Testimony before the United States House of Representatives
Committee on Science and Technology
Hearing on
Leadership Under Challenge: Information Technology R&D in a Competitive World
(2007 report of the President's Council of Advisors on Science and Technology)

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1. Background

Thank you for the opportunity to appear before you today. I am providing testimony to the House Science and Technology Committee in response to a request from Chairman Gordon. Chairman Gordon in his letter of invitation asked for comments on the President's Council of Advisors on Science and Technology (PCAST) 2007 report *Leadership Under Challenge: Information Technology R&D in a Competitive World*[1] and the merit of the recommendations therein. To provide context for my comments, I am the Chair of the Coalition for Advanced Scientific Computing (CASC) (http://www.casc.org), an educational nonprofit 501(c)(3) organization with 53 member institutions, representing many of the nation's most forward thinking universities and computing centers. CASC is dedicated to advocating the use of the most advanced computing technology to accelerate scientific discovery for national competitiveness, global security, and economic success, as well as to developing a diverse and highly skilled 21st century workforce. In preparing my testimony I have sought the advice of my colleagues within CASC. My testimony is reflective of the views of CASC members overall, and any errors are my responsibility alone.

In addition to my role as Chair of CASC, I serve Indiana University as the Associate Dean for Research Technologies and the Chief Operating Officer for the Pervasive Technology Labs at Indiana University. As such, I am responsible for many of the advanced networking and information technology services provided to Indiana University researchers. Through support from the State of Indiana and Federal agencies, I am also responsible for services delivered to public and private sector researchers in

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[1] President's Council of Advisors on Science and Technology (PCAST). 2007. *Leadership Under Challenge: Information Technology R&D in a Competitive World*. http://www.nitrd.gov/pcast/reports/PCAST-NIT-FINAL.pdf.

Indiana and researchers at institutions of higher education throughout the U.S. I came to be involved in networking and information technology originally as a biologist, using computers as a tool in my biological research. I thus value advanced technology first and foremost for what it can do practically to improve the quality of human life and our understanding of the world around us.

2. Observations on the 2007 PCAST Report

In their letter submitting the 2007 PCAST report, Co-Chairs John H. Marburger III and E. Floyd Kvamme summarized the challenges facing the U.S. in Networking and Information Technology (NIT) in two sentences:

> "While the United States clearly is the global leader today, we face aggressive challenges from a growing list of competitors. To maintain – and extend – the Nation's competitive advantages, we must further improve the U.S. NIT ecosystem – the fabric made up of high-quality research and education institutions, an entrepreneurial culture, strong capital markets, commercialization pathways, and a skilled NIT workforce that fuels our technological leadership."

I strongly endorse this statement and the findings and recommendations included in the report. The key summary of the past, included on page 1, that " … the NITRD [Networking and Information Technology Research and Development] Program has by and large been effective at meeting agency and national needs" is correct. Indeed, the NITRD program has accelerated innovation in information technology that has led to new insights and practical, valuable changes in industry (including improved fuel efficiency, health and medical care, homeland security, and the creation of many physical devices that improve our productivity and overall quality of life).

I fully support the overall recommendations stated in the PCAST report. General George S. Patton stated, "A good plan, violently executed now, is better than a perfect plan next week." The findings of PCAST are more than just good; they are – overall – spot on. Any expert could quibble with certain details, but in general the recommendations, if enacted and well funded, would be far better than inaction or continuation with the status quo in the Networking and Information Technology Research and Development (NITRD) Program.

3. Summary of recommendations

Speaking as Chair of CASC, and as an individual researcher, I offer the following key recommendations:

- The recommendations in the PCAST report should be enacted, and well funded, so as to assure the continued global leadership of the U.S. in Networking and Information Technology.
- Investment in subareas of NIT should be as consistent over time as possible, including investment in basic NIT research; advanced NIT facilities to support advanced research and development in science, engineering, and technology; and research in developing and delivering the next generation of such advanced NIT facilities.

- The U.S. Government, at all levels, should invest strongly in the creation of an excellent, well-trained 21st century NIT workforce. Two specific recommendations are made to supplement the recommendations in the 2007 PCAST report:
    - Increase the number of students receiving a bachelor's degree in a field related to NIT by funding programs that encourage students to explore NIT majors, and increase digital scholarship in all courses of study.
    - Continue and strengthen emphasis on STEM (Science, Technology, Engineering, and Mathematics) disciplines in elementary and secondary education, to increase the absolute numbers and relative percentages of high school graduates who plan to enter college in an NIT-related discipline.
- As recommended in the PCAST report, a U.S. High End Computing (HEC) roadmap should be developed that includes the areas noted in that report, as well as opportunities and needs that have become more clear since the writing of that report:
    - Support the creation of complexity-hiding interfaces that will dramatically expand the ability of scientists and engineers generally to use HEC infrastructure and applications.
    - Investigate and then implement methods for sustainable support for software critical to the U.S. NIT agenda.

- Support coordination of U.S. cyberinfrastructure to maximize benefit to U.S. national interests by taking best advantage of investments at the college, university, state, and regional levels, in addition to Federal investments.

In the remainder of this written testimony these points are explained in more detail.

4. Pattern of investment over time

Without strong, continued, and consistent investment in networking and information technology (NIT), the U.S. will not have the administrative and technical leadership to support consistent and directed change. Government investment in NIT will be of greatest value if there is as much consistency in levels of investment as possible over time. The uniform experience of CASC members is that strong variations in funding of specific areas of NIT over time are counterproductive to U.S. efforts in research and development in NIT. When funding for particular areas of NIT is decreased significantly, even if for a relatively short period of time, experienced and knowledgeable professionals go to the private sector and are permanently lost to public service. This means that the knowledge and skills of individuals who desire to pursue a career of public service, developed over years of investment by the government, leaves Federally-funded NITRD programs and does not return even when funding for particular areas is subsequently restored. U.S. global competitiveness, innovation, and homeland security are thus best served by consistent investment in basic NIT research; advanced NIT facilities to support advanced research and development in science, engineering, and technology; and research in developing and delivering the next generation of such advanced NIT facilities.

5. Workforce Development

The PCAST report makes several important recommendations regarding workforce development aimed at increasing the supply of professionals with bachelor's, master's, and doctoral degrees in NIT areas. The recommendations focus on actions that should increase the supply of skilled NIT professionals in the U.S. in the short term. This is critically important, and I support all of those recommendations. I would like to make two suggestions for funding emphasis that are in addition to the recommendations made in the report.

Recommendation: Increase the number of students receiving a bachelor's degree in a field related to NIT by funding programs that encourage students to explore NIT majors, and increase digital scholarship in all courses of study. An effective way to increase the number of students receiving a bachelor's degree in a field related to NIT would be to support programs that use telecollaboration technologies to enhance the NIT-related course offerings at small colleges and universities, particularly those that serve large populations of students from groups traditionally underrepresented among NIT professionals. For example, students at Jackson State University, an HBCU (Historically Black College or University), and Navajo Technical College (a college located within the Navajo Nation) took, via teleconference, computer science courses from IU School of

Informatics Professor Geoffrey C. Fox, an esteemed leader in computer science. Students who took these courses indicated that they found the class inspirational and that it affected their career plans. This activity was enabled by relatively modest funding from the National Science Foundation. Similarly, telecollaboration enabled students at the University of Arkansas and Louisiana Tech University to take classes from Louisiana State computer science professor Thomas Sterling, the inventor of Beowulf computing and an internationally recognized expert in NIT. Investment in collaborative distance education should include access to leading edge cyberinfrastructure resources for instructors and students from small institutions. Increased investment in collaborative distance education, either in absolute terms or as a relative share of the NITRD budget, would have disproportionately great long-term impact on the supply of professionals with college degrees in NIT. In addition, the global competitiveness of the U.S. will depend heavily on a workforce skilled generally in digital scholarship. By digital scholarship, I mean the ability to find and use authoritative digital scholarly resources effectively in research. Digital scholarship should be a critical part of education at the secondary and postsecondary levels, considered as basic in the future as the ability to think critically about quantitative information and to write effectively.

Recommendation: Continue and strengthen emphasis on STEM (Science, Technology, Engineering, and Mathematics) disciplines in elementary and secondary education, to increase the absolute numbers and relative percentages of high school graduates who plan to enter college in an NIT-related discipline. CASC includes member organizations in most states of the nation. In all states that include CASC members, and I believe in all states in the nation, there are areas where the educational system and social environment do not provide incentive or opportunity for our young people to become excited by STEM disciplines and acquire the primary and secondary education needed to successfully pursue an undergraduate (and advanced) education in NIT-related areas. The PCAST report recommends steps to increase the importing of talent to the U.S. from abroad at the same time that we are losing the opportunity to develop our own talent. In the case of my home state of Indiana, innately bright young people in the rural southwest and urban northwest of Indiana are lost to the U.S. 21st century workforce because they are provided neither the inspiration nor the education that would enable them to pursue careers in NIT. The U.S. should do everything possible to cultivate the talent of our own young people to create the skilled NIT workforce needed for U.S. competitiveness in the future, and make available to our young people the opportunity to pursue a rewarding career in NIT or an NIT-related area of science and technology.

6. High End Computing Research and Development Roadmap

The PCAST report makes several recommendations regarding investments in High End Computing. I would like to expand on one of the recommendations (made on page 40 of the PCAST report):

> "Recommendation: The NITRD Subcommittee should develop, implement, and maintain a strategic plan for Federal investments in HEC [high-end computing] R&D, infrastructure, applications, and education and training. Based on the strategic plan, the NITRD Subcommittee should involve experts from academia and industry to develop and

maintain a HEC R&D roadmap."

As noted in the PCAST report, such a roadmap should be based on the 2004 Federal Plan for High-End Computing[2]. Since the writing of that 2004 report, several new developments in the NIT ecosystem have taken place, creating new opportunities for increased innovation, more widespread practical benefits resulting from those innovations and enhanced leverage of Federal investments. I thus offer four suggestions regarding the plan called for in this recommendation, to be added to the bullet points listed on page 40 of the PCAST report. A strategic plan for Federal developments in HEC R&D should:

- Support the creation of complexity-hiding interfaces that will dramatically expand the ability of scientists and engineers generally to use HEC infrastructure and applications.
- Investigate and then implement methods for sustainable support for software critical to the U.S. NIT agenda.
- Support coordination of U.S. cyberinfrastructure to maximize benefit to U.S. national interests by taking best advantage of investments at the college, university, state, and regional levels, in addition to Federal investments.

I would like to explain briefly each of these points below.

Support the creation of complexity-hiding interfaces that will dramatically expand the ability of scientists and engineers generally to use HEC infrastructure and applications. An important new trend in HEC software environments is the concept of a Science Gateway. A Science Gateway is a web-accessible tool that provides end-to-end support

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[2] National Science and Technology Council. Federal Plan for High-End Computing. Washington, D.C.: May 2004, available at http://www.nitrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf.

for a scientific workflow, such as the prediction of tornadoes or earthquakes, or the analysis of a genome. For example, one Science Gateway developed with NSF support provides an intuitive interface that allows a weather expert to select input data from Doppler radars, process multiple predictions of tornado formation using some of the U.S.'s fastest supercomputers, and produce a visualization on a laptop computer in time to send emergency warnings and save lives. Science Gateways provide this sort of sophisticated capability to scientists and engineers without requiring that such people, who have invested years in becoming experts in their own specific disciplines, also invest years in becoming expert computational scientists. Using HEC systems to predict earthquakes, analyze genomes, understand complex physical phenomena, etc. should be as easy – for researchers who understand the underlying science – as buying a book over the Internet; identifying and understanding the critical aspects of terabytes of data should be like starting with a web-accessible image of North America and zooming in on your own back yard. For decades, national and discipline-specific agendas of a few grand challenge problems in high end computing have catalyzed innovation within the U.S. Today there are thousands of important theoretical and practical problems that can and will be solved if the HEC infrastructure of the U.S. can be made more easily usable. In addition, such complexity hiding interfaces gives undergraduate and even high school students the opportunity to use high-end computing, which will aid the STEM education and 21st century workforce development I have already recommended.

Support for development of complexity hiding must be in addition to the much-needed investments in software development on which such gateways depend and which are already called for in the PCAST report. For example, new programming models and approaches to programming are needed to take advantage of emerging HEC architectures, particularly multi-core processors and specialized computational hardware. In addition, today's high quality (including 3D) computer displays, enhanced by research and development in visualization, can provide new tools for extracting insight from the massive streams of data now produced by digital instruments.

Investigate and then implement methods for sustainable support for software critical to the U.S. NIT agenda. The Federal government invests heavily in research and development of important software tools, and as noted in the PCAST report. In some cases, software critically important to U.S. global competitiveness is not viable as a commercial product, yet sustaining and maintaining such software over time is critical to U.S. interests. Sometimes open source software development is a solution. A new approach – community source software – is emerging within universities to coordinate and leverage development and maintenance of educational and financial management software. This approach may or may not be applicable to scientific software. But it is notable that a relatively modest investment by the Mellon Foundation enabled the Sakai Collaboration[3] to develop a completely new approach to the sustainability of educational software. I thus recommend that the Federal Government investigate models of scientific software sustainability in addition to those already in use, in the belief that such investigation may identify innovative ways to meet a critical U.S. strategic needs that are also sensitive to the many demands on the Federal budget.

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[3] http://sakaiproject.org/

Support coordination of U.S. cyberinfrastructure to maximize benefit to U.S. national interests by taking best advantage of investments at the college, university, state, and regional levels, in addition to Federal investments. I would like to introduce into my testimony the term cyberinfrastructure. While not used in the PCAST 2007 report, it is useful in discussion of NIT and national competitiveness. The first usage of the term cyberinfrastructure that I can find is from a 1998 press briefing by Richard Clarke, then National Coordinator for Security, Infrastructure Protection, and Counter-terrorism[4]. The term became widely used after its inclusion in a very important report by a blue-ribbon committee commissioned by the NSF[5]. There are several definitions of cyberinfrastructure; the one I like best (admittedly developed by my group at Indiana University) is as follows:

> "Cyberinfrastructure consists of computing systems, data storage systems, advanced instruments and data repositories, visualization environments, and people, all linked together by software and high performance networks to improve research productivity and enable breakthroughs not otherwise possible."[6]

Cyberinfrastructure is indeed the foundation for innovation for our nation. Leadership class systems within the national cyberinfrastructure are funded by NITRD, and that is likely to continue for some time. However, the broad foundation for innovation will best serve the needs of the nation if Federal leadership can aid the coordination of the

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[4] Press briefing by Richard Clarke, National Coordinator for Security, Infrastructure Protection, and Counter-Terrorism;; and Jeffrey Hunker, Director of the Critical Infrastructure Assurance Office. 22 May, 1998. http://www.fas.org/irp/news/1998/05/980522-wh3.htm

[5] Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyberinfrastructure. http://www.nsf.gov/od/oci/reports/atkins.pdf

[6] Indiana University Cyberinfrastructure Newsletter, March, 2007. http://racinfo.indiana.edu/newsletter/archives/2007-03.shtml

collective cyberinfrastructure assets funded by NITRD agencies and those funded by other sources, including colleges, universities, states, and regional consortia. The resulting extension and leverage of Federal investment in NIT, HEC, and cyberinfrastructure would be tremendous and far-reaching, enabling the U.S. to increase its global competitiveness far beyond what would be possible on the basis of Federal investment without such coordinated leverage.

7. Conclusion

In conclusion, let me return to the starting point of the PCAST report. NITRD has been tremendously important to U.S. innovation and global competitiveness, the quality of life of Americans, and the security of our homeland. I strongly endorse the recommendations contained in the PCAST report, and hope that the comments I have made regarding particular areas of emphasis or addition of recommendations will be of value to this Committee as it embarks upon activities to plan for an even better future of new, important, and practical accomplishments through legislation related to NITRD.

I'd like to return to the title of the PCAST report - *Leadership Under Challenge: Information Technology R&D in a Competitive World*. U.S. leadership is indeed under challenge in many ways across the globe. With respect to networking and information technology, these challenges are unprecedented. Without strong investment in NIT, the U.S. is at risk of losing its longstanding position of global leadership, and the consequences of this would be catastrophic. However, the recommendations made in the PCAST report, if enacted into legislation and well funded, will continue and extend U.S. leadership in network and information technology. Leadership in networking and information technology will fuel U.S. global leadership in innovation. This will lead to continued and improved prosperity, health, and security for Americans and indeed all citizens of the world.

Thank you for the opportunity to appear before you today. I am happy to answer any questions now or at any time in the future.

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Craig Stewart is Associate Dean for Research Technologies and Chief Operating Officer for the Pervasive Technology Labs at Indiana University. In these roles, Dr. Stewart oversees activities conducive to and supporting research in advanced information technology. He received his Ph.D. in Biology from Indiana University in 1988, and has held a variety of positions in Information Technology at Indiana University. His longstanding career interests are in high performance computing and computational biology. In high performance computing his areas of concentration are HPC architectures and grid computing. In the area of computational biology his areas of concentration are computational phylogenetics, computationally intensive simulation methods in systems biology, and biomedical data grids. Dr. Stewart is currently chair of the Coalition for Academic Scientific Computing.

Dr. Stewart served as guest editor for *Bioinformatics: transforming biomedical research and medical care,* the November 2004 special issue of Communications of the Association for Computing Machinery. He has co-authored numerous papers, including *Measuring quality, cost, and value of IT services in higher education* for the 2001 American Quality Congress, *Parallel computing in biomedical research and the search for peta-scale biomedical applications* for Advances in Parallel Computing in 2004, and *Implementation of a distributed architecture for managing collection and dissemination of data for fetal alcohol spectrum disorders research* for Grid Computing in Computational Biology in 2006. Dr. Stewart has also presented many tutorials, including a 2005 introduction to computational biology at High Performance Computing Center, Stuttgart, Germany. He also helped lead two winning projects at the premier annual international supercomputing conference: Global Analysis of Arthropod Evolution, the 2003 HPC Challenge winner; and Using the Data Capacitor for Remote Data Collection, Analysis, and Visualization, the 2007 Bandwidth Challenge winner.

Dr. Stewart is an active participant in several federally funded grants, including: TeraGrid Resource Partners (NSF); Acquisition of PolarGrid: Cyberinfrastructure for Polar Science (NSF); the Open Science Grid (NSF/NIH); and Major Research Infrastructure: Data Capacitor (NSF).