**United States House of Representatives**
**Committee on Science and Technology**

Hearing on
*Networking and Information Technology Research and Development (NITRD) Act of 2009*

Dr. Peter Lee
peter.lee@cmu.edu

Incoming Chair, Computing Research Association (CRA)
1100 17th Street, NW
Washington, D.C. 20036

and

Professor and Head, Computer Science Department
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, Pennsylvania 15213

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**Testimony of Peter Lee**
**Incoming Chair, Computing Research Association (CRA)**

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Good morning, Mr. Chairman and Members of the Committee. Thank you for this opportunity to comment on the proposed changes to the research content, planning, and implementation mechanisms of the Networking and Information Technology Research and Development (NITRD) program. I am Peter Lee, incoming Chair of the Board of Directors for the Computing Research Association (CRA). The CRA is widely recognized by the U.S. computing research community as its representative organization, with a membership of over 225 academic institutions, 30 government and industrial laboratories, and the leading professional societies in the computing field.

I have been actively involved in computing research for the past 22 years as a Professor at Carnegie Mellon University. Today I am the Department Head for Carnegie Mellon's Computer Science Department. I am also the Vice-Chair of the DARPA Information Science and Technology (ISAT) advisory board; a member of the National Research Council's Computer Science and Telecommunications Board (CSTB); and a member of the CRA's Computing Community Consortium (CCC).

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On March 25, 2009, I had the great privilege to participate in a special symposium held at the Library of Congress entitled, *Computing Research that Changed the World: Reflections and Perspectives*[1], which was organized by the CCC and co-sponsored by several members of your committee. The symposium, which was attended by members of academia, industry, and the government, reviewed the past two decades of "game-changing" advances in networking and information technology (henceforth referred to as "IT") and provided a forum for discussing how to foster these kinds of advances into the future. The presentations and discussions at the symposium made clear the astonishing importance of IT research:

- **Advances in IT are transforming all aspects of our lives**. Virtually every human endeavor today has been touched by information technology, including commerce, education, employment, health care, energy, manufacturing, governance, national security, communications, the environment, entertainment, science, and engineering.

- **Advances in information technology are driving our economy.** IT research has shown an extraordinary ability to create transferable technologies, resulting in remarkable growth in the industrial IT sector over the past two decades. The impact of IT research on the nation's industrial base is not restricted to just the IT sector; information technology has been a driver for economic growth in nearly every sector, since every industry is now "powered" by advances in IT. Recent analysis suggests that the remarkable economic growth the U.S. experienced

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[1] The symposium web site can be found at http://www.cra.org/ccc/locsymposium.php.

between 1995 and 2002 was spurred by an increase in productivity enabled almost completely by factors related to IT[2]. The processes by which advances in information technology enable productivity growth, enable the economy to run at full capacity, enable goods and services to be allocated more efficiently, and enable the production of higher quality goods and services are now well understood[3].

- **Advances in information technology are enabling innovation in all other fields.** In business, advances in IT are giving researchers powerful new tools, enabling small firms to significantly expand R&D, boosting innovation by giving users more of a role, and letting organizations better manage the existing knowledge of its employees[2, pp. 46-48]. In science and engineering, advances in IT are enabling discovery across every discipline – from mapping the human brain to modeling climatic change. Researchers, faced with research problems that are ever more complex and interdisciplinary in nature, are using IT to collaborate across the globe, and to collect, manage, and explore massive amounts of data.

The most exciting aspect of the *Computing Research that Changed the World* symposium was that it showed that networking and information technology is still in its infancy. In all likelihood, **the most important advances in IT are still ahead of us**. We are on the cusp of new media and communication technologies, new tools for managing our energy and environment, new technologies for improving healthcare, and even entirely new paradigms for scientific discovery. Worldwide there appears to be no slowdown in the pace of innovation, the production of new ideas, and the discovery of additional opportunities to advance the economy and improve the quality of life for all people through IT.

Several months ago, the National Academy of Engineering unveiled 14 *Grand Challenges for Engineering* for the 21st century[4]. The majority of these – the majority of the "Grand Challenges" for *all* of engineering – have either substantial or predominant information technology content:

- Secure cyberspace
- Enhance virtual reality
- Advance health information systems
- Advance personalized learning
- Engineer better medicines
- Engineer the tools of scientific discovery
- Reverse-engineer the brain
- Prevent nuclear terror (to a great extent a sensor network and data mining problem)

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[2] Jorgenson, Dale W., Mus S. Ho, and Kevin J. Stiroh. *Productivity, Volume 3: Information Technology and the American Growth Resurgence*. MIT Press. 2005.
[3] Atkinson, Robert D., Andrew S. McKay. *Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution*. Information Technology and Innovation Foundation. 2007. http://www.itif.org/files/digital_prosperity.pdf
[4] http://www.engineeringchallenges.org/

And there are many more information technology challenges of equally high impact:

- Empower the developing world through appropriate information and communication technology
- Revolutionize transportation safety and efficiency
- Build truly scalable computing systems, and devise algorithms for extracting knowledge from massive volumes of data
- Engineer advanced "robotic prosthetics" and, more broadly, enhance people's quality of life
- Instrument your body as thoroughly as your automobile
- Engineer biology (synthetic biology)
- Revolutionize our electrical energy infrastructure: generation, storage, transmission, and consumption
- Achieve quantum computing

*It is impossible to imagine a field with greater opportunities to change the world.*

For me, the inescapable conclusion is that **leadership in information technology is essential to the nation**. Today, many countries are investing heavily in facilities, education, and research in IT. Industry today is not providing support for long-term, speculative research; hence, government coordination and sponsorship research is the foundation for maintaining our leadership.

It is against this backdrop that I would now like to consider the four questions you have asked me to address here today.

**Question 1:** *Does the legislation ensure that the NITRD program is positioned to help maintain U.S. leadership in networking and information technology? What are the research community's needs for this program and are they adequately addressed?*

Advances in networking and information technology enable advances in science, economic growth, and quality of life. A key element of the NITRD program involves fostering communication and coordination across thirteen federal agencies where IT is relevant, thereby creating a diverse ecosystem for IT R&D spanning across many areas. The current legislation strengthens the program by addressing several key recommendations from the 2007 assessment of the NITRD program by the President's Council of Advisors on Science and Technology (PCAST)[5].

While the coordination provided by NITRD has proven effective, adequate funding diversity for IT research in universities has proven to be quite challenging. Over the past twenty years, two federal agencies have been dominant in university-based IT research: the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (DARPA). Most of the other NITRD agencies – for example, the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the Department of Energy

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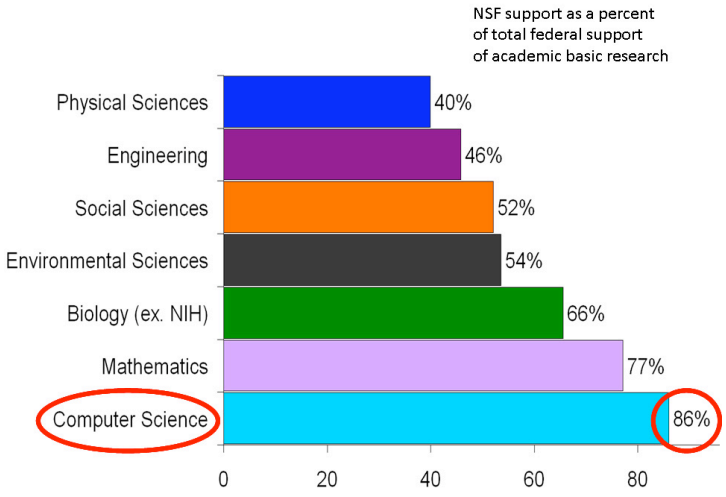
[5] President's Council of Advisors on Science and Technology. *Leadership Under Challenge: Information Technology R&D in a Competitive World*. 2007. http://www.ostp.gov/pdf/nitrd_review.pdf

(DOE), and the National Institutes of Health (NIH) – have invested far less in university-based IT research, choosing instead to leverage the NSF and DARPA efforts. **IT research would be strengthened by urging agencies such as NIH, DOE, and DHS to take greater responsibility for advancing IT in areas specifically relevant to their missions, particularly via university-based research**.

Furthermore, for academic IT research, policies at DARPA have left NSF standing largely alone. Frequent "go/no-go" program reviews and an overly aggressive approach to security classification have greatly reduced our leadership in the IT area and limited the DoD's access to the best minds in the country. The overall effect is the significant reduction in university participation in DARPA IT programs. Indeed, today NSF provides 86% of the federal support for academic research in computer science[6], a far greater proportion than for any other field.




In my own analysis of the situation,[7] the dramatic reduction of DARPA from the IT R&D ecosystem has had several a damaging effects. To a significant extent, increases in NSF funding for IT research at the start of this decade merely offset decreased DARPA academic engagement, thereby diminishing the possibilities for transformative impact of that funding. Coupled with increased competition for research funding, many researchers have become more risk averse. **Increasing participation by DARPA or another agency in university-based research in fundamental IT would strengthen IT research in all agencies.** This would provide greater leverage for increases in IT investments in NSF, NIH, DOE, and other agencies. Furthermore, the traditional DARPA model of higher-risk ventures within the context of focused program objectives provided a unique set of strategic advantages – an important feature of a strong R&D ecosystem.

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[6] National Science Foundation. *FY 2008 Budget Request to Congress.* 2007. http://www.nsf.gov/about/budget/fy2008/pdf/EntirePDF.pdf

[7] Peter Lee and Randy Katz. Re-envisioning DARPA. CCC whitepaper. http://www.cra.org/ccc/initiatives.php

**Question 2:** *Does the legislation address the key recommendations of the recent PCAST assessment for making the NITRD program more effective and more relevant to the research needs and opportunities in information technology?*

I am encouraged that the draft addresses many key recommendations of the 2007 PCAST assessment. I believe the provisions of that assessment will certainly make the NITRD program more effective in meeting the needs and opportunities in networking and information technology R&D. The PCAST assessment noted that the most critical need is to "rebalance the NITRD investment portfolio to include more long-term, large-scale, multidisciplinary IT R&D." In this respect, the explicit focus on supporting such large-scale multidisciplinary research is greatly welcomed. However, **it is equally important to maintain strong investments in core IT research, in balance with multidisciplinary research.** As we learned at the symposium on *Computing Research that Changed the World,* strength in multidisciplinary research is based on a foundation of strong core research. To the extent that core research activities are often conducted by single investigators or small groups, this also implies a balance between large-scale and small-scale efforts.

The legislation includes cyber-physical systems (CPS) research and development, as recommended in the PCAST assessment. One can observe that many of the grand research challenges listed earlier involve a deep embedding, coordination, and control of networking and information technologies with the physical world, making it clear that CPS is indeed an emerging area of opportunity. It is critical that **the legislation is phrased to reflect the full breadth CPS**. CPS pertains not just to man-made devices, but to any IT-enabled combination of physical sensing and actuation devices in the real world.

One of the most important recommendations of the PCAST assessment pertains to the oversight and review of NITRD investment and accountability against the program's strategic plan. Specifically, the legislation specifies the re-establishment of the President's Information Technology Advisory Committee (PITAC), functioning as a separate Presidential advisory committee of academic and industry leaders. As Daniel Reed testified before this committee in 2008, "**an independent PITAC is needed that can devote the time, energy, and diligence to ongoing assessment of successes, challenges, needs and opportunities in information technology**." In such a fast-moving field offering so many opportunities for university-industry partnerships, such focused oversight is crucial for maximizing the payoff of NITRD investments.

**Question 3:** *Are there key research gaps or program management concerns not covered in this legislation? Are the mechanisms for industry and academic input into the planning process sufficient?*

The legislation encourages large-scale, multidisciplinary research. It is equally important to have **a renewed emphasis on long-term research, through sustained, stable funding, is critical for re-energizing high-risk, high-impact proposals.** As

the National Research Council's "tire tracks" figure shows[8], there can be long incubation periods for game-changing technologies. Providing the "patience" for such incubation is a key function of the NITRD program. As the 2007 PCAST assessment recommends, NITRD should "rebalance our research portfolio to encourage greater innovation and risk taking."

Another area of emerging need and opportunity is cybersecurity, as pointed out in a 2005 report from the President's Information Technology Advisory Committee[9] and, more recently, in a 2009 report from the Government Accountability Office[10]. Addressing the nation's pressing needs in cybersecurity will require a broad, coordinated effort. Agencies such as DARPA that have invested significantly in cybersecurity can play a key role by broadening to the larger academic research community, thereby achieving what PITAC referred to as "fundamental research on civilian cybersecurity." To first approximation, aside from NSF the funding for cybersecurity research at universities has been too modest relative to the threats that the nation faces. I suggest that **an explicit focus on cybersecurity that coordinates the efforts of multiple agencies and enables full participation by academia should be considered**.

An area that deserves special attention, as pointed out in the 2007 PCAST assessment, is to **increase the pipeline of talent in IT to meet both the demands of industry as well as future IT research, with a particular focus on women and underrepresented groups**. Simply put, today we are not attracting enough people into computing education and careers, and this problem is particularly acute with underrepresented groups. Recently, in a letter written by the ACM and joined by CRA and the National Center for Women & Information Technology, we urged that this crucial talent pipeline be strengthened by expanding and coordinating existing efforts within the NITRD program. We believe this can be done in ways that also gain better leverage for these efforts. Four specific recommendations were:

- Promote computing education, particularly at the K-12 level, and increased exposure to computing education and research opportunities, especially for women and minorities as core elements of the NITRD program;

- Require the NITRD program to address education and diversity programs in its strategic planning and road-mapping process;

- Expand efforts at the National Science Foundation (NSF) to focus on computer science education, particularly at the K-12 level through broadening the Math Science Partnership program; and,

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[8] National Research Council. *Innovation in Information Technology*. National Academies Press. 2003. http://www.nap.edu/catalog.php?record_id=10795&page=5

[9] President's Information Technology Advisory Committee. *Cyber Security R&D: A Crisis of Prioritization*. 2005. http://www.nitrd.gov/pitac/reports/20050301_cybersecurity/cybersecurity.pdf

[10] General Accountability Office. *National Cybersecurity Strategy: Key Improvements Are Needed to Strengthen the Nation's Posture*. GAO-09-432T, March 10, 2009, http://www.gao.gov/products/GAO-09-432T.

- Enlist the Department of Education and its resources and reach in addressing computer science education issues.

Each of these recommendations would **bring a federal focus to issues in computer science education at the K-12 level, enabling emerging concepts in "computational thinking" to make their way into the education of all Americans**.

**Question 4:** *Does the legislation effectively implement the PCAST recommendation for support of large-scale, multidisciplinary research and development projects? What are the most appropriate mechanisms to undertake these projects? Are the requirements for these projects sufficient to encourage industry/university partnerships?*

It is encouraging to see that the legislation explicitly recognizes the importance of large-scale, multidisciplinary research and development projects, and provides for direct support for such activities. Key to the role that IT plays in enabling innovation is the role of the IT R&D ecosystem that enables innovation. A 1995 study by the National Research Council[11] describes 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." That study, and a subsequent 1999 report by the President's Information Technology Advisory Committee[12], emphasized the "spectacular" return on the federal investment in long-term IT research and development. Indeed, a 2003 NRC study[13] identified 19 multibillion-dollar IT industries – industries that are transforming our lives and driving our economy – that were enabled by federally sponsored research.[14] This year, National Research Council completed a study on *Assessing the Impacts of Changes in the IT R&D Ecosystem*[15]. The study makes four recommendations:

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 US IT R&D ecosystem, while maintaining other important political and economic objectives.
4. Ensure that the US has an infrastructure for communications, computing, applications, and services that can enable US IT users and innovators to lead the world.

**Significant progress towards encouraging large-scale, multidisciplinary research this can be obtained by launching a second Information Technology Research (ITR) program in the NSF CISE Directorate**, as recommended in the

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[11] National Research Council. *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure.* National Academies Press. 1995. http://www.nap.edu/catalog.php?record_id=4948

[12] President's Information Technology Advisory Committee. *Information Technology Research: Investing in Our Future*. 1999. http://www.nitrd.gov/pitac/report/pitac_report.pdf

[13] National Research Council. *Innovation in Information Technology*. National Academies Press. 2003. http://www.nap.edu/catalog.php?record_id=10795

[14] See http://books.nap.edu/openbook.php?record_id=10795&page=5.

[15] See http://books.nap.edu/openbook.php?record_id=12174&page=R1

2007 PCAST assessment. Between FY2000 and FY2004, the original ITR program added $218 million to what is today (FY2008) an NSF CISE budget of $535 million – which constitutes 86% of the federal support for academic research in computer science. (ITR also added $77 million to other Directorate's budgets.) ITR was managed as a distinct program, and had a particularly important impact in encouraging *longer-term*, *larger-scale*, *multidisciplinary* IT R&D focused on *areas of particular opportunity*.

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In summary, networking and information technology research and development is the cornerstone of America's future infrastructure and economic competitiveness. By

a. encouraging broader agency support for advancing IT R&D,
b. restoring investment in long-term, stable university-based research in IT,
c. balancing core and multidisciplinary research activities,
d. increasing the pipeline of IT talent, especially from underrepresented groups,
e. bringing federal focus to K-12 computer science education, and
f. launching a second NSF ITR program,

we can ensure U.S. leadership in IT R&D and contribute real solutions to many of the challenges facing our nation today. Federal investments, as enabled by the NITRD program, are paid back many times as the field's ability to create effective university-industry partnerships and transferable technologies has shown time and again. The proposed legislation makes much-needed changes to the NITRD program and will help us meet many of the challenges facing us today. In order for the U.S. to remain the world's leader, further improvements will be needed; the proposed legislation makes a good first step.

Mr. Chairman, thank you and this committee for your interest in the future of the NITRD program and its importance to innovation and U.S. competitiveness. Thank you for your time and attention. At the appropriate time, I would be pleased to answer any questions you might have.

**Biographical Sketch**

Peter Lee is the head of the Computer Science Department at Carnegie Mellon University. He joined the CMU faculty in 1987, immediately after completing his doctoral studies at the University of Michigan.

Peter Lee is an active researcher, educator, administrator, and servant to the academic community. His research contributions lie mainly in areas related to the foundations of software reliability, program analysis, security, and language design. He has published extensively in major academic journals and international symposia, with several of his papers receiving "test of time" awards for their seminal contributions to the field. Peter Lee is the recipient of several research awards, including the ACM SIGOPS Hall of Fame Award, for the seminal contribution of "proof-carrying code" in computer systems research. He is an elected fellow of the Association for Computing Machinery.

As the head of the Computer Science Department, Peter Lee oversees one of the top computing research organizations in the world. In addition to its substantial research program, the department offers highly rated doctoral and undergraduate programs in computer science, with the Ph.D. program consistently ranked among the top in the US. Prior to assuming his current position, Dr. Lee was briefly the Vice Provost for Research. In this role, he provided administrative oversight and strategic guidance for the university's research activities, an enterprise that exceeds $400M in annual expenditures. From 2000 to 2004, Peter Lee was the Associate Dean for undergraduate programs in the School of Computer Science. During this period, Dr. Lee shepherded the rise of Carnegie Mellon's undergraduate computer science programs to national prominence, including a #2 ranking in the Gourman Report and a six-fold increase in the number of women enrolled.

Peter Lee is dedicated servant to the computing community. He is the incoming Chair of the Board of Directors of the Computing Research Association and chairs it's Government Affairs Committee. He also sits on the CRA's Education Committee. He is a member of the Computing Community Consortium Council, the National Research Council's Computer Science and Telecommunications Board, and the Defense Research Projects Agency's Information Science and Technology Board (where he is the Vice-Chair). Dr. Lee is called upon as an expert in diverse venues, including distinguished lectures at major universities, memberships on senior government advisory panels, corporate and university advisory boards, and court testimony (such as the Sun v. Microsoft "Java lawsuit"). He maintains the CSDiary weblog.

## About the Computing Research Association

The Computing Research Association (CRA) is an association of more than 200 North American academic departments of computer science, computer engineering, and related fields; laboratories and centers in industry, government, and academia engaging in basic computing research; and affiliated professional societies. CRA's mission is to strengthen research and advanced education in the computing fields, expand opportunities for women and minorities, and improve public and policymaker understanding of the importance of computing and computing research in our society.

The CRA Board of Directors and its Executive Officers are a distinguished group of leaders in computing research from academia and industry. The board is elected by CRA's member organizations. Representatives from each of our affiliated professional societies are also appointed to serve on the board. CRA relies on the volunteers that serve on its committees, as well as its professional staff, to carry out its programs.

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