Computing Research: A Looming Crisis

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ABSTRACT
On June 11, Vint Cerf and Bob Kahn received computing's highest prize, the A.M. Turing Award, from the Association for Computing Machinery. Their Transmission Control Protocol (TCP), created in 1973, became the language of the Internet.

In the May 6 issue of *Science* [1], we used this as the "news hook" for an invited editorial on the current state of computer science research in the United States. "Where will the next generation of groundbreaking innovations in IT arise?" we asked. "Where will the Turing Awardees 30 years hence reside?" Our conclusion: "Given current trends, the answers to both questions will likely be 'not in the United States.'"

We take this opportunity to explore in greater depth the issues we raised in that editorial. What are the trends that concern us? What can all of us, as computer scientists, do to reverse them?

Categories and Subject Descriptors
A.0 [**General**]

General Terms
Management.

Keywords
Computing research, innovation.

1. THE PAST
Advances in information technology (IT) are changing our lives, driving our economy, and transforming the conduct of science, engineering, and many other fields.

America is the world leader in IT innovation because of a long-standing and complex interplay of universities, industry, and the federal government.

Essentially every aspect of IT upon which we rely today – every billion-dollar sub-category of the IT industry – bears the clear stamp of federally-supported university-based research. These relatively modest investments have played an essential role in the past, and will play an essential role in the future.

This "IT innovation ecosystem" has been well-studied, particularly by the National Research Council, which published a report in 2003 [2], "refreshing" a report from 1995, which illustrates the origins of nineteen different billion-dollar sectors of the IT industry. The "tire tracks diagram" of that report is reproduced as Figure 6 in this paper.

2. THE PRESENT
Recent changes in the U.S. funding landscape have put this innovation pipeline at risk. While 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 flat-lined. And the overall federal research budget has now asymptoted and actually started to decrease. (See Figure 1.)

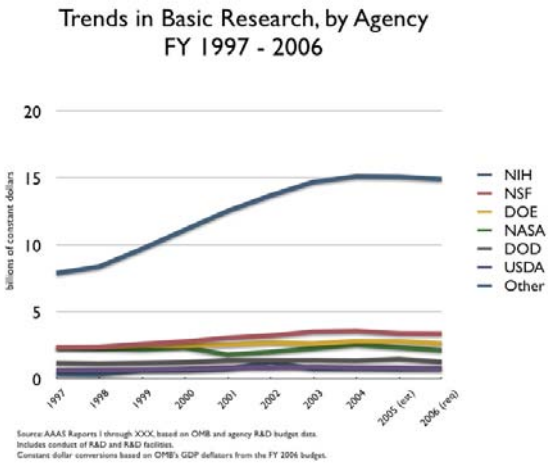


Figure 1

The situation in IT is even more grim than the situation overall. In 1999, the President's Information Technology Advisory Committee recommended a doubling of the federal investment in IT R&D [3]. Actual budgets have fallen far short of that target, and have now begun to trend sharply downward. (See Figure 2.)

2.1 The Defense Advanced Research Projects Agency
Compounding this is the behavior of certain agencies. While many federal agencies are engaged in supporting IT R&D, two of these agencies have played by far the dominant role in driving IT innovation over the past 50 years: NSF and DARPA. No other agencies come close.

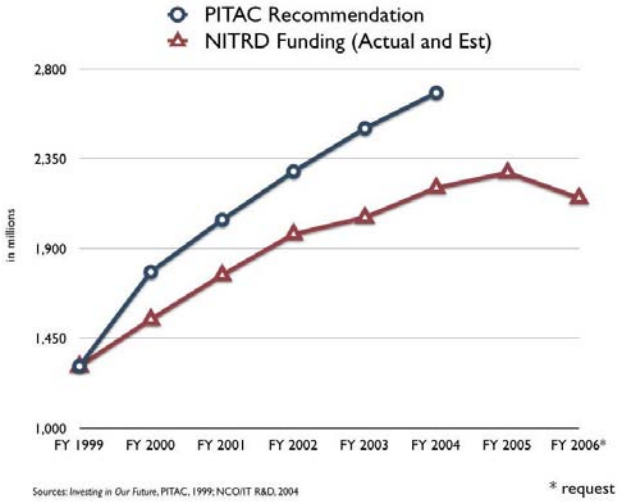


Figure 2

The Defense Advanced Research Projects Agency funded TCP. The shock of Sputnik in 1957 led to the creation of the agency, which was charged with preventing future technological surprises. From its inception, DARPA funded long-term non-classified IT research in academia, even during several wars, in order to leverage all the best minds. Much of this research was dual-use, with the results ultimately advancing military systems and spurring the IT industry.

However, in the past 3 years, DARPA IT research funding at universities has dropped by nearly half. (See Figure 3.) Policy changes at the agency, including increased classification of research programs, increased restrictions on the participation of non-citizens, and "go/no-go" reviews applied to research at 12 to 18 month intervals, discourage participation by university researchers and signal a shift from pushing the leading edge to "bridging the gap" between fundamental research and deployable technologies. In essence, the National Science Foundation is now relied on to support the long-term research needed to advance the field.

2.2 The National Science Foundation

At NSF, the strain is starting to show. Last year, NSF supported 86% of Federal obligations for fundamental research in IT at academic institutions. The funding rate for competitive awards in the IT directorate (CISE – Computer and Information Science and Engineering) fell to 16 percent, the lowest of any directorate [4]. (See Figure 4.) Such low success rates are harmful to the discipline and, ultimately, to the nation.

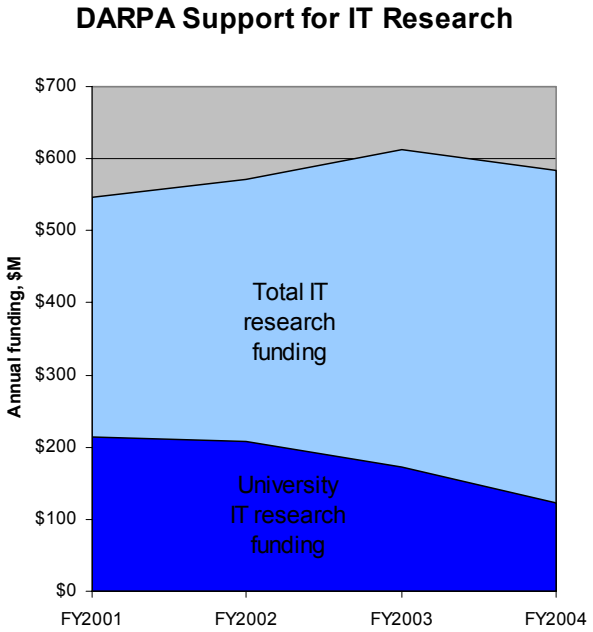


Figure 3

In certain key fields, the funding rate is far lower. For example, in FY 2004, the Cyber Trust program (information security – surely a pressing problem!) was able to fund only 8% of the proposals received [5]! One might think that the Department of Homeland Security would take up some of the slack here, but of DHS's Science & Technology budget of more than $1 billion, less than 2% is being invested in cybersecurity R&D. And even this shockingly low level of investment was the result of a Congressional outcry – DHS initially proposed less than 1%. IT systems constitute the "control loop" of most other elements of our nation's critical infrastructure (e.g., the electric power grid, the air traffic control grid, the financial grid, the telecommunications grid), and constitute a significant vulnerability.

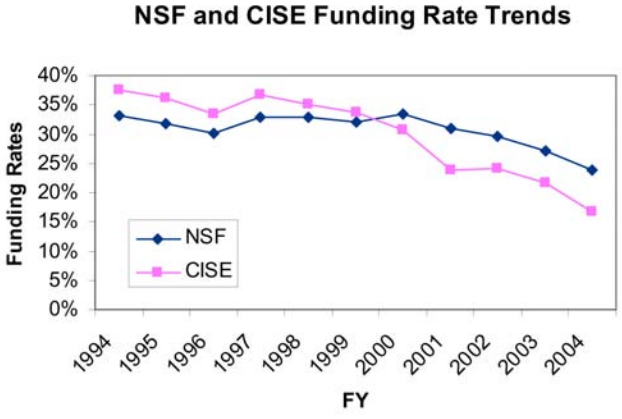


Figure 4

2.3 Workforce

An important aspect of federally-supported university-based research is that it produces people, as well as ideas. Despite what you may have heard on the news, there is a huge projected shortfall in IT workers over the next 10 years – the vast majority of the entire projected workforce shortfall in all of science and engineering is in information technology. (See Figure 5.)

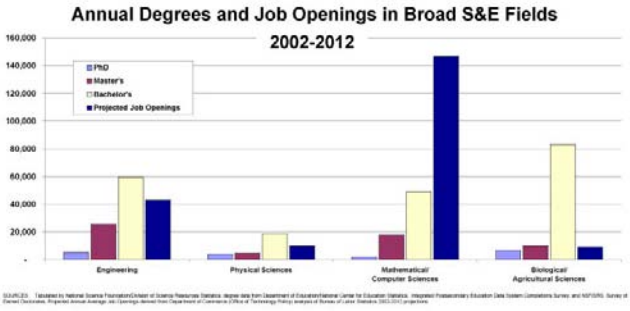


Figure 5

There is a demonstrated strong correlation between federal research investment and the production of highly qualified workers. Further, when our nation disinvests in research and education, we are pulling the plug on precisely those factors that contribute to productivity growth in the economy – precisely those factors that allow us to remain competitive despite our high standard of living.

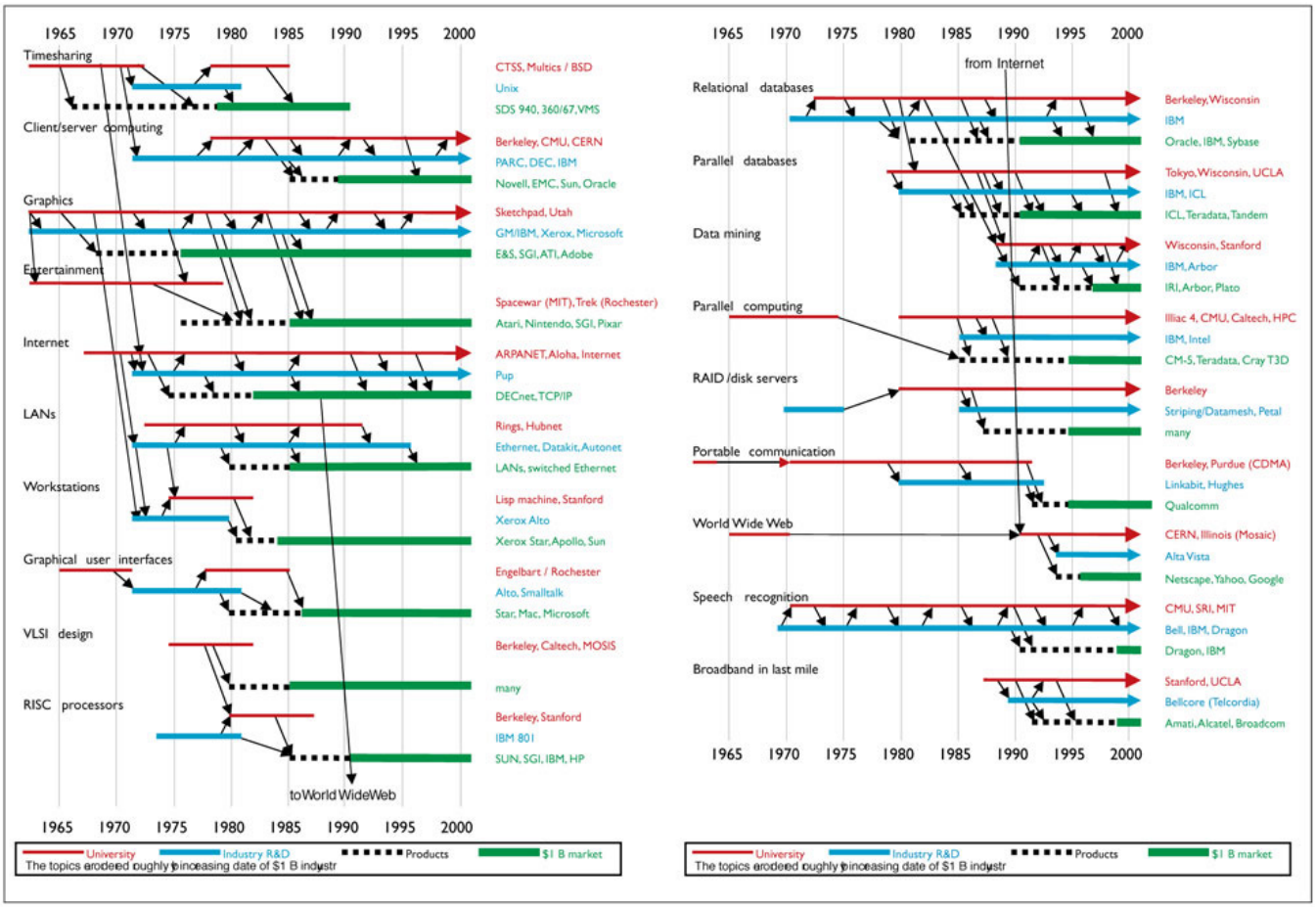
3. THE FUTURE

As members of the computing research community, what can we do to reverse these trends?

First and foremost, we must articulate a compelling research vision! In networking, a first attempt was made several years ago by The National Academies [6]. What are the problems that we can solve? What are the concomitant benefits to the nation? What are the risks if we do not succeed?

Secondly, communicate this research vision to the federal relations officer at your university or company. He or she will help you hone your "pitch," and then will carry it to others.

We have a great story! It is up to us to tell it! If we fail to do so, the future will be grim indeed – and not just for us. *Please* do your part.



Source: From [6], reprinted with permission from the National Academy of Sciences, courtesy of the National Academies Press, Washington D.C. © 2003.

Figure 6 (From [2], National Academies Press)

As we concluded our invited editorial in *Science*: "Given the importance of IT in enabling the new economy and in opening new areas of scientific discovery, we simply cannot afford to cede leadership. Where will the next generation of groundbreaking innovations in IT arise? Where will the Turing Awardees 30 years hence reside? Given current trends, the answers to both questions will likely be 'not in the United States.'" The future is in our hands.

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