

# Support of Research

by David G. Messerschmitt

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Research is the ultimate driving force for the computing and communications industries. Many technologies successfully used in the industry were once the subject of research, and many future commercial advances in the industry will presumably be created in today's research laboratories. Industry supports considerable research, with the goal of deriving a financial return in future products and product improvements. What is the role of government in sponsoring research?

## Industrial Research

Industry invests considerable resources in research, although it is strongly biased toward research with a relatively short-term payoff. There are several disincentives for industrial research, and especially with a long time horizon.

Investments in research are competing against other investment options (such as production facilities or bonds) and must achieve a similar or higher returns to be justifiable from a business perspective. Thus, research in industry is justified its *return-on-investment* (ROI) in relationship to that available on other investments. ROI discounts future returns from an investment according to the interest rate available on other investments. If the prevailing interest rate is  $r$  (expressed as a fraction, like 0.1 for an interest rate of 10%), then an anticipated return  $n$  years in the future is discounted by the factor  $1/(1+r)^n$ . ROI thus values a given monetary return less and less as the time horizon increases.

There are several disincentives raised by this:

- As a financial metric, ROI doesn't take into account the wealth of future generations, but emphasizes the wealth of those making the research investment—the return on their capital. Future generations, who are not in a position to invest in research today, are often the primary beneficiaries of long-time-horizon research. While some shareholders are interested in the wealth of progeny who may inherit their stock, most (and especially institutional shareholders) discourage such justification.
- ROI rewards research with short-term payoff not only because it is discounted less in a financial sense, but also its outcomes are more visible and predictable. Few doubt that long-time-horizon research *sometimes* has large rewards, but the problem is that those benefits are unpredictable and the ROI difficult to quantify. A few major successes justify investment in a lot of fundamental research, but a more predictable reward necessitates a portfolio of research. This is not to say that industrial firms never support such research—indeed some do—but it is usually justified by secondary benefits such as staying in touch with the research community (including university researchers for benefits to recruiting), or enhancing the ability to rapidly understand and appropriate major advances by other firms.
- The patent protects some of the outcomes of industrial research from appropriation by others.

However, ROI rewards commercial exploitation only within the life of a patent. While the 20 year duration of a patent sounds like a long time, historically many fundamental research outcomes have taken longer to reach commercial acceptance. Patents also provide limited protection, as they can sometimes be circumvented by changing the method of implementation. (In this respect, patents in biotechnology tend to be more fundamental.)

## Government-Sponsored Research

Government-sponsored research, whether performed in government laboratories, universities, or industry, is an important supplement to industrially sponsored research in the computing and communications industry. Not motivated by patents, government can fund research that pursues fundamental ideas as well as practical embodiments and improvements, and outcomes can be exploited by all, maximizing public benefit (see the sidebar "Economic Basis for Government-Supported Research"). Government is also better able to advance the well-being of future generations, even though there is little evidence voters consider future generations much more than company shareholders. Finally, government has a strong commitment to education, and most government-funded research in universities has a substantial educational benefits.

If long-time horizon and fundamental research is important to the future of the network computing industry, then government funding is important to sustain. But how important is long time-horizon research to the industry? Will the major advances be made through a series of incremental steps, or are there substantial gains to be made by attempting bigger leaps? Although this cannot be answered definitively, past history provides insight. A study of this question concluded that many of the major technologies that are important in the industry today were once the subject of government-sponsored research, and in many cases the initial idea germinated in government-sponsored research [CST95]. Examples include multitasking operating systems, graphics and the graphical user interfaces, computer networking, VLSI design technologies, and parallel computing. Further, the time between the initiation of the research and the point at which these became billion U.S. dollar industries—typically from 10 to 15 years and sometimes as great as 30 years—illustrates the futility of patents in incentivizing fundamental advances.

**Example:** Computer networking research was initiated in about 1967 in government-sponsored

### Economic Basis for Government-Supported Research

Government-sponsored research has been justified by economic arguments [CST99a]. Just as information can be replicated at low cost, ideas that result from research can easily be appropriated. In fact, when one party adopts an idea it may not reduce the value of that idea to others (this is called *nonrival in use*). Further, it is difficult to put a new idea to use without revealing it, or at least revealing its possibilities. These two properties define a *pure public good*. The value of a pure public good is typically much greater for society at large than for the entity that paid to develop it. This results in a market failure mechanism—normal market incentives result in underinvestment in research because much of the benefit may accrue to free riders. Patents address this problem by preventing appropriation by others, but at the expense of a government-sanctioned monopoly that sacrifices much of the public-good benefits to society as a whole. Patents also require disclosure, permitting others to seek alternative means to achieve the same end. Well-managed government support of research maximizes the benefits of pure public goods if the results are freely disseminated.

university projects. Industrial research laboratories initiated their own research in about 1973, and computer networking became a billion-dollar industry in about 1983. Today, the industries surrounding the Internet are growing at a remarkable rate, and they may be a major economic driver for the next century. Today's young people will benefit tremendously from the investments made by taxpayers in the late 1960's.

This last example illustrates another important effect. Often a period of speculative long time-horizon research is required to qualify an idea and lower risk sufficiently that industry can justify investments in researching and commercializing that idea. Once industry joins in, it plays an important role.