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The State of Funding for New Initiatives in Computer Science and Engineering

The intellectual opportunities are huge, the social benefits transforming, yet redesigning a workable funding model for CS&E research will require our collective imagination and collaboration between many IT sectors.

Last month's "President's Letter" called for a new manifesto for the 21st century, moving Security, Privacy, Usability, and Reliability (SPUR) ahead of the 20th century goals of performance and cost [8]. This column addresses approaches and resources required to enable SPUR. I use the U.S. as the prime example, but comment more widely later.

Our field has an enviable record of advances in research that changed the world; TCP/IP, Ethernet, and RAID are just a few examples. Figure 1, from the U.S. National Research Council [7], shows 19 case studies of research ideas that led to billion-dollar IT industries. These examples demonstrate the close synergy of government-funded academic research with industrial research and product development. Similar studies in other parts of the world may have different examples, but I bet they tell the same story.

The figure suggests how to meet the SPUR challenge: Follow the proven path of starting relevant research programs in academia, funded by the government, and in industry.

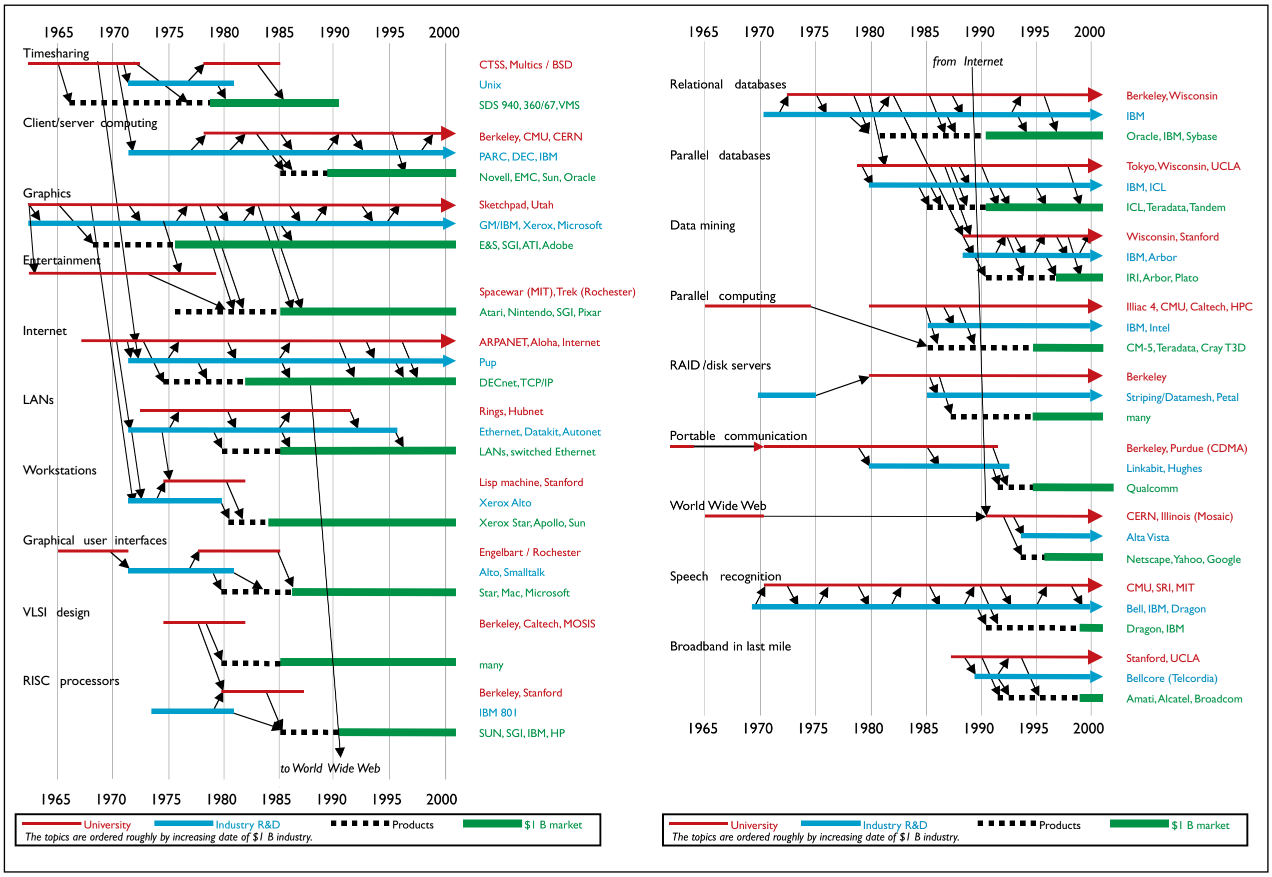
Alas, the world has changed since the heady days of the 1970s that laid the foundation of 20th century IT. While the industry has expanded dramatically, and many IT companies spend billions on research and development, little is for long-term research. For example, Microsoft spends $7.5 billion on R&D, but less than 5% on long-term research via Microsoft Research [3]. Yet Microsoft is to be congratulated, for many of the newer companies that expanded IT—for example, Cisco, Dell, and Oracle—do not make any significant investment on R&D that looks forward more than one product cycle; in fact, they have no research labs.

Traditional IT companies had research labs, and made seminal contributions, such as the Alto from Xerox PARC, the 801 from IBM Research, and Unix from Bell Labs. They generally target more near-term research today than in the 1970s, and only IBM Research is large and growing.

Hence, it appears the industrial portion of the innovation partnership has not kept pace, and so we must rely more on government-funded academic researchers to perform long-term research in the 21st century. What is its current state of that funding?

DARPA and DoD Support

For the last few decades of the 20th century, the agencies that funded most of the U.S. academic research in IT were the National Science Founda-



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

Figure 1. The "tire tracks" diagram illustrates time from concept to billion-dollar industry.

tion (NSF) and the Department of Defense (DoD) Advanced Research Projects Agency (DARPA). The funding from these two sources grew with the field over the years. For example, a study of 335,000 papers in computer science found NSF and DARPA the most acknowledged agencies [2]. The other DoD labs—Air Force Office of Scientific Research, Army Research Office, and the Office of Naval Research—supplied much of the rest of the U.S. computer research support.

DARPA funded high-risk, high-impact research based more on the vision and the reputation of researchers than on the consensus, peer-review model of the NSF. Perhaps as a result, the study [2] found that papers acknowledging DARPA had the highest mean number of citations compared to papers acknowledging other agencies. More importantly, though, the two contrasting modes of research support surely aided the rapid advance of 20th century IT research in the U.S.

It appears the industrial portion of the innovation partnership has declined, and so we must rely more on government-funded academic researchers to perform long-term research in the 21st century. What is its current state of that funding?

DARPA has changed in this century. The current DARPA director presented his view of the agency's role at a public meeting of the President's Information Technology Advisory Committee (PITAC) [11]. He said DARPA does not fund fundamental research per se, but instead innovates by rapidly bridging the gap between inventions funded by other agencies and military applications of those inventions. The chair of a PITAC subcommittee summarized DARPA's current position as [4]:

	Berkeley	CMU	MIT	Stanford
Decline in DARPA funding 1999 to 2004 (unadjusted dollars)	38%	41%	54%	46%
Proportion of funding from DARPA, 1999	18%	53%	62%	69%
Proportion of funding from DARPA, 2004	9%	20%	24%	26%

DARPA's diminishing role in top-ranking CS departments over the last decade.

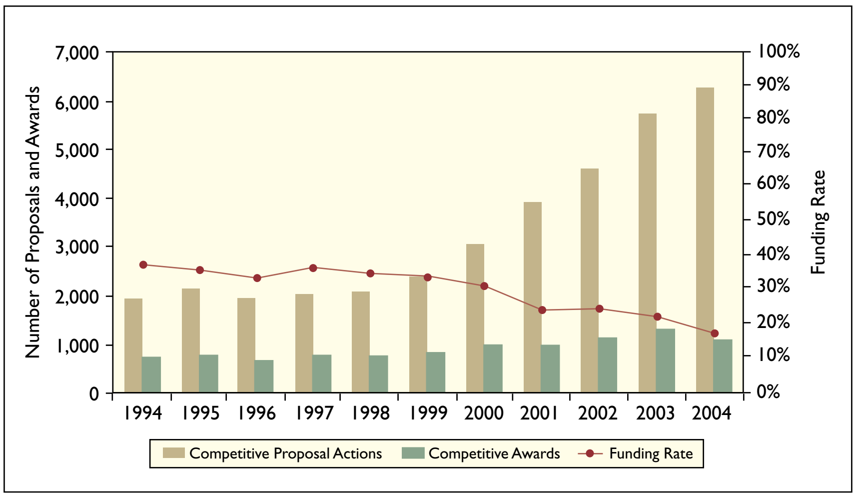
"... a departure from its historical support of longer-term research. [Its] programs are increasingly classified, thereby excluding most academic institutions—also a departure from historical support of university researchers. [DARPA] assumes other agencies, especially NSF, will fund basic research—DARPA's (new) strategy is to incorporate preexisting technology into products for the military."

Funding data is difficult to find, so we can only show the impact on a few departments. The table here shows the drop in dollars as well as the percentage of funding from DARPA in 1999 and 2004[1] for the four CS departments rated number one over the last decade in the U.S. [12]. The table shows DARPA's dramatically reduced role in these top-ranked departments.

The other DoD labs are also less likely to fund research that is long-term and more likely to fund research that is classified or have publication restrictions. Another study from the National Academy of Science found [6]:

"In real terms, the resources provided for Department of Defense basic research have declined substantially over the past decade."

Thus, recent practices of DARPA and other DoD agencies are less likely to involve academia, which in the past has been an important and successful ingredient in such research.



Source: From [1], reprinted with permission by the Computer Research Association.

Figure 2. Funding rate for competitive awards in CISE.

In addition to delivering successful research, academia also trains the next generation of leaders in a new technology. As technology transfer is a "contact sport," this new generation is critical to transferring the ideas into practice, often via startups. Hence, a drop in funding will affect the training of the next generation of IT leaders and startups.

[1]Private communication with Ed Lazowska, Feb. 2005.

Changes will likely take time, yet we cannot postpone the SPUR Manifesto, as the problems it addresses affect millions of IT users every day.

NSF and Alternatives

Figure 2 illustrates the number of requested proposals, awarded proposals, and the proposal success rate over the last decade for the Computer and Information Science and Engineering (CISE) Directorate of NSF. In the last five years the success rate has fallen from 32%, above the NSF average, to 16%, the lowest of the nine NSF directorates [1]. Since this average includes some small proposals that are normally funded, the rates in emerging areas are typically much worse. For example, NSF funded just 8% of cybersecurity proposals in 2004. At such low rates, peer review is likely to be more conservative, making it even more difficult to fund ambitious proposals.

The low funding rate is due to many reasons: the decline in DoD support, increasing the size of NSF awards, and an increase in the size of the field. The funding rate would have been much worse had not the Executive Branch and Congress not doubled the budget for CISE between 1999 and 2002, partially fulfilling a PITAC recommendation [10].

In the U.S., some hoped the Department of Homeland Security (DHS) would start funding IT research. The entire DHS IT budget is less than $20 million, and only $2 million of that is for IT research, as DHS spends about 90% of its funding on deployed systems.

Just as it would have been unwise for DARPA to expand and replace NSF, its not clear that expanding the NSF to a single funding agency is optimal for CS&E. For example, a recent article in *Science* quotes a young, award-winning scientist as saying an NSF review that begins with "This is a very ambitious proposal..." is actually the kiss of death rather than high praise. He opines [5]:

> "You learn the hard way not to send high-risk proposals to NSF ... because they will get dinged by reviewers. Instead, you're encouraged to tone down your proposal and request money for something you're certain to be able to do."

If this perception of NSF is widespread, then perhaps the lack of big idea conference papers I noted in a previous column [9] reflects the changes in research funding as much as conservatism by program committees.

If this picture of funding is accurate, it is a sobering assessment. It is difficult to imagine how to make progress on bold challenges like SPUR if long-term industrial research is down, if there is basically a single funding agency, if that agency funds less than 10% of proposals, and if investigators believe that successful proposals must look like sure things.

If the funding decline were only in one country, it might not be as big an issue for an international organization like ACM. It is very difficult to obtain data from many countries, but it appears that most funding agencies have not kept up with growth in the field. For example, the U.K.'s Ministry of Defence has reduced long-term IT research funding and proposal rates are down for other U.K. agencies.

Changing the Game

Changing government policies require public education to the importance of IT research and then informing their elected representatives. Leaders of industry can be very effective advocates for research, via op-ed pages, testimony, and other vehicles. Individuals can contact their elected representatives on such issues; it is more effective than you might expect, as few citizens comment on research. The current PITAC is tentatively recommending an increase in funding for cybersecurity [4], and it will need the support of the public to become law. The Computing Research Association has blogs and Web sites showing how to advocate for research in North America,[2] and I believe clever people can translate CRA's advice to match their own cultures.

Such changes will likely take time, yet we cannot postpone the SPUR Manifesto, as the problems it addresses affect millions of IT users every day. However, it may take a long time to restore the funding model of the 20th century IT, so we should explore new paths during this funding drought:

- Agencies can find new ways to fund innovative IT research, such as the Director's Pioneer Awards at the National Institute of Health [5].
- Find new government agencies to fund new challenges like SPUR.
- A greater challenge is to find new, synergistic ways for academic researchers to work with industry.
- Although research is traditionally federal in the U.S., California recently voted to start a $3 billion Stem Cell Research Center. One argument was to give the state a head start in the industries that could spin off from such research.[3] Perhaps a center dedicated to IT issues would be attractive to some states as well.
- A downturn in research funding by traditional IT companies and the U.S. government is opportunity for other companies and countries to take the lead in 21st century IT via initiatives like SPUR.

CS&E remains a field of huge intellectual opportunity and potentially huge social benefit—changing our lives, driving our economy, and transforming the conduct of science and commerce—but the goals and the model of research funding need work. Although reengineering the CS&E research model for the 21st century is a stiff challenge, others have overcome more difficult obstacles. Quoting Jean Monnet, a founder of European Union:

"If it's important, how can you say it's impossible if you don't try?" C

[2]See www.cra.org/govaffairs/blog/index.php or www.cra.org/govaffairs/advocacy/cran/.

[3]The California Stem Cell Research and Cures Initiative, www.smartvoter.org/2004/11/02/ca/state/prop/71/.

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