

An Approach to Invention

Numerical Control. Making a New Technology. J. FRANCIS REINTJES. Oxford University Press, New York, 1991. xvi, 223 pp., illus. \$39.95. Oxford Series on Advanced Manufacturing, 9.

Numerical Control is a straightforward narrative of the invention of a method of automatic machining of metal—now known as numerical control or simply NC—at the Servomechanisms Laboratory of the Massachusetts Institute of Technology between 1950 and 1960. The book further traces the work of the following decade, as the NC project evolved into general research on computer-aided design (CAD).

The author, professor emeritus and senior lecturer at MIT, was an active participant in both phases of this work. His narrative draws from personal recollections, correspondence and interviews with other participants, and voluminous files at MIT. The main chapters of the book chronicle the day-to-day events, highlighting the actions of key persons, critical decision points along the way, and technical hurdles the lab faced. Reintjes says in the preface that his narrative “contains no comedy, intrigue, drama, nor confrontations, because there were none” (p. xii). He is being too modest: the development of this technology was accompanied by a lot of tension and conflict, and his narrative does convey at least some sense of the drama.

The Servomechanisms Lab took on this project because of the U.S. Air Force’s desire for tooling that could make the complex parts required for new generations of supersonic, jet-propelled aircraft then being designed. For the first phase of this program, the Air Force invested \$1.05 million; in return it got a system that met those needs. Reintjes further states that the NC system transformed metalworking in general and gave the U.S. machine tools industry “five to ten years lead time,” once that system had spread to other applications (p. 169). The benefits to American manufacturing were thus many times the \$4 million the Air Force invested, although “its exact magnitude may never be tallied” (p. 173).

That leads to a primary theme of the book, namely an analysis of the Servomechanisms Laboratory and how and why it was such a fertile environment for technical innovation. The author emphasizes again and

again that the university environment, with its stream of students who graduate and go to work in private industry, constantly renews itself and thereby avoids the stagnation and sterility he asserts is typical of corporate or government research labs. He also ascribes the Servomechanism Lab’s success to its insistence on a “systems” approach to problems, an approach skillfully promoted by the lab’s founder, Gordon S. Brown.

These assertions, which the author makes in his concluding chapters, and which also appear in the foreword by Brown, reveal a dimension to the book that goes beyond the chronological narrative. Reintjes tells the story of NC’s invention in a simple, direct fashion, but neither he nor Brown can avoid the fact that there has been a precipitous decline in American manufacturing capability, especially the machine tools industry, since 1980. Nor can they ignore the charges by some writers that MIT’s shaping of NC technology is at least partly to blame.

Chief among these critics has been David F. Noble, whose *Forces of Production* (Knopf, 1984; reviewed in *Science* 227, 47 [1985]) criticized the MIT approach as being overly complex and too much concerned with taking control of the work away from skilled machinists. Reintjes acknowledges Noble’s criticism, as well as that from Seymour Melman, who argues that the Air Force’s involvement unnaturally skewed NC development toward very large machines and away from the small-scale work that was the life-blood of the machine tools industry. Reintjes rebuts both critics in the book’s afterword, but he is not overly concerned with either of them. Indeed, both he and Gordon Brown feel that what is needed today is simply *more* government-industry-university collaborations like the NC project. And Reintjes emphatically rejects criticism of the Servomechanism Lab’s systems approach, employing a carefully reasoned argument about the nature of modern technology and its use in a society. But *Numerical Control* is neither a policy paper on modern American competitiveness nor a rebuttal of David Noble’s view of history. The author feels that there are already enough of both. Still, it would be a shame if the two camps, who share a concern for machine tool technology and for those who work in that industry, only talk past one another.

One major theme of this book is how the Servomechanisms Lab, faced with what they saw as a modest proposal to automate a function of machine tooling, chose instead to start with a clean sheet of paper and look at the entire process of metal-working from a “systems” perspective. The result was a system that was radically more versatile than the “Cardamatic” scheme initially presented to MIT by John T. Parsons, to the benefit of all. It was the lab’s insistence on drawing a wide circle around the problem that Reintjes praises; it was the complexity of the resulting system that others criticize.

The book’s conclusion, however, with its discussion of the decline of the U.S. machine tool industry after 1981, suggests something more: perhaps MIT did not draw its circle wide enough. But how wide would it have had to be to prevent the loss of America’s technological lead? Reintjes suggests some simple factors, such as the inherent conservatism of the machine tool industry, bred during the Depression. But ultimately he recognizes that the causes of this decline are deeply rooted in fundamental policies of America’s political and economic “systems.” Could MIT have insisted that *these* be modified, as it insisted that Parsons’s conception be abandoned? Perhaps not. But that implies a deterministic view of history that goes against everything that *Numerical Control* describes. It is no fault of the author’s that he provides no satisfying answer to this question. This book is rather to be praised for presenting so well a case study that brings such issues into clear focus.

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Collaboration in Japan

The Market and Beyond. Cooperation and Competition in Information Technology Development in the Japanese System. MARTIN FRANS-MAN. Cambridge University Press, New York, 1991. xvi, 333 pp., illus. \$54.50.

In recent years many popular and academic analyses of Japanese industrial policy and cooperation among rival firms in research and development have appeared. Martin Fransman, a reader in economics at the University of Edinburgh, approaches these issues as a specialist in technology policy and development economics, rather than in Japanese studies or science and engineering. He links himself to Adam Smith and *The Wealth of Nations* in the concern with why some nations perform better than others economically, as well as to Oliver Williamson and

Alfred Chandler in the concern with how markets affect economic and technological development. On the basis of research conducted during a year spent at the University of Tokyo, Fransman provides descriptions of major Japanese cooperative projects in the areas of computing, related electronic devices, and optoelectronics, as well as conceptual discussions of technical change, economic development, and what he calls the "Japanese technology-creating system."

There is one overview chapter on the development of Japanese computer and device technology between 1948 and 1979, and then the organization of particular projects is examined in a series of case studies: the VLSI (very-large-scale integrated circuits) Project, 1976–1980; the Optical Measurement and Control System Project, 1979–1985; the Japanese Supercomputer Project, 1981–1989; the Future Electronic Devices Project, 1981–1990; and the Fifth Generation Computer Project, 1982–1991. Some of the case studies contain details that are not easily accessible in English, notably those on the Supercomputer Project, which promoted research on high-speed gallium arsenide and Josephson junction devices, and the Optical Measurement Project, concerned with optoelectronic integrated circuits. The case studies are followed by an analysis of the history and current status of cooperation and competition in these sectors of Japanese industry.

Fransman's main point is by no means original, but it is correct and perhaps not universally accepted by economists: that one must look beyond market forces to understand all the factors that influence the process and institutions of technical change. In particular, he argues that "for-profit" companies, even in Japan, do not have sufficient incentives to conduct basic research. A related notion is that of "bounded vision," that is, that organizations' views of what is important are constrained by their existing activities, profit motives, and other forms of self-interest. This, too, is hardly a new idea for readers familiar with organizations and administrative theory, particularly Herbert Simon's idea of "bounded rationality."

According to Fransman, bureaucrats from the Ministry of International Trade and Industry (MITI) during the 1950s, '60s, and '70s acted on the belief that cooperative research would help Japan catch up with the West, especially with IBM in computers. Since market forces did not spontaneously encourage firms to cooperate, the Japanese developed national research programs, focusing initially on catching up with the West and then on creating new technology. Even within Japanese national programs, however, Fransman concedes that Japanese firms

have still been too competitive with each other to cooperate very extensively, and he cites the scarcity of joint patents.

He does argue that the Japanese have conducted some cooperative R&D successfully because of how they have organized it. First, they have pursued two kinds of cooperation: coordinated in-house research, where companies work individually but with some external coordination; and joint research, where companies send personnel to joint facilities. The former has been the dominant form of cooperative research in Japan because of the competitive nature of Japanese firms, although Fransman believes that the joint form leads to more true creation and sharing of knowledge. Second, the Japanese have allowed some firms to dominate projects by sending more researchers, thus recognizing the value of "tacit knowledge": know-how that can be obtained only by direct participation in a research group. It follows that a firm that sends more researchers to a project than other participants can learn more and thus has incentives to cooperate; secondary participants can also learn under this arrangement. In addition, Fransman argues that, rather than "pre-competitive research" (which he sees as a "contradiction in terms" because all knowledge eventually affects competition), the Japanese do "oriented basic research"—basic research that is guided by specific, detailed goals and that might be called long-term applied research. As a result, projects usually achieve something.

While these are interesting and important ideas and the book should interest academics, managers, and policy-makers concerned with cooperative R&D in Japan or in general, there is not much in it that will be new to observers of Japan who are familiar even just with English-language sources. The underlying arguments can be found in works of Chalmers Johnson, Marie Anchodoguy, Kenneth Flamm, and Ronald Dore, among others; better English sources exist on specific projects, such as the VLSI and Fifth Generation Computer efforts; and there also exists a large collection of studies, both theoretical and empirical, of the management of technological innovation in R&D labs, transfer of technology among and within firms, and information sharing. None of this, nor the large economics literature on cooperative research among rivals, is cited. Nor is Fransman's key conclusion new, though it is correct: that Japanese government subsidies provided more money for research than would have been available otherwise, albeit without promoting much knowledge sharing across firms, and that these funds and even limited knowledge diffusion probably pushed Japanese industry

forward faster than it would otherwise have moved, although firms were clearly going in the same directions anyway.

The most disappointing chapter is the most ambitious sounding: "Cooperation and competition in the Japanese computing and electronic devices industry: a quantitative analysis." Rather than an economic analysis of industry concentration and levels of competition or of cooperative research, the "quantitative" in this heading refers to numerical answers to a short questionnaire concerning four cooperative projects filled out by senior managers from four Japanese companies. The questions dealt with the managers' perceptions of the intensity of competition and their assessments of the benefits of the cooperative projects. The proper way of doing such an analysis is to sample a much larger number of managers and perhaps researchers and subject the responses to some sort of statistical analysis that would tell us something about their reliability or consistency. The idea of a questionnaire such as this is a good one, but in its present form the quantitative analysis does no more than assign numbers to subjective impressions of a few managers.

Finally, the author has squeezed into the book various things he learned or found interesting while in Japan, regardless of whether they fit with his story about cooperative R&D. There are hasty references to Japanese "just-in-time" (JIT) inventory control practices, total quality control (including an appendix that maps out NEC's TQC system with no discussion), and other Japanese modes of operation or organization that seem to encourage information flows suitable for stimulating incremental innovations. Elaborating on these observations and relating them to the other material in the book would have made a unique contribution.

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Interpreting Fossils

Owls, Caves and Fossils. Predation, Preservation, and Accumulation of Small Mammal Bones in Caves, with an Analysis of the Pleistocene Cave Faunas from Westbury-sub-Mendip, Somerset, U.K. PETER ANDREWS. University of Chicago Press, Chicago, IL, 1991. viii, 231 pp., illus. \$39.95.

The fossil record is not an unbiased snapshot of the past. To interpret it properly, paleontologists must understand the various processes that have affected fossil assemblage-