EDITORIAL

Research Pays Off

When it is budget-cutting time, among the usual early casualties are all forms of research. Yet the history of government-supported research shows that basic research supplies the raw materials from which useful applications can be fashioned, and applied research pays for itself many times over in the production of tax revenues, jobs, exports, and vital improvements in national security. In this essay, I consider national security to include not only military readiness but also a strong and growing economy and positive participation in global commerce.

Researchers take risks when they explore unknown territory. Some paths may lead to dead ends, others to unexpected and bountiful payoffs, but it is seldom possible to tell ahead of time what the result will be. Indeed, if there were no research "failures," one would be justified in concluding that the work was not really research at all. To achieve a high payoff, it is often necessary to take a comparable amount of risk; and failure to conduct adequate research can have disastrous national security and business consequences.

When the Advanced Research Projects Agency (ARPA) was formed in the late 1950s, its general charter was to help the nation avoid technological surprises such as Sputnik. It has since produced a cornucopia of technological results that have benefited U.S. national security in myriad ways, both directly in militarily relevant results and indirectly through expansion of the country's technology base, upon which industry has drawn to produce new businesses, products, and services not possible before. I believe that this is also true of the other government agencies that support basic and applied research.

Some critics believe that all or most applied research should be funded by industry. The trouble with this view is that a great deal of risky applied research simply cannot be funded in the context of Wall Street's thirst for quarterly profits. Publicly held corporations often have difficulty in justifying high-risk research that may not pay off for years or possibly not at all, yet sustained funding for precompetitive technology research and development is frequently the only way to uncover productive technical opportunities. ARPA provided funds for research in data networking when conventional wisdom said that packet switching was impractical and, some thought, downright crazy. The same may be said for high-performance parallel computing, for network-based chip design, and more recently for microelectromechanical systems, in which computation is merged with sensing and actuation at a microscopic level, enabling entirely new classes of applications.

ARPA's efforts to make its results widely known and readily shared have paid off in new product developments, paid for by industry and based on freely available research results, prototypes, source software, and the like. Many of the research efforts sponsored by ARPA have had 100 percent or more matching funding from industry, which afterwards puts in vastly more funding than that to create new products and services. Companies that could not justify the risks alone can do so in conjunction with ARPA and in other industry consortia cooperating with the government. The Internet's skyrocketing growth has been leveraged through industry investment hundreds of times larger than the small but persistent base of support from various U.S. government agencies, originating with the ARPANET project in 1969. ARPANET spawned packet radio and packet satellite research efforts, which were linked together to form the first three networks of the Internet. My colleague Bob Kahn started this research program at ARPA in 1973, and together we developed the basic Internet architecture and protocols (TCP/IP). U.S. government research agencies provided sustained support for this work, first to develop the technology until it became commercially available in the 1980s and then to support the standards work needed for Internet evolution. Today, the Internet is a global multibillion-dollar business. Government investment in the research over a 25-year period has probably amounted to less than $250 million.

The U.S. knowledge and technology base is second to none. Keeping it that way has paid and will continue to pay off in multiple dimensions. Support for quality applied and basic research is one of the most highly leveraged investments the government can make. I hope that the members of Congress will take time to consider this as they struggle to produce a fiscally responsible budget.

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