TESTIMONY OF
EDWARD D. LAZOWSKA
UNIVERSITY OF WASHINGTON

BEFORE THE HOUSE SCIENCE, SPACE AND TECHNOLOGY COMMITTEE
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

HEARING ON
OVERSIGHT OF THE NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAM AND PRIORITIES FOR THE FUTURE

SEPTEMBER 21, 2011

Thank you Chairman Brooks, Ranking Member Lipinski, and the other members of the Subcommittee, for this opportunity to discuss the Federal government's Networking and Information Technology Research and Development program. I am pleased to add my perspective on the Committee's questions, drawn from nearly 40 years in academia as a member of the computing research community, my experience as the current chair of the Computing Research Association's (CRA) Computing Community Consortium (CCC), and as a member and chair of many Federal IT advisory committees – including, most recently, as the co-Chair of the Working Group of the President's Council of Advisors on Science and Technology (PCAST) to review the NITRD program. However, I present this testimony as an informed individual and not as a representative of any particular organization, although my comments have the endorsement of the Computing Research Association.

Information Technology R&D Changes the World

The importance of this hearing's topic is hard to overstate. Advances in information technology are transforming all aspects of our lives. Virtually every human endeavor today has been touched by IT, including commerce, education, employment, health care, energy, manufacturing, governance, national security, communications, the environment, entertainment, science and engineering. We have the world's products available to us with the click of a mouse, instruction tailored to individual students and delivered from hundreds or thousands of miles away, the ability to be productive and connected regardless of location, doctors empowered by virtual agents that can help navigate subtle drug interactions or diagnose with data rather than gut feelings, an emerging intelligent power grid working together with smart structures to more efficiently utilize power resources, advanced robotics that will enable the nation to retain a competitive manufacturing sector, government that works more transparently, a military that achieves dominance through information superiority, a network of friends reachable instantly anywhere around the globe, a planet wired with sensors feeding us real-time information about its health, movies and music and games that engage all our senses and take us to places no previous generation has ever seen, and a science and engineering enterprise primed with all the tools and data to enable discovery at a pace never before seen – all because of advances in computing systems, tools and services enabled by information technology research and development.

Information Technology R&D Drives Our Prosperity

Advances in information technology are also driving our economy – both directly, in the growth of the IT sector itself, and indirectly, in the productivity gains that all other sectors achieve from the application of IT. IT R&D creates new industries that create new jobs, and transforms existing industries in ways that increase their productivity and make them more competitive. In fact, it is this latter effect that has had the most profound impact on the economy and the Nation's competitiveness. Across every sector of the economy, businesses large and small have used IT systems, tools and services to improve their productivity, boost their efficiency, and increase their economic output to an unprecedented extent. Large companies like Walmart and United Parcel Service have used advanced IT tools to track and manage inventory on a minute-by-minute basis. Companies like Boeing and Procter & Gamble use high-performance computing in applications ranging from designing super-efficient airframes to modeling the airflow over potato chips on a production line to minimize breakage and loss. Small manufacturers use IT to do virtual prototyping, avoiding costly prototype construction and allowing them to compete with much larger firms for lucrative manufacturing contracts. And sites like Etsy and Ebay allow individual artists or entrepreneurs to set up virtual storefronts and sell to the world. Advances in IT empower U.S. businesses, augment their competencies, and enable them to compete in an increasingly global economy. The development and application of IT-related systems, services, tools and methodologies have boosted U.S. labor productivity more than any other set of forces in recent decades.

Information Technology is the Dominant Factor in American S&T Employment

Given information technology's influence in so many sectors of our lives, it should not be surprising that demand for IT workers is strong. Indeed, as the PCAST review of the NITRD program released last year noted, *"all indicators – all historical data, and all projections – argue that [Networking and Information Technology (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."*[1] Bureau of Labor Statistics projections indicate that more than 60% of all new jobs in all fields of science and engineering in the current decade will be for computer specialists. Increasing the number of graduates in IT fields at all levels should be a national priority; the NITRD program should increase its focus on computer science education, from kindergarten through higher education, as one way to help meet that goal.

---

1 *Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology*. Report to the President and Congress, President's Council of Advisors on Science and Technology, December 2010.

Federal Support is a Key Part of the Vibrant Ecosystem that Drives IT Innovation

The advances in IT that have had such a profound effect on every aspect of our lives are driven by innovation that itself is the product of a vibrant research ecosystem – an ecosystem comprised of university research in academic departments, industrial research facilities, Federal research labs, industrial development organizations, and the people and ideas that flow between them. The National Research Council has called this *"an extraordinarily productive interplay"* and the President's Information Technology Advisory Committee (PITAC) emphasized the *"spectacular return"* on the Federal investment made as part of this ecosystem.[2]

The Federal role in this system is largely limited to investments in long-term, early stage scientific research, typically at U.S. universities. This research often occurs many years, or even decades, before a product is developed for the marketplace.

The great majority of industry-based research and development is of a fundamentally different character than university-based research. Industry-based research and development is, by necessity, much shorter term than the early-stage research performed in universities. It tends to be focused on product and process development, areas which will have more immediate impact on business profitability. Industry generally avoids long-term research because it entails risk in several unappealing ways. First, it is hard to predict the outcome of fundamental research. The value of the research may surface in unanticipated areas. Second, fundamental research, because it is published openly, provides broad value to all players in the marketplace. It is difficult for any one company to "protect" the fundamental knowledge gleaned from long-term research and capitalize on it without everyone in the marketplace having a chance to incorporate the new knowledge into their thinking. Those companies that do make significant fundamental research investments tend to be the largest companies in the sector. Their dominant position in the market increases the likelihood that they benefit from any market-wide improvement in technology basic research might bring. For example, IBM and Microsoft are among the companies that invest the largest proportion of their R&D expenditures on research looking out more than one product cycle, but at Microsoft, as reported by PCAST, it is estimated that this still constitutes less than 5% of total R&D. At most other companies, it is far less. University research does not supplant industry research, or vice-versa.

An example might be instructive here. Apple's iPad is a seemingly miraculous little machine. Available for about $500, it's a sleek, thin little slab of glass and metal that sits darkly in a purse or a pocket, then comes to life with a button push and a swipe of a finger, quickly figures out where it is, and then connects itself to the largest collection of humanity's knowledge ever assembled. It's a remarkable confluence of technologies – processing capability powerful enough to have appeared on the list of the world's fastest

---

[2] *Information Technology Research: Investing in Our Future*. Report to the President, President's Information Technology Advisory Committee, February 1999.

supercomputers as recently as 1994, a sensor suite (global positioning system, compass, accelerometer, microphone, camera, light sensor) robust enough to allow it to know where it is and what it's looking at, and an interface revolutionary in its ease of use. These technologies have enabled some truly game-changing capabilities – applications that allow turn-by-turn directions, or the ability to translate signs in a foreign language just by pointing its camera at them, or truly high-speed, ubiquitous connectivity to the power of the Internet, instantly, almost anywhere in the world.

What Apple has managed to do to bring these technologies together and meld them in a seamless way to enable these applications has been nothing short of remarkable. Without exception, however, all these technologies have their roots in early-stage scientific research, and all bear the stamp of Federal government support.

Take, for example, the revolutionary multi-touch iPad interface – the pinch-to-shrink, swipe-to-scroll, twist-to-rotate gestures that make a tablet like the iPad intuitive and very easy to use. All were born out of university research, largely funded by the Federal government, conducted as early as the late 1960s and early 1970s. In fact, in 1998, researchers at the University of Delaware, whose work had earlier been enabled by research funding from the National Science Foundation, established a company called FingerWorks to market an early touch-screen keyboard based on their research. In 2005, Apple bought the company and its technology, then spent over two years adapting it for the first iPhone.

A similar case can be made for the processor – the brain of the device – which has its roots in the design of the original integrated circuit back in 1958, by a young Texas Instruments engineer named Jack Kilby. But it's a far cry from that original design to the modern chip that powers the iPad. Industry research at TI and Fairchild, and later at IBM, Intel and others was obviously important in moving development along, but just as important was research at U.S. universities, on Reduced Instruction Set Computing (RISC) and Microprocessor without Interlocked Pipeline Stages (MIPS) technologies, as well as Very-Large-Scale Integration (the process of creating integrated circuits by combining thousands of transistors into a single chip) – technology that put computer design in the hands of computer system architects (and graduate students) rather than only in the hands of engineers and technicians in costly chip fabrication plants. Federal investment in research (through DARPA and increasingly NSF) and government-industrial partnerships like SEMATECH were crucial in catalyzing research across institutions, accelerating the pace of innovation – and work at universities in particular helped generate the people and ideas that fueled industry's advancements.

It is possible to draw similar timelines for all the other key technologies in the iPad. This is not to diminish the accomplishment of Apple – on the contrary, what Apple has done has been to blend these technologies into a harmonious whole in a way that maybe only Apple could do. But it highlights the crucial role of early-stage research, in many cases supported by the Federal government (and often *only* by the Federal government), in enabling world-changing innovation. And it shows that Federal support for early stage research is truly an investment – an investment that has a history of demonstrating extraordinary payoff in the explosion of new technologies that have touched nearly every aspect of our lives, and in economic terms – in the creation of new industries and literally millions of new jobs.

<u>There is Tremendous Potential – and Tremendous Need – for Further Breakthroughs</u>

The history of innovation in computing is impressive, but the future opportunities are even more compelling. Research in the future of networking, revolutionizing transportation, personalizing education, powering the smart grid, empowering the developing world, improving health care, enabling advanced manufacturing and driving advances in all fields of science and engineering are all compelling challenges well suited to advancements in IT. Indeed, without continued progress in computing research, our ability to address key national and global priorities in energy and transportation, education and life-long learning, healthcare, and national and homeland security will be seriously constrained.

<u>Many Areas of IT R&D are Crucial to National Priorities and National Competitiveness</u>

In its 2010 report *Designing a Digital Future*, PCAST identified three areas of research that the Council felt were *"particularly timely and important."* I support the Council's recommendations. They called for:

- *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.*
- *A national, long-term, multi-agency, multi-faceted research initiative on NIT for energy and transportation.*
- *A national, long-term, multi-agency research initiative on NIT that assures both the security and the robustness of cyber-infrastructure.*

In addition, the Council identified a broader set of research frontiers of the field that require increased focus from NITRD agencies, including:

- *A broad multi-agency research program on the fundamentals of privacy protection and protected disclosure of confidential data.*
- *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.*
- *Fundamental research in data collection, storage, management, and automated large-scale analysis based on modeling and machine learning.*
- *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.*

It is critical to recognize that many areas of IT are now equal in importance to high performance computing (HPC) as measures of our nation's competitiveness. Twenty years ago, at the time of passage of the High Performance Computing and Communications Act of 1991 (which established the modern NITRD program), it was appropriate that much of the focus of the Federal effort in computing was on the importance of HPC to scientific discovery and national security. Today, many other aspects of IT have risen to comparable levels of importance. Among these are the interactions of people with computing systems and devices; the interactions between IT and the physical world (e.g., robotics); large scale data capture, management and analysis (critical, today, to scientific discovery and national security); systems that protect personal privacy and sensitive confidential information; scalable systems and networking; software creation and evolution; and critical infrastructure protection (e.g., the financial system, the power grid, the air traffic control network). World leadership in *all of these areas* is crucial to our nation's security and prosperity.

<u>The Nation is Investing Far Less on IT R&D than is Shown in the Federal Budget</u>

One of the difficulties of assessing the adequacy of the Federal investment in various areas of IT R&D is the ambiguity of the data about IT R&D investments reported by the various agencies participating in NITRD. PCAST found that much of what gets reported by NITRD agencies represents spending on IT that supports research in other fields – such as computing clusters for scientists in other fields – and not spending on research in information technology. In some cases, the discrepancy in reporting leads to a dramatic over-reporting of IT R&D investments by the agencies: at one major NITRD agency, PCAST estimated that *only between 2 percent and 11 percent of reported NITRD expenditures truly represented investments in IT R&D*. I share PCAST's concern that *"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."*

<u>The Federal Government Needs High-Level, Sustained, Expert Strategic Advice on IT R&D</u>

Another key recommendation contained in the PCAST report with which I concur is the call for the establishment of a *"high-level standing committee of academic scientists, engineers, and industry leaders dedicated to providing sustained strategic advice in NIT."* Given the pace of innovation and change within the field, the challenge of its multi-disciplinary, problem-driven research, and the size and scope of the Federal investment, having sustained guidance from a free-standing, independent advisory committee seems crucial to NITRD's success. I was pleased to see recognition of this in H.R. 2020, and I feel it is imperative that the recommendation of the PCAST report be implemented.

<u>Computer Science Must Be Viewed as an Essential Component of Science, Technology, Engineering and Mathematics (STEM) Education</u>

As I noted above, the workforce needs of the IT fields going forward demand a sustained effort to increase the number of students going into computing fields. National security needs will require that a large number of those students be American citizens. In addition, participants in many other workforce fields will need IT knowledge and skills. Making progress on this effort will require reversing trends not just in computing, but across the STEM disciplines. I am pleased that PCAST has called for the National Science and Technology Council's Committee on STEM Education to exercise strong leadership to bring about fundamental changes in K-12 STEM education in the U.S. Among these changes has to be the incorporation of computer science as an essential STEM component. As they note, *"fluency with NIT skills, concepts and capabilities; facility in computational thinking; and an understanding of the basic concepts of computer science must be an essential part of K-12 STEM education."* Groups like ACM's Education Policy Committee have expended great effort to get computer science recognized as a key part of the K-12 curriculum, but must be met with more acceptance if we are to meet the needs of our information-driven economy now and in the future.

<u>In Some Areas, H.R. 2020 Did Not Go Far Enough</u>

As co-Chair of the Computing Research Association's Government Affairs Committee back in 2009, I joined in endorsing the passage of H.R. 2020, the *Networking and Information Technology Research and Development Act of 2009*. I believe the Act would make the NITRD program stronger by enacting several of the recommendations of PCAST. In particular, I was pleased that the NITRD Act included a requirement that the NITRD program undergo periodic review and assessment of the program contents and funding, as well as develop and periodically update a strategic plan – both necessary in helping ensure the significant federal investment in IT R&D is used as effectively as possible. This review and assessment is best done by an independent standing advisory committee composed of experts from academia, industry and government. As noted earlier, the creation of such a committee is essential.

I do not believe the Act went far enough in addressing the nation's IT workforce and education needs. As CRA noted in a joint letter with the Association for Computing Machinery and the National Center for Women and Information Technology back in March 2009, we felt it is critical that federal efforts to educate young people in computer science improve, and that investments recognize that all racial, gender and socioeconomic groups are crucial to the continued health of and future innovations in the computing field. The three organizations made four specific recommendations for the bill, which I support:

- *Promote computing education, particularly at the K-12 level, and increased exposure to computing education and research opportunities for women and minorities as core elements of the NITRD programs;*
- *Require the NITRD program to address education and diversity programs in its strategic planning and road-mapping process;*

- *Expand efforts at NSF to focus on computer science education, particularly at the K-12 level through broadening the Math Science Partnership program; and,*
- *Enlist the Department of Education and its resources and reach in addressing computer science education issues.*

<u>Conclusion: Federal Investment in Information Technology R&D Has Yielded, and Will Continue to Yield, Extraordinary Payoff</u>

Computing research – networking and information technology R&D – changes our world, drives our prosperity, and enables advances in all other fields.

The Federal Government has played an essential role in fostering these breathtaking advances. The Federal investment in computing research is without question one of the best investments our Nation has ever made. The payoff has been an explosion of new technologies that have touched nearly every aspect of our lives, and the creation of new industries and literally millions of new jobs.

The future is bright. There is tremendous opportunity – and tremendous need – for further breakthroughs. The Federal Government's essential role in fostering these advances – in supporting fundamental research in computing and other engineering fields – must continue.