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BEFORE THE
HOUSE COMMITTEE ON GOVERNMENT REFORM
SUBCOMMITTEE ON TECHNOLOGY, INFORMATION POLICY,
INTERGOVERNMENTAL RELATIONS AND THE CENSUS
HEARING ON

"Defining Federal Information Technology Research and Development: Who? Where? What? Why? And How Much?"

July 7, 2004

Thank you, Mr. Chairman, Ranking Member Clay, and members of the Subcommittee for holding this hearing and for the invitation to testify before you. I'm pleased to focus my testimony today on two important questions the committee posed in convening this hearing: What is the government gaining from its investments in information technology research and development, and why should the government continue to make these investments? My comments are informed by my 30-year experience in academia as a member of the computing research community, and by my involvement as the co-Chair of the Computing Research Association's (CRA) Committee on Government Affairs, as the co-Chair of the President's Information Technology Advisory Committee (PITAC), and as a member of the Technical Advisory Board for Microsoft Research since its inception in 1991. I also have served as a member of the National Research Council's Computer Science and Telecommunications Board, where I participated in two studies of how innovation occurs in information technology, and as Chair of the National Science Foundation's Advisory Committee for Computer and Information Science and Engineering. I present this testimony as an informed individual, rather than as a representative of any particular organization, although my comments have the endorsement of the Computing Research Association and the Association for Computing Machinery U.S. Public Policy Committee (USACM).

The Impact of New Technologies

The importance of computing research in enabling the new economy is well documented. The resulting advances in information technology have led to significant improvements in product design, development and distribution for American industry, provided instant communications for people worldwide, and enabled new scientific disciplines such as bioinformatics and nanotechnology that show great promise in improving a whole range of health, security, and communications technologies. Federal Reserve Board Chairman Alan Greenspan has said that the growing use of information technology has been the distinguishing feature of this "pivotal period in American economic history." Recent analysis suggests that the remarkable growth the U.S. experienced between 1995 and 2000 was spurred by an increase in productivity enabled almost completely by factors related to IT. "IT drove the U.S. productivity revival [from 1995-2000]," according to Harvard economist Dale Jorgenson.

Information technology has also changed the conduct of research. Innovations in computing and networking technologies are enabling scientific discovery across every scientific 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, visualize large and complex datasets, and collect and manage massive amounts of data.

The Ecosystem that Gives Birth to New Technologies

A significant reason for this dramatic advance in computing technology and the subsequent increase in innovation and productivity is 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," according a 1995 report by the National Research Council. That report, and a subsequent 1999 report by the President's Information Technology Advisory Committee (PITAC), emphasized the "spectacular" return on the federal investment in long-term IT research and development.

The 1995 NRC report, *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure*, included a compelling graphic illustrating this spectacular return. The graphic was updated in 2002, and I've included it in my testimony today. (See figure 1.)

It's worth a moment to consider the graphic. The graphic charts the development of technologies from their origins in industrial and federally-supported university R&D, to the introduction of the first commercial products, through the creation of billion-dollar industries and markets. The original 1995 report identified 9 of these multibillion-dollar IT industries (the categories on the left side of the graphic). Seven years later, the number of examples had grown to 19 – multibillion-dollar industries that are transforming our lives and driving our economy.

The graphic also illustrates the complex interplay between federally-supported university-based research and industrial R&D efforts. In some cases, such as reduced instruction set computing (RISC) processors (a chip architecture that forms the basis for processors used by Sun, IBM, HP, and Apple, and has significantly influenced all microprocessor design) and RAID disk servers ("redundant arrays of inexpensive disks"), the initial ideas came from industry, but government-supported university research was necessary to advance the technology. In other cases, such as timesharing, graphical user interfaces, and the internet, the ideas originated in the universities long before they matured to a point where subsequent research by industry helped move the technologies towards commercialization. In each example, the industry/university research relationship has been complementary. University research, focused as it is on fundamental questions and long-term problems, does not supplant industry research and development. And industry, which contributed $190 billion in 2002 (down from $198 billion in 2001) in overall R&D geared primarily towards short-term development, does not supplant university research.

This is an important point that bears some development. The great majority of industry-based research and development is of a fundamentally different character than university-based research. Industry-based research and development is, by necessity, much shorter term than the fundamental research performed in universities. It tends to be focused on product and process development, areas which will have more immediate impact on business profitability. Industry generally avoids long-term research because it entails risk in couple of unappealing ways. First, it's hard to predict the outcome of fundamental research. The value of the research may surface in unanticipated areas. Second, fundamental research, because it's published openly, provides broad value to all players in the marketplace. It's difficult for any one company to "protect" the fundamental knowledge gleaned from long-term research and capitalize on it without everyone in the marketplace having a chance to incorporate the new knowledge into their thinking.

Those companies that do make significant fundamental research investments tend to be the largest companies in the sector. Their dominant position in the market ensures that they benefit from any market-wide improvement in technology basic research might bring. But, even with that advantage, the investment of companies like Microsoft and Intel in fundamental research remains a small percentage of their overall IT R&D investment (in Microsoft's case, it's estimated at around 5 percent of the company's R&D budget), and many companies of equivalent size (Oracle, Dell, Cisco) don't invest in long-term R&D at all.

The complex nature of the chart also illustrates one other important characteristic of the IT R&D ecosystem – it's very interdependent. Note that the arrows that show the flow of people and ideas move not only between industry, university and commercial sectors, but between subfields as well, sometimes in unanticipated ways. Developments in internetworking technologies led to the development of the Internet and World Wide Web (and the rise of Yahoo and Google), but also to developments in Local Area Networking and Workstations. Work on timesharing and client and server computing in the 1960s led to the development of e-mail and instant messaging. In addition, this interdependence increasingly includes subfields beyond traditional IT, helping enable whole new disciplines like bioinformatics, optoelectronics, and nanotechnology.

Perhaps the most noteworthy aspect of the graphic is its illustration of the long incubation period for these technologies between the time they were conceived and first researched to the time they arrived in the market as commercial products. In nearly every case, that lag time is measured in decades. This, I believe, is the clearest illustration of the results of a sustained, robust commitment to long-term, fundamental research. The innovation that creates the technologies that drive the new economy today is the fruit of investments the federal government made in basic research 10, 15, 30 years ago. Essentially every aspect of information technology upon which we rely today –the Internet, web browsers, public key cryptography for secure credit card transactions, parallel database systems, high-performance computer graphics, portable communications such as cellphones, broadband last mile…essentially every billion-dollar sub-market – is a product of this commitment, and bears the stamp of federally-supported research.

One important aspect of federally-supported university research that's only hinted at in the flow of arrows on this complex graphic is that it produces people – researchers and practitioners – as well as ideas. This is especially important given the current outlook for IT jobs in the coming decade. Despite current concerns about offshoring and the end of the IT boom times, the U.S. Bureau of Labor Statistics this year released projections that continue to show a huge projected shortfall in IT workers over the next 10 years. As figure 2 illustrates, the vast majority of the entire projected workforce shortfall in all of science and engineering is in information technology. These are jobs that require a Bachelors-level education or greater. In addition to people, university research also produces tangible products, such as free software and programming tools, which are heavily relied upon in the commercial and defense sectors. Continued support of university research is therefore crucially important in keeping the fires of innovation lit here in the U.S.

Important Characteristics of Federal Support

The two dominant federal agencies in the development of the discipline of computing and the resulting innovation in IT have been the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (DARPA). The fact that the agencies have had two significantly different approaches to funding IT R&D has been an overall benefit to the discipline. Historically, NSF has focused on funding smaller awards to the individual investigator; in the process ensuring a broad range of research in the field was performed. DARPA, created in response to the Soviet launch of Sputnik and charged with insuring the nation was never caught "flat-footed" by a technologically superior adversary again, has historically focused on larger awards and building communities of researchers to address critical research problems – creating centers of excellence, many of which formed the basis of some of the top computer science departments in the country. In addition, funding opportunities at other mission-oriented agencies – NASA, Department of Energy, Office of Naval Research, the Air Force Research Labs – meant university researchers had a number of possible outlets for their ideas, and consequently, many good ideas that may have otherwise gone unfunded found their way into the knowledge base.

But in addition to a diversity of funding sources, the discipline (and, by extension, the nation) has been well-served by especially visionary program managers, especially at DARPA, drawn from university and industrial research labs who knew the discipline well and were given the flexibility to take risks with the research they supported with their program funds. As the National Research Council noted in the 2002 *Innovation in Information Technology* report:

> This style of funding and management allowed researchers room to pursue new venues of inquiry. The funding style resulted in advances in areas as diverse as computer graphics, artificial intelligence, networking, and computer architecture.

> As that experience illustrates, because unanticipated outcomes of research are so valuable, federal mechanisms for funding and managing research need to recognize the inherent uncertainties and build in enough flexibility to accommodate midcourse changes.

Unfortunately, there is significant concern building within the academic computing research community that DARPA has lost much of what made it so important to the discipline by adopting policies that discourage university participation in defense-related IT R&D. Of particular concern is DARPA's recent focus on shorter-term research efforts, its implementation of a "go/no go" decision matrix for DARPA funded research projects, the classification of research on certain topics (for example, cyber security, an area in which I know this committee has been particularly active), and restrictions on the participation of foreign nationals (e.g., U.S. graduate students who are not U.S. citizens).

The idea of "scheduling" breakthroughs or demonstrable results on 12-month timelines results in research that is evolutionary instead of revolutionary, with potential grantees only proposing research they can be sure will deliver results within the shorter timeframe.

There are, of course, important reasons for classifying federal research, especially when it's clear that the research might reveal our capabilities or vulnerabilities. However, it should also be understood that there are real costs – including that the research is unavailable for public dissemination and scrutiny, and that many university researchers, arguably some of the best minds in the country, are no longer able to contribute to the work. In the case of classifying Defense Department cybersecurity research, there is another significant cost to bear as well. The military (and the government overall) has a huge dependence on our nation's commercial infrastructure, but classifying the research in information security means that it is largely unavailable for use in protecting this commercial infrastructure.

There are additional concerns within the computing community about the under-investment in cybsersecurity research at the Department of Homeland Security, a concern I believe this committee shares. As you know, of DHS's new R&D budget of nearly $1 billion, less than 2 percent is being invested in cybersecurity R&D. And even this shockingly low level of investment was the result of Congressional outcry – DHS originally proposed less than 1 percent. IT systems constitute the "control loop" of most other elements of our nation's critical infrastructure – the electric power grid, the air traffic control grid, the financial grid, the telecommunications grid – and constitute a significant vulnerability. With the number of cyber attacks increasing annually at an almost exponential rate, it has never been more important to focus research on reducing our exposure to this threat. I applaud the subcommittee's work to focus attention on this critical issue.

PITAC is likely to examine these concerns as we move forward with our review of the nation's cybersecurity R&D effort this year.

I’d like to share one final concern about the nation’s overall research and development portfolio. While it is true that the overall federal investment in research has been increasing over the past 30 years, the vast majority of this increase has been in the biomedical fields. Compared to that, all other fields have been essentially flat. (See figure 3.) The increase in investment in biomedical fields is incredibly important to the overall health and welfare of the Nation. However, I would argue that the disproportionate funding between the life sciences and the physical sciences and engineering actually has the effect of constraining innovation and advancement in biomedical fields. Information technology, for example, has enabled huge steps forward in biomedical research and in the practice of medicine – allowing for the visualization of molecules, the modeling of cellular and physiological processes, the imaging of the human body in extraordinarily detailed ways, and the sequencing of the human genome. New disciplines like bioinformatics and nanotechnology are poised to further revolutionize the field, but are both heavily dependent upon IT research and research in the physical sciences. The federal government must take a balanced approach to funding research and development to create the environment for innovation to flourish.

The role of PITAC

PITAC is a congressionally-chartered, presidentially appointed committee charged with assessing the overall federal investment in IT R&D. The committee is comprised of 25 non-federal academic and IT industry members. I am pleased to serve as co-Chair along with Mr. Marc Benioff.

In 1997, President Clinton charged the members of his PITAC with evaluating the full breadth of the federal government’s IT R&D portfolio. The resulting report, *Investing in Our Future*, released in 1999, emphasized the “spectacular” return on the federal investment in long-term IT research and development.

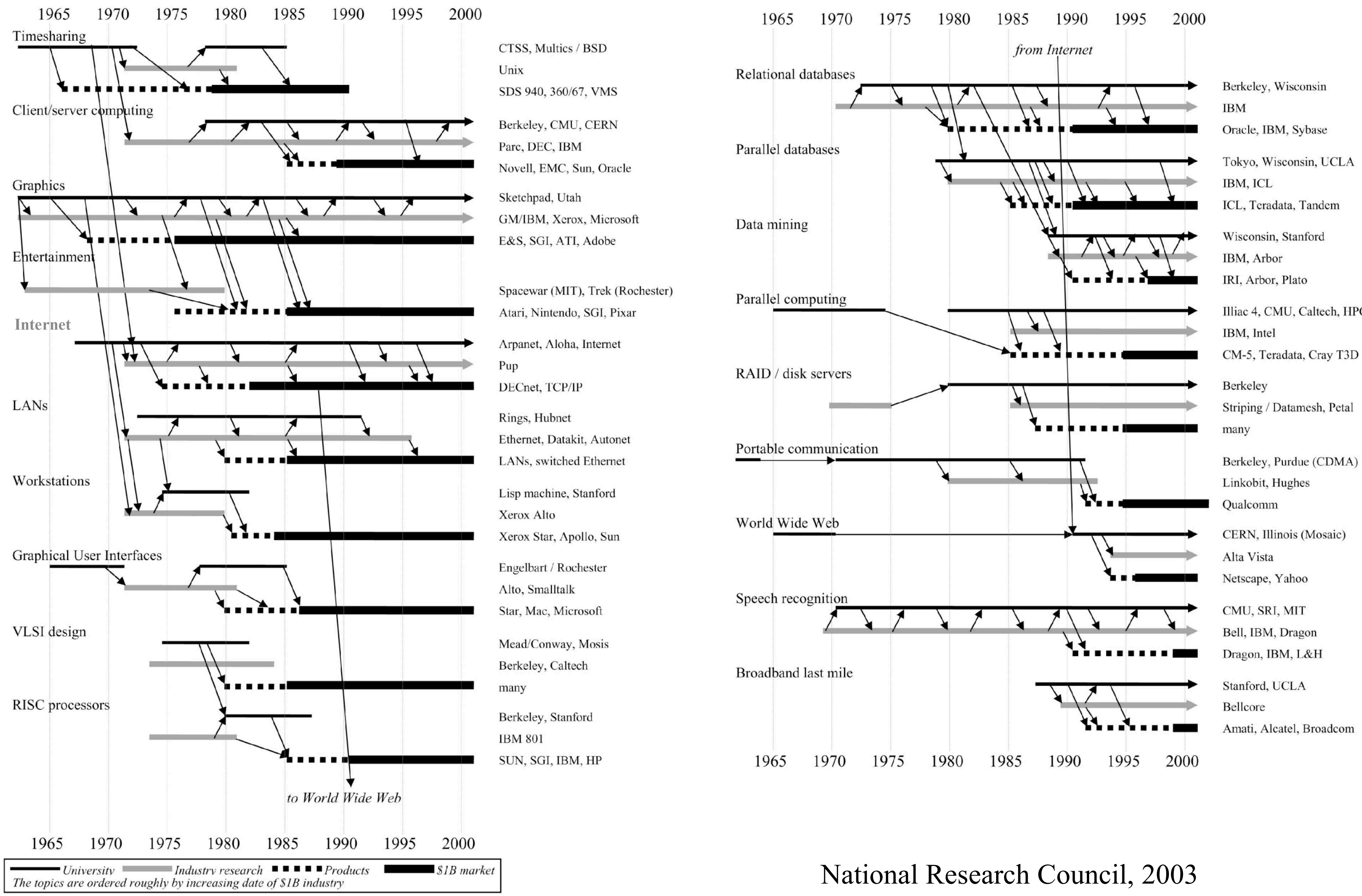
However, PITAC also determined that federal support for IT R&D was inadequate and too focused on near-term problems; long-term fundamental IT research was not sufficiently supported relative to the importance of IT to the United States' economic, health, scientific and other aspirations; critical problems in computing were going unsolved; and the rate of introduction of new ideas was dangerously low. The PITAC report included a series of recommendations, including a set of research priorities and an affirmation of the committee's unanimous opinion that the federal government has an "essential" role in supporting long-term, high-risk IT R&D. This opinion was buttressed by the inclusion of a recommendation for specific increases in funding levels for federal IT R&D programs beginning in FY 2000 and continuing through FY 2004 – an increase of $1.3 billion in additional funding over those five years. Actual appropriations for federal IT R&D have never reached the PITAC recommended levels, however. (See figure 4.)

The current PITAC was reconstituted in the spring of 2003 and has begun its work in three particular areas: IT and Health Care, Cyber Security, and the Current State of Scientific Computing. The first report of the Committee – on IT in Health Care – has been approved and should be released later this summer, with reports on the other focus areas to follow.

Conclusions

In my testimony today I've tried to make the case that the relatively modest federal investment in IT R&D has paid enormous dividends: changing our lives, driving our economy, and transforming the conduct of science. The federal investment helps fuel the innovation that insures the U.S. remains the world leader in business, that we have the strongest possible defense, and that we continue to find ways to live longer, healthier lives. To keep the fires of innovation lit, we should continue to boost funding levels for fundamental IT R&D. We should follow the recommendations of the NRC Computer Science and Telecommunications Board and insure that NSF and DARPA have broad, strong, sustained research programs in IT independent of any special initiatives. And we should work to maintain the special qualities of federally-supported university research.

Interplay of university research, industrial research, and development for IT in the US



National Research Council, 2003

Figure 1.

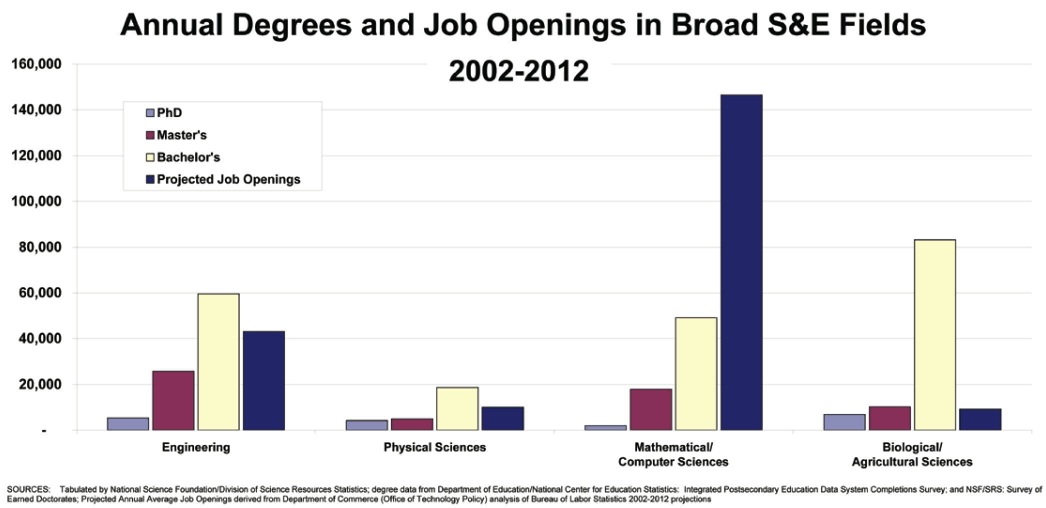


Figure 2

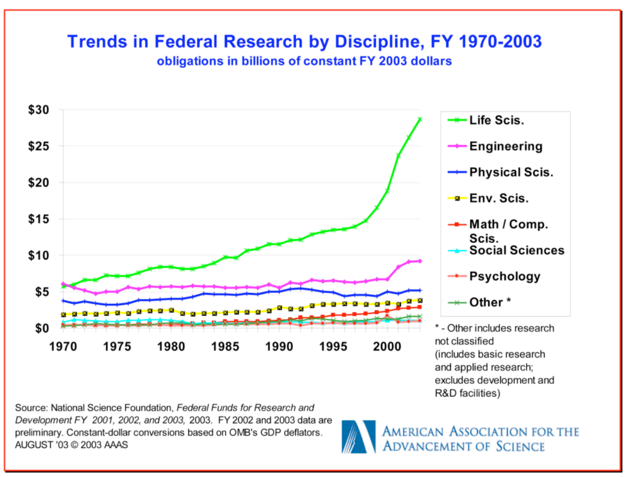


Figure 3

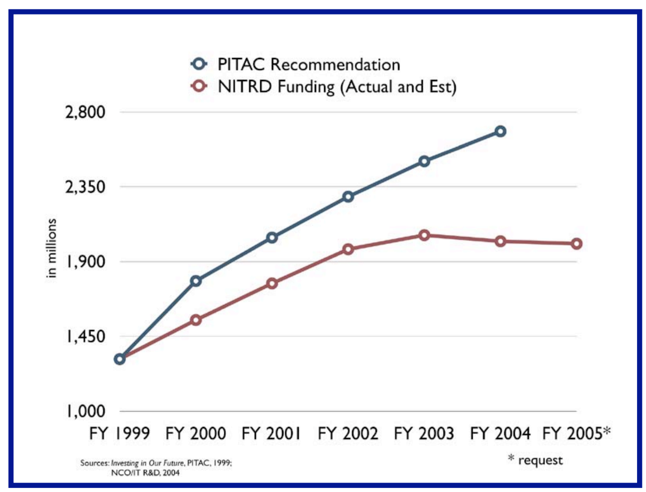


Figure 4