Here is a stark portrayal of what big science has become in the post-war period. As the author frequently points out, what may appear from the outside to be a straightforward technical accomplishment is actually the end-product of a frightening mixture of political, financial, technical, social, industrial, scientific, and ethical concerns that mesh in a sometimes violently confrontational manner. Examples abound: Constrained by Defense Department concerns, Marshall's staff involvement at major subcontractor (and reconnaissance satellite manufacturer) Perkin-Elmer was too small, and NASA management lost control over both budget and schedule for the 70-million-dollar optical system. To correct this without seriously impairing the scientific capability of the HST required NASA to go back to Congress for additional money from a House committee whose chair had strongly opposed the telescope in the first place. Or this: Thermal effects of the HST cycling between direct sun and earth shadow every 90 minutes produce instabilities on the order of 10,000 times the intended stability of the optical system; this necessitated development by Lockheed of a decoupling mechanism between substructures at increased cost and delay. The planetary astronomers' need for sensitivity in red light led to the use of unproven Charge-Coupled Device videcons, which very late in the testing revealed that what had been looked at before would degrade what was looked at later unless the videcon was periodically flooded with ultraviolet light; a special tube had to be introduced long after the camera design was fixed to avoid having to point the entire HST directly at the sun.

One of the chief proponents of what became HST, and a savvy lobbyist when needed, has been George Field, a student of Spitzer's and sometime director of the Harvard-Smithsonian Center for Astrophysics. Realizing from his experience that publicly funded efforts require an informed and supportive public, Field has teamed with astronomer-popularist Goldsmith to laud the program in time for the launch. What emerges is a remarkably clear, non-condescending, and reasonably complete description of the HST, its value and its mission, and a good deal of modern astronomy, aimed at an interested lay audience like the readership of *Scientific American*. It is definitely not history, being quite a different story from that emphasized by Smith; it downplays the problems (after initial funding "the next seven years were good ones for the Space Telescope and led to its completion") and includes many more of the technical matters. Of particular interest are the discussions of possible serious damaging effects of the four years in storage; of concerns about launching during a period of increased solar flaring; of how a necessary 55-meter focal length could be fit into the 12-meter Shuttle bay; and of how the new Space Telescope Science Institute will coordinate use of the satellite. For readers unfamiliar with the immense changes in how science is done in modern times, this last chapter alone will be an eye-opener.

"NASA administrator James Fletcher explains a model of the Space Shuttle to President Ford," 1976. "In contrast to the previous year, in 1976 the Space Telescope sailed through its [Office of Management and Budget] reviews. There are even stories of meetings—unusual, certainly, by OMB standards—that were brought to a halt as staff members pondered what it meant to peer back many millions of years." [From *The Space Telescope: A Study*; courtesy of Gerald R. Ford Library]

There does seem to be an essential factor that is given short shrift in both books. In light of recent revelations of how important reconnaissance satellites have been in preventing arms proliferation in the last 30 years, this reader finds the consideration of their relevance surprisingly brief. Perkin-Elmer had been in the earth-directed optical reconnaissance satellite business for at least a decade before NASA selected them as the prime contractor for the optical subassembly of the HST, and the same can be said of Lockheed, selected for the rest. Indeed, we even know from a public statement by President Carter in 1979 just what the optical resolution of the latest KH satellites was at about the time the HST was funded. One book questions whether reconnaissance was going on at all, the other barely mentions its role though does emphasize the influence of the Department of Defense in limiting NASA's oversight ability in the early years of HST fabrication.

Notwithstanding this perhaps over-inquisitive reader's desire to understand more fully the evident influence of prior defense reconnaissance work on the HST's origins, possible emergency uses, and contractual difficulties, we have here two immensely useful books on the eve of the HST launch. They address quite different audiences, but both are well deserving of praise from their respective readerships.

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A Rise and Fall

Gene Dreams. Wall Street, Academia, and the Rise of Biotechnology. ROBERT TEITELMAN. Basic Books, New York, 1989. xii, 237 pp. $19.95.

Robert Teitelman's *Gene Dreams* is a book about the biotechnology "revolution" that began more than a decade ago. Teitelman argues that this "revolution," as it was initially promoted by entrepreneurs, the press, and the financial community, has failed. According to Teitelman, "Biotechnology sold itself on the belief that it could remedy the most profound economic and medical ills of the age, and please Wall Street as well." More than ten years later, in comparing the promises to the results, Teitelman concludes: "Although biotechnology has changed the way the drug business works, it has not sparked anything approaching a Schumpeterian economic revolution."

Why has the "revolution" failed? For Teitelman, the answer lies not in the failures of a particular body of science but with the institutions and people who promised miracles in the first place and who underestimated and intentionally minimized the difficulties of transforming science into technology. There are three villains in this story: the biotechnology entrepreneurs, the press, and the financial community. Their respective roles in feeding the biotechnology mania in the early 1980s are examined in detail through the case of Genetic Systems, a biotechnology company "assembled by a pair of Wall Street deal makers and run by a young scientific entrepreneur."

The entrepreneur lies at the heart of what Teitelman calls "the mythos of biotechnology":

> The industry, of course, has a much grander image of itself than just another industrial enterprise. Particularly in its early days, biotech entrepreneurs talked as if they were assembling academic laboratories that happened to be funded by Wall Street instead of some nonprofit or govern-

mental body. They argued that they could combine both the pure science of the academic world and product development of the drug industry; that they could excel as both scientists and inspired entrepreneurs; that armed with these powerful tools and their own inspiration, they could, like some romantic hero, transcend the realities of corporate life.

If biotechnology entrepreneurs, with the help of the press, were being manipulative, then it was Wall Street and ultimately investors who were being manipulated. Wall Street is not absent of malice in this story. Teitelman suggests that Wall Street got caught up in and even fueled the mania because it was ignorant and perhaps too greedy to learn more about the limits of the technology. The later chapters of the book focus on how the "revolution" began to unravel in the mid-1980s as technical and commercial hurdles (which were not part of the mythos) became too compelling to ignore any longer.

The principal strength of *Gene Dreams* lies in its exploration of the process by which beliefs about technology and its commercial potential are formed and transformed. The book reminds us that these beliefs, whether or not they ultimately turn out to be sound, sway billions of investment dollars. Thus it is useful to think about where they come from and how specific groups and institutions shape them. Teitelman's detailed exploration of Genetic Systems and his gifts as a writer enable *Gene Dreams* to tell a graphic story about the interaction of entrepreneurs, the press, and Wall Street.

At the same time, the book's focus on the experience of Genetic Systems is also one of its principal weaknesses. While the story of Genetic Systems may be very accurately told, we do not know (from this book) how typical it is. Teitelman says that he chose Genetic Systems as the central case "because it seemed to illuminate more aspects of the industry than any other." However, one is left wondering whether the Genetic Systems case may not be somewhat extreme. The book places strong emphasis on the personalities of Genetic Systems' founders, David and Isaac Blech and Bob Nowinski. It does an outstanding job illustrating how founders' backgrounds, styles, and personalities shape a start-up firm's strategy and affect its fate. However, if founders' personalities play such an important role, then it is natural to wonder the extent to which Genetic Systems' founders were typical biotechnology entrepreneurs. This question is difficult to answer, and the book provides little relevant evidence. The fact that Genetic Systems has been one of the relatively few biotechnology firms to be fully acquired by a major pharmaceutical company suggests that its experience has not been typical. Skeptics will question whether the case of Genetic Systems fairly represents the biotechnology entrepreneur and the financial community.

Diversity is a fundamental and important characteristic of the biotechnology industry. There are several hundred firms around the world engaged in various aspects of biotechnology. These firms represent a highly heterogenous group in terms of founders' backgrounds, financial resources, R&D focus, manufacturing capabilities, and commercialization strategies. *Gene Dreams* filters out much of this diversity by compressing the story of the biotechnology industry into the case of Genetic Systems.

Gene Dreams is not for someone looking for a rigorous, scholarly, and comprehensive examination of the development of the biotechnology industry. However, if one is looking for a concrete, exciting, and eloquently written story about the rise of biotechnology mania and its fall back to reality *Gene Dreams* is a good choice.

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Metrology Institutionalized

An Institute for an Empire. The Physikalisch-Technische Reichsanstalt, 1871–1918. DAVID CAHAN. Cambridge University Press, New York, 1989. xx, 315 pp., illus. $49.50.

In subtle ways measurement ties industry, research, government, and consumers together. It forms a basis for making work in laboratories usable elsewhere and, perhaps more obviously, it makes possible mass production, consumption, and regulation. The benefits of national and even international systems of measurement became increasingly evident in the latter part of the 19th century. As a result, several nations followed the lead of the newly unified Germany in creating new institutions to establish standards for measurement. In 1887 Germany founded the Imperial Physical-Technical Institute (PTR)—a translation of the subtitle given above. The British opened the National Physical Laboratory in 1899, and two years later the United States formed the Bureau of Standards.

David Cahan describes the origins and development of the PTR from 1871, when Germany was unified, until the end of World War I. He notes the crucial collaboration between the electrical manufacturer Werner von Siemens and Germany's leading physicist, Hermann von Helmholtz, in establishing an institution to control standards and to provide a research site superior to those then found in German universities and free of teaching duties. Both Siemens and Helmholtz argued that "pure" scientific research benefited technological development in unpredictable ways and thus had to be supported. By the 1880s Siemens had marshaled enough interest to persuade the state to establish the PTR and make Helmholtz its first president. Helmholtz built facilities for the Scientific Section before starting work on the Technical Section. After 1895, his successor, Friedrich Kohlrausch, a physicist known for his work in measurement, built the PTR into a leading research institute. The third president, Emil Warburg, sought to reorganize the PTR when he took over in 1905, but World War I interfered with his reforms.

Helmholtz, Kohlrausch, and Warburg hoped to do research. But Cahan's survey of activities in the Scientific and Technical Sections in the years 1892, 1903, and 1913 demonstrates that testing equipment for the electrical and precision instrument industries, a major rationale for the PTR, left little time for research. Electrical companies needed a variety of properly calibrated meters and viable mechanisms for measuring luminosity. In developing instruments necessary to carry out routine testing, physicists at the PTR sometimes worked at the cutting edge of physical research. In their work on luminosity, for instance, they contributed significantly to research on black-body radiation. Success meant, however, that physicists at the PTR were offered positions in universities that were increasingly supporting research. After 1900 the PTR faced personnel problems resulting from inadequacies in state financing.

Cahan does not analyze Helmholtz's ideology of "pure" science so much as use it in his analysis. Whether a hierarchical relationship exists in which technology merely derives from science is an important issue with policy ramifications. Some scholars argue that technology, a body of knowledge in its own right, sets the agenda for science through, for instance, instrumentation or by solving engineering problems prior to the development of a science that could explain or even predict the solutions. Cahan himself notes the contributions that work on a technological problem, luminosity, contributed to research on black-body radiation. The claim that "pure" science should be supported because it might in the future produce economic benefits is now widely recognized as a rhetorical device used to generate funding and legitimize research agendas. The relationships between science and technology are more complex, but Cahan sets up two categories—"pure" scien-