Hon. Sherwood Boehlert, Chairman
Committee on Science
Suite 2320 Rayburn House Office Building
Washington, DC 20418

Dear Mr. Boehlert,

I am pleased to have had the opportunity to testify before the Committee on Science in May on the issue of federal funding of Computer Science research, and am equally pleased to respond to your written questions. My answers follow:

Question 1. *What kind of computer science research isn't DARPA supporting that you think it should? Is it a matter of more funding or are there programs that are of lower priority that should be cut?*

Answer: There are two dimensions to the answer of this question – (1) the topics of research, and (2) the "style" of the support for that research, by which I mean the level of funding, the duration of that funding, the degree of control exercised by the funder, etc. The current DARPA management is, I believe, failing the country on both dimensions.

Along both dimensions, there are many organizations that support essential incremental improvements – the service laboratories and service R&D support organizations, for example. There is now no DoD organization like the "old DARPA", however, that fills the role of discovery of breakthrough technologies.

Concerning the topics of research – as I noted in my written testimony, there is a fifteen year delay between discovery of basic knowledge and its appearance in product. Failure to fill this pipeline will not be immediately evident, but the future consequences will be cataclysmic. I could name a long list of areas where filling the pipeline is needed, but just as a sampler:

- As I have testified before, our basic model of computer security (perimeter defense) is fatally flawed – we will *never* have secure computing systems so long as this is the underlying model! We need a breakthrough, and the only way to get that is to support a variety of radical approaches – and to expect most of them to fail! The short term, risk-averse approach being currently taken by DARPA will not yield such a breakthrough.
- Our ability to produce reliable, effective software seems to always totter on the brink of disaster – and 100+ million dollar examples are all too common (e.g., the recent problem with the FBI TRILOGY system). It ought to be obvious that doing just "more of the same" will not solve the problem; a breakthrough is needed, and, as above, the only way to get that is to support a variety of approaches with a risky, long-term, basic emphasis.
- It is a bit more than slightly embarrassing that our current computer components are individually a million times faster than our brain cells, yet computers either

cannot, or with great difficulty do what humans do easily. There simply *must* be a model of computing, especially of parallel computing, that we do not understand and that, if we did, would produce computing architectures and algorithms of immense power.

- The use of computers in education has progressed little from the "automated drill" model of the Plato system from the 1960's. Yet we now know much more about the way that people learn, physiologically and psychologically. We also have tacit knowledge about how emotion interacts with learning, and how to evoke emotion to train, for example, first responders and troops in urban combat zones.

I picked each of the examples above because they have a clear and compelling link to the mission of the DoD. Security, reliable software, high performance computing and education/training are all central to that mission – but there are undoubtedly many more such examples. To fail to "fill the pipeline" on any of them is akin to criminal – yet the current DARPA is AWOL on all of them!

Concerning the "style" of support for topics such as those above – I think it is important to understand that they can't be bought on a competitive market in the way that incremental technology improvements can. I am an engineer, former CEO of an engineering company, Director of another engineering company, and a big fan of commercial development. I am also a skeptic of the academic belief that basic research is the source of all new ideas. But, that said, I also deeply believe that a program of long-term, academic, risky, basic research is *essential* to the mission of the DoD; that is a role that DARPA used to play but is no longer playing. Not in the near term – but in the 10-15 year time frame – the U.S. is endangered by DARPA's current style of funding!

Question 2. *At the hearing, Dr. Tether mentioned several times that his agency's work on cognitive computing as an example of long-range research underway at DARPA. Is that the kind of long-range computer science research that you believe DARPA should be doing? Why or why not?*

Answer: I am very sorry, but I am not sufficiently acquainted with this program to answer. My schedule since the hearing in May has been such that I have not been able to inform myself about it. If the committee wishes, I will be delighted to inform myself after returning from Australia in late July and submit an answer at that time.

Question 3. *What criteria should we be using to determine if federal support for fundamental research in computer science in general and cybersecurity in particular is adequaqte?*

Answer: That is, of course, one of the hardest questions to answer since one can never know with certainty whether the next incremental dollar will fund the breakthrough that

revolutionizes a field, or results in a technology with profound implications for our quality of life.

At least at NSF, however, the success rate for proposals is probably a good surrogate. Historically NSF has funded about 30% of the proposals it receives. Informal conversations with program officers at NSF suggests that, in fact, probably 50% of the proposals they receive are worthy of funding, so a 30% success rate is covering the really outstanding proposals. If the success rate for cybersecurity were 30%, I would judge the funding to be adequate.

A general answer for mission agencies such as DoD and DoE is harder to give; each such agency must think in terms of its own needs in various areas. In the case of these two specific agencies, which are the most heavily dependent on high quality security and spend literally billions of dollars annually on largely manual systems, it is hard for me to understand why they aren't investing more on basic research in this area.

Question 1 from Ranking Member Gordon: *The President's Information Technology Advisory Committee report on cybersecurity finds that the academic research community in cyber security is below critical mass.*

a) *To what extent would this be corrected simply by increasing the amount of research funding available?*
b) *Are there other impediments to bringing more researchers to this field aside from the availability of research funding?*

Answer: I am strongly in agreement with the PITAC conclusion, and there is no question that additional funding would help increase the amount of research done and hence increase the production of trained professionals in the area of cybersecurity. The fact that NSF received 12 times as many proposals as it was able to fund in its recent Cyber Trust Initiative demonstrates that there is a pent-up demand to do research in this area. I have long pointed out that there are some deep and very interesting problems in cybersecurity, and I think the response to NSF's initiative demonstrates that, given support, the CS community will be attracted to these problems.

But, as I have said before to this committee, at least as important as the amount of funding is its stability – an assurance that there will be funds in the future. Academic reputations are built on a lifetime of research and so the best researchers choose problem areas where there is likely to be funding over their whole research career.

Finally, the current tendency to classify security related research is an impediment to academic research. Speaking as one who has done cybersecurity research, much of this classification is counterproductive. There is a saying in the cybersecurity research community that "There is no security in obscurity" – meaning that if your security depends on hiding information, it is inevitable that information will leak out and you will be left insecure. That is why, for example, all cryptographic techniques are public. So, while I believe that there are a few cases associated with offensive cybersecurity that

need to be classified, virtually nothing else does – and in fact classifying it will ultimately lead to less security.

In short, more funding would be helpful, but stable funding and an open approach to security research are *essential* to bringing more academic researchers into this field.

Question 2 from Ranking Member Gordon*: In your written testimony you mentioned that a significant portion of the NSF's computer science directorate's budget goes to fund cyberinfrastructure, which largely supports research in fields other than computer science. This means that less funding is available for research in computer science.*

Do you think this organizational arrangement at NSF for the support of cyberinfrastructure makes sense, or should the cyberinfrastructure be managed in a separate office and funded through a dedicated appropriations category?

Answer: In the spirit of full disclosure I should first note that from 1988-1991 I was the Assistant Director of NSF responsible for what is now called the cyberinfrastructure, and I have wrestled with this question off-and-on for 17 years.

I want to be clear that the fact that cyberinfrastructure in housed in the Computer and Information Science and Engineering (CISE) Directorate causes some *confusion*, but in fact has worked quite well. The confusion results from a simplistic look at the NSF budget that leads some outside CS to assume that computer science is funded much better than it actually is. A similarly simplistic look at the CISE budget by some computer scientists leads them to assume that a lot of "their money" is being spent on cyberinfrastructure. In truth, the support of cyberinfrastructure is strongly in the national interest, and if its management were moved out of CISE, so would the resources to support it; that money would not become available for CS. To repeat, the problem is one of confusion arising from simplistic analyses; it is *not* a real problem of reduced funding of CS because of the infrastructure.

At least when I ran CISE, I tolerated this confusion because I believed (and still believe) that both the users of the infrastructure and computer science research benefited from the close and coordinated management of a research program on the infrastructure and its use. For example, we quickly learned that users of supercomputers needed to be able to visualize the results of their computations, which spawned a very fruitful program of research in computer graphics with wide application but that specifically was of great benefit to the supercomputer users. Thus my first preference would be to maintain the current arrangement, but it would not be a disaster to move the management of the cyberinfrastructure to a separate office – however, if that were done, I would think *very* carefully about how to maintain that close relationship of its use and further research on it. What we now call cyberinfrastructure has evolved very rapidly in part because of that relationship

Question from Representative Jackson Lee: *While I am unsatisfied by the status of computer science research being conducted at the federal level, I am also disturbed by the lack of female and minority representation in the field of computer science. The statistics show that women and minorities are not being proportionally represented in academia when it comes to computer science. In 2003, women represented barely 20% of the doctoral degrees granted. The same statistics show that in 2003 the White male population made up about 70% of the doctoral degrees to US citizens and permanent residents. At the same time, Asian/Pacific Islanders made up about 20% of the doctoral degrees granted, but black, Hispanics and American Indian/Native Alaskans made up lless than 5% of the doctoral degrees granted. These statistics are discouraging and show that we are not reaching out to our entire population. Indeed, the problem starts in the classroom, where many under-privileged youth do not have this background at an early age, its not surprising that they don't pursue the field in higher education and later in life. What are we doing to reach women, minorities and the under-privileged in our society?*

Answer: I share Representative Jackson Lee's concern. Indeed it is perhaps even worse than she indicates. Taking engineering as a whole, not just computer science (which, incidentally does a bit better than the rest of the physical sciences and engineering, but much worse than the life sciences), for thirty years we made steady progress on the representation of women and minorities as a fraction of the graduating class. One might argue that the progress should have been faster – but at least there was steady progress. But then something happened in the early 90's and the proportion has been essentially flat since, and no one has been able to satisfactorily explain what happened.

I have attached (Attachment 1) an analysis by a joint committee of the Association for Computing Machinery (ACM), the Institute for Electrical and Electronic Engineers (IEEE), and the Computing Research Association (CRA) – the ACM and IEEE are the two principal professional societies in computer science, and the CRA is an organization of the CS departments and research laboratories. Although this list isn't complete (it doesn't mention the Academy of Engineering program on diversity, the Anita Borg Institute for Women and Technology, or MentorNet, just to mention three that I am involved in), I think it does demonstrate that the computer science community broadly shares your concerns and is trying to do something about them.

Sincerely,

Wm. A. Wulf
President

Attachment 1: Information on Coalition to Diversify Computing (CDC) efforts

A joint organization of the ACM, CRA and IEEE-CS
http://www.cdc-computing.org/

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Major progress in computing technologies over the last decade has been accompanied by vast improvements in computing middleware, hardware and networking. An unexpected consequence of these advancements has been a shortage of a highly trained workforce of scientists and engineers capable of understanding and implementing the resources. The Coalition to Diversify Computing (CDC) seeks to address the shortfall through the development of a diverse community of professionals that can effectively meet the computing demands of an evolving society. CDC projects target students and faculty with the expressed intent of increasing the number of minorities successfully transitioning into computing-based careers in academia, federal labs and industry. Additional projects seek to increase the available pool of faculty members through partnerships and mentoring. Current emphasis is placed on the following three areas: (1) recruitment of minority undergraduates to MS/Ph.D. programs, (2) retention of minority graduate students enrolled in MS/Ph.D. programs, and (3) transition of minority MS/Ph.D. graduates into academia and industry. Current projects include:

1. Richard Tapia Celebration of Diversity in Computing Conference
   Next conference (October 19-22, 2005 in Albuquerque, New Mexico), URL:
   http://www.ncsa.uiuc.edu/Conferences/Tapia2005/
2. Distributed Rap Sessions
3. CDC Database
4. Sending Students/Mentors to Technical Conferences
5. Collaborative Research Experiences for Undergraduates (CREU)
6. Workshop for Minority Junior Faculty

The diverse membership of CDC from areas of academia, industry and federal laboratories enables a variety of different perspectives and approaches to be utilized in achieving the above stated goals. CDC also partners with a number of organizations with similar missions to leverage resources to optimize outcomes.

CDC Programs

According to the 2003-2004 Taulbee Survey, in 2004 only 1.1 percent of the doctorates in computer engineering and computer science went to Hispanics, 1.5 percent went to African-Americans, and none went to Native Americans or Alaskan Natives.

The number in the pipeline is not increasing by much, either. In fall 2004, 1.3% of enrolled PhD students were Hispanic, 1.8% were African-American, and only 0.2% were Native American.

"Underrepresentation of our communities in computing is an unacceptable loss of talent, creativity, and achievement for the nation and the world and we must all work to change this situation," says Roscoe C. Giles (Professor, Department of Electrical and Computer Engineering, Boston University and team member of the NCSA Alliance Steering Committee). Prof. Giles also serves as Executive Director, Institute for African-American ECulturE.

CDC focuses its efforts on programs that increase the visibility of minorities, and on providing networking opportunities for minority researchers, faculty, and students. The CDC, founded in 1996, is a program of the Computer Research Association (CRA), the Institute of Electrical and Electronic Engineering (IEEE-CS), the Association of Computing Machinery (ACM), and The National Computational Science Alliance (Alliance), a nationwide partnership of more than 50 academic, government and business organizations working together to prototype an advanced computational infrastructure for the new century. Started in 1997, the Alliance is one of two national partnerships funded by the National Science Foundation's Partnerships for Advanced Computational Infrastructure (PACI) program and receives cost-sharing at partner institutions.

Information on CRA's Committee on the Status of Women in Computing Research (CRA-W) efforts

As Rep. Lee correctly points out, the problem of different levels of access to computer technology begins before college. While this is certainly a problem with under-privileged students, there are subtle social factors that affect pre-college girls in this regard as well. It is certainly the case that not getting computer experience and coursework in K-12 can affect initial interest in pursuing a computer degree in college. Fortunately, skills acquired in high school math and science courses – rather than high school programming – are more important in preparing for computing research. Women are now taking math and science courses in high school (with the exception of physics) at almost the same rate as men, so they are not coming into higher education totally unprepared to move into computing if their interest can be engaged. It is interesting to note that while the proportion of B.S. degrees granted to women has been declining since 1985 (NSF data), both the number and proportion of graduate degrees (MS and PhD) granted to women have generally increased (albeit slowly). One possible interpretation for this is that any advantage accrued by males of pre-college computer experience is more significant at the undergraduate level than at the graduate level leading to research careers where women are continuing to slowly make gains.

CRA-W has become a national leader in efforts to increase the number and success of women in computing research and innovation. CRA-W is an action-based committee, implementing projects aimed at eliminating barriers to the full participation of women at all stages of the research pipeline beginning at the undergraduate level. It is a

group of very prominent, dedicated, senior women who volunteer their time and energy to design and manage projects and to secure funding needed to sustain those projects. CRA-W programs have had a direct impact on over 2500 women and indirectly influenced thousands of others. We run a range of programs with the following aims:

1. To mentor individuals, by providing research experiences, information, access to role models, and networking opportunities that guide, support, and encourage women in computing,
2. To educate and influence organizations on issues, policies, and procedures that promote the full participation of women in computing, and
3. To build a community for women researchers that provides visibility for their accomplishments and reduces isolation.

CRA-W has recently been recognized for our past efforts. In 2003 CRA-W was awarded the *Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring* for "significant achievements in mentoring women across educational levels," and this year, it was awarded the *National Science Board's Public Service Award*.

Programs for Undergraduates

CRA-W programs that are aimed at undergraduate women are designed to show them what a career in computing research can offer (and how research is qualitatively different from stereotypical IT programming jobs). The programs tend to focus on one-on-one research-oriented mentoring to encourage women to go on to graduate school in computer science and engineering.

- **Distributed Mentoring Project (DMP):** Since 1994, the DMP has matched outstanding female undergraduates with female faculty mentors for a summer of research at the mentor's research university. Students participate in a research project, observe graduate life, and benefit from a close mentoring relationship with their advisors. They also gain the prior research experience and personal recommendation letters that are increasingly important factors in graduate admission decisions. DMP students receive support for transportation to the host university, a weekly stipend for the 10-week project, and funding to attend a conference with their mentor to present their work. The two evaluations of the DMP by the Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center at the University of Wisconsin show that the program has been very effective: 52% of DMP participants who had graduated by 2001 had gone on to graduate school. When asked what was most influential in that decision, students ranked their DMP experiences second—before career goals, technical interests, advisor/mentor at home institution, and influence of family members—only success in undergraduate CS&E courses ranked higher. When this success rate was compared with a comparable population of high-achieving computer science women undergraduates (with GPA's above 3.5), it was found that only 2.5% attended graduate school. 55% of the participants were students from 4-year colleges and universities who had no other exposure to graduate-level research.

Collaborative Research Experiences for Undergraduates (CREU): Started in 1998, the primary goal of this program, like DMP, is to provide undergraduates with research experiences that will increase their likelihood of continuing on to graduate

school. Originally, the program focused on women, but in 2004 CRA-W formed an alliance with the Coalition to Diversify Computing and expanded the program to include all underrepresented groups. The students, all of whom are CS&E majors, work on research projects in collaborative teams of two or three students at their home institution under the guidance of a faculty member during the academic year. Students are selected on a competitive basis from proposals written jointly with their mentor. CREU provides a collaborative experience to help combat the stereotype of computer scientists as lone hackers toiling away in sterile cubicles, to increase students' team building skills, and to decrease any sense of isolation they may feel in their male-dominated classes. The CREU program has grown from 19 women students in 1998 to 65 students in 2004, with 6 students on minority-based teams. Initial findings from an evaluation study of the CREU program done by the LEAD Center for 1998-2001, conclude that the program has served as a vehicle that promoted skills building, knowledge building, mentoring relationships, role modeling, and enhanced student career aspirations. The program appears to be successful in encouraging students to continue on to graduate school and the students themselves are enthusiastic about their experiences. Preliminary results found that 32% of the participants responding were in graduate school. 21% had plans to pursue a Ph.D. and 11% were receiving an MS degree. Another 32% were employed but still had plans to eventually return to graduate school in CS&E.

Plans for the future include introducing a multi-disciplinary CREU-like program that will involve students and mentors from both computing and scientific disciplines that rely on computing in a collaborative project. This will expose women scientists in other fields to computing research.

- **Distinguished Lecture Series (DLS):** The DLS aims to increase the number of women undergraduates who successfully apply to graduate school in CS&E and to increase the visibility of distinguished women researchers from academia and industrial research labs. Selected sites host an event typically consisting of a lunch with the visitors for women faculty and students, a technical talk by the distinguished lecturer, and a panel discussion with women representing both academic and industrial career paths. The panels also include current women graduate students who give a "view from the trenches." Even at research universities, undergraduates have so many misconceptions about graduate school and the career choices open to those with advanced degrees that the information provided by these panels can be invaluable.

Programs for Graduate Students

With small numbers of women entering graduate school, it is important to ensure their success at navigating the challenges they will face. CRA-W programs for graduate students aim to improve their graduate school experience and increase the chances for successful completion of their graduate degrees.

- **Graduate Student Cohort Project:** The Cohort Project aims to build a community of female students from across the country as they enter graduate school. The program begins with a two-day mentoring workshop for all participants. At the workshop, a number of prominent senior women serve as role models, give practical advice and information, and provide personal insights on the challenges and rewards of their careers. As envisioned, established cohorts will return to the mentoring workshop at regular intervals to get advice on the later stages of graduate school and to provide peer

mentoring to the newer cohorts. The Cohort Project provides increased access to information, a range of role models, networking skills and opportunities, and peer support among students at the same stage of their graduate careers. This relatively new project held its first workshop in February 2004 for 100 first-year graduate students, and held the second workshop in March 2005 for 288 first- and second-year graduate students. Informal feedback from participants was extremely positive. The design of the graduate cohort project allows long-term tracking of cohort members throughout their graduate careers and this kind of evaluation study is in progress. Microsoft funded the 2004 workshop for first group. Microsoft and Google jointly funded the 2005 workshop.

- **Best Practices Report on Retaining and Recruiting Women in CS&E Graduate Programs:** In 2000, CRA-W ran an NSF-sponsored workshop on recruiting and retaining women in CS&E graduate programs. Participants included long-time members of the CS&E academic and research communities, social scientists engaged in relevant research, and directors of successful retention efforts. Their findings were reported in the Best Practices Report, which aimed to provide practical advice to faculty, departments, and university administrations. It included recommendations in four categories: increasing the number of women enrolling in specific departments; increasing the number of women in CS&E graduate programs nationally; improving student-student and student-faculty relations; and fostering a research life. The report has been widely distributed. It was an insert in the September 2001 issue of *Computing Research News* (circulation 3,500 research faculty), reprinted for the 2002 *SIGCSE Bulletin* Special Issue on Women in Computing, and distributed at workshops and conferences. It is also available on the web. The report aimed to increase awareness of issues affecting the participation of women in CS&E, give well-meaning faculty a list of specific things that they can do to change their institution, and use the credibility of CRA to get people involved at the departmental level.

Programs for Faculty Career Development

The goal of CRA-W programs aimed at women who have earned their PhD degrees and embarked on an academic/research career is to continue serving their mentoring needs until they become established leaders in their fields and inspiring role models for their women students.

- **Career Mentoring Workshops:** CRA-W has sponsored a series of Career Mentoring Workshops for women since 1993. Women often find themselves a minority at their workplace, and the CRA-W workshops bring them together with women already established in their fields. The established professionals provide practical information, advice, and mentoring support to their younger colleagues. The workshops have speakers and panels on varying topics. Recently, the Mentoring Workshops were expanded to include tracks for more established academics and to include panelists from industrial and government labs in order to raise awareness about alternate career paths and provide mentors from outside of academia. Each of the workshops has been held in conjunction with a major professional meeting, providing many attendees with the opportunity to attend technical talks and make contacts in their research areas. CRA-W runs a second version of the Mentoring Workshop at the SIGCSE (Special Interest Group in Computer Science Education) Conference. That workshop provides

information on building successful academic careers that focus on undergraduate teaching.

- **Cohort of Associate to Professors Project (CAPP):** Less than 10% of the full professors in CS&E departments are women. Yet, they provide the role models and mentors for our students. CRA-W is attempting to address the problem by forming and mentoring a cohort of women from the associate professor ranks. The cornerstone of the project is the involvement of 15 senior women, appointed as CRA-W Distinguished Professors, who actively participate as role models, mentors, and advisers. The project hopes to accelerate the successful promotion of associate professors by providing them with mentoring, leadership training, encouragement, and ongoing peer-support activities. The first workshop was held in April 2004 and the second occurred in June 2005.