REPORT TO THE PRESIDENT AND CONGRESS

DESIGNING A DIGITAL FUTURE: FEDERALLY FUNDED RESEARCH AND DEVELOPMENT IN NETWORKING AND INFORMATION TECHNOLOGY

Executive Office of the President

President's Council of Advisors on Science and Technology

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Executive Report

From smartphones to eBook readers to game consoles to personal computers; from corporate datacenters to cloud services to scientific supercomputers; from digital photography and photo editing, to MP3 music players, to streaming media, to GPS navigation; from robot vacuum cleaners in the home, to adaptive cruise control in cars and the real-time control systems in hybrid vehicles, to robot vehicles on and above the battlefield; from the Internet and the World Wide Web to email, search engines, eCommerce, and social networks; from medical imaging, to computer-assisted surgery, to the large-scale data analysis that is enabling evidence-based healthcare and the new biology; from spreadsheets and word processing to revolutions in inventory control, supply chain, and logistics; from the automatic bar-coding of hand-addressed first class mail, to remarkably effective natural language translation, to rapidly improving speech recognition – our world today relies to an astonishing degree on systems, tools, and services that belong to a vast and still growing domain known as Networking and Information Technology (NIT). NIT underpins our national prosperity, health, and security. In recent decades, NIT has boosted U.S. labor productivity more than any other set of forces.

The United States has a proud history of achievement and leadership in NIT. The Federal Government has played an essential role in fostering the advances in NIT that have transformed our world. Steady Federal investment in NIT research over the past 60 years has led to many of the breakthroughs noted above, often a decade or more after the research took place. The Federal investment in NIT research and development is without question one of the best investments our Nation has ever made[1,2,3].

In order to sustain and improve our quality of life, it is crucial that the United States continue to innovate more rapidly and more creatively than other countries in important areas of NIT. Only by continuing to invest in core NIT science and technology will we continue to reap such enormous societal benefits in the decades to come.

Recent technological and societal trends place the further advancement and application of NIT squarely at the center of our Nation's ability to achieve essentially all of our priorities and to address essentially all of our challenges:

- **Advances in NIT are a key driver of economic competitiveness.** They create new markets and increase productivity. For example, an investment in the National Science Foundation's Digital Library Initiative in the 1990's led to Google, a company with a market capitalization of nearly $200 billion[4] that has transformed how we access information.
- **Advances in NIT are crucial to achieving our major national and global priorities in energy and transportation, education and life-long learning, healthcare, and national and homeland security.** NIT will be an indispensable element in buildings that manage their

1. National Academies Press. (1995). *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure*.
2. National Academies Press. (2003). *Innovation in Information Technology*.
3. President's Information Technology Advisory Committee Report to the President. (1999). *Information Technology Research: Investing in Our Future*.
4. See the Section 12 sidebar "Why We're Able to Google" (page 107).

own energy usage; attention-gripping, personalized methods that reinforce classroom lessons; continuous unobtrusive assistance for people with physical and mental disabilities; and strong resilience to cyber warfare.

- **Advances in NIT accelerate the pace of discovery in nearly all other fields.** The latest NIT tools are helping scientists and engineers to illuminate the progression of Alzheimer's disease, elucidate the nature of combustion, and predict the size of the ozone hole, to cite just a few examples.
- **Advances in NIT are essential to achieving the goals of open government.** Those advances will allow better access to government records, better and more accessible government services, and the ability both to learn from and communicate with the American public more effectively.

Both the science and the practice of NIT have seen dramatic changes during the sixty-year history of the field. The ability of the computing research community, coupled with a vibrant NIT industry, to deliver those changes – to discover and advance new areas of NIT research and development (R&D) that stimulate technological progress and meet societal challenges – has been essential to the Nation's success. There are enormous opportunities for future transformations. To meet the challenge of change, America must continue to make R&D investments in new areas of NIT.

Of course, the Government is not alone in investing in NIT R&D. Industry has made, and continues to make, major contributions. It is important, however, not to equate the very large industry R&D investment in NIT with fundamental research of the kind that is carried out in universities and a small number of industrial research labs. The vast majority of industry R&D in NIT is focused on development – on the engineering of future products and product versions. Few major NIT companies have formal research organizations, and even those that do invest relatively little in research compared to their investment in development activities. Fundamental research with the potential for future transformational application represents a small fraction of overall industry R&D in NIT – a situation that is both appropriate and unlikely to change[5]. For that reason, among others, Federal investment in NIT R&D is and will remain essential.

As a field of inquiry, NIT has a rich intellectual agenda – as rich as that of any other field of science or engineering. In addition, NIT is arguably unique among all fields of science and engineering in the breadth of its impact. Computer science research, carried out to a great extent in America's research universities with funding from Federal agencies such as the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (DARPA), lies at the heart of our Nation's leadership. It is this research – which ranges from the design of computers and networks to robotics, software, and algorithms – that has repeatedly led to the introduction of entirely new product categories that became multi-billion-dollar industry sectors. The "extraordinarily productive interplay of federally funded university research, federally and privately funded industrial research, and entrepreneurial companies founded and staffed by people who moved back and forth between universities and industry"[6] has been well documented.

5. See Section 12.
6. National Research Council. (1999). *Funding a Revolution: Government Support for Computing Research*. Washington, DC: National Academies Press.

Essentially all unclassified federally funded R&D activities in NIT and related fields fall within the scope of the Networking and Information Technology Research and Development (NITRD) Program. The term "NITRD Program" refers both to the mechanism by which the Federal Government coordinates its unclassified R&D investments in NIT, and to the unclassified Federal NIT R&D portfolio itself. The NITRD member agencies report aggregate NIT R&D investments in excess of $4 billion annually. The largest investments are reported by the National Institutes of Health (NIH) and NSF (roughly $1 billion each), followed by the Office of the Secretary of Defense and the Department of Defense Service research organizations (OSD/DoD), the Department of Energy (DoE), and DARPA (roughly $500 million each)[7]. However, analysis indicates that a substantial fraction of the NITRD crosscut budget (the multi-agency spending summary) represents spending on NIT that supports R&D in other fields, rather than spending on R&D in the field of NIT itself. For example, an expert review of the top 100 awards (by award size) in NIH's NITRD portfolio – totaling nearly $600 million, roughly half of NIH's NITRD crosscut total – concluded that only between 2% and 11% (by dollar value) should be considered NIT R&D[8]. The remainder is spent on various forms of NIT infrastructure that provide essential support for biomedical research, but not on NIT R&D. We have used NIH as an example only because the laudable transparency of its records and reporting allowed such an analysis to be performed. Although other agencies do not report NIT R&D spending in sufficient detail to make the same analysis possible, it seems likely that in many cases a similar confusion in classification of NITRD investment occurs. An important finding of this report is that the Nation is actually investing far less in NIT R&D than is shown in the Federal budget.

In summary, the transformative NIT research that fuels innovation and achievement and strengthens our Nation needs to come from Government investment, yet it is currently difficult to ascertain the magnitude of that investment. Furthermore, going forward, the participating agencies in the NITRD Program must more aggressively embrace the expanding role that advances in NIT play in America's future. A broad spectrum of Federal agencies – those currently participating in NITRD and some which are not yet doing so – must recognize that their abilities to accomplish their missions are inextricably linked to advances in NIT, and must invest in NIT R&D to catalyze the advances that are critical to their missions. Strategic leadership must come from the top – from those within the Federal Government with the authority to implement new strategies.

The PCAST NITRD Program Review Working Group was asked to assess not only the coordination function of NITRD but also the investment portfolio itself. In the remainder of this Executive Report, and in greater detail and breadth within the body of the report, we describe some of the compelling and important scientific and technical problems that must be addressed in order to maintain and strengthen the transformative effect of NIT on the Nation and the world, and we describe some of the essential research that will be needed to solve those problems. A bottom-up analysis of some of the key initiatives that we recommend in this report suggests that an investment of at least $1 billion annually will be needed for new, potentially transformative NIT research. Uncertainty regarding the precise nature of current expenditures makes it difficult to determine how much of this investment can be obtained

7. *Networking and Information Technology Research and Development Supplement to the President's FY 2011 Budget,* (February 2010) (page 21).

8. Analysis conducted for this report by the Science and Technology Policy Institute of the Institute for Defense Analysis. See sidebar, "The NITRD Crosscut Budget Significantly Overstates the Federal Investment in NIT R&D," in Section 10. http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stpi-nitrd-9-15-2010.pdf

through repurposing and reprioritization and how much will require new funding. We believe, however, that a lower level of investment in this critically important area could seriously jeopardize America's national security and economic competitiveness.

Recommended Initiatives and Investments in NIT R&D to Achieve America's Priorities and Advance Key NIT Research Frontiers

The Federal Government's investment in NIT R&D dates from the birth of the field more than sixty years ago. NITRD as a coordination effort, though, had its genesis in the High-Performance Computing Act of 1991 – "An Act to provide for a coordinated Federal program to ensure continued United States leadership in high-performance computing." Its scope was broadened by the Next Generation Internet Research Act of 1998, and again by the America COMPETES Act of 2007.

In its early years, NITRD's role was seen as coordinating research in the fundamentals of computing, while the use and advancement of the resulting technology to address our national priorities was left to individual agencies. In recent years, the value and importance of multi-agency coordination in the development and application of NIT to achieve the Nation's priorities has become apparent, and has led to the creation of NITRD Senior Steering Groups in the vital areas of Cyber Security and Information Assurance, and Health IT. NITRD is well-positioned to facilitate similar coordination in NIT for other important national priorities, among them energy and transportation, and education and life-long learning.

The role of NIT in addressing our national priorities, and the NIT research frontiers that contribute to making progress in strengthening our NIT capabilities, raise many important research questions that must be tackled. It is essential that short term needs not crowd out the longer term research that anticipates future needs. It is also essential that some NIT research explore bold, unconventional ideas that would have enormous impact if they could be realized. A recent report from the American Academy of Arts & Sciences[9] describes both the benefits of such transformative research and the mechanisms that can be used to foster it.

The Federal Government must invest in new multi-agency NIT R&D initiatives in areas of particular importance to our national priorities. Such investments should include funding for high risk/high reward research with the potential to move these areas in unanticipated directions. Some of this research will require large project teams and sufficiently long time horizons to allow ambitious goals to be achieved. We see three areas in which such initiatives are particularly timely and important.

9. American Academy of Arts & Sciences. (2008). *ARISE: Advancing Research in Science and Engineering – Investing in Early-Career Scientists and High-Risk High-Reward Research.*

Recommendation [Section 5]: **The Federal Government, under the leadership of NSF and Health and Human Services (HHS), with participation from the Office of the National Coordinator for Health Information Technology (ONC), the Centers for Medicare and Medicaid Services (CMS), the Agency for Healthcare Research and Quality (AHRQ), the National Institute of Standards and Technology (NIST), the Veterans Health Administration (VHA), DoD, and other interested agencies, should invest in a national, long-term, multi-agency research initiative on NIT for health that goes well beyond the current national program to adopt electronic health records.** The initiative should include sponsorship of multi-disciplinary research on three themes:

- to make possible comprehensive lifelong multi-source health records for individuals;
- to enable both professionals and the public to obtain and act on health knowledge from diverse and varied sources as part of an interoperable health IT ecosystem; and
- to provide appropriate information, tools, and assistive technologies that empower individuals to take charge of their own health and healthcare and to reduce its cost.

This program should build on national activities promoting the adoption and meaningful use of electronic health records that are usable by all appropriate organizations; it should complement the shorter-term ONC programs; and it should augment the research investments that the various agencies are currently able to make. In addition to increased attention on using NIT for wellness and for addressing chronic conditions, the departments and agencies mentioned above should continue to investigate novel uses of NIT, such as NIT-assisted surgery, to deliver care for acute conditions. They should continue to pursue advances in the innovative use of NIT, such as sensing and monitoring, to understand the basic biological and psychological mechanisms that underlie disease. And they should continue to address NIT research opportunities that support current and continuing work by HHS and NSF on transformational innovation in healthcare delivery and basic research in health and wellness.

Recommendation [Section 5]: **The Federal Government should invest in a national, long-term, multi-agency, multi-faceted research initiative on NIT for energy and transportation.** As part of that initiative:

- DoE and NSF should be major sponsors of research for achieving dynamic power management in applications ranging from single devices to buildings to the power grid.
- NIST should organize the multi-stakeholder formulation of interoperable standards for real-time control. Interoperability facilitates repeated cycles of innovation by multiple vendors, promoting the development of versatile and robust NIT.
- DoD should continue to be a major sponsor of research on using NIT to achieve low-power systems and devices.
- The Department of Transportation (DoT) should sponsor ambitious NIT research relevant to surface and air transportation.

Current research in the computer simulation of physical systems should be expanded to include the simulation and modeling of proposed energy-saving technologies, as well as advances in the basic techniques of simulation and modeling.

Recommendation [Sections 5 and 7]: **The Federal Government should invest in a national, long-term, multi-agency research initiative on NIT that assures both the security and the robustness of cyber-infrastructure.** NSF and DoD, in collaboration with the Department of Homeland Security (DHS), should aggressively accelerate funding and coordination of fundamental research

- to discover more effective ways to build trustworthy computing and communications systems,
- to continue to develop new NIT defense mechanisms for today's infrastructure, and most importantly,
- to develop fundamentally new approaches for the design of the underlying architecture of our cyber-infrastructure so that it can be made truly resilient to cyber-attack, natural disaster, and inadvertent failure.

Infrastructure to be protected includes the Internet and the national telecommunication system as well as computing systems controlling such national resources as the electric power grid and the financial system. Where fundamental NIT advances are needed to support these initiatives, mission agencies should invest in fundamental research in NIT, either alone or in collaboration with NSF, and should not limit their programs to application-specific research.

Effective use of NIT in increasing our economic competitiveness and achieving our other national priorities depends not only on incorporating innovative NIT into a wide variety of domains, but also on ensuring that the basic science and engineering of NIT remain vibrant and strong. At the time of the High-Performance Computing Act of 1991, the importance of high performance computing and communication (HPCC) to scientific discovery and national security was a major factor underlying the special attention given by Congress to NIT. Although HPCC continues to contribute in important ways to scientific discovery and national security, many other aspects of NIT have now risen to comparable levels of importance. Among these NIT areas are the interactions of people with computing systems and devices, both individually and collectively; the interactions between NIT and the physical world, such as in sensors, imaging, robotic and vision systems, and wearable and mobile devices; large-scale data capture, management and analysis; systems that protect personal privacy and sensitive confidential information, are robust in the face of malfunction, and stand up to cyber-attack; scalable systems and networking (i.e., systems and networks that can be either increased or decreased in complexity, size, generality, and cost); and software creation and evolution. HPCC is but one of many important areas of NIT, and America's prowess in HPCC is but one of many measures of our international competitiveness in NIT.

To achieve our national priorities, and to stimulate the next generation of transformative advances in NIT, we must ensure that the modern and emerging research frontiers are well supported. Investment in those areas must include funding for high risk/high reward research with the potential to move these areas in unanticipated directions.

Recommendation [Section 7]: **The Federal Government must increase investment in those fundamental NIT research frontiers that will accelerate progress across a broad range of priorities.** Among such investments:

- NSF and DARPA, with the participation of other relevant agencies, should invest in a broad, multi-agency research program on the fundamentals of privacy protection and protected disclosure of confidential data. Privacy and confidentiality concerns arise in virtually all uses of NIT.
- NSF, DARPA, and HHS should create a collaborative research program that augments the study of individual human-computer interaction with a comprehensive investigation to understand and advance human-machine and social collaboration and problem-solving in a networked, on-line environment where large numbers of people participate in common activities. Understanding such collective human-NIT interactions is increasingly important for defense, for health, and for the activities of daily life.
- NSF should expand its support for fundamental research in data collection, storage, management, and automated large-scale analysis based on modeling and machine learning. Our ever-increasing use of computers, sensors, and other digital devices is generating huge amounts of digital data, making it a pervasive NIT-enabled asset. In collaboration with NIT researchers, every agency should support research, to apply the best known methods and to develop new approaches and new techniques, to address data-rich problems that arise in its mission domain. Agencies should ensure access to and retention of critical community research data collections.
- NSF and DARPA, in collaboration with those agencies tackling problems whose solution entails instrumenting the physical world – including the Environmental Protection Agency (EPA), DoE, DoT, parts of DoD other than DARPA, NIH, the Department of Agriculture (USDA), and the National Oceanic and Atmospheric Administration (NOAA) – should increase research in advanced domain-specific sensors, integration of NIT into physical systems, and innovative robotics in order to enhance NIT-enabled interaction with the physical world.

At the same time, new investments must not supplant continued investment in important core areas such as high performance computing, scalable systems and networking, software creation and evolution, and algorithms, in which government-funded research is making important progress. Topics of importance within these more established core areas continue to change in response to advances in technologies and applications. High performance computing (HPC) is a case in point. Although HPC plays a critical role in ensuring our national security, our economic competitiveness, and our scientific and technological leadership, the United States must anticipate and adapt to the broadening of its high-end computational needs and changes in the underlying technologies available to address them. Highly influential comparative rankings of the world's fastest supercomputers are for the most part based on metrics relevant to only some of our national priorities, and must not be regarded as the sole measure of our continued leadership in this essential area. Although it is important that we not fall behind in the development and deployment of HPC systems that address pressing current needs, it is equally important that we not allow either the funding allocated to the procurement of large-scale HPC systems, or undue attention to a simplistic measure of competitiveness, to "crowd out" the fundamental research in computer science and engineering that will be required to develop truly transformational next-generation HPC systems. To lay the groundwork for such systems, we will need to undertake a substantial and sustained program of fundamental research on hardware, architectures, algorithms and software with the potential for enabling game-changing advances in high-performance computing.

The Importance of Government Leadership

Many of our recommendations address multiple agencies – sometimes in collaborative roles, sometimes in coordinated roles, and sometimes in addressing different issues within an overall area of need. A successful coordinated attack on the Nation's most challenging and important problems requires focused attention on multi-disciplinary, problem-driven research in NIT. That focus must come from Federal leadership. NITRD is chartered and staffed to *coordinate* multi-agency programs, not to create them. Strategic leadership, when necessary, must come from those with the authority to implement new strategies, namely the Office of Science and Technology Policy (OSTP) and the National Science and Technology Council (NSTC), to which NITRD reports. That leadership must have continuity, breadth and depth, and a focus on NIT.

Both the need for leadership and the need for broad multi-disciplinary research require action on the part of the Federal Government.

Recommendation [Section 11]: **The Federal Government must lead in ensuring that strong multi-agency R&D investments are made in NIT to address important national priorities**:

- OSTP should establish a broad, high-level standing committee of academic scientists, engineers, and industry leaders dedicated to providing sustained strategic advice in NIT.
- The NSTC should lead in defining and promoting the major NIT research initiatives that are required to achieve the most important existing and emerging national priorities.

In addition to ensuring that NIT research in support of the Nation's priorities is conducted and that the results are translated into practice, it is essential that appropriately motivated and educated individuals are available as both researchers and practitioners. All indicators – all historical data and all projections – argue that NIT is the dominant factor in America's science and technology employment, and that the gap between the demand for NIT talent and the supply of that talent is and will remain large. Increasing the number of graduates in NIT fields at all degree levels must be a national priority. Fundamental changes in K-12 education are needed to address this shortage. Here too the Federal Government must take the lead.

Recommendation [Section 9]: **The NSTC's Committee on STEM Education proposed in a recent PCAST report[10] must exercise strong leadership to bring about fundamental changes in K-12 STEM education in the United States, among them the incorporation of computer science as an essential component.**

Improved Effectiveness of NITRD Coordination

Thus far, we have focused primarily on the Federal NIT R&D portfolio and the need for multi-disciplinary collaboration in many areas. We now turn to the government coordination process for those investments.

The NITRD inter-agency coordination mechanism is widely – and we think correctly – viewed as successful and valuable. The collection of NITRD working groups has, over the years, enabled government research managers to become familiar with the activities of their colleagues in other agencies, and to formulate joint programs in areas of mutual interest. Nonetheless, steps can and should be taken to improve the effectiveness of the coordination process.

Recommendation [Section 11]: **The effectiveness of government coordination of NIT R&D should be enhanced**:

- The number of NITRD member agencies should be increased. The duration, management levels, and topic areas of the NITRD coordinating groups should be flexible. Budget reporting categories should be decoupled from the coordinating structure.
- The National Coordination Office (NCO) for NITRD should create a publicly available database of government-funded NIT research, and should provide regular detailed reporting to the Director of OSTP.
- The Office of Management and Budget (OMB) and OSTP should reflect NITRD priorities in their annual Budget Priority Memorandum.

In addition, it is important to recognize the inherent limitations of any such process. In particular, each agency's representatives are charged with advancing that agency's mission, and not with devising a broader national strategy. As recommended previously, the NSTC must provide strategic leadership where necessary.

Continued attention must also be given to stable, evolvable, state-of-the-art shared NIT infrastructure for research, as well as new forms of infrastructure to support new research areas and paradigms. Shared NIT infrastructure – whether computational resources, communication networks, community databases (e.g., PubMed and the Protein Data Bank), or collaboration tools – has become essential to research in virtually all fields. NIT is one such field; NIT infrastructure that supports NIT research is a crucial component of NIT R&D, essential to achieving advancements in networking and information technology, which (among many other benefits) will yield the next generation of NIT infrastructure for all fields.

10. President's Council of Advisors on Science and Technology. (September 2010). *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future.* http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf

The Federal investment currently included in the NITRD crosscut budget includes NIT R&D, NIT infrastructure that supports NIT R&D, and NIT infrastructure that supports R&D in other fields. PubMed and the Protein Data Bank are examples of NIT investments that provide essential shared infrastructure for *biomedical* R&D; they do not represent NIT R&D. Similarly, high-end computing facilities, while essential for many types of research, are for the most part shared NIT infrastructure for physical, biological, and engineering fields other than NIT.

It is appropriate that investments in shared NIT infrastructure for R&D be included within the NITRD Program. However, it is important that investments in NIT that support R&D in other fields be clearly differentiated from investments in NIT R&D. A large portion of the "High End Computing Infrastructure and Applications" budget category, which accounts for roughly $1.5 billion of the $4.3 billion NITRD crosscut total, is attributable to computational infrastructure used to conduct R&D in other fields, and not to NIT R&D or to infrastructure for NIT R&D. In addition, as illustrated earlier by the analysis of the NIH NITRD portfolio, various agencies include in their reports for other NITRD budget categories investments in NIT that support R&D in non-NIT fields. Thus the aggregate NITRD crosscut budget significantly overstates the actual Federal investment in NIT R&D. By leading policymakers to believe that we are spending much more on such activities than is actually the case, this discrepancy contributes to a substantial, systematic underinvestment in an area that is critical to our national and economic security.

Recommendation [Section 11]: **The NCO and OMB should redefine the budget reporting categories to separate NIT infrastructure for R&D in other fields from NIT R&D, and should ensure more accurate reporting of both NIT infrastructure investment and NIT R&D investment.**

In summary: The United States has a proud history of achievement and leadership in NIT that has yielded enormous benefits for our economic competitiveness, our national security, and our quality of life. Execution of recommendations in this report will play an essential role in ensuring the vitality of our Nation's NIT endeavors and enabling us to address our priorities and meet our challenges.

Crosscutting Themes

The five broad themes listed below recur throughout this report, and are of great importance to the future of all Federal agencies:

- Data volumes are growing exponentially. There are many reasons for this growth, including the creation of nearly all data today in digital form, a proliferation of sensors, and new data sources such as high-resolution imagery and video. The collection, management, and analysis of data is a fast-growing concern of NIT research. Automated analysis techniques such as data mining and machine learning facilitate the transformation of data into knowledge, and of knowledge into action. Every Federal agency needs to have a "big data" strategy.
- Engineering large software systems to ensure that they are secure (behaving as expected in the presence of an adversary) and trustworthy (behaving as expected in the absence of an adversary) remains a daunting challenge. The growing complexity of the systems we are building and our increasing societal reliance upon them outpace our ability to reason about them, and to engineer them to be secure and trustworthy.
- As NIT increasingly pervades daily life, systems are storing and processing a greater volume and diversity of private information about individuals. Privacy is a critical issue in all societal applications of NIT – most obviously in areas such as healthcare and electronic commerce, but also in areas such as energy, transportation, and education. Privacy challenges do not and must not require us to forgo the benefits of NIT in addressing national priorities. Rather, we need a practical science of privacy protection, based on fundamental advances in NIT, to provide us with tools we can use to reconcile privacy with progress.
- Interoperable interfaces – the means by which components of the smart grid can talk to each other, for example, or by which electronic health records can be shared and added to by many parties – are an important stimulus to technology innovation and adoption. Optimally, these interfaces would be *open*: anyone may create products that use the interfaces without paying fees; and a public, transparent process is used to establish and revise the standards that define the interfaces.
- The NIT supply chain is vulnerable. The hardware and software components used to build systems are sourced worldwide. We must anticipate and be prepared for various forms of threats to supply, quality, and security.

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