

## BOOK REVIEW

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Donald Mackenzie, Knowing Machines: Essays on Technical Change (Cambridge, MA: MIT Press, 1996). Inside Technology Series. 338 pp.. Notes, index, figures, illustrations. \$35.00 (hardcover).

In Knowing Machines, just as in his extraordinary Inventing Accuracy (1990), Donald Mackenzie blends the best elements of sociology and history. From sociology, Mackenzie brings theoretical sophistication and a keen sense of the many-dimensional, often contradictory character of knowledge and practice in vivo. From history, he brings a gift for beautifully crafted narratives, backed by definitive documentary research. His supple, fluent weaving of the two traditions and their techniques avoids the pitfalls of each, while strengthening the possibilities of both.

Mackenzie has reflected deeply upon recent lessons from the sociology of scientific knowledge, especially actor-network theory (ANT). ANT holds that materials and physical principles rarely determine unique paths to the conception, design, or long-term success of a technology. Instead, new artifacts succeed to exactly the degree that their proponents can enroll people, institutions, and things in heterogeneous “actor-networks” which support them. The social elements of actor-networks affect competition between designs by determining the efforts, resources, and loyalties committed to each. ANT’s prescription for historical insight is to make the actor-network, rather than the artifact, the unit of analysis.

These themes won’t surprise T&C readers. But Mackenzie’s rendition of them is a cut above the rest. More than almost anyone writing today, Mackenzie grasps the practical relevance of sociological theory to real, momentous issues. Yet theory does not dominate this book. Mackenzie’s exceptionally lucid, sober writing masks a passionate engagement with some of the most pressing issues of our times, including nuclear weapons proliferation and safety-critical computing. In his hands, social constructivism leaves relativist dogma behind in favor of hard-headed, historically grounded analysis.

Knowing Machines collects nine previously published articles. In a new introductory chapter and two theoretical essays, Mackenzie cuts to the heart of current debates over the relative roles of economic, social, and material factors in technological change. First, he revisits Marx. Neither economic nor technological determinism, Marx’s account of the machine as a durable, material anchor for the once strongly resisted social system of wage labor still offers a central lesson: that technological change must be seen within the larger context of capitalist political economy. Second, Mackenzie attacks the idea —

popular among economists — of “natural trajectories” of technological change. Physical reality constrains technical possibilities. But within those constraints, impartial attention to the real conditions of both failures and successes reveals that any given technology’s “momentum” may stem more from self-fulfilling prophecy than inherent technical superiority. One design’s marginal advantage quickly becomes overwhelming when developers lavish money, research, and social commitment upon it.

The following chapters cash out these theoretical arguments through case studies. In a fascinating piece on laser gyroscopes, Mackenzie traces their roots to the famous 1880s Michelson-Morley experiments on the speed of light. Those experiments did not, as many believe, resolve the question of the ether. Indeed, the scientific result which eventually inspired the laser gyroscope (the “Sagnac effect”) formed the basis for a 1913 “proof” that the ether did exist. Mackenzie then shows that despite seemingly definitive advantages (no moving parts, long lifespan, high accuracy), laser gyroscopes turned out to be far more expensive and complicated to build, and far less accurate under real-world conditions, than theory alone had suggested. Only a vast, two-decade effort — involving social persuasion and marketing as much as technical design — eventually made laser gyroscopes the standard in civilian aircraft guidance systems.

Five subsequent chapters explore aspects of computer technology. One describes the profound influence of American nuclear weapons laboratories on the development of supercomputers from the 1950s on. With their heavy demands for particular kinds of computation, such as Monte Carlo simulation and vector processing, the labs’ needs shaped computer designs. As the principal market for the world’s fastest computers, they also shaped the very meaning of computer “speed.”

Two essays address the momentous issue of formal correctness proofs for computer programs and hardware designs. Since these are essentially logic structures, some computer scientists argue that such proofs are both possible and highly desirable. Mackenzie shows that this view depends upon a distorted image of the nature of mathematical proof. The validity of certain essential principles of proof, such as the law of the excluded middle, remains hotly contested — and cannot itself be proven. Most “proofs” of computer programs do not meet mathematicians’ standards anyway. Thus correctness proofs cannot definitively guarantee the real-world functioning of computer programs. Mackenzie predicts that issues like these will soon be litigated in the courts.

The penultimate chapter quantifies human deaths directly resulting from failures either of computer systems or of human-computer interactions in which the computer played a critical role. The toll to date, Mackenzie finds, is around 2000. However sobering, this number also inspires some guarded optimism, for it could be far larger. “Self-negating prophecies” of computer-caused disaster, promulgated by an extremely conscientious and vocal technical community (primarily computer scientists), have become a major force for the public good.

In his final chapter, Mackenzie asks what would happen if a total ban on nuclear weapons testing were to remain in force for, say, two generations. He argues that the complex knowledge required to design and construct working nuclear explosives contains a substantial “tacit” component, possessed only by a tiny and shrinking cadre of experienced designers. Such knowledge can be acquired only through direct, hands-on experience (and not, for example, purely through work with computer simulations). Mackenzie predicts, perhaps too optimistically, that this obstacle could prevent future

would-be nuclear powers from building bombs rapidly and secretly enough to escape the notice of the international community.

Mackenzie's prediction of litigation over correctness proofs has already come true, with lawsuits (settled out of court) over the British VIPER microchip project. Let us pray with all the power we can muster that his second prediction comes to pass as well.