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 and context

I am pleased to have this opportunity to provide testimony to the House Science and Technology Committee in response to a request from Chairman Gordon. Chairman Gordon, in his letter of invitation to the Coalition for Advanced Scientific Computing, 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 this testimony, I serve as 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 and development 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. My testimony this morning has been endorsed by a majority of the members of CASC, and represents the general consensus of opinion within CASC.

I also 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 Indiana and researchers at institutions of higher

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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.

education throughout the U.S. I came to be involved in networking and information technology originally as a biologist. 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. Key observations

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

> "While the United States clearly is the global NIT 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."

CASC strongly endorses 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's support of fourteen Federal agencies, including the Department of Defense, Department of Energy, and DARPA, has accelerated innovation in information technology, leading 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).

The Community I represent fully supports 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 – overall – spot on. It is easy to quibble over details, but in general the recommendations, if executed aggressively, would be far better than inaction or continuation with the status quo in the NITRD Program.

With that overarching endorsement as the key point of this testimony, we would like to make three additional points to emphasize and add to the PCAST recommendations regarding *investment patterns over time*, *workforce development*, and *creation and implementation of a High End Computing Research and Development plan*.

3. 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 consistency in levels of investment over time. The men and women who execute the national NIT agenda represent a tremendous store of experience, skill, and knowledge. The uniform experience of CASC members is that when there are strong variations in funding in specific areas of NIT over time, lean times for particular areas of research in NIT cause skilled professionals to leave public sector NIT research. This means that years of investment by the government in developing a knowledge and experience base in individuals who desire to pursue a career in the public service sector are lost to the public sector, not to return even when funding for particular areas is subsequently restored. U.S. global competitiveness, innovation, and homeland security are thus best served by consistent and strong 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.

4. 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 CASC supports all of those recommendations. We 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. An effective way to do this would be to support programs that use tele-collaboration 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. Students who took these courses indicated that they found the classes inspirational and that they affected their career plans. This activity was enabled by relatively modest funding from the National Science Foundation. Similarly, Thomas Sterling, the inventor of Beowulf computing and a computer science professor at Louisiana State, has taught classes in high performance computing classes via tele-collaboration to students of the University of Arkansas and Louisiana Tech. 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.

Recommendation: Continue to strengthen and expand the emphasis on STEM (Science, Technology, Engineering, and Mathematics) disciplines in elementary and secondary education, so as to increase the absolute numbers and relative percentages of high school graduates who plan to enter college in an NIT-related discipline. We would like to commend Chairman Gordon for his leadership in creating and supporting the development of the STEM program. The uniform experience of CASC member organizations is that within their home states, there are areas where the educational system and social environment do not provide adequate incentive or opportunity for our young people to become excited by STEM disciplines and then acquire the primary and secondary education needed to successfully pursue an undergraduate (and then 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. Each CASC institution can provide data to support this. In my home state of Indiana, for example innately bright young people in the rural southwest and urban northwest of the state 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. We recognize that this area is beyond the statutory responsibility of NITRD, but it is important and related to NITRD and the PCAST recommendations. Chairman Gordon, we hope that you might now consider leveraging the successful STEM program by expanding it to include Computing.

5. High End Computing Research and Development Roadmap

The PCAST report makes several recommendations regarding investments in High End Computing. We endorse those recommendations and 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. CASC offers two 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:

- Implement methods for sustainable support for software development critical to the U.S. NIT agenda. This must include supporting creation of complexity-hiding interfaces that will dramatically expand the ability of scientists and engineers generally to leverage and effectively use HEC infrastructure.
- Support the coordination of U.S. cyberinfrastructure that maximizes the total 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 briefly explain these points below.

Implement methods for sustainable support for software development critical to the U.S. NIT agenda. This must include supporting creation of complexity-hiding interfaces that will dramatically expand the ability of scientists and engineers generally to leverage and effectively use HEC infrastructure. The Federal government needs to significantly increase its investment in research, development, and sustained support of important

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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.

software tools. As noted in the PCAST report, software critically important to U.S. global competitiveness is not always viable as a commercial product, yet sustaining it 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 efforts in development 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 sustainability of educational software. Similarly a modest investment by the William and Flora Hewlett Foundation enabled the Connexions[4] project to develop a global open and free repository for authors, instructors, and students to share and develop educational material. CASC recommends that the Federal government investigate and support new models for scientific software sustainability in addition to those already in use.

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 for a scientific workflow, such as the prediction of tornadoes or the analysis of an earthquake or 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,

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[3] http://sakaiproject.org/
[4] http://cnx.org/

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 tornadoes, analyze genomes, understand earthquakes, 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 give 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 interfaces 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.

Support the coordination of U.S. cyberinfrastructure that maximizes the total 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. While the term cyberinfrastructure is not used in the PCAST 2007 report, it is useful in a 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[5]. The term became widely used after its inclusion in a very important report by a blue-ribbon committee commissioned by the NSF[6]. 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."[7]

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 collective cyberinfrastructure assets funded by NITRD agencies and those funded by

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[5] 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

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

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

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 capable on the basis of Federal investment without such coordinated leverage.

6. 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. CASC members endorse the recommendations contained in the PCAST report, and hope that the comments made in this testimony 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.

The 2007 PCAST report is titled *Leadership Under Challenge: Information Technology R&D in a Competitive World*. U.S. leadership is indeed under challenge in many ways across the globe. As regards 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, and will fuel future 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).