Review
Reviewed Work(s): To Engineer Is Human: The Role of Failure in Successful Design by Henry Petroski
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the historical literature on it has been sparse. The most thorough account of the program was prepared in 1948 by Brendan J. O'Callaghan of the Division of Information of the Reconstruction Finance Corporation (RFC), the federal body ultimately responsible for synthetic rubber production. The first volume covered the natural rubber activities of the RFC. The second volume, dealing with the synthetic rubber program, was revised by Bertram H. Weimar in 1955 when the program came to an end. Unfortunately, this history was never published, although it is available in the National Archives. The best published account, especially for the technical and corporate aspects of the development of synthetic rubber, is Frank Howard's *Buna Rubber: The Birth of an Industry* (1947). Obviously this book, now out of print, does not cover the important technological advances, such as oil-extended rubber and cold rubber, that took place between 1947 and 1955.

Drawing on their own technical expertise and their experience in explaining technical matters in *CHEMTECH*, Vernon Herbert and Attilio Bisio have woven the material in these two sources into a readable book of modest compass. To a lesser extent they also use materials from other sources, such as Robert Solo's critical account of the project, now available as *Across the High Technology Threshold: The Case of Synthetic Rubber,* and government publications. The result is a compact account of the program that deals with its technical, financial, and organizational aspects. There are two chapters on the natural rubber side of the program, and the chapter on the disposal of the plants to the private sector in 1955 is one of the best parts of the book. Another particularly good chapter covers the postwar achievements of the government-sponsored research program, refuting Solo's contention that the results "were zilch, zero, nothing."

In two final chapters Herbert and Bisio offer their own reflections on the program's successes and mistakes. They then apply the lessons of the program to the synfuels project, which was in the public eye while the book was being written but has since been terminated. Contrary to what President Carter thought when he set up the Synthetic Fuels Corporation, Herbert and Bisio show that the differences between the two projects were so great as to make comparison almost meaningless. Apart from the huge difference in the scale of the two programs, they doubted that the necessary will to succeed existed in the synfuels project, and they have already been proved right. There is a larger question posed by their reasoning, which they do not seek to answer: Can any government-sponsored project of this kind, involving collaboration with industry and academia, be successful in a situation in which there is no obvious or urgent national need for it to succeed?

It would be possible to criticize this book for being too dry and technical for the general reader or, conversely, to complain that Herbert and Bisio have not gone back to the original sources. However, as a general history of one of the most important scientific projects in World War II, this is an excellent book that provides all the useful facts in a clear and readable manner. It is a fitting tribute to those scientists and engineers whose hard work made it possible for the project to succeed. *Synthetic Rubber* is strongly recommended to historians of technology, historians interested in World War II, historians of chemistry, business historians, and chemists and chemical engineers.

PETER J. T. MORRIS

Henry Petroski. *To Engineer Is Human: The Role of Failure in Successful Design.* xvi + 227 pp., illus., bibl., index. New York: St. Martin's Press, 1985. $16.95.

This book argues that engineers learn more from failure than from success and that the elimination of risk and failure could be achieved only by "declaring a moratorium on innovation, change, and progress." To demonstrate this hypothesis, the author, a civil engineer at Duke University, takes the reader through a short course in modern engineering. This is "an introduction to technology," says the author. "Indeed, this book is my answer to the questions 'What is engineering?' and 'What do engineers do?' "

The evidence for his analysis comes primarily from historical case studies of spectacular engineering failures: the collapse of the skywalks in the lobby of the Kansas City Hyatt Regency Hotel in 1978, the failure of the Tacoma Narrows Bridge in 1940, the crashes of three Comet aircraft in 1953 and 1954, the capsizing of the *Alexander L. Kielland* oil rig in the North Sea in 1980,

the cracking of Grumman Flxible bus frames on the streets of New York City in the early 1980s, and the collapse of a section of the Mianus River Bridge on Interstate 95 in Connecticut in 1983—to cite just some of the examples. To these well-known major events Petroski adds homey examples from his own ken—the failing keys on his son's Speak & Spell toy, the frustrations of designing and perfecting a homemade slingshot, the detective work involved in analyzing the cracks on a set of stainless steel eating utensils. In short, this is an eclectic book that draws on a wide variety of evidence.

The results, as Petroski's own analysis would have suggested, are mixed. "Innovation involves risk," he argues, and this is an innovative book. Experts from a variety of disciplines and perspectives will find bones to pick. Not all historians, for example, will agree with his assertion that "hindsight is always 20/20"; even retrospection can be decidedly myopic. The etymology of the word "engineer" that he extracts from the *Oxford English Dictionary* overlooks the military engineering from which the term originally derived. Astronomers will question whether "our belief that the sun will rise tomorrow is basically a matter of faith rather than of rigorously established fact." Some will find the organization curious and will lament the redundancy it introduces. Scholars in several disciplines will regret the lack of documentation.

But the quibbles of scholars and specialists should not be allowed to mask the real achievement of this book. This is a truly interdisciplinary study, in the best sense of the term. Petroski constructs a story accessible to engineers and laymen alike. He writes clearly and effectively, putting the lie to the old stereotype of engineers as literary clods. Anyone who cites Oliver Wendell Holmes, Bruno Bettelheim, Ralph Waldo Emerson, William Wordsworth, Nathaniel Hawthorne, Robert Frost, Wallace Stevens, T. H. Huxley, Nevil Shute, and Henry Adams in a book on engineering is obviously not your garden-variety engineer. Like Samuel Florman, with whom he may be compared, Petroski combines a productive career in engineering with a wide-ranging curiosity, a taste for interdisciplinary inquiry, and a facility with the English language.

Among the strongest chapters in the book are those on cracks and computers. "Fifty to ninety percent of all structural failures," says Petroski, "are believed to be the result of crack growth," making this a most revealing and significant topic indeed. With clarity and conciseness, he explains how the welded seams that replaced traditional riveted ones on Liberty ships contributed to one ship's breaking up at pierside in Portland, Oregon, in 1943, how neutron irradiation is making metal pipes in nuclear power plants more susceptible to cracking than anticipated, and how pipes designed to leak before they break can help maintenance personnel identify potential problems before they become catastrophes.

The remarkable message of the chapter "From Slide Rule to Computer" is that "thus far the computer has been as much an agent of unsafe design as it has been a super brain that can tackle problems heretofore too complicated for the pencil-and-paper calculations of a human engineer." The roof of the Hartford Civic Center, for example, was designed using a computer model to analyze the stresses. So confident were the designers that they brushed aside the questions of workmen who had noticed the large sag in the roof well before it collapsed under the snow and ice of a January 1978 storm. The problem, says Petroski, is that too many engineering computer programs are beyond verification, inexperienced engineers are tempted to work beyond their competence because of the availability of powerful software, and once the numbers are crunched engineers tend to rely on the results rather than on their own judgment. The computer is a powerful tool in engineering, but it may be used for good or ill.

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We are not likely to eliminate engineering failure in the foreseeable future. Nor does Petroski believe we should, for that way lies technological stagnation. But we can minimize the danger when failures do occur and we can limit the range of possible accidents. "Engineers should be familiar with the history of technology." They would never have designed the Tacoma Narrows Bridge the way they did had they known the sorry history of the Wheeling Suspension Bridge or Thomas Telford's Menai Straits Bridge. Petroski has surely profited from his historical researches. The result is a charming and engaging book that can tell the historian as much about technology as it tells the engineer about history.

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