Systems of Control

Forces of Production. A Social History of Industrial Automation. DAVID F. NOBLE. Knopf, New York, 1984. xviii, 409 pp. + plates. $22.95.

This is a deliberately provocative book. It takes as its target the notion of "technological determinism," which "absolves people of responsibility to change [the status quo] and weds them instead to technological projections of those in command" (p. xiii). David F. Noble's aim is "to shatter such habits of thought . . . to demystify technological development and thereby to challenge and transcend the obsessions and fantasies that artificially delimit our imagination and freedom of action" (p. xiii). The vehicle that Noble has chosen for this enterprise is the development of automatically controlled machine tools after World War II, and, in particular, the triumph of numerical control (N/C) over alternative systems. His case study, says Noble, demonstrates that "the process of technological development is essentially social" and that within it "there is always a large measure of indeterminacy, of freedom" (p. xiii).

The range of indeterminacy never extended, of course, to the perceived problem, which was to achieve for general-purpose machine tools the kinds of efficiencies that special-purpose machine tools had long since gained in mass production—in effect, to streamline the set-up process for small-batch, precision runs. The long-term assault on this problem had made steady headway, culminating during the 1930's in a tracer technology that enabled milling machines to do automatic contour cutting under the guidance of templates. During World War II a quantum leap, deriving from servomechanical and electronic advances in weapons-control systems, brought within reach fully programmable machine-tool control. Although at this point, in Noble's view, a fairly wide range of possibilities existed, he identifies two main avenues of advance, relating to the locus of control—that is, whether control would be lodged on or off the shop floor. A shop-floor locus had its best shot in the record-playback system, which captured on tape the motions of a machine tool run initially under manual control. Under numerical control, on the other hand, guidance of the machine tool was derived from mathematical computations—in effect substituting a numerical program for the skills of the machinist and thereby making the programmer in his remote office the master of machine-tool set-up. Though not necessarily incompatible with degrees of shop-floor intervention, N/C had the capacity wholly to monopolize the translation of design specifications into instructions and to transmit those instructions directly to the machine tools. It was in this optimum form that N/C came to prevail in American machine-tool automation after World War II.

There is much to recommend in Noble's handling of this tangled story. His approach has the great merits of, first, considering the alternative lines of technological development, and second, exploring the social-political context in which innovation took place. And, though much of the history will be familiar to specialists, there are areas in which Noble breaks fresh ground. This is true especially of his treatment of the decisive role of the Massachusetts Institute of Technology in N/C development, which is based on MIT's archives; of the access he gained to John T. Parsons's files, which enables him to tell that manufacturer-inventor's sadder side of the N/C story; and of his extensive use of interviews with many of the participants, which illuminates much that is masked or absent in the written record. Finally, Noble has a talent for conveying difficult technical matters in terms that are understandable to the lay reader. Altogether, he has written a valuable and accessible history of a major strand of modern American technological development.

Noble would not, however, want his book to be judged by this limited criterion. He has bigger fish to fry—he aims at nothing less than a full-scale analysis of the nature of American technological development. And here, unfortunately, his book comes off rather less well. The general thrust of his argument is in itself unexceptionable. Since the work of Thomas S. Kuhn on the Copernican revolution, certainly, historians have become acutely aware that science and technology have been the creatures of the cultures in which they developed. Noble's account makes clear that the triumph of the N/C system must be understood within the context of Cold War military thinking and of a potent applied-science establishment. Noble, however, has a more specific case to make. He attacks the subject from a Marxist perspective, arguing that technology is an expression of class relations and, more specifically, that technological choices are made that maximize managerial domination of workers in the labor process. N/C prevailed because it was seen as superior to rival systems at undercutting the autonomy of machinists and shifting control into the hands of management.

The difficulties that Noble encounters in making that case permeate his book. He must, for one thing, contend with the intractable facts that two of his key actors—the Air Force and MIT scientists—favored N/C for reasons far removed from concerns over labor-management relations. Noble suggests that "the ideology of total control" (p. 266) of the military and scientists was somehow linked to the managerial concern for control over workers—and that "these military and technical impulses, financed and justified in the name of national security and scientific progress, reflected, complemented, and furthered the aims of management in industry" (p. 85). This is too evasive by half. What we need is some careful weighting that will indicate the relative importance of the managerial as against the military and scientific inputs into the adoption of N/C, and this Noble never gives us. How much importance did management attach to N/C as a mechanism for shop-floor control? Noble is never lacking for the right kinds of quotations, but the actions of industry speak quite otherwise. By Noble's own account, industry was highly reluctant to adopt N/C and for at least 20 years did so only to the extent that it was underwritten by military contracts. At the start of his case study of General Electric's experience with N/C at its Lynn plant, Noble asserts that "GE viewed N/C as the latest step in a familiar direction—the key to total managerial control" (p. 266). If this was GE's vision—and Noble offers no evidence—it was swiftly shattered. At this point, a remarkable change of tone creeps into Noble's account. So omnicompetent in the abstract struggle for class domination, American management turns into a bunch of bumblers in the real world of Lynn, Massachusetts. On installing N/C in the aircraft engine department (and nowhere else), GE cut the ratings of the machinists there, sparking a revolt that amply demonstrated that N/C had not deprived them of their power on the shop floor. Desperate for production, GE thereupon embarked on one of the more remarkable experiments in conceding workers a high degree of autonomous workplace control. As for Noble, he can only comment lamely on the "central contradiction" of a control system that attacked "the very people upon whose knowledge and good will the optimum utilization, and the cost effectiveness, of N/C ultimately depended" (p. 269).

By the dogmatism of his approach, ironically, Noble has done something of a disservice to the thesis he is advancing. For it is becoming a well-established fact that the struggle over shop-floor control constitutes one of the central—and perhaps distinguishing—themes of American working-class history. We need empirical studies of this problem, not the certitudes that Noble espouses in this book. Beyond that, Noble has done something of a disservice to his own quite genuine achievement at writing technological history. It would be a shame if readers were deflected by what is dubious in this book—and by its tone of moral hectoring—from benefiting from Noble's excellent account of the development of the N/C technology.

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The Interior of the Earth

Materials Science of the Earth's Interior. ICHIRO SUNAGAWA, Ed. Terra Scientific Publishing, Tokyo, and Reidel, Boston, 1984 (U.S. distributor, Kluwer Boston, Hingham, Mass.). xvi, 653 pp., illus. $120. Materials Science of Minerals and Rocks.

Compared with the vast amount of information that we have gathered from space, we have very little information about the earth's interior, according to Sunagawa. In response to this argument the Japanese government in 1978 funded a three-year interdisciplinary research program aimed at improving our knowledge of the materials of the earth. This book is a collection of research papers prepared at the end of the program. The volume is the first in a series of advanced textbooks entitled Materials Science of Minerals and Rocks.

The 31 papers in the volume provide a view of the operation of Japanese science and of the unique contributions Japanese scientists have made to this field. The most striking aspect of the research program is the breadth of interests it evidences. In addition to the traditional earth science disciplines, there is strong representation from materials science, solid state physics, and chemistry.

An understanding of the earth's interior requires an understanding of the properties of the constitutive materials. These properties can be determined only after the successful synthesis of samples, preferably in the form of single crystals. Several papers are devoted to crystal growth. Sunagawa discusses natural single crystals, emphasizing their growth conditions and processes with particular attention to diamonds. Takei *et al.* have been very successful in using the floating-zone method to grow large crystals of materials that melt incongruently, such as ferromagnesian olivines. Akimoto *et al.* describe crystal synthesis at elevated pressures and temperatures, using as an example the growth of a large single crystal of a nickel silicate spinel within a host single crystal of the low-pressure olivine phase.

Roughly two-thirds of the book has the objective of understanding the properties of the earth's materials. The other third is devoted to inferring the earth's state and processes, and here the coverage is diverse and somewhat spotty. Chemical analyses of argon isotopes and trace elements in natural diamonds lead Ozima *et al.* to conclude that diamonds are derived from material that was originally subducted into the mantle as oceanic crust. From high-temperature–high-pressure (27 GPa) experiments, Ito concludes that the 670-kilometer discontinuity in seismic velocity could be a result of the phase transition of ferromagnesian silicates to a perovskite phase and magnesiowustite. Several papers discuss the role of water, both in the mantle and as a chemical reagent associated with the formation of ore bodies.

Though the volume provides an excellent discussion of the current understanding of the materials science of the earth's interior, it does not cover every aspect of this vast field. For example, it does not express the excitement generated during the past decade by the use of diamond anvil cells to obtain extremely high pressures, which has produced significant results concerning properties of earth materials.

The book demonstrates that Japanese laboratories are extremely well equipped. Most noteworthy is the fact that facilities such as those described by Kumazawa and Endo for conducting large-volume experiments at pressures greater than 8 GPa have been developed in a dozen Japanese laboratories. In contrast, there are as yet no such facilities in the United States. Though this disparity is a reflection of the different orientations of the research, it is also a reflection of the nature and style of funding in the United States over the past several years. The book demonstrates the type of research that can be accomplished with such equipment and provides a model for non-Japanese national programs.

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Volcanic Deposits

Pyroclastic Rocks. R. V. FISHER and H.-U. SCHMINCKE. Springer-Verlag, New York, 1984. xiv, 472 pp., illus. $49.50.

Pyroclastic rocks do not readily fit into traditional classification schemes. They are the result of explosive volcanic eruptions and have both igneous and sedimentary affinities; the material making them up is mostly of igneous origin whereas the mode of emplacement is essentially sedimentary. In the dynamic environment of their deposition, they may be modified, eroded, redeposited, or intermixed by either igneous or sedimentary processes. During the first third of this century investigators who were making great progress toward understanding both igneous and sedimentary processes largely ignored the pyroclastic rocks, perhaps because of their complexities or their ill-defined classification niche. Even though violently explosive eruptions were the cause of most great historic volcanic disasters, such as Vesuvius (A.D. 79), Krakatau (1883), and Pelée (1902), little heed was paid to the shattered remnants of exploded magma, and, until recently, geology textbooks contained but cursory descriptions and discussions of them.

Intriguing papers about the massive deposits from the 1912 eruption near Katmai, Alaska, sparked interest in pyroclastic rocks, and in the 1930's and 1940's pyroclastic deposits began to be used as clues to interpret prehistoric volcanic events and to solve regional stratigraphic problems. By the 1950's geologists were discovering that many massive sheet-like deposits initially thought to be lava flows were actually of pyroclastic origin. Since 1960 the rate of publication of papers on the rocks has been almost as explosive as the process-