other a materials scientist and laboratory administrator, characterize their approach here as "science criticism." They are "presenting a case, based on our discussions with a number of scientific managers in government, industry, and universities" (p. 2) and have (p. 139) "reserved the right . . . to be outrageously unscientific and play our hunches, aided by our experience, research, and exchange of ideas with experts." (Brief responses from some of those experts are included at the end of the book.)

The authors believe that the elevation and success of basic science have led to an undervaluing of applied science, engineering, and technology. They trace this situation to Vannevar Bush's 1945 "blueprint" for federal science policy, *Science—The Endless Frontier*. Bush's report was indeed a call for federal support of basic research. However, the authors note, "It does not treat basic research in a vacuum, but as one of the steps in a chain of endeavor that leads to industrial advance, better health, and stronger national defense" (p. 7). Unfortunately, Bush cited a "perverse law," this being that "applied research invariably drives out the pure" (p. 15). Shapley and Roy take the view that the converse may be happening in today's science policy environment.

The problem began with the use to which Bush's ideas were put in the 1950's. The scientific profession—based in the universities and led by such spokesmen as Alan Waterman, first director of the National Science Foundation—created an ideology to rationalize support for basic science. This ideology reached its zenith with President Reagan's science adviser George Keyworth, who strongly supported basic research and generally opposed federal involvement in nondefense applications. The administration's assumption is that industry will serve the function of creating useful technologies.

In effect, Shapley and Roy contend that the interests of basic scientists and the present conservative political leadership work in tandem, with the United States the loser. The patterns and ideology of the past 40 years will not be adequate to the realities of the future. In the meantime, other nations, particularly Japan, are showing that an applied research policy can pay dividends even in the absence of a significant basic research effort.

What is to be done? "First, U.S. science should be reorganized to give equal weight to undirected basic research, purposive basic research, applied science, engineering, and technology." And "Second, there should be a change in the values of our scientists, particularly young people starting their careers, to stress the *interconnections* among disciplines, institutions, and across artificial barriers and obstacles now separating basic and applied science, engineering, and technology" (p. 18).

Shapley and Roy are with those who believe the federal government, rather than the market or state and local governments, should play the lead in applying science to national problems. There is relative consensus today that the federal government is relevant at the "front end" of the research and development continuum and that industry and other users should dominate at the "back end." The issue is who does what, under what conditions, in between. Recent attempts to achieve agreement have focused, as the authors have, on concepts such as "purposive" basic research and "generic" technology. Some federal efforts relevant to applied research have been launched (for example, the new NSF program of Engineering Centers). These are exceptions to the general trends, however, and in the absence of a coherent national policy applied research programs rise and fall on the winds of political sentiment, seldom lasting long enough to accomplish what their creators would have hoped.

Shapley and Roy's book is not as deep and penetrating as many readers might like, and their broad-brush treatment may militate against their winning converts. After all, the connections between basic research and applied science, engineering development, and operations are elusive and complex, and there are numerous examples of failures in federal applied research efforts. Moreover, it is almost impossible to separate applied research from the purposes of policy in which it is embedded. If there is to be change, its potential beneficiaries must assert their claims more forcefully. Who will gain from the reforms Shapley and Roy espouse? Who speaks for applied science in America? Toward what ends? Whose ends? What is the applied science constituency? What are the incentives for the scientific profession to shift from the relative continuity and comfort of basic science to the conflict and change of applied research?

These questions notwithstanding, Shapley and Roy have highlighted an important issue. There is a need for a national science and technology policy that provides a framework for linking not only science and technology but also federal, state, local, and private institutions. Such a policy requires political and administrative leadership and a long-term approach. It is still not clear what should fill the gap and how. But this book may encourage a better debate of the issues.

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The American Telephone Industry

The Telephone Enterprise. The Evolution of the Bell System's Horizontal Structure, 1876–1909. ROBERT W. GARNET. Johns Hopkins University Press, Baltimore, 1985. xxvi, 212 pp., illus. $22.50. The Johns Hopkins/AT&T Series in Telephone History.

The Anatomy of a Business Strategy. Bell, Western Electric, and the Origins of the American Telephone Industry. GEORGE DAVID SMITH. Johns Hopkins University Press, Baltimore, 1985. xxiv, 238 pp., illus. $20. The Johns Hopkins/AT&T Series in Telephone History.

From Invention to Innovation. Long-Distance Telephone Transmission at the Turn of the Century. NEIL H. WASSERMAN. Johns Hopkins University Press, Baltimore, 1985. xxvi, 162 pp., illus. $17.50. The Johns Hopkins/AT&T Series in Telephone History.

The history of the American telephone industry is, of course, largely the history of the Bell System/AT&T, its attainment of monopoly status, and the successive challenges to its hegemony by dint of early competition, changing technology, and the advent of public regulation. The dramatic divestiture decision of 1983, the effects of which are revolutionizing the communications sector, closed out a distinctive epoch in American business history. The early landmarks in the history—all of which are reconsidered in the three books under review—included the 1879 market-division agreement by which Western Union left the telephony field to the Bell System; the Western Electric agreement of 1882, by which Bell acquired a manufacturing arm; the formation in 1885 of AT&T as a long-distance service company and keystone of the projected national network; and AT&T's acquisition of the Pupin circuit-loading patent in 1900, vital to restoring the national hegemony of the company in the telephone business.

To the historian of American law, the "natural monopoly" characteristics of franchised telephonic communications systems make the AT&T story a fascinating case

study of both the management of technology by entrepreneurial leaders and the impact of public utilities regulation. To the student of business organization and management, the Bell companies' record is a historical treasure trove of lore and data on both vertical and horizontal integration strategies. It also illustrates how standardization, integration, and a balance of centralized and decentralized management control functioned in a giant national firm grappling with the diverse problems of manufacturing, operations, and marketing. For historians of science and technology, the Bell System's development offers an opportunity to analyze the process of invention, application, and diffusion (or, in some parts of the story, purposeful nondiffusion); the relationship of business strategies to patent management and R&D; and, both in the record of Western Electric and then in the Bell Laboratories, the institutionalization within the business structure of organized industrial research. This is a case in which an integrated technological system developed in nearly complete congruence with a single firm's boundaries.

The history of Bell/AT&T in all these aspects has attracted attention from numerous scholars in the past. There is an excellent literature on the telephone monopoly, especially with regard to how expansion of the communications market, pricing, and the application of available technology were all adversely affected by the monopoly. The burden of scholars' findings has been to substantiate the judgment of one of the company's chief legal counselors in the 1880's that the firm constituted "a monopoly more profitable and more controlling—and more generally hated—than any ever given by any patent."

There is also a large body of first-rate historical analysis of the telephone industry's pioneering role in development of organized industrial research; and several recent scholarly works have probed the "internal" history of telephone and communications technology, both in relation to basic science of the period 1870 to 1920 and in relation to the changing goals of the engineers.

The three new works reviewed here go beyond the existing literature and cast new light not only on Bell's history but also on some leading interpretative themes in the scholarship on American business history. These books are the initial offerings in a new series in telephone history that will be based upon the vast archival records of AT&T. Unlike many "company histories" in the business literature, these studies are not sequential, comprehensive works that deal with chronological periods; they are monographs on special themes, complementary and in some measure overlapping. Apparently AT&T has taken the initiative in defining certain themes for investigation, and it has extended financial support. Editorial direction is exercised, however, by a senior member of the Johns Hopkins history faculty, and the authors assert that they have been given complete freedom of access and interpretation.

Still, a patron's influence can work on scholars in ways well familiar to those who populate the world of sponsored research. To the credit of the three authors whose work is reviewed here, there is abundant material in these studies revealing the classic robber-baron tactics that have often been termed "predatory" in the critical literature. It should come as no surprise, however, that the general tone and rhetoric of these studies betray little criticism of the firm's basic strategy to "occupy the field" and monopolize it. The reader is not given full analysis, for example, of statistical data that rather compellingly indicate enormous differences in AT&T pricing policies, profits, and service-expansion rates during the periods of monopoly and during the periods of competition. Nor is there much of substance on the firm's public critics or on the important antitrust and other prosecutions undertaken (or threatened) over the years against the local companies or AT&T. The perspective largely reflects that of the company's inside archives and of the managers who produced this remarkable, gigantic paper record of their activities.

In his study of the Bell System's horizontal structure from 1876 to 1909, the broadest subject undertaken in any of these three books, Robert W. Garnet presents a balanced and lucid analysis of how the Bell firm prior to 1880 pursued the narrow strategy of managing the telephone patent through licensing of instruments to local franchised companies. The 1879 agreement with Western Union removed the telegraph firm from direct competition with Bell and led to formation of AT&T six years later, and it permitted an ingenious redefinition of the company's operations with a focus on buying into control of the local companies.

The entrepreneurial leadership provided by Theodore Newton Vail and some of the company's other key figures, the quest to turn regulation to the firm's own advantage as part of Vail's strategy of "one system, one policy, universal service," the successive corporate reorganizations that put the company on a broader financial foundation, and finally the management and structural reforms that provided a solid organizational basis for integrated operations on a national scale all are etched carefully and persuasively by Garnet. It is a study that every student of business development and of communications will find indispensable.

The tyranny of the archival (that is, management) perspective is also evident, however, in Garnet's analysis. The consumer is only a shadow presence, scarcely identified, let alone revealed as to either behavior or interests; and the consumer's viewpoint is altogether absent. Similarly, the political and legal history of regulation (a history vitally shaped by consumers—including business customers of the phone companies—and their representatives) is presented only in sketchy form, and then only from the evidence found in AT&T files. All this is disappointing in a work that forthrightly challenges the common tendency in the modern literature to banish political and legal dynamics from the interpretative framework of business history.

The Anatomy of a Business Strategy, which overlaps somewhat both chronologically and substantively with Garnet's book, is concerned with the vertical-integration aspect of the Bell and AT&T history down to World War I. The main focus is the decision to acquire Western Electric, a manufacturing firm previously controlled by the Western Union telegraph company—with the immediate impact of doubling the market price of Bell stock, and with the longer-range effect of permitting AT&T to institute R&D and manufacturing policies that would be articulated with expansion and competitive strategies. Smith portrays vividly how AT&T linked its emerging service monopoly with a captive manufacturing and R&D firm to which it extended protection both through defensive (but certainly aggressive) patent litigation and through exclusive use in its own operations.

Again, "control of the field" was of the essence. Smith writes:

> What Bell had acquired . . . was a greatly expanded production capacity and an enlarged patent portfolio, along with the opportunity to manage more efficiently its source of supply. The company now had the means . . . to eliminate the pricing and distribution problems inherent in [former licensing arrangements with manufacturers].

Only one brief chapter is allocated to the period after 1882, so that Smith offers us only a tantalizing glimpse of the relationship of the Western Electric acquisition (and the institutionalization of R&D that followed) to coil loading and long-distance transmission, improved switching, and other technical advances and challenges. The reader is left to wonder what light material in the AT&T business and engineering archives will cast upon the controversial issue of how much the AT&T–Western Electric nexus in fact served to impede or even lock up inno-

vative processes on important competitive fronts (a main contention, for example, of David Noble's work, *America By Design: Science, Technology, and the Rise of Corporate Capitalism*, 1979).

The narrowest of the three books is Neil Wasserman's, a work of only 125 pages of main text that offers a detailed treatment of both the invention and the implementation of coil loading, the invention at the turn of the century that made high-quality, long-distance voice transmission possible. Wasserman considers the basic scientific contributions of the British physicist James Clerk Maxwell and others, and, at greatest length, the contribution of AT&T's own George A. Campbell, who lost out in the race for a patent so that AT&T was left with no choice but to purchase the coil-loading patent from Michael Pupin at a price that was handsome even by modern Silicon Valley (or Hollywood) royalties standards. A key to why AT&T stumbled, ironically enough, was poor advice from its lawyers, who were so adept at other things, when it came to patent strategies and requirements.

Wasserman has in common with Garnet a keen eye for the role of happenstance and contingency in historical development of both technology and business organization and marketing. He is at pains particularly first to set out in neat diagrammatic form a "process of innovation" flow chart that he then uses as his straw man, modifying it to reflect the complexities, switchbacks, and turnarounds that the real-world history of implementation involved once AT&T sought to apply loading technology in its operations.

The book closes with the assertion that the company's experience with the loading coil "strongly influenced the way AT&T, and, indirectly, the way other large corporations have dealt with science, technology, and the management of change in the twentieth century." The suggestion, though intriguing, is undeveloped here; readers interested in that problem will need to consult the new historical studies on industrial research by Leonard Reich and older work by Kendall Birr and others.

None of these three books, withal, has the comprehensiveness or theoretical importance for historical analysis of technological change in relation to science, law, public policy, and market competition of Hugh G. J. Aitken's truly brilliant tour de force on the parallel and intersecting developments in radio technology and American business. But all three works are of distinct value to students of American science, with Garnet's in particular transcending specialists' concerns to provide a complex, though only partial, portrait of a fascinating industry in an epoch that seems far removed in time but startlingly similar in some of its competitive dimensions to today's brave new world of communications.

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Labors at Menlo Park

Edison's Electric Light. Biography of an Invention. ROBERT FRIEDEL and PAUL ISRAEL. With Bernard S. Finn. Rutgers University Press, New Brunswick, NJ, 1986. xvi, 263 pp., illus. $35; until 1 July 1986, $27.95.

Mention the name of Thomas A. Edison to almost any American and he or she will probably think of his most famous invention, the incandescent electric light. So persuasive and enduring is Edison's electric light as a symbol of invention and creativity that a light bulb coming on over the head serves as a conventional way of representing a good idea. Nearly everyone is familiar with the basic story of how Edison invented the electric light in 1879, and the story is regularly used to celebrate how American virtues such as ingenuity and perseverance can lead to technological progress.

Yet beyond the symbolism and myth, what do we really know about the history of this invention? Not much, according to Robert Friedel and Paul Israel, and what little we know is based "more on hearsay and foggy memory than on historical evidence" (p. xii). Drawing on a wealth of manuscript material at the Edison National Historic Site in West Orange, New Jersey, the authors set out to retell the making of the incandescent lamp. For them the story is an exciting one, filled with insight into the personal and human aspects of creativity.

In narrating how Edison invented his system of incandescent lighting, Friedel and Israel surpass the earlier Edison biographies by providing a clear description of the technical challenges faced by Edison at each step in the innovation process. Their understanding of the technology is based on their masterly analysis of over 250 laboratory notebooks. Friedel and Israel are the first scholars to study the notebooks in their entirety, and through them they have secured a complete overview of the events in the Menlo Park laboratory from 1878 to 1882. Because their narrative is close to the records, it comes across as fresh and stimulating, with the reader sharing in every breakthrough and false lead. This sense of intimacy with the creative act is further enhanced by the extensive use of illustrations from the notebooks, which provide a rich visual record of how Edison worked.

Though they do not substantially change the general outline of how Edison invented the electric light, Friedel and Israel give the story a number of new twists. From the outset, they tell us much about Edison's associates and the role they played in the project. Other historians have identified the important contributions made by Francis Upton, Charles Batchelor, and John Kruesi, but Friedel and Israel in addition discuss how Charles Deane, Wilson Howell, and Ludwig Boehm helped create the incandescent light. Curiously, at times the authors tell us much more about the work of these men than they do of Edison; for instance, they reveal that it was not Edison but Upton and Batchelor who performed the crucial experiments with carbon filaments on 22 October 1879. Edison's apparent absence may be the result of the fact that Upton and Batchelor kept records of their work that day and Edison did not, but the authors do not speculate on this point.

Another novel feature of the book is that the authors provide a detailed analysis of the craft aspects of invention. During the early months of 1879, for instance, we learn how Edison used a microscope to observe that the platinum filaments in his lamps were not melting but oxidizing. On the basis of these experiments, Edison and his staff decided to enclose the filament in a vacuum. Friedel and Israel then recount how the Menlo Park team designed an improved vacuum pump, building upon the work of Geissler and Sprengel. In later chapters, the authors provide additional examples of the craft of invention by describing the intricacies of fashioning miniature clamps for the filament, designing large-scale dynamos, and perfecting insulation for the underground conductors. Throughout their narrative, the authors emphasize that Edison succeeded with the incandescent lamp not so much because he had a profound theoretical understanding of the light as because he and his staff were able to attend to all the requisite details.

Friedel and Israel also examine Edison's relationship with the press. Earlier accounts of the electric light have mentioned how Edison received a great deal of coverage in the New York daily newspapers. In this study the authors consider this publicity as both an asset and a liability. For example, in the fall of 1878, Edison skillfully elicited extensive press coverage in order to stimulate investment in the Edison Electric Light Company. At other times, however, he found it difficult to restrain the press. In the fall of 1879, as the carbon filament lamp