sponsors who do not encumber their largesse with conditions, and the process of mutual accommodation with industrial sponsors may take time, but I believe accommodations are inevitable. The economics of university-based research are beginning to change to a new model with diversified sources of revenue.

Federal science policy should encourage this change. Not only will it enable an expanded research enterprise, it will also promote development of capacity in areas likely to produce economically relevant outcomes. Moreover, economists have documented a positive correlation between industrial research investment and national economic productivity, and to the extent this correlation indicates a causal relationship, increased industrial research will be good for the economy.

The message here is that federal funding for science will not grow fast enough in the foreseeable future to keep up with the geometrically expanding research capacity, and that state and private sector resources should be considered more systematically in formulating federal science policy.

John Marburger, Director
White House Office of Science and Technology Policy
Remarks before the 2007 AAAS Policy Forum

While investigator-driven research remains the cornerstone of Federally supported academic R&D, the Federal government should increase attention to emerging opportunities for interdisciplinary and multidisciplinary research, including a focus on centers of research excellence where rapid development of innovations requires this type of collaboration.

This includes reaching out to academic institutions in geographic regions in which the potential for innovative capacity exists—such as high quality research and researchers — but needs further nurturing.

65. National Science Foundation.

4.7 Reaping the Benefits of Our R&D Investment

The U.S. public investment in R&D is substantial, and predicated on the belief that this investment will generate economic and social returns to the nation. In many cases, this R&D has commercial potential that could generate returns to the nation in the form of economic growth and job creation. However, for the most part, these returns cannot be accrued without private sector investment and action to commercialize the results of this R&D, including manufacturing.

But, today, many companies are global in nature, and seek to locate some R&D and manufacturing in the markets they serve. Also, because the cost of manufacturing is relatively higher in the United States than in many other nations, especially labor-intensive manufacturing, firms are increasingly attracted to low cost offshore manufacturing.

It may be inevitable that the United States will not be competitive in most labor-intensive manufacturing. However, the United States can take steps to increase the likelihood of establishing and retaining on its shores higher-end manufacturing operations with high-skill and sophisticated technical requirements. This would increase opportunities for the United States to capture fuller benefits from its public R&D investments, and increase the return on investments to U.S. taxpayers.

To ensure the United States reaps the benefits of Federal R&D investments, the Federal government should examine what incentives can be put in place to enable adequate returns from public R&D to be captured domestically. For example, the United States should consider devoting a small part of the Federal research portfolio to investments in applied research, technology prototyping, demonstration, testing, pilot-scale production, and other pre-competitive activities to increase the likelihood of eventual commercialization on our shores.

5. Developing a Workforce for the Innovation Economy

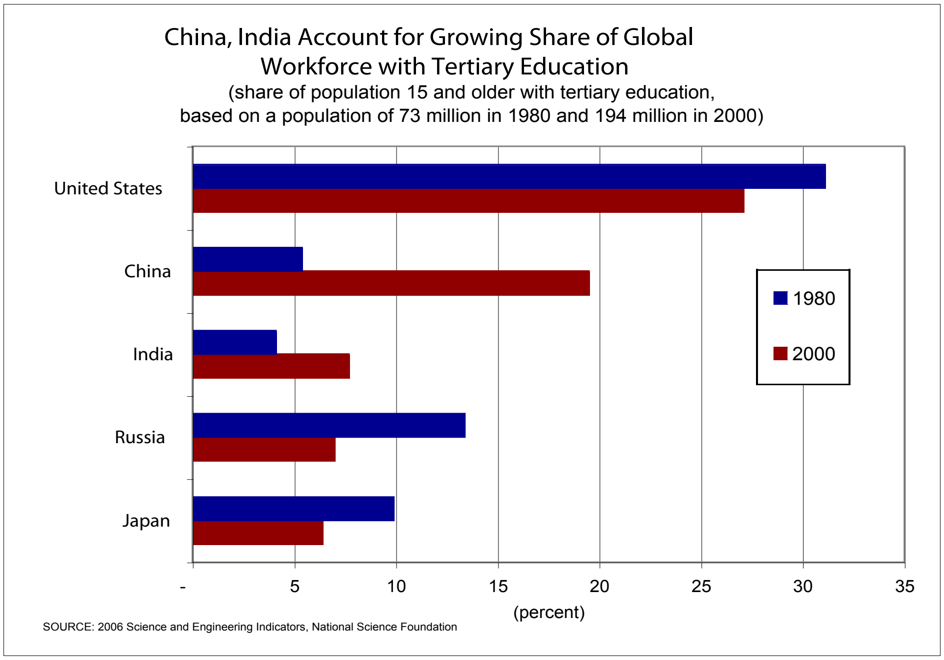
Emerging economies, by virtue of the size of their markets and skilled, often low cost labor pools, are becoming more attractive for global business investment and operations. Today, developing countries' share in world exports of goods and services requiring skilled workers is on the rise. China is moving toward more skill-intensive products in its exports, and India is increasing its presence in skill-intensive services. It will be difficult for the U.S. workforce to compete in routine, yet skill-intensive products and services delivery against these low wage workforces.

The United States must have a workforce who can do what these low wage workforces typically cannot—unleash innovation—melding ideas and inventions, seeing technical and new market opportunities, and creating value for consumers worldwide. This includes, not only the development of innovative products and services, but also innovative design, new business models and processes, and work practices. For the most part, these activities require well-educated, highly skilled, creative workers. In addition, in a fast-paced economy, workers who learn and adapt quickly to new technical and market conditions will have an advantage over workers who cannot.

Developing a Workforce for the Innovation Economy

- **Examine the adequacy of U.S. education and skill levels for an innovation economy.**
- **Provide better and more detailed information on the nation's need for scientists, engineers, and information technology workers.**
- **Ensure STEM workers have a broad skill set, and real world business experience as part of their training.**

The number of people with a postsecondary education can serve as an approximate measure of a highly educated workforce. The global pool of individuals with post-secondary education has grown enormously over two decades, from about 73 million in 1980 to 194 million in 2000. This broad measure of those who are highly skilled includes persons with at least a technical school or associate's degree and all advanced degrees (including doctorates and professional degrees). Over the period, the U.S. share of the total fell from 31% to 27%, while China's and India's shares doubled to 10% and 8%, respectively, and Russia's share decreased by nearly half but remained the fourth largest.



Economic benefits are increasingly linked to education, for both individuals and regions. People with higher education qualifications command significantly higher salaries than those with only secondary education, and in the United States these wage premiums are particularly high. In the United States, earnings in 2005 for higher education graduates in the 25-to-64 year old age group were 75% higher on average than those for people with only secondary education, a differential that is greater than in only three other countries for which data is reported by the OECD. Also, in the United States, the private internal rates of return (earnings) for obtaining a university degree are 13-14 percent.[66]

Not only is higher education linked with better earnings for individuals, gains in education by the workforce can enhance productivity and economic growth at the national level. In one analysis, over the long run, a one-grade increase in the average years of schooling in the United States would boost real GDP per worker by almost one-half percent. Increasing the college completion rate from 25 to 27.5% would increase real GDP per worker by one percent, adding about $125 billion to the U.S. economy.[67] In addition, the study estimated that the long-term effect on economic output of one additional year of education in the OECD countries is generally between 3% and 6%, suggesting that education has significant positive effects on growth.[68] In another example, a recent analysis of census data showed that relative growth in per capita income is increasing in the Nation's most educated metropolitan areas, and declining in the least educated metropolitan areas.[69]

5.1 U.S. Workforce Educational Attainment and Skills Appear Inadequate for an Innovation Economy

The United States falls below many countries in the percentage of students who complete upper secondary education programs. Of OECD countries, the United States ranked 10th in upper secondary level educational attainment among 25-to-34 year- olds.[70] In the same OECD study, the United States ranked 10th for the percentage of 25-to-34 year-olds who complete a tertiary-level of education.

An OECD study examined the mathematics performance of 15 year-old students. Of the 29 countries for which data were presented, U.S. students ranked 24th in mathematical proficiency, and one-quarter of U.S. 15 year-old students failed to reach a baseline proficiency in mathematics. This means these students cannot use direct inference to recognize the mathematical elements of a situation; they are not able to use a single representation to help explore and understand a situation; they cannot use basic algorithms, formulae and procedures; nor make literal interpretations and apply direct reasoning.[71]

While the United States does not rank among the top countries in these measures of educational attainment, it ranks number two in annual expenditure on educational institutions per student, and fourth on expenditure on educational institutions as a percentage of GDP. Research indicates that the skill mix in the United States is moving upscale. A recent study showed that jobs requiring higher order skills—such as complex communications and expert thinking—are growing, while jobs that require routine and non-routine manual skills, and routine cognitive skills are on the decline.[72]

In addition, work that can be done at lower cost by computers or workers in lower wage countries continues to decline. The result is both a changing mix of jobs and a changing mix of tasks within jobs. It is widely accepted that students need to be taught problem-solving skills. But, problem-solving skills have often been taught using rules-based solutions that are easy to teach and test. However, if a problem can be solved by rules, it can also be programmed for computer processing, or written down in a set of rules that can instruct workers overseas what to do. For example, the higher-skilled jobs that have been off-shored to lower wage nations are typically technical jobs, such as routine computer programming, that involve the use of rules and standardized procedures. As a result, routine problem solving has diminishing value in the labor markets of advanced nations.

However, solving new problems cannot be programmed in this way, because rules have yet to be established. This increases the importance of teaching students in the advanced nations how to solve problems for which solutions or rules have yet to be developed. The growth in certain professional and managerial occupations is driven by the inability to capture high end thinking activities in rules, such as formulating and solving new problems, exercising good judgment in the face of uncertainty, creating new products and services, and recognizing what needs to be done and what rules may apply. These are the skill sets needed in the innovation economy.[73]

> ***It is important to gain a more detailed understanding of how this transformation is changing skill requirements and the ways that these required skills can be taught. To do otherwise is to educate our children to compete against either a computer or low-wage workers – a competition our children cannot win.***
> ***— Frank Levy and Richard Murnane[74]***

A recent study of the literacy skills of U.S. students nearing the end of their degree programs at two-year and four-year colleges suggests that such students may not be well prepared for a high skill, high knowledge, innovation-based economy. Around 80 percent of students in the two-year colleges, and around 60 percent of students in four-year institutions did not have proficient levels of prose, document, or quantitative literacy. A proficient level indicates the skills necessary to perform more complex and challenging literacy activities, such as comparing viewpoints in two editorials; interpreting a table about blood pressure, age, and physical activity; and computing and comparing the cost per ounce of food items.[75]

Many of these students had reached an intermediate level of literacy. But, sample tasks at that level would involve consulting reference materials to determine which foods contain a particular vitamin, identifying a specific location on a map, or calculating the total cost of ordering specific office supplies from a catalog. Of even greater concern is that one-third of U.S. adults are at or below the level of literacy needed to perform a task such as using a television guide to find out what programs are on at a specific time, and that more than half are at or below the level of literacy needed to calculate the difference between ticket prices for two events.[76] These literacy levels are in contrast to the skills needed in the top jobs for college graduates, which include: accounting, consulting, management trainee, financial/treasury analysis, project engineering, design/construction engineering, and software design and development.[77]

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66 Education at a Glance 2007, Briefing Note for the United States, Organization for Economic Co-operation and Development.

67 America in the Global Economy, A Background Paper for the New Commission on the Skills of the American Workforce, National Center on Education and the Economy, December 2006.

68 Education at a Glance 2006, Highlights, Organization for Economic Co-operation and Development.

69 Cities' Incomes Rise Faster with More College-Educated Workers, Case Western Reserve University Study Links Education to Regional Pay, Productivity, www.case.edu/pubaff/univcomm/rei-city.htm

70 Education at a Glance 2007, OECD Briefing Note for the United States, Organization for Economic Cooperation and Development.

71 Education at a Glance 2006, Organization for Economic Cooperation and Development.

The United States needs to examine whether prevailing skill levels are adequate for an innovation-based economy and its success in a growing global "trade in tasks," in which routine work, or work that is easily codified is also easy to ship offshore.

5.2 Provide Better and More Detailed Information on the Nation's Need for Scientists, Engineers, and Information Technology Workers.

The science, technology, engineering, and mathematics (STEM) labor market changes in response to scientific and technological developments, and business needs. Demand in certain STEM disciplines may increase while, during the same time period, demand in others wanes. Moreover, technological advancements can significantly affect the STEM labor market. For example, the digital, biotechnological, and nanotechnology revolutions may have significant labor market effects.

The education system, as well as current and prospective STEM workers, must be prepared to move quickly in response to technical and market change, and new jobs and careers as they emerge. For the nation, this is especially important when technological disruptions occur. For example, capitalizing on new innovations made possible by a technological disruption may require rapid development of new skills needed to work with new technologies. Also, such technological change may make some skills obsolete; workers who are affected may need assistance quickly in areas such as training, labor market information, and job seeking.

The National Science Foundation should: encourage employers to better articulate their current and prospective STEM workforce needs, and the types of skills and disciplines needed; ensure students and workers understand what these specific skills and disciplines are; as well as encourage a significant shortening of the feedback loop between employers and their needs, and the responses by education and training institutions. This includes providing career information and nurturing to groups underrepresented in STEM—such as minorities and women—to increase their knowledge of the opportunities in STEM education and careers.

Recruiting domestic science and engineering talent depends on students' perceptions of the science and engineering careers awaiting them. The U.S. Department of Labor has not traditionally focused on the labor markets for professional workers, while the National Science Foundation has generally focused on the traditional science and engineering occupations, paying less attention to the professional IT workforce where much of the growth in the STEM workforce is projected to occur.

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72 How Computerized Work and Globalization Shape Human Skill Demands, Frank Levy, Department of Urban Studies and Planning, Massachusetts Institution of Technology, and Richard J. Murnane, Graduate School of Education, Harvard University, May 31, 2006.

73 How Computerized Work and Globalization Shape Human Skill Demands, Frank Levy, Department of Urban Studies and Planning, Massachusetts Institution of Technology, and Richard J. Murnane, Graduate School of Education, Harvard University, May 31, 2006.

74 How Computerized Work and Globalization Shape Human Skill Demands, by Frank Levy, Department of Urban Studies and Planning, MIT, and Richard J. Murnane, Graduate School of Education, Harvard University, may 31, 2006.

5.3 U.S. Scientists, Engineers, and Information Technology Workers Need a Broader Skill Set

Science and technology have become ever more central to core business functions in a wide range of companies and industries. But, for them, it's not about great science and technology, but great science and technology from which revenues can be generated. U.S. scientists, engineers, and information technology professionals need to possess the multi-dimensional skill set that employers need, and that can underpin—not just the creation of new knowledge—but innovation in its many manifestations. These skills are also needed to strengthen the global competitiveness of the U.S. science and engineering workforce in light of the developing technical workforce in emerging economies.

U.S. research universities do an outstanding job of imparting technical skills to scientists and engineers, and training them to perform R&D in academic-type research settings. However, most scientists and engineers work in industry, not academia, where research and its translation into competitive innovations require a broader skill set.

For example, ABET, an accrediting body for post-secondary applied science, computer, engineering and technology programs has incorporated a broader skill sets into its accreditation criteria.[78] Examples include an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic or manufacturability; an ability to function on multidisciplinary teams; an ability to communicate effectively; and the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

In addition, many nations increasingly have the capability to perform ever more sophisticated R&D, and scientific advancements and important technology developments will more frequently occur outside of the United States. The United States needs to develop a stronger capability to identify, assess, and exploit foreign technologies.

The Federal government should encourage university educators to ensure that scientists, engineers, and information technology workers have: global and cultural awareness; knowledge that helps them understand business, markets, marketing, and customers; the ability to work as a member of and communicate effectively in teams of diverse disciplines; some understanding of business finance such as cost-benefit and return on investment concerns; as well as project management abilities.

Also, opportunities to gain real-world business experience as part of their training would enhance their value to future employers. Such hands-on, experiential learning should be a significant component of the training of U.S. scientists, engineers, and information technology workers. In addition, the United States needs to develop a cadre of technical personnel, who also have business knowledge and skills, who are trained to mine foreign technologies and technological developments for their exploitation in the United States.

5.4 Developing and Attracting to the United States the Most Promising Science and Technology Talent

While more routine science, technology and software development can be and is performed in many other countries, including emerging economies, the most advanced levels of science and technology work remain an activity vital for continued U.S. science and technology leadership. The highest expression of scientific and technical work—for example, groundbreaking research, research program design, the education and training of future scientists and engineers, or research and engineering project management—is often the responsibility of an individual who has obtained a Ph.D. degree. This includes researchers who are leaders in their field pursuing groundbreaking work that may have profound or other important implications.

The United States has been a world leader in producing highly talented Ph.D. degree holders. For example, Americans have won more than twice the number of Nobel prizes than any other nation. The United States has also been a magnet for foreign-born science, engineering, and technology talent. More than one-third of U.S. Nobel laureates are foreign born.[79]

As the world's largest economy, largest educator of foreign students, and as a traditional nation of immigration, the United States is an important nexus for the international movement of highly skilled workers. The 2000 Decennial Census showed that a large proportion of highly skilled U.S. workers are foreign born, including 37.6% of doctorate holders in science and engineering (S&E) occupations.[80] In 2003, this ranged from about 10% of psychology doctorate holders to 51% of doctorate holders in engineering and 57% in computer science.

The United States also remains a highly desirable destination for pursuing graduate-level education in science and technology. However, the U.S. share of international students worldwide has declined, partly because of expanding higher education options abroad and growing competition from countries with coordinated recruitment strategies.

Some foreign-born, U.S.-educated science, engineering, and technology professionals go on to launch technology-related companies. One-quarter of technology and engineering companies launched in the United States between 1995 and 2005 had at least one-foreign-born founder. More than half (52%) of Silicon Valley startups had one or more immigrants as a key founder. Nationwide, these enterprises generated $52 billion in sales and employed 450,000 workers in 2005. More than half of these foreign-born founders of U.S. technology and engineering businesses initially came to the United States for the purpose of education. Nearly three-quarters of these immigrant founders held graduate or postgraduate degrees. Seventy-five percent of the highest degrees among immigrant entrepreneurs were in science, technology, engineering, or mathematics. And, 53% of the immigrant founders of U.S.-based technology and engineering companies completed their highest degrees in U.S. universities.[81]

75 The Literacy of America's College Students, American Institutes for Research, January 2006.

76 National Assessment of Adult Literacy, A First Look at the Literacy of America's Adults in the 21 Century, National Center for Education Statistics, 2006. Question: The price of one ticket and bus for "Sleuth" costs how much less than the price of one ticket and bus for "On the Town"?

77 Spring 2007 *Salary Survey*, National Association of Colleges and Employers.

78 ABET Criteria for Accrediting Engineering Programs.

79 Chronology of Nobel Prize Winners in Physics, Chemistry, and Physiology or Medicine Web Site, Nobel e-Museum—The Official Web Site of the Nobel Foundation.

80 Research Issues in the International Migration of Highly Skilled Workers: A Perspective with Data from the United States, National Science Foundation, June 2007.

81 Education, Entrepreneurship, and Immigration: America's New Immigrant, Kauffman Foundation, June 2007.

In addition, these international students help foster the global and cultural knowledge and understanding necessary for effective U.S. leadership and competitiveness in today's diverse global marketplace. As the global competition shifts from control of raw materials to the acquisition of knowledge-based assets, the United States must develop, attract, and retain highly skilled Ph.D. degree holders to ensure that a large share of the world's most advanced work in science and technology is performed within the United States. However, three factors may undermine the U.S. ability to do so.

First, foreign students comprise a large share of those receiving Ph.D. degrees awarded by U.S. universities in key science and engineering fields. The share of U.S. Ph.D. degrees awarded to foreign students is especially large in engineering fields and physics. Increasingly, these Ph.D. degree holders have opportunities to perform science and technology research in their home countries. The United States needs to retain a substantial share of this U.S.-educated talent.

Percentage of Science and Engineering Ph.D. Degrees Awarded by U.S. Higher Education Institutions to Non-U.S. Citizens, By Field, 2005

Field	% Non-U.S. Citizen
Science and Engineering Total	41%
Biological Sciences	30%
Computer Science	58%
Physics	55%
Engineering Total	63%
Aeronautical/Astronautical Engineering	54%
Chemical Engineering	58%
Civil Engineering	68%
Electrical Engineering	69%
Industrial Engineering	65%
Materials/Metallurgical Engineering	61%
Mechanical Engineering	65%

Source: National Science Foundation

Second, as other nations build their science and technology capabilities, and adopt economic growth strategies based on science and technology, global competition for highly-skilled technical talent is increasing, as are efforts to lure ex-patriots back home. Cross-border migration of highly skilled persons has expanded markedly.

In both the developed and less-developed world, keeping or attracting highly skilled workers is a key part of national economic policy and is a consideration not just for immigration policies but also plans for higher education, research funding, and international investment. For example, Singapore is aggressively recruiting science and technology talent globally for its Biopolis bio-medical research complex, where the country is creating an environment to foster interaction and idea exchange among researchers, entrepreneurs, and scientists. Singapore seeks to develop Biopolis into a leading global center of biomedical research in areas such as biotechnology, bioengineering, and nanotechnology. It is offering state-of-the-art laboratories, lucrative pay, and sizable government research grants. In 2006, it was reported that Biopolis had recruited 50 senior scientists, including several top U.S. biomedical researchers from research universities such as MIT and Stanford. The research institutes that are a part of Biopolis are also playing an active role in spinning off companies to develop and commercialize new products.[82]

Third, U.S. immigration policies can inhibit U.S. attraction and retention of foreign scientists and engineers. The number of skilled foreign workers waiting for U.S. visas is significantly larger than the number that can be admitted to the United States. This imbalance creates the potential for the exit of these skilled workers to return to their home countries. A recent study estimated that there are more than 500,000 employment-based foreign-born individuals (and an additional 555,000 family members) waiting in line for legal permanent U.S. resident status. Approximately 120,000 permanent resident visas are available annually for employment-based principals and their families in the three main employment visa categories. In addition, the number of visas that can be issued to immigrants from any one of the major sending countries— including China and India—is less than 10,000 per year.[83]

In addition, in the post-9-11 era, some foreign scientists and engineers report experiencing greater scrutiny and difficulty in obtaining visas to visit or work in the United States.[84] This includes scientists unable to obtain visas to attend scientific conferences held in the United States. Such difficulties may cause some organization to move scientific conferences to non-U.S. locations, hurting the United States as a global center of science and technology.

In order to compete with countries that are rapidly expanding their scientific and technological capabilities, the United States needs to bring to the country those whose skills will benefit society and enable us to compete in a high-value innovation economy. However, the United States lacks an integrated, strategic approach to recruiting and retaining international students and STEM professionals. High tuition costs and growing costs for universities related to recruiting international students may make it more difficult to attract these students. In addition, the nonimmigrant visa process or the permanent immigration system may not adequately serve U.S. efforts to attract international students and high-skill science and technology professionals.[85] This strategic approach should include incentives to attract leading foreign-born scientists, engineers, and technologists, including public funding for their research if they migrate to and carry out that research in the United States.

The United States should strengthen its efforts to attract top foreign students and Ph.D.-level professionals in science, engineering, and technology. This includes developing a national strategic plan for recruiting top international students, scientists, engineers, and technologists, and evaluating the U.S. immigration system to remove barriers to these talented individuals migrating to the United States.

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82 Singapore Woos Top Scientists with New Labs, Money, Associated Press, April 12, 2006; Singapore's Reply to Offshoring—Build Biopolis, Create New Jobs, SFGate.com, April 18, 2004; A*STAR Burns Brightly Thanks to Active Leader, Asia-Pacific International Molecular Biology Network, May 23, 2006.

83 Intellectual Property, the Immigration Backlog, and a Reverse Brain Drain, Ewing Marion Kauffman Foundation, August 2007.

84 Scholars Kept Out, Foreign Academics Barred by the United States, The Chronicle of Higher Education, June 15, 2007; The Impact of U.S. Visa Policy on the Department of Energy Office of Science Missions, Statement by Dr. Raymond Orbach, Director, Office of Science, U.S. Department of Energy, before the Senate Foreign Relations Committee Roundtable, April 4, 2005; Policy implications of International Graduate Students and Postdoctoral Scholars in the United States, National Academies Press, 2005.

85 Highlights of a GAO Forum: Global Competitiveness: Implications for the Nation's Higher Education System GAO-07-135SP, January 23, 2007.

6. Creating a Business Environment the Supports Innovation and U.S. Competitiveness

Previous chapters have focused on R&D investment and talent development as key assets enabling the United States to retain its scientific and technological leadership. While investment in R&D and development of world-class scientific and engineering talent are necessary foundations of an innovation economy, investment in these assets alone is insufficient to ensure America remains the world leading economy. Innovation does not simply flow from some earlier process of scientific discovery. It is not a linear process that proceeds directly from science to the enterprise and then the marketplace. There are many additional factors that drive the transformation of knowledge into useful products and services and value for society.

Today, innovation is increasingly a global, multidisciplinary, distributed, and interactive activity. While R&D is performed in academic, government laboratory, and business settings, business is a key player in moving technology from concept to commercial product or service. Successful innovation draws on many non-technical activities, such as organizational design, training, financial engineering, marketing and customer relationships. Entrepreneurs and innovating enterprises are the prime agents for transforming knowledge and commercializing products, services, and processes.

6.1. Understanding the Innovation Ecosystem

When today's modern enterprise innovates, it rarely does it with only its own internal resources. Rather innovating enterprises interact with an innovation "ecosystem," a system made of many players, connections and linkages between customers, suppliers, government, education, research, and other economy actors. Elements that contribute to an "ecosystem" that supports innovation include:[86]

- Capital resources are needed to invest in the innovation process, and new product, service, and market development. Large companies provide their own capital to finance technology development and commercialization. Venture capital and angel investing play key roles in moving innovations in small companies from the laboratory to the marketplace.

- Government regulatory, tax, and trade policies can create an environment that encourages and rewards or serves as a barrier to innovation. In addition, the effects of external conditions, such as ever increasing health care costs, affect competitiveness. U.S. firms face higher compliance costs in labor, environmental, and other government regulatory areas than do many of their trading partners, particularly in the developing world. These costs can affect a firm's financial ability to invest in innovation, as well as its decisions about where to locate business activity and manufacturing. The need to comply with both Federal laws and often widely varying state and local approaches can discourage the location of research, engineering and production facilities in the United States. Regulatory approaches also can discourage the creation and deployment of more innovative technologies.

- State and local economic development entities play an important role in fostering innovation, and the formation and growth of entrepreneurial firms. For example, they sponsor efforts to increase

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86 Innovate America, National Innovation Initiative Summit and Report, Council on Competitiveness; Manufacturing in America: A comprehensive Strategy to Address the Challenges of U.S. Manufacturers, U.S. Department of Commerce, January 2004; Innovation Vital Signs Project, Innovation Vital Signs Workshop, Project Final Report, and Periodic Table of Innovation Elements, ASTRA and the Center for Accelerating Innovation.

the transfer of research and technologies developed by universities for commercialization by local businesses. Some of these state and local entities provide seed capital and other assistance to entrepreneurs. A nation's culture can foster entrepreneurship, risk taking, and innovative thinking. This has been a significant U.S. strength.

- Telecommunications and social networks enable the flow of innovative ideas and activities, and help connect people with ideas to the resources needed for product and service commercialization.

When these factors come together, they create an innovation-friendly environment, and the country is enabled to create economically valuable outcomes—new products and services, market share, new business start-ups, satisfied customers, jobs, and returns on investment. The Periodic Table of Innovation below was developed as part of ASTRA's *Innovation Vital Signs* project to illustrate this complex and dynamic system of innovation.

Key U.S. Innovation Elements: What are they and how do they interact?

U.S. innovation indicators tend to focus on measurable data sets which have been readily collected by governmental and private entities for many years. While policy makers have traditionally looked at patent production, R&D spending, science & engineering degrees conferred and scientific article citation, the U.S. "innovation eco-system" is a more complex series of interrelated phenomena. ASTRA has created a ***Periodic Table of Innovation Elements*** suggesting how key innovation elements interact and seem to affect one another. The more recognized innovation elements depicted below are organized according to eight "element" groups: **Inputs, Process, Outputs, Impact, Macro-Economy, Policy, Infrastructure** and **Mindset**. The key innovation elements selected by ASTRA are organized and color-coded depending upon their primary role.

Periodic Table of Innovation Elements

R&D														
Expenditures														
R&D	Capital											Impact	Impact	MacroEcon
Patents	Gross Capital Formation											# Innovative Enterprise	Birth Rate New Enterprises	Average Hourly Earnings
Talent	Capital											Impact	Impact	MacroEcon
# Researchers	ICT Investment											S&T Employment	Net Change Enterprises	Gross Private Investment
Talent	Capital	Networks	Networks	Networks	Management	Prod Dev.	Process	Process	Output	Output	Output	Impact	MacroEcon	MacroEcon
No. with Higher Education	Initial Public Offerings	Broadband Penetration	SMEs with Cooperation Arrangements	# Business Incubators	Entrepre-neurship	# Approved Patents	# Cooperation Agreements	R&D Used From Overseas	Sales New to Market	# New Products Introduced	New Markets Created	Leading Competitiveness Indicators	Real GDP	Real Interest Rates
Talent	Capital	Networks	Networks	Networks	Management	Prod Dev.	Process	Process	Output	Output	Output	Impact	MacroEcon	
Verbal SAT	Angel Networks	Computer Use per Capita	Intern'l Alliances	# Internet Domains	Quality of Management	Time & Money to Develop	Early Stage Entrepreneurial Activity	Innovation Expenditure	Sales New to Firm	Output per Sector	Export Sales	High Tech Jobs Gained & Lost	Real GDP per Capita	
Talent	Capital	Networks	Networks	Management	Management	Efficiency	Process	Process	Output	Output	Impact	Impact	MacroEcon	
Math SAT	SBIR Funding	Internet Use by Business	Federal Lab CRADAs	Shareholder Value	# of Ideas	Availability Competent Managers	Research Quality	Enterprises Innovating In-House	Royalty, License Fees	New Companies Created	High Tech Exports	Income per Capita	Inflation Rate	
Talent	Capital	Networks	Networks	Management	Prod Dev	Efficiency	Process	Process	Output	Output	Impact	*Future*	*New*	*Metrics*
Pop with Life Long Learning	Investment Risk	Broadband Costs	University Spinouts	Customer Satisfaction	Technology Absorption	Cost Reduction	Quality of University Collaboration	Product Launch Speed	Overall Productivity	Value Add of SMEs	Employment in High Tech Sector			

Innovation Element Groups (Families)*			
Inputs	Process	Outputs	Impact
Macro-Economy	Policy	Infrastructure	Mindset

Policy	Policy	Policy	Policy	Policy	Infrastruc	Infrastruc	Infrastruc	Infrastruc	Mindset	Mindset	Mindset	*Future*	*New*	*Metrics*
Corporate Tax Rate	# New Taxes, Excises, Duties	Time Required to Start Business	Foreign Ownership Restrictions	Rule of Law Governance	IP Rights	Environment Governance	Legal Rights Index	Home Affordability	Public Source of S&T Information	Informed about Policy Issues	Value Place on Creativity			
Policy	Policy	Policy	Policy	Infrastruc	Infrastruc	Infrastruc	Infrastruc	Mindset	Mindset	Mindset	Mindset	*Future*	*New*	*Metrics*
Overall Tax Burden	# Procedures to Start Business	Trade Barriers	IP Protection	Judicial Independence	Infrastructure Quality	Openness to Competition	# of New Bldgs Designed	Youth Interest in Science	Public Interest in S&T	Science Literacy	Wish to Own Business			

The next President should launch a White House initiative to perform a comprehensive review of U.S. laws and regulations relating to the business climate for innovation. This would include regulations promoting human health and safety, standards, and environmental protection, as well as tax, trade and antitrust laws, to determine whether changes are needed to meet the nation's public policy goals while at the same time promoting innovation and competitiveness.[65]

6.2 Measuring the Innovation Economy

Knowledge and innovation are increasingly important to the U.S. economy. Yet, many elements of our measurement systems were designed to measure an economy dominated by manufacturing and physical goods production. The United States needs to develop a portfolio of metrics to better understand the unfolding innovation economy, and the relative position of the United States and U.S.-based firms' competitiveness in the global economy.

In recognition of this need, ASTRA launched its *Innovation Vital Signs* project. To support the development of a portfolio of indicators that describes the nation's capacity for innovation, ASTRA developed an innovation framework that provides a foundation for understanding the processes and interrelationships of the innovation ecosystem, performed a comprehensive survey of public and private sector innovation indicator sources, and developed a systematic data base of innovation indicators, including an analysis of the utility and quality of available indicators.

To review work performed by ASTRA's Vital Signs project team, ASTRA conducted an Innovation Vital signs workshop. At this workshop, ASTRA solicited expert advice to identify strengths and gaps in the current system of innovation measures. Experts reviewed a number of indicators currently used to measure some aspect of the innovation ecosystem in the U.S. economy, such as quantity and quality of available talent for R&D, and levels of R&D investment, which is one of the strongest statistical areas currently available to measure the innovation ecosystem. Other key indicators currently used to measure innovation include:

- Given that innovation is connected closely to science and technology, measures of student achievement in mathematics and science are important indicators of a country's innovative capacity. This is an are of measurement conducted on an equivalent basis across international boundaries.

- U.S. shares of peer reviewed science and technology literature in a variety of scientific and engineering disciplines is a well-known indicator of the overall vitality and creativity of the nation's scientific community.

- Venture capital data is one of the stronger data points reflecting innovation and innovative activity.

- Patents are recognized as an indicator of innovation in virtually all sectors of the economy. However, this data could be further analyzed to identify high value patents, and the clustering of patents around key researchers and key technologies.

87 Section 1002 of the *America COMPETES Act of 2007* calls for a study that would include a review of: certain aspects of laws and regulations related to business financial reporting; the costs faced by U.S. businesses engaging in innovation compared to foreign competitors, including health care costs; Federal regulations that may discourage or encourage innovation; and provisions of the Federal tax code that discourage innovation.

However, ASTRA's Innovation Vital Signs project identified many key aspects of the innovation economy that are difficult to measure, or not measured at all. For example, measurement of intangibles in the economy is an area in need of significant improvement. The economic and statistical constructs of the United States—as represented in the economic and financial data gathered by government—are still largely focused on their roots in manufacturing. These measures largely focus on tangible assets—physical assets such as plant, equipment, and inventory; and financial assets, such as cash, securities, and investments. This bias needs to be addressed given how the economy has changed in the past 50 years, and how it is likely to change in the next 50 years. It has been estimated that investment in intangibles in the U.S. economy is as high as $1 trillion, about the same as investment in tangible capital.[66]

At the national level, intangibles that are important in an innovation economy include patents and copyrights, the percent of the workforce with higher degrees in science and technology-related fields, the level of entrepreneurial activity, and the level and availability of venture capital. At the firm level, intangibles might include management leadership, the organization's technology and processes, human and intellectual capital, workplace organization and culture, and brand equity. The measurement of intangibles is improving; we have a much better overall idea of the size and importance of intangibles to national and firm-level economic activity. However, our measures are still approximate estimates. Much more needs to be done to bring our economic measurement systems into the age of information, knowledge, and intangibles. Other areas where new systems of measurement is required include:

- It is generally acknowledged that much innovation occurs at the entrepreneurial and small firm level. But very little is being done to measure the innovation contribution made by these sectors of the U.S. economy. This would include a focus on angel investing, an investment component that is believed to have grown as large as the venture capital industry. Any effort to measure innovation and its impact on the economy must include the small business and entrepreneurial sectors.

- Measurement of service sector innovation is a significant weakness in the current structure of reporting on innovation. Innovation in the service sector comes in many guises, ranging from things such as patents, which are relatively easy to quantify, to items such as business model innovations that are highly productive and highly profitable for the firms that employ them, but largely unquantifiable. Given the large role services play in U.S. gross domestic output, as well as the rapidly growing R&D activities in this sector, this is an area of significant need.

- It is widely believed that, in all areas of academic and corporate research, there is an increasing focus on and need for multidisciplinary approaches to solving technical issues. This reflects an emerging and evolving research model that is far more complex than in the past. However, there is no effort ongoing to capture this change in the way research is being conducted.

- Of significant importance are the infrastructural conditions that support innovation. These enable individuals to benefit directly from their innovations through some form of commercialization. Components such as legal, financial, education, and energy systems are preconditions for successful innovation, and they vary country-to-country. Yet, no attempt has been made to define, in a rigorous and quantitative way, these infrastructure conditions for innovation, though much of this data is currently compiled.

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88 Intangible Capital and Economic Growth, by Carol Corrado, Charles Hulten, and Daniel Sichel, Federal Reserve Board, Washington, DC, April 2006.

The current inventory of indicators and measurement methods does not adequately describe the dynamics of innovation today. The *Innovation Vital Signs* project found that there is not a commonly accepted framework for innovation indicators based on a widely accepted theory of innovation.

Innovation is a very complex activity with many dimensions, a fact that makes a better understanding of innovation that much more important. Any potential innovation indicator, at best, provides only a partial and limited view of the innovation process; there is no single indicator that properly captures the complexity of the process. The *Innovation Vital Signs* project reviewed thousands of indicators, but found only a very limited number that can be said to have a strong connection to the measurement of innovation.

The United States needs to develop a structured system for capturing data, and routinely reporting on "innovation vital signs." The purpose of such a system would be to provide policymakers a tool to evaluate the nation's innovation capabilities and performance, and to better assess policy choices and potential impacts. This system should take a multi-dimensional and comprehensive view that recognizes the complexity of the innovation process and the context in which innovation takes place.

In addition, the Federal government lacks adequate capacity and resources devoted to innovation-related policy analysis and development. Over the past two decades, competitor nations have dramatically increased the level of national attention and resources devoted to research and analysis regarding the global economy, national systems of innovation, and development of strategies to promote technology development and commercialization. In contrast, the United States has downsized its innovation-related analytical and policy-making infrastructure, including the elimination of the Congressional Office of Technology Assessment in the mid-1990s, and the Technology Administration within the U.S. Department of Commerce in 2007.

The development of globalization in many markets, and the ongoing rapid shift to a knowledge economy, require that the United States have a better sense of where we are and where things are going.

The United States needs to develop a meaningful set of innovation indicators to help guide policy and strategy. The Federal government should lead an effort to determine where the priorities are, and begin the process of developing some high level indicators around the key drivers of innovation that are known and recognized.

The U.S. must create—and provide meaningful financial resources to—institutions within the Federal government capable of performing high quality analysis of U.S. and foreign innovation systems, and formulating a Federal innovation policy and investment agenda commensurate with new economic realities and 21st century competitiveness challenges.[87]

89 Section 1006 of the *American COMPETES Act* calls on the President of the United States to establish a President's Council on Innovation and Competitiveness which would, among other duties, provide advice to the President with respect to global trends in competitiveness and innovation, and the allocation of Federal resources in education, job raining, and technology R&D considering such global trends in competitiveness and innovation; and develop metrics for measuring the progress of the Federal government with respect to improving conditions for innovation, including through talent development, investment, and infrastructure improvements.

About ASTRA

Founding ASTRA Organizations

Alfred P. Sloan Foundation
American Association for the Advancement of Science
American Association of Engineering Societies
American Chemical Society
American Institute of Chemical Engineers
American Institute of Physics
American Physical Society
American Mathematical Society
Association of American Universities
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National Association of Manufacturers
Optical Society of America
Rensselaer Polytechnic Institute
Sandia National Laboratories
The Science Coalition
Semiconductor Industry Association
The Minerals, Metals and Materials Society (TMS)
University Corporation for Atmospheric Research (UCAR)
University of Arkansas, Fayetteville
University of Arkansas, Little Rock
Worcester Polytechnic Institute

ASTRA Background

ASTRA, the Alliance for Science and Technology Research in America, was founded in 2001 as an *Internal Revenue Code (IRC)* §501(c)(3) entity after a trial period beginning in 2000. Key scientific and academic institutions across the U.S. donated seed monies for ASTRA's start-up. As its logo suggests, ASTRA is a unique collaboration made up of many sectors of the Scientific, Engineering and Technology communities. ASTRA's membership is well-balanced between industry, academe, nonprofit trade and professional organizations, small businesses and entrepreneurs. Dues payments are tax deductible to many.

ASTRA's Mission

ASTRA's core mission since 2000 has been to increase federal funding for fundamental research in the physical, mathematical and computational sciences and engineering. ASTRA has grown to a 100-plus membership organization with 6,600-plus "friends" nationwide.

Since 2000, ASTRA has performed the research, surveyed the public created new networks, and developed advocacy materials and programs to help the general public understand the importance of science and engineering to our economy, standard of living, and national security. ASTRA has assisted in laying out the policy framework for important efforts like the *America COMPETES Act*, the American Competitiveness Initiative and other agency-specific issues related to federal R&D funding.

ASTRA Products and Services

ASTRA creates a variety of research products and enables other coalitions and membership groups. ASTRA volunteers identify emerging issues and help provide analysis for Congressional testimony and other agencies of government. Much of our research on science spending is also used by the general public. ASTRA provides annual State-specific ***R&D Sheets*** for each state, as well as annual ***State STEM Education Report Cards***.co-sponsored by ASTRA members.

Recently, ASTRA has been involved in identifying key gaps in innovation metrics and is attempting to determine how small business, venture capital and entrepreneurial sectors affect the overall competitiveness and innovation capacities of the U.S. economy in order to promote better policy decisions.

ASTRA Briefs is available on-line. It provides readers a quick update on events, issues and developments affecting science and engineering policy. It is an excellent source of statistical data and science metrics as well.

For More Information ...

ASTRA hosts two Web Sites: www.aboutastra.org and www.usinnovation.org. These sites provide extensive materials related to science and engineering policy and news. Podcasts, videos, survey data, RSS feeds from various science sources and survey capability are among the features of the ASTRA Web Sites. For more information, contact ASTRA's Executive Director, Robert Boege at r.boege@comcast.net

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Computing Research Association*
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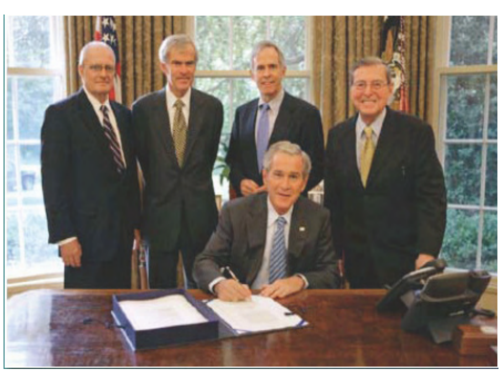

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IEEE-USA
Integrated Manufacturing Technology Initiative*
Intel
IPC — Association Interconnecting Electronics Industries*
Kent State University
Luna Innovations*
Materials Research Society
NanoBusiness Alliance*
National Association of Manufacturers*
National Council for Women and Information Technology (NCWIT)*
National Center for Manufacturing Sciences (NCMS)
National Science Teachers Association
National Semiconductor Corporation
National Venture Capital Association
NEC Research Institute
New Economy Strategies
NJIT — New Jersey Institute of Technology
Northern Illinois University
ONAMI — Oregon Nanoscience and Microtechnologies Institute*
Optical Society of America (OSA)
Optoelectronics Industry Development Association(OIDA)*
Orbital Research, Inc.*
Purdue University
Rensselaer Polytechnic Institute
Rockwell Collins
Rohm & Haas
SAE International
Sandia National Laboratories
Semiconductor Equipment & Materials International (SEMI)
Semiconductor Industry Association (SIA)
Small Business Technology Council*
Semiconductor Research Corporation (SRC)
Southeastern Universities Research Association (SURA)
SPIE
Stanford University
TechVision 21*
Texas Instruments*
Texas State University, San Marcos
Texas Tech University*
The Minerals, Metals and Materials Society (TMS)
The Science Coalition
University Corporation for Atmospheric Research (UCAR)
University of Alaska, Fairbanks*
University of Arkansas, Fayetteville
University of Arkansas, Little Rock
University of California, Los Angeles
University of California, Office of the President
University of California, Santa Barbara
University of Central Florida
University of Florida
University of Illinois, Chicago
University of Illinois, Springfield
University of Illinois, Urbana-Champaign
University of Massachusetts
University of Missouri
University of New Mexico
University of North Texas
University of South Carolina
US Car*
Worcester Polytechnic Institute

** denotes "friend of ASTRA"*

Riding the Rising Tide:

A 21st Century Strategy for U.S. Competitiveness and Prosperity