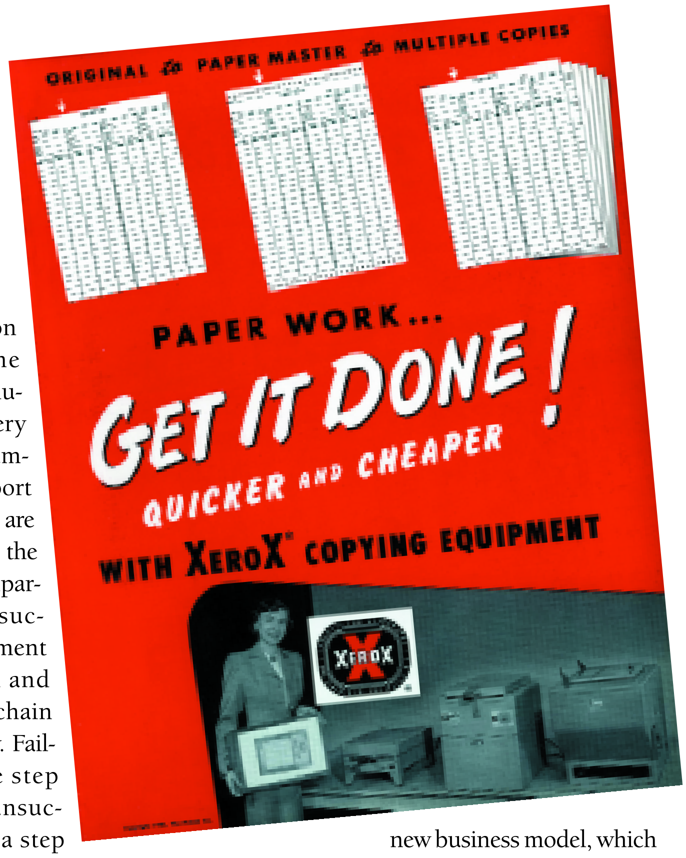
BUSINESS

by Charles B. Duke



Creating Economic Value from Research Knowledge

Creating economic value from research requires four activities: selecting a strategy for accomplishing this goal; creating potentially valuable new knowledge and intellectual property via research; connecting this intellectual property to an appropriate market demand with a complete value chain (the demanding step-by-step process by which a concept is converted into a profitable product or service); and orchestrating the flows of money and customer service to make a profit, as described in a business model. All these activities have changed dramatically during the past two decades under the impact of a geopolitical environment that is vastly modified from that of the Cold War era that followed World War II. These changes are fundamental rather than transient, and they are profoundly affecting the career and work life of every industrial physicist.

Academic research is performed to create new knowledge. Research is distinct from development, which seeks to create designs and prototypes of new products or services. Industrial research is performed to create investment options: opportunities but not obligations to carry a concept for a new product or service to the development stage. The new knowledge created in this process is embedded in intellectual property, typically patents and associated know-how. In industry, intellectual property is a business asset, typically owned by a firm, rather than a personal asset owned by an individual. The conversion of knowledge to intellectual property is the process used by firms to create assets that ultimately can be converted into economic value.

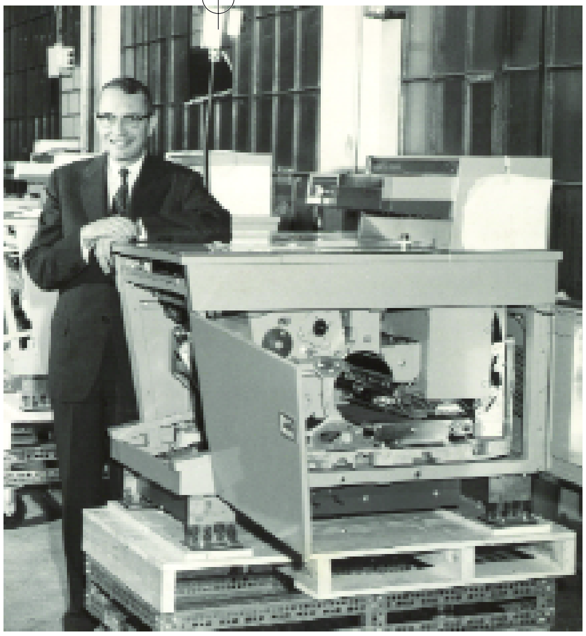
Creating economic value from intellectual property requires a value chain that links intellectual assets all the way from R&D to a final product or service in the hands of a customer. A concept is created in the research phase. Product definition and design occur in the development phase. Manufacturing, product delivery (by a sales force, for example), and customer support (including a service force) are separate but vital steps in the value chain. Studies comparing successful with unsuccessful product-development efforts reveal that each and every step in the value chain must be done adequately. Failure to execute a single step acceptably creates an unsuccessful product. Doing a step exceptionally well, however, costs more and takes longer. Thus, the key to successful product development is doing each step just well enough to meet customer requirements. This insight formed the key to the quality movement in the 1980s.

A value chain is, however, not enough. A product must create economic value for the company that introduces it, that is, a profit after accounting for all expenses, including the cost of invested capital. The creation of economic value requires a business model that outlines and tracks the flow of money throughout the value chain. A business model describes how a company makes money. Economic value is created by a company if and only if the total costs incurred in making its products and services are less than the price received for them. A business model links intellectual property and the creation of economic value through each output of the value chain.

The introduction of the Xerox 914 plain paper copier in 1959 illustrates the importance of business models. To make this copier a commercial success, Xerox invented a new business model, which was to rent the copier under contract, charge for individual copies (while providing dry ink (developer), parts, and service at no extra charge), rebuild and upgrade copiers returned by customers, and re-rent the modernized units. This approach differs dramatically from the practice—standard then with duplicating systems and common now with copiers—of selling the unit, its supplies, and its servicing separately. This marketing innovation created the fastest-growing company in American history up through the 1960s, from a product that a 1958 A. D. Little study predicted would result in at most a few thousand units. Instead, 200,000 of the 914 copiers were built and rented. Most of these machines were rebuilt and upgraded at least twice, first as the 720 model and later as the 1000. Ultimately, total placements of the original 914s reached about 600,000.

Open innovation

The end of the Cold War created geopolitical conditions that led to the rise of a global economy. Competition between nations moved from the military to the economic



Xerox Historical Archives

Joseph C. Wilson, chief executive officer of Xerox from 1946 to 1966, with one of the first Xerox 914 copiers at the production facility on Orchard Street, Rochester, New York, shortly after the copier was announced in 1959. An early advertisement for XeroX copying equipment is shown on the previous page.

sphere. The world sought peace through global prosperity. But a global economy spawned conditions vastly different from those characteristic of the Cold War. National markets and firms became global markets and firms. The information era made inexpensive and instantaneous communication a reality. Vertical industry structures gave way to horizontal industry structures. Technical talent and knowledge became plentiful, mobile, and globally available. Financial capital, especially venture capital, also became readily available. Moreover, in retrospect, all of this is no great surprise. As described by Carlota Perez in *Technological Revolutions and Financial Capital*, the world is in the midst of its 5th technological revolution in the past 300 years, with dynamics and consequences that can be broadly anticipated. Nonetheless, the unfolding of the latest information and telecommunications revolution has proven highly unsettling to the order of industrial R&D established after World War II.

The rise of a global economy has caused industrial science and technology in the United States to undergo a dramatic change, from closed innovation to open innovation. In the old closed-innovation model, companies were vertically integrated, that is, every step of the development of a new product was done in-house. A company would conceive, design, manufacture, and deliver the product, as well as support its customers. The whole value chain—from idea to product—occurred within the company. Basic research was the first step in the value chain. Large companies owned great industrial-research laboratories, such as Bell Laboratories (then part of AT&T), IBM's Yorktown Heights facility, General Electric's Research Laboratory in Schenectady, DuPont's Central Research and Development organization, and Xerox's Palo Alto Research Center (PARC). That era has disappeared.

Open innovation is the new business paradigm in American industry. Under open innovation, a company's value chain no longer exists fully within the company. Ideas, people, and products flow across company boundaries, to and from other companies, universities, and countries. Innovation is now a global game characterized by both cooperation and competition among firms and nations. Apple Computer buys disk drives from IBM; Amgen buys rights to leptin, a weight-loss protein, from Rockefeller University; IBM builds personal computers using chips from Intel and an operating system from Microsoft; and Lucent Technologies' Bell Laboratories sells its inventions to other companies to develop. Companies are less insular; they are a part of a complex web, or innovation ecosystem, as the President's Council of Advisors on Science and Technology described it earlier this year. Under open innovation, a multiplicity of paths leads through different companies, universities, and countries—from concept to customer.

As a consequence of this free flow of ideas, people, and products, in-house basic research is dying out in industry. A problem with closed innovation in a global economy is the inability of companies to capitalize on their research discoveries. Research sometimes creates concepts that have no obvious fit with a company's business model. In the 1970s and 1980s, PARC proved to be an exceptionally innovative research institution within Xerox. Yet for years, its inventions contributed little to the corporation's bottom line. During that period, PARC practically created the modern era of personal computers and networks through inventions so deeply novel that no one could see how to use them immediately to improve the company's existing lines of light-lens copier and duplicator products. Eventually, these innovations became the basis for Xerox's highly successful DocuTech line of networked digital production presses that created the print-on-demand industry in the 1990s.

However, those same inventions, when acquired by other companies and modified for other purposes, created new industries and generated far more value for others than for Xerox. The combined value of the companies founded on work at Xerox PARC—3Com, Adobe, and others—is now more than twice the value of Xerox itself. Closed-innovation companies restrict themselves to live within narrow business models, whereas many of their research discoveries can prosper only outside those models. Because such companies did not reap adequate rewards from basic research, they have stopped regarding such efforts as a valuable investment.

Examples of the new open-innovation model include Intel and Cisco, companies that have minimal in-house research groups. These companies leverage their research budgets by partnering with academia, other established companies, and start-ups. In 2000, Intel outsourced its research in 300 grants totaling $100 million. The new model aims to maximize the capture ratio—the number of ideas used divided by the number of ideas generated. As noted in Merck's annual report for 2000: "Merck accounts for about 1% of the biomedical research in the world. To tap into the remaining 99%, we must actively reach out to universities, research institutions, and companies worldwide to bring the best of technology and potential products to Merck. The cascade of knowledge flowing from biotechnology and the unraveling of the human genome—to name only two recent developments—is far too complex for any one company to handle alone." And at Intel, according to Paolo Gargini, its director of technology strategy, "The point is to make excellent chips, not to publish brilliant papers."

Industrial physicists

The combined influence of these changes has exerted profound effects on the careers of physicists in industry. Companies have essentially abandoned unfettered basic research of the sort performed in universities and funded by the U.S. government. Industrial research increasingly concentrates on conceiving and designing new products and/or value chains rather than on exploring physical phenomena. Physics careers in industry now center almost exclusively in development, where the physicist serves as a subject-matter expert on a cross-functional team conceiving or designing a new product or service.

In such a role, the industrial physicist may want to consult with academic colleagues for help in solving problems in areas in which she or he has only a passing knowledge. Thus, the new open-innovation paradigm has created new career opportunities for academic physicists as consultants and partners to their industrial counterparts. It has also opened new business opportunities for organizations such as the member societies of the American Institute of Physics to create the easy availability of such partnering arrangements via the Internet. Indeed, the success of a physicist in industry is increasingly based on the acquisition and exploitation of good people skills, such as teamwork, team organization and management, networking, and contributing to the activities of others, especially those on the same team.

The rise of the global economy, in short, has caused the Bell Laboratories era of industrial research to morph into the Intel era. Industry, and the nation, must now rely on intimate contacts between industrial and university researchers to continue to grow the seed corn of the next technological revolution. The post–World War II institutional arrangements for incorporating the knowledge created by basic research into a stream of new products are now obsolete. Eventually, perhaps soon, today's arrangements will have to be replaced with new ones, or the nation's economic prosperity will falter. Critical skills in this new arena include the ability to assemble and manage complete value chains to transform the fruits of research into economic value. The creation of new knowledge per se is, at best, only one input among many. Firms pursue new knowledge for themselves only if they cannot outsource this task to a more competent supplier such as a university, a national laboratory, or a specialized start-up firm.

This profound change is engulfing us all as the information era matures, bringing with it the globalization of science and technology as well as business and industry. Nations that lead technological revolutions acquire the power and influence to create strong defense and economic prosperity for their peoples. Those that lose their nerve or make the wrong investments fall by the wayside. The challenge for the United States is to orchestrate its academic, governmental, and industrial research into a new and improved engine of innovation that will ensure that we lead the next technological revolution.

Further reading

Chesbrough, H. W. *Open Innovation*; Harvard Business School Press: Boston, 2003; 272 pp.

Christensen, C. M. *The Innovator's Dilemma*; Harvard Business School Press: Boston, 1997; 225 pp.

Christensen, C. M.; Raynor, M. E. *The Innovator's Solution*; Harvard Business School Press: Boston, 2003; 288 pp.

Pell, E. *From Dream to Riches: The Story of Xerography;* Xerox: Rochester, NY, 1998; 225 pp.

Perez, C. *Technological Revolutions and Financial Capital*; Edward Elgar: Northampton, MA, 2002; 225 pp.

Rosenbloom, R. S.; Spencer, W. J.; Eds. *Engines of Innovation*; Harvard Business School Press: Boston, 1996; 278 pp.

BIOGRAPHY

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