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Government Role in Technical Computing: Lessons from the United States

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Since the early 1980s, various U.S. government agencies, especially the Defense Advanced Research Projects Agency (DARPA), have been funding research, hardware and software development, purchase, and porting of applications for massively parallel computers aimed primarily at the technical market. After more than a decade of funding, scalable parallel computers are finally at a stage that applications running on several different scalables can be designed and ported with less than an order of magnitude more work than designing and porting applications to a uniprocessor or standard multiprocessor. The market for large scalable computers, however, remains limited to government-funded sites at the Department of Defense (DOD), Department of Energy (DOE), National Aeronautics and Space Administration (NASA), National Security Agency (NSA), National Science Foundation (NSF), large university centers, and equivalent international sites. Other sites, such as small universities, industrial laboratories, and state centers, continue to use smaller computers because they are not awash in grant money.

Direct Funding Flaws

Direct government funding of a company to develop a product, followed by funding of product purchases, does not appear to produce healthy companies, as exemplified by Thinking Machines' difficulties. State-sponsored computer companies (companies that have significant direct government support of their research and development, such as Cray Research, Intel computer products, Teracomputer, and Thinking Machines) are likely to impede the natural evolution of technology and product development. ARPAnet is probably the most successful funded-product development, but it can be argued that funding Bolt, Beranek, and Newman (BBN) to develop ARPAnet impeded the wide-scale adoption of packet switching because of BBN's choice of proprietary hardware and the absence of pressure to reduce costs. Furthermore, state-sponsored products create an artificial market and nonlevel playing field that deny privately funded companies the early-adopter market characterized by universities and government laboratories.

The worst effect of government funding has been to encourage too many companies to enter a tiny market. As a result of overfunding, the process of standardization has been thwarted because each company has selected some unique technology to lock in its customers, thereby reducing the number of portable applications.

Seven Heuristics on Government Support

I have derived seven heuristics from a quarter century of observing U.S. government-funded computer systems research:

1. Direct funding of university or laboratory research for technology and prototypes of products that are then carried over to start up a company or serve as the basis of new products in an existing company provides the most successful model for the development of technology and products and technology transfer that lead to significant applications.

   Funding of technology development that allows a company to start up and create new products can be effective (e.g., Evans and Sutherland's graphics processors and Kuck Associates' parallelizing compilers). The flow of Cal Tech's computer clusters to Intel is a significant transfer because it involved an existing company, even though the efficacy of the resulting product compared with the original design is questionable. In contrast, Carnegie Mellon University's (CMU) Warp, which was a "systolic" or "programmable pipeline" processor, failed to become successful at General Electric (GE), Honeywell, or Intel because none of these companies had market outlets.

2. Computer systems development has also progressed rapidly using a "demand-side" approach; that is, a customer or user who demands the latest in high-tech products but is tolerant of the setbacks that occur in introducing new technology.

   The "Livermore (or Fernbach) approach" that Sid Fernbach, former head of computation at Livermore, used to help supercomputing come into existence was to specify needs; become a purchaser; and be a knowledgeable, demanding, tolerant, and helpful customer. This approach was used successfully for supercomputers, high-speed networks, large file systems, and large-scale, high-performance graphics terminals.

   In contrast to the Livermore approach, the "Los Alamos approach" of funding its engineers to develop special devices is unlikely to create any commercial residue and is likely to be wasteful because technology transfer is so difficult. Start-ups and products that a company acquires and builds based on a lab's technology and designs are unlikely to succeed. No start-ups or significant technology or products have come from Los Alamos. Although the High Performance Parallel Interface (HIPPI, a minor derivative of Cray's interconnect) was developed there, it had a prolonged evolution and is likely (we hope) to be short-lived.

3. Direct funding of large-scale projects is risky in terms of its commercial outcome and the long-term training of staff who can work with and support new computer structures that will have broadly based applicability. An example from the early 1970s of DARPA's funding of BBN to develop packet switching for ARPAnet illustrates why direct product development and product purchase do not work well. Perhaps the only way to build ARPAnet was by funding its development by a single contractor, but an architecture and standard that allowed many suppliers to build equipment could have achieved even more-impressive results. Ironically, this was exactly what happened when universities got involved in network research.

BBN became the sole source to DARPA and the military for switching and also sold some switches commercially. To increase its prices and margins, BBN built proprietary hardware that rapidly became obsolete. BBN was a high-priced producer and the market barely moved because BBN had a sole customer—the military. Concurrently, DEC developed its own packet switching using ARPAnet ideas. With no ARPAnet implementers, the technology had to be redeveloped before commercial products could be designed. In the 1990s, computer networking is the hot area of the computing industry, and the HPCC will further expand the market. Hundreds of start-ups have been formed and some, such as Cisco (derived from Stanford) and Wellfleet, now have annual revenues of more than $100 million. These companies have grown rapidly and profitably (staffed with BBN and DEC alumni), while BBN has remained a minor supplier.

4. Funding product development, targeted purchases, and other subsidies to establish state-sponsored companies that selectively subsidize product development in a vibrant and overcrowded market is wasteful and likely to impede the development of technology by creating an overpopulated industry that then needs to be fed. State funding does not build a strong company because it establishes a safety net, which spares the company the effort to build a revenue stream sufficient to support itself. Furthermore, such a company uses its profitable government business to subsidize commercial business, thereby creating an unfair and artificial market. Because state-sponsored companies have a monopoly on the leading edge, early-adopter, university and laboratory market, privately funded companies are denied market entry.

5. University and company collaboration is a new and worthwhile area of government R&D. Any company should be free to work with a government-funded university project or laboratory to produce technology or product prototypes. Researchers should consider industrial partners based on their ability to market the product. For example, Burroughs (now part of Unisys), GE, Honeywell, and Motorola have been especially inept partners for computing because they lacked adequate market presence in the customer and application sectors where new computer structures have been most relevant. None of these efforts should have been funded.

6. Government-funded efforts should (and the marketplace will) discourage designs from companies that have not used or built a successful computer. The world is drowning in massively parallel computers that absorb programmer time chasing peak announced performance. Furthermore, the number of computers (and options) will increase over the next decade as Convex, IBM, Japanese computer manufacturers, and other companies enter the market. It is unclear whether many universities are qualified or need to develop computer systems, but universities capable of working on systems and applications software are essential to the huge software effort implicit in massive parallelism.

7. The worst effect of massive funding has been to inhibit and detract from the development of workstation-based scalable parallel processing because companies had too much money to pursue elaborate designs and too many noncompatible languages (e.g., Fortran 90/D/M/HPF and MPP Fortran).

Neither Convex nor IBM had government funds; hence they use unmodified workstations. Also, based on their experience and compiler technology, Convex and IBM have the most to offer.

About the Author

Gordon Bell is a computer industry consultant at large. He spent 23 years at Digital Equipment Corporation as vice president of research and development, where he was the architect of various minicomputers and time-sharing computers and led the development of Digital's VAX and the VAX environment. Mr. Bell has been involved in, or responsible for, the design of many products at Digital, Encore, Ardent, and a score of other companies. He is on boards at Adaptive Solutions, Chronologic Simulation, Cirrus Logic, Kendall Square Research, Microsoft, Visix Software, University Video Communications, Sun Microsystems, and other firms.

Mr. Bell is a former professor of computer science and electrical engineering at Carnegie-Mellon University. His awards include the IEEE Von Neumann Medal, the AEA Inventor Award, and the 1991 National Medal of Technology for his "continuing intellectual and industrial achievements in the field of computer design." He has authored numerous books and papers, including *High Tech Ventures: The Guide to Entrepreneurial Success,* published in 1991 by Addison-Wesley. Mr. Bell is a founder and director of The Computer Museum in Boston, and a member of many professional organizations, including AAAS (Fellow), ACM, IEEE (Fellow), and the National Academy of Engineering.

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