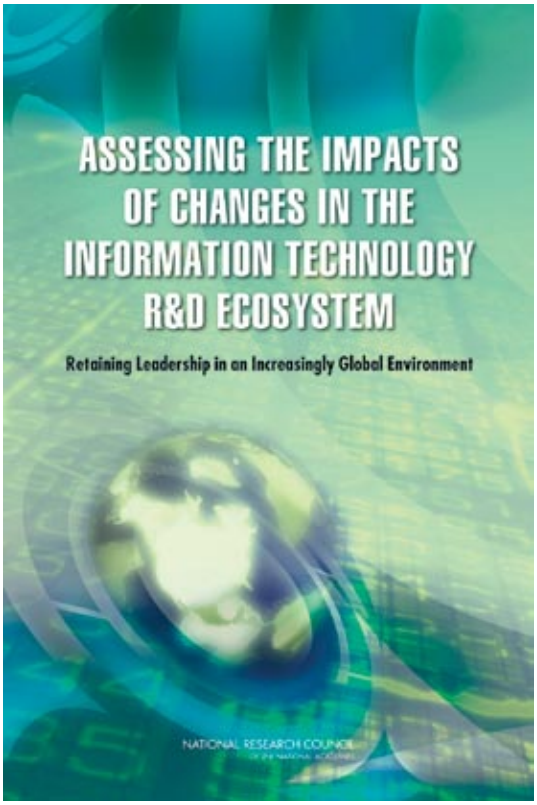
THE NATIONAL ACADEMIES

ASSESSING THE IMPACTS OF CHANGES IN THE INFORMATION TECHNOLOGY R&D ECOSYSTEM

Retaining Leadership in an Increasingly Global Environment

Computer Science and Telecommunications Board

Division on Engineering and Physical Sciences



THE IMPACT OF INFORMATION TECHNOLOGY

Advances in information technology (IT) and its applications are integral to the unparalleled success of U.S. scientific, engineering, business, and governmental communities in the past 50 years.

IT has transformed, and continues to transform, all aspects of our lives: commerce, education, employment, health care, manufacturing, government, national security, communications, entertainment, science, and engineering. IT also helps drive the economy—both directly (the IT sector itself) and indirectly (other sectors that are powered by advances in IT).

To appreciate the magnitude and breadth of these achievements, imagine spending a day without IT. This would be a day without the Internet and all that it enables. A day without diagnostic medical imaging. A day during which automobiles lacked electronic ignition, antilock brakes, and electronic stability control. A day without digital media—without wireless telephones, high-definition televisions, MP3 audio, DVD video, computer animation, and video games. A day during which aircraft could not fly, travelers had to navigate without benefit of the Global Positioning System, weather forecasters had no models, banks and merchants could not transfer funds electronically, factory automation ceased to function, and the U.S. military lacked technological supremacy. It would be, for most people in the United States and the rest of the developed world, a "day the Earth stood still."

IT and its impact on the economy continue to grow in size and importance. According to estimates of the Bureau of Economic Analysis, for 2006 the IT-intensive "information-communications-technology-producing" industries accounted for about 4 percent of the U.S. economy but contributed more than 14 percent of real gross domestic product (GDP) growth. (As a point of reference, federal funding in fiscal year 2008 for computer sciences research was around $3 billion, less than 0.025 percent of GDP.) This substantial contribution to the economy reflects only a portion of the overall long-term benefits from IT research investments. It is in the nation's interest for these benefits to continue to grow and accrue.

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ASSESSING THE U.S. IT R&D ECOSYSTEM

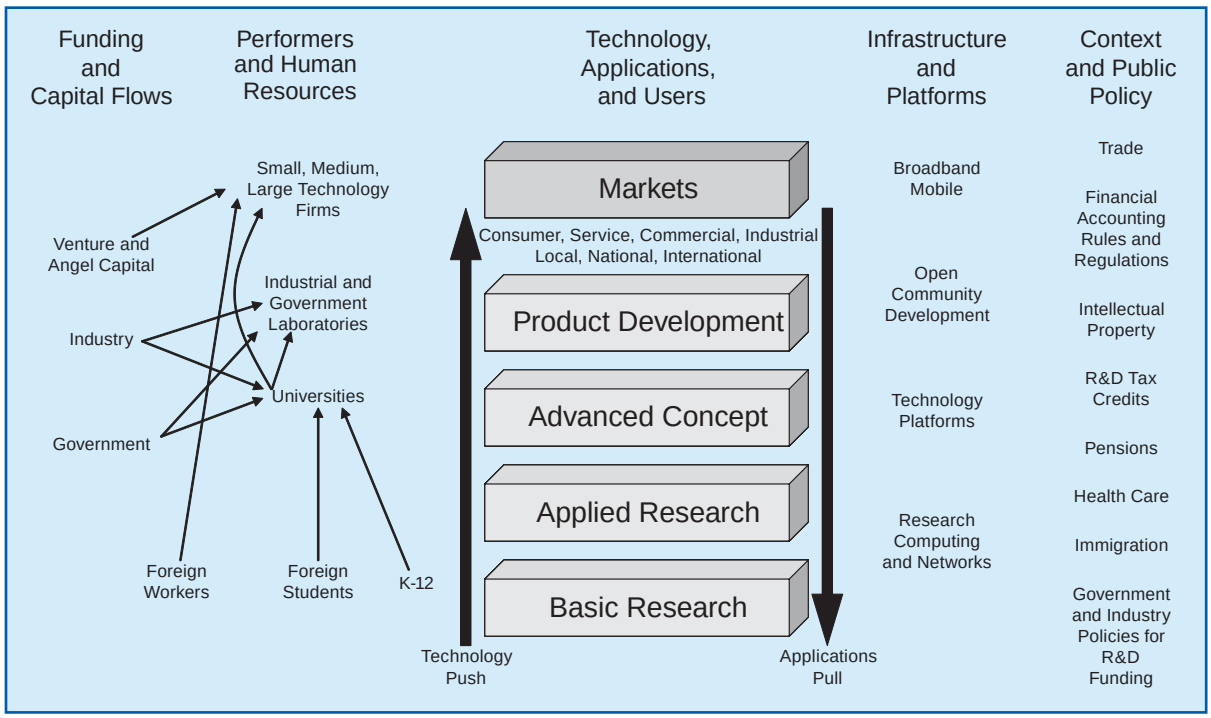
The U.S. IT research and development (R&D) ecosystem was the envy of the world in 1995—from the perspective of IT, the United States enjoyed a strong industrial base, an ability to create and leverage ever newer technological advances, and an extraordinary system for creating world-class technology companies. But the period from 1995 to the present has been a turbulent one for the U.S. IT R&D ecosystem. Today, this ecosystem—encompassing university and industrial research enterprises, emerging start-up and more mature technology companies, the industry that finances innovative firms, and the regulatory environment and legal frameworks—remains unquestionably the strongest such ecosystem in the world.

However, this position of leadership is not a birthright, and it is now under pressure. The IT industry has become more globalized, especially with the dramatic rise of the economies of India and China, fueled in no small part by their development of vibrant IT industries. Moreover, those nations represent fast-growing markets for IT products, and both are likely to grow their IT industries into economic powerhouses for the world, reflecting deliberate government policies and the existence of strong, vibrant private-sector firms, both domestic and foreign. Ireland, Israel, Korea, Taiwan, Japan, and some Scandinavian countries have also developed strong niches within the increasingly globalized IT industry. Today, a product conceptualized and marketed in the United States might be designed to specifications in Taiwan, and batteries or hard drives obtained from Japan might become parts in a product assembled in China. High-value software and integrated circuits at the heart of a product might be designed and developed in the United States, fabricated in Taiwan, and incorporated into a product assembled from components supplied from around the world.

During the same period, national policies have not sufficiently buttressed the ecosystem or have generated side effects that have reduced its effectiveness. This is particularly true for such areas as IT education,

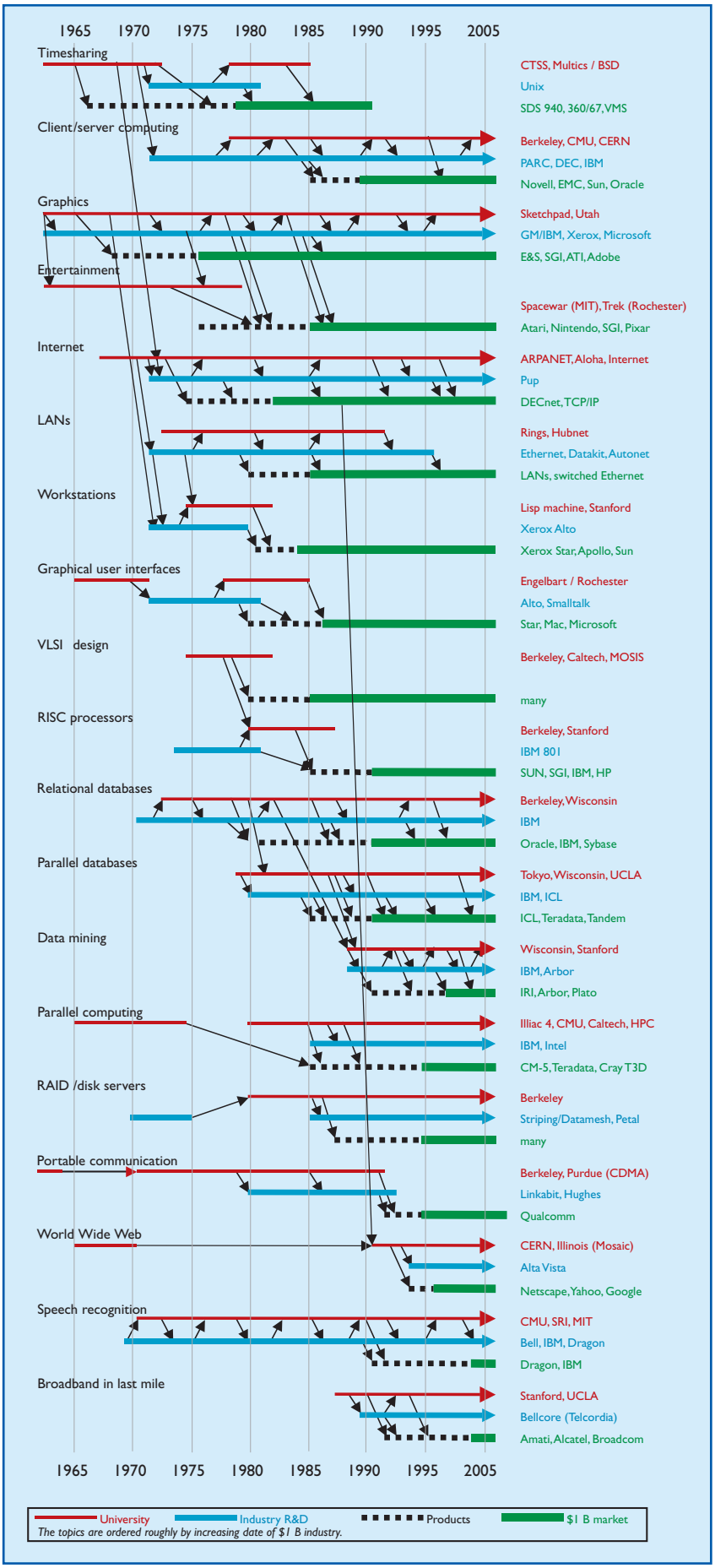
Shocks to the U.S. IT R&D Ecosystem 1995-2007

- Globalization of IT R&D, production, and markets
- "Irrational exuberance" and the 2000 NASDAQ bust
- Aftereffects of September 11, 2001, on foreign student enrollments and defense research priorities/horizons
- 2001 financial scandals/bankruptcies and subsequent emphasis on regulatory compliance and reduced access to public equity capital by young, innovative IT firms
- Post-bust increase in outsourcing and offshoring to reduce costs



Some key elements and relationships in the U.S. IT R&D ecosystem.

Examples of government-sponsored IT R&D in the creation of commercial products and industries.



federal IT research funding, and the regulations that affect the corporate overhead and competitiveness of innovative IT companies. As a result, the U.S. position in IT leadership today has materially eroded compared with that of prior decades, and the nation risks ceding IT leadership to other nations within a generation unless it recommits itself to providing the resources needed to fuel U.S. IT innovation, to removing important roadblocks that reduce the ecosystem's effectiveness in generating innovation and the fruits of innovation, and to becoming a lead innovator and user of IT.

In 2009, the IT R&D ecosystem also faces new challenges from a global economic crisis that continues to unfold. A marked reduction in the availability of venture capital funds following losses in pension funds and endowments; a dramatic reduction in initial public offerings by technology companies and a decline in mergers and acquisitions; steep declines in consumer confidence; and significant layoffs and hiring cutbacks in IT firms and across the global economy seem all but certain to adversely affect the IT R&D ecosystem, undermining the partial recovery seen over the past couple of years, although the magnitude, duration, and enduring impacts on the ecosystem of the downturn are not yet clear.

RETAINING LEADERSHIP IN AN INCREASINGLY GLOBAL ENVIRONMENT

Globalization is a broad and sweeping phenomenon that cannot be easily stemmed, let alone contained. If embraced rather than resisted, it presents more opportunities than threats to the U.S. national IT R&D ecosystem. To thrive in this landscape, the United States should play to its strengths, notably its continued leadership in conceptualizing the idea-intensive new concepts, products, and services that the rest of the world desires and where the greatest increments of value-added are captured.

Toward this end, it is necessary for the United States to have the best-funded and most-creative research institutions; to develop and attract the best technical and entrepreneurial talent among its own people as well as those from around the world; to make its economy the world's most attractive for forming new ventures and nurturing small, innovative firms; and to create in the United States itself an environment that will ensure the deployment of the most advanced technology infrastructures, applications, and services for the benefit of the nation's people, institutions, and firms.

U.S. IT R&D Ecosystem Objectives

1. Strengthen the effectiveness and impact of federally funded IT research.
2. Remain the strongest generator of and magnet for technical talent.
3. Reduce friction that harms the effectiveness of the U.S. IT R&D ecosystem, while maintaining other important political and economic objectives.
4. Ensure that the United States has an infrastructure for communications, computing, applications, and services that can enable U.S. IT users and innovators to lead the world.

OBJECTIVE 1. Strengthen the effectiveness and impact of federally funded IT research.

Much of the feedstock for long-term innovation is to be found in the nation's universities. As a result, support for university education and research is essential to generating the stream of innovations that nourish the rest of the ecosystem. Measures to enhance the productivity of university research funding, as well as that of other R&D funding, would increase the payoff from these investments.

Although the advances of IT over the past 50 years have been truly breathtaking, the field remains in its relative infancy, and continuing advances over the coming decades can be expected as long as the IT

Examples of Advances Expected from Continued Commitment to IT R&D

- Safer, robotics-enhanced automobiles
- A more scalable, manageable, secure, and robust Internet
- Personalized and collaborative educational tools for tutoring and just-in-time learning
- Personalized health monitoring
- Augmented cognition to help people cope with information overload
- IT-driven advances in all fields of science and engineering

Lessons about the Nature of Research in IT

The Results of Research

— America's international leadership in IT—leadership that is vital to the nation—springs from a deep tradition of research. . . .

— The unanticipated results of research are often as important as the anticipated results. . . .

— The interaction of research ideas multiplies their impact—for example, concurrent research programs targeted at integrated circuit design, computer graphics, networking, and workstation-based computing strongly reinforced and amplified one another. . . .

Research as a Partnership

— The success of the IT research enterprise reflects a complex partnership among government, industry, and universities. . . .

— The federal government has had and will continue to have an essential role in sponsoring fundamental research in IT—largely university-based—because it does what industry does not and cannot do. . . . Industrial and governmental investments in research reflect different motivations, resulting in differences in style, focus, and time horizon. . . .

— Companies have little incentive to invest significantly in activities whose benefits will spread quickly to their rivals. . . . Fundamental research often falls into this category. . . . the vast majority of corporate R&D addresses product and process development. . . .

— Government funding for research has leveraged the effective decision making of visionary program managers and program office directors from the research community, empowering them to take risks in designing programs and selecting grantees. . . . Government sponsorship of research especially in universities also helps to develop the IT talent used by industry, universities, and other parts of the economy. . . .

The Economic Payoff of Research

— Past returns on federal investments in IT research have been extraordinary for both U.S. society and the U.S. economy. . . . The transformative effects of IT grow as innovations build on one another and as user know-how compounds. Priming that pump for tomorrow is today's challenge.

— When companies create products using the ideas and workforce that result from federally sponsored research, they repay the nation in jobs, tax revenues, productivity increases, and world leadership. . . .

SOURCE: National Research Council, *Innovation in Information Technology*, The National Academies Press, Washington, D.C., 2003, pp. 2-4.

R&D ecosystem's capacity to sustain innovation is preserved and enhanced.

Current decisions about how the nation should allot federal investments—both civilian and military—to basic IT research do not seem to reflect the full impact of IT on society and the economy. Data indicate that the United States lags behind Europe and Japan in civilian funding for IT R&D. The European Union and China—the latter a strong emerging competitor—have aggressive plans for strengthening their global positions in IT through substantial and increasing IT R&D investments.

Regaining a lead position will require aggressive action, including setting and meeting ambitious targets for increased R&D investment. It is appropriate and necessary for the United States to adjust its own federal IT R&D spending level correspondingly, just as individual businesses, following best practices, track their global competitors' business models in order to avoid falling behind in global market share. Increased federal investment in IT research would reflect the importance of IT to the nation's society and economy as a whole and would allow the United States to build and sustain IT's already large positive impact on the economy.

The desirability of increased federal investment in IT R&D was recognized in a 2007 report of the National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, and, to some extent, by provisions in the subsequently passed America COMPETES Act of 2007. Moreover, in its August 2007 report, the President's Council of Advisors on Science and Technology (PCAST) found an imbalance in the current federal R&D portfolio in that more long-term, large-scale, multidisciplinary R&D is needed. PCAST concluded that current interagency coordination processes for networking and IT R&D are inadequate for meeting anticipated national needs and for maintaining U.S. leadership in an era of global competitiveness.

A strategic reassessment of national R&D priorities is needed—an analysis meriting the attention of first-tier scientists and engineers from academia, industry, and government. A strong focus on IT will be important because of the unique role of IT within science and engineering.

Toward that end, a means of delivering to the highest levels of the U.S. government the best possible advice on the transformational power of IT would help ensure that the nation invests at appropriate levels in IT research and that these investments are made as efficiently and as effectively as possible—in part through improved coordination for federal R&D investments. This advice could be provided in a number of ways, including the augmentation of the current presidential science and technology advisory structure, the establishment of a high-level IT adviser to the President, or the reestablishment of an IT-specific presidential advisory committee (such as the President's Information Technology Advisory Committee, which operated from 1997 to 2005).

Finding. A robust program of federally sponsored research and development in IT is vital to the nation.

Finding. The level of federal investment in fundamental research in IT continues to be inadequate.

Recommendation. As the federal government increases its investment in long-term basic research in the physical sciences, engineering, mathematics, and information sciences, it should carefully assess the level of investment in IT R&D, mindful of the economic return, societal impact, enablement of discovery across science and engineering, and other benefits of additional effort in IT, and should ensure that appropriate advisory mechanisms are in place to guide investment within the IT R&D portfolio.

OBJECTIVE 2. Remain the strongest generator of and magnet for technical talent.

There is cause for concern that an undersized and insufficiently prepared workforce for the IT industry will accelerate the migration of higher-value activities to other nations. This report does not address the entire array of technology-sector wage and job-security issues. However, without a workforce that is knowledgeable with respect to technology and that has sufficient numbers of highly trained workers, the United States will find it difficult to retain the most innovation-driven parts of the IT industry. Despite the demand for such workers, the number of students specifying an intention to major in computing and information sciences has dropped significantly in the past 6 years. The problem of declining enrollments in the computing disciplines (as compared with the projected demand) is compounded by the very low participation of underrepresented groups in IT.

The United States should rebuild the national IT educational pipeline, encouraging all qualified students, regardless of race, gender, or ethnicity, to enter the discipline. Without sustained, amplified intervention, the United States is unlikely to produce an educational pipeline yielding a revived and diverse IT workforce over the next 10 years. To achieve the needed revitalization, the United States should pursue a multipronged approach: it should improve technology education at all levels from kindergarten through grade 12; broaden participation in IT careers by women, people with disabilities, and certain minorities, including African-Americans, Hispanics, and Native Americans; and retain foreign students who have received advanced degrees in IT. Immigrants have been especially significant in high-technology entrepreneurship; for at least one-quarter of the U.S. engineering and technology companies started between 1995 and 2005, mostly in software and innovation and in manufacturing-related services, at least one of the key founders was born outside the United States.

Finding. Rebuilding the computing education pipeline at all levels requires overcoming numerous obstacles, which in turn portends significant challenges for the development of future U.S. IT workforce talent.

Finding. The participation in IT of women, people with disabilities, and certain minorities, including African-Americans, Hispanics, and Native Americans, is especially low and is declining. This low level of participation will affect the ability of the United States to meet its workforce needs and place it at a competitive disadvantage by not allowing it to capitalize on the innovative thinking of half of its population.

Recommendation. To build the skilled workforce that it will need to retain high-value IT industries, the United States should invest more in education and outreach initiatives to nurture and increase its IT talent pool.

Finding. Although some IT professional jobs will be offshored, there are more IT jobs in the United States than at any time during the dot-com boom, even in the face of corporate offshoring trends.

Recommendation. The United States should increase the availability and facilitate the issuance of work and residency visas to foreign students who graduate with advanced IT degrees from U.S. educational institutions.

OBJECTIVE 3. Reduce friction that harms the effectiveness of the U.S. information technology R&D ecosystem.

Such factors as intellectual property litigation and corporate governance regulations have become sources of increased friction in the conduct of business in the United States and can have the effect of making other countries more attractive places to establish the small, innovative companies that are an essential component of a vibrant ecosystem. These issues are not simple—for example, in the case of corporate governance, the dampening effects of increased regulation have to be weighed against the benefits of restoring and maintaining public confidence in equity markets. But to keep the United States attractive for new venture formation and to sustain the nation's unrivaled ability to transform innovative new concepts into category-defining products and services that the world desires, the potential impacts on the IT R&D ecosystem should be weighed heavily in considering new measures or reforms in such areas as corporate governance or intellectual property litigation.

Finding. Fewer young, innovative IT companies are gaining access to U.S. public equity markets.

Recommendation. Congress and federal agencies such as the Securities and Exchange Commission and the Patent and Trademark Office should consider the impact of both current and proposed policies and regulations on the IT R&D ecosystem—and especially on young, innovative IT businesses—and consider measures to mitigate these where appropriate.

OBJECTIVE 4. Ensure that the United States has an infrastructure that can enable U.S. IT users and innovators to lead the world.

The United States has long enjoyed the position of being the largest market for IT; global demographics and relative growth rates suggest that this advantage is unlikely to endure. Fortunately, although a healthy domestic IT market is an important element of a healthy domestic ecosystem, market size is not the only factor in leadership. The environment fostered by leading-edge users of technology—including those who can leverage research, innovate, and create additional value—creates the essential context for technology's next wave and its effective application. In such an environment, all sectors of society (including consumers, businesses, and governments) exploit and make the best use of advanced IT. But there are indications that the United States has lost its leadership in the use of IT. In particular, the U.S. broadband infrastructure is not as advanced or as widely deployed as that in many other countries. Should this situation persist into the future, the United States will no longer be the nation in which the most innovative, most advanced technology and highest value-added products and services are conceptualized and developed.

Moreover, in addition to broadly fostering research and commercial innovation, government-sponsored R&D can help meet particular government demands. Although the government is no longer a lead IT user across the board, it continues to have an appropriate leadership role where federal agencies' requirements are particular to their missions and commercial analogues are scarce or nonexistent.

Finding. The most dynamic IT sector is likely to be in the country with the most demanding IT customers and consumers.

Finding. In terms of nationwide availability, use, and speed of broadband, the United States—the inventor of broadband technology—has been losing ground compared with other nations.

Recommendation. The United States should establish an ambitious target for regaining and holding a decisive lead in the broad deployment of affordable gigabit broadband services. Federal and state regulators should explore models and approaches that reduce regulatory and jurisdictional bottlenecks and should increase incentives for investment in these services.

Recommendation. Government (federal, state, and local) should foster commercial innovation and itself make strategic investments in IT R&D and deployment so that the United States can retain a global lead position in areas where it has particular mission requirements.

This booklet is based on the report *Assessing the Impacts of Changes in the Information Technology R&D Ecosystem: Retaining Leadership in an Increasingly Global Environment* (ISBN-13: 978-0-309-11882-8; ISBN-10: 0-309-11882-4).

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