Between Human and Machine: Feedback, Control, and Computing before Cybernetics. *By David A. Mindell.* Baltimore: Johns Hopkins University Press, 2002. xiv + 440 pp. Index, notes, bibliography, figures, illustrations, photographs. Cloth, $46.00. ISBN 0-801-86895-5.

Reviewed by Thomas Haigh

As its subtitle suggests, this book is a history of the quintessentially cybernetic concepts of feedback and control in the decades immediately before there was such a thing as cybernetics. Cybernetics was to the 1950s what chaos theory was to the 1980s: a new way of looking at the world that, according to breathless and best-selling books, would rearrange the intellectual landscape by uncovering the fundamental regularities underlying apparently disparate natural and social processes. Mathematician Norbert Wiener coined the term in his *Cybernetics, or Control and Communication in the Animal and the Machine* (1948), which argued with rambling verve that the hitherto obscure concepts of feedback (positive and negative) and systems (open and closed) would, when properly applied, model everything from nervous systems to economies. Cybernetic systems language was seized on by ambitious young experts in fields from biology to management science as a way of injecting theoretical rigor into overly fuzzy disciplines. From the beginning, cybernetics was entangled with the newly invented technology of the electronic computer, the newly formalized mathematics of information theory, and the newly coined concept of automation.

Chronologically speaking, Mindell stops almost exactly where the story of cybernetics formerly started, with Wiener’s work. What we thought we knew, from the work of culturally and intellectually inclined analysts of science and technology like Peter Gallison, Andrew Pickering, Paul Edwards, and David Noble, was that Wiener’s World War II work on automated antiaircraft fire-control systems and universal theories of feedback led to a profound conceptual rupture with the past. This work, performed under the direction of mathematician Warren Weaver and wartime science planner supreme Vannevar Bush, thus profoundly shaped the Strangelovian mentality of the early cold-war decades. Wiener, Weaver, and Bush have become archetypal figures, as historians spin modern fables about the birth of new relationships—between science and the state and between technology and humanity.

In contrast, Mindell depicts this wartime work as an extension of what had gone before. Throughout the book, he focuses on distinct, local communities of engineering practice and their interaction with new mathematical techniques. Early chapters explore the long history of naval fire-control systems developed by the Ford Instrument Company and document Sperry Gyroscope's creation of semiautomatic control systems for ships, planes, and antiaircraft guns. One key chapter, already published as an award-winning article, documents the evolution of electric feedback amplifiers and control theory at Bell Labs. Another recounts the parallel development at MIT of new computation and simulation techniques to improve electric power networks. This produced the differential analyzer, the most powerful and generalized analog computation device of its day. (Those interested in the history of computing will find James S. Small's recent *The Analogue Alternative: The Electronic Analogue Computer in Britain and the USA, 1930–1975* [2001] a valuable complement to this story.)

The second half of the book edges into more charted territory, to focus on the wartime efforts of Bush's National Defense Research Committee (NRDC) to use scientific brilliance to improve fire control and radar. Much of this work took place in MIT's newly formed Servo Lab and its massively expanded Radiation Lab. Mindell does not dispute our earlier impression that this hothouse environment led to a fundamentally new and generalized understanding of feedback and control systems, in which mechanical, electronic, and human components were conceptually equivalent. But rather than a cybernetic eureka moment, this achievement appears instead as the conjunction and assimilation of the distinct prewar engineering traditions so carefully documented in earlier chapters. The mechanical devices developed and manufactured by Sperry were integrated with new control techniques developed by the mathematically and computationally skilled MIT staff and with theoretical tools originally developed for telephone engineering.

Mindell shows that Wiener's own account of the history of feedback deliberately ignored the importance of interwar engineering work and of pragmatic, military-driven development work during the war. Wiener instead strove to place cybernetics in a highminded nineteenth-century tradition of science and philosophy, striving for universality and elegance. Mindell's sympathies lie more with engineers struggling to solve real and pressing problems. His discussion of the NRDC emphasizes its commitment to short-term, practical projects and balances the influence of elite scientists and mathematicians with the less well-documented importance of expertise drawn from the military contractors and engineering cultures of the time. While acknowledging Wiener's brilliance, Mindell points out that his design for a statistical antiaircraft predictor was far too complicated to be useful during the war, noting that the NRDC terminated this project in favor of simpler, equally effective alternatives.

Mindell performs a valuable task by pinning down the origins of a number of concepts. He documents the often overlooked use of the word "computer" prior to 1945 to describe mechanical control devices, and demonstrates that many of the key ideas in Claude Shannon's famous late-1940s codification of information theory were articulated by telephone engineers as early as the 1920s. He also argues that the systems integration approach associated with cold war projects, such as the development of the Atlas missile, had its origins in the wartime work of MIT's Radiation Lab and its efforts to assert systemwide authority over military contractors, government departments, and the rival Servo Lab.

Though based on Mindell's doctoral dissertation, this is his second book to be published, following *War, Technology, and Experience Aboard the USS Monitor* (2000), winner of the Society for the History of Technology's Sally Hacker Prize. The story flows smoothly. Mindell's prose style is exemplary, achieving clarity and elegance while generally avoiding ostentation. Archival sources underpin every chapter, but the text is refreshingly free of excessive quotation or blow-by-blow summaries of meetings, minutes, and memos. Throughout, Mindell gets inside one machine after another, giving us an idea of what it did and how it worked, explaining what assumptions formed the basis of its particular design. His lavish use of illustrations helps a great deal here. In some cases this is supplemented with considerable technical detail, particularly in the discussion of early feedback amplifiers. In other cases, he edges into epistemological issues with discussion of the relations of models and analogs to reality. Overall, there is just the right amount of substance to give us a sense of the principles involved, without being drowned in a sea of facts.

The primary audience of this book will be historians of technology and science. Those with an interest in the history of engineering firms and the early relation of high-technology contractors to military projects will find much of potential relevance here. This is not, however, a book written with much reference to the business history literature or to more general managerial issues.

Excellent as this book is, it leaves much work to be done in exploring the relation of these pre-1945 developments to the events of the immediate postwar period, in which many of the groups and individuals it describes went on to become leaders in the evolution of early computer projects. While Mindell does allude to these matters, his grasp of the subsequent history of computing seems less sure, as in his erroneous claim (p. 306) that the EDVAC, designed as a successor to the ENIAC, was never built. Another implicit issue is more important. It has long been apparent that attempts to apply cybernetics to areas beyond engineering worked largely as metaphor, rather than as a truly universal discipline. Mindell has now shown that engineering communities produced their own local versions of "cybernetic" concepts independently from Wiener, and apparently continued to rely on them subsequently. Why, then, should historians care about cybernetics at all? Answering this question will surely require us to abandon cybernetics itself as a neutral category, one that usefully describes a wide range of postwar technologies and scientific knowledge, reinterpreting it instead more narrowly as an intellectual marketing tool and cultural phenomenon. Mindell drops hints in this direction but leaves us mostly alone with the challenge of reinterpreting postwar cybernetics in the light of his findings.

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