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.

PAUL E. CERUZZI
National Air and Space Museum, Washington, DC 20560

Collaboration in Japan

The Market and Beyond. Cooperation and Competition in Information Technology Development in the Japanese System. MARTIN FRANSMAN. 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