cessful book. Despite the presence of a few problems—an arid first chapter that is rather disconnected from the rest of the volume is the biggest one—there is a lot offered here for both the specialist and the general reader. The book elevates the methodology of the case study to a level that has been previously seen only in such organizational classics such as *Union Democracy*. Most important, it reminds us of a basic truth of organizational and social life: the natural and rigid distinctions that frame our most important decisions are not necessarily either.

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A Cooperative Innovation

The American Synthetic Rubber Research Program. PETER J. T. MORRIS. University of Pennsylvania Press, Philadelphia, 1989. xii, 191 pp., illus. $34.95. The Chemical Sciences in Society.

Evaluating the effectiveness of research programs has been a problem that has plagued every industrial research director since Willis Whitney joined General Electric's new and pioneering laboratory in 1900. Because technological innovation is a process that encompasses a much larger sphere than the immediate laboratory environment, the relationship between a research program and any innovation is a complex one. At opposite ends of a spectrum, researchers can provide a host environment into which outside developments can be implanted, or they can invent and innovate radically new technologies. In this small book Peter Morris attempts to say some big things about research and innovation. Through the example of the research arm of the American synthetic rubber program, Morris asserts that cooperative research is less productive than proprietary research between competing firms, the reason being that companies undertake research to develop patented products or processes that will give them a competitive advantage. In making this assertion, Morris assumes that major developments score the most points in the research contest; but before accepting the final tally on his scorecard, it is necessary to put the research program in a broader perspective.

In late 1941 as the Japanese Empire spread into Malaya and the Dutch East Indies, the United States found itself cut off from its supply of natural rubber. To remedy this situation, the wartime government managed a massive effort to create a synthetic rubber industry based on a butadiene-styrene copolymer developed in Germany in the 1930s. American rubber companies had done some work in this area, but low prices of natural rubber had kept the work in the laboratory stage. Not only were there economic problems but technological ones as well; the rubber companies knew how to make tires, but their knowledge of petrochemicals and polymerization was limited. The wartime program overcame these obstacles—production went from virtually nothing in 1943 to 850,000 tons in 1945—because the technical capabilities of the chemical, oil, and rubber companies were combined in a cooperative effort that probably could not have happened in peacetime. Overall, synthetic rubber was a successful innovation.

In this book, Morris focuses more narrowly on the official "research" arm of the project. Founded in October 1942, this effort was initially headed by Robert R. Williams, an experienced Bell Telephone Laboratories chemist and an expert on natural rubber. Over the next year Williams enlisted 12 universities to join the program, the key figures being Carl Marvel at Illinois, Piet Kolthoff at Minnesota, and William Harkins and Morris Kharasch at the University of Chicago. Other participants were the major rubber companies, Bell Laboratories, and the National Bureau of Standards. During the war when the large-scale production of a standardized product was the goal, the researchers' role was troubleshooting and doing fundamental studies of the process and polymer. Even Morris agrees that this research was largely successful, even though it failed to develop an all-synthetic-rubber truck tire. That problem would not be solved until the mid-1950s when it became possible to make synthetic natural rubber.

After the war the government did not turn over the synthetic rubber plants to the private sector immediately because there was considerable uncertainty about the ability of synthetic rubber to compete against its natural counterpart. For strategic reasons the military wanted America to have the capability to be self-sufficient with regard to this critical material. In addition to the military concerns, the government had invested $677 million, which it hoped could be partly recouped by auctioning the plants to private industry. For these reasons, the government-funded research program continued after the war with the general goal of improving synthetic rubber until it was comparable in price and properties to natural rubber. This goal was accomplished in the late 1940s and early 1950s, but the major innovations—cold polymerized butadiene-styrene rubber, oil-extended rubber, and synthesized natural rubber—all came from outside the program. Major new innovations that come from outside established industries are commonplace in the history of technology. Very often the rewards of invention do not go to those who make the breakthrough but to those who innovate making maximum use of the new technology. This appears to have been the case in the postwar rubber industry.

With synthetic rubber on a sound economic and technological footing, the government auctioned the plants to industry in 1955, raising over $260 million. At this point the government research program was disbanded after having spent $56 million over 13 years. After 1956, funding of new synthetic rubbers fell to the military. Although a number of commentators, including Morris, have lamented the alleged waste of money by the civilian program, no one has cast a critical eye at the military programs. Industrial and academic scientists who had benefitted from the government program probably were happy to see the funding shifted to the military, where outside criticism would be muted by the exigency of the Cold War.

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Words About Invention

Inventing for Fun and Profit. JACOB RABINOW. San Francisco Press, San Francisco, CA, 1990. x, 278 pp., illus. $18.75. History of Technology Monographs.

Engineers are notoriously nonverbal, preferring to think and work in the media of drawings and numbers. When they put pencil to paper, it is more than likely to sketch a new idea or to calculate a new arrangement of materials and things. But engineering drawings and calculations are not ends in themselves, for they serve mainly to communicate the artifact to other engineers, to machinists, and to technicians. When the artifact is realized in tangible form, the drawings and calculations are often forgot-