Preface

Technology is a part of everyday life, yet to most people the engineering that creates it is remote and opaque. Few know much about the principal technologies that underpin modern life, how in a basic sense they work, or how they came about. The aim of this book is to explain, in brief narrative accounts, the origins and basic working of certain key engineering innovations since 1920 that brought America and the world to the early twenty-first century. The book also uniquely describes these innovations through simple numerical formulas, or simple graphics. The numbers and concepts in the book are used by engineers but they are presented here without the calculus that professional engineers would need to know.

The United States and many other countries train world-class engineers but a broader technical literacy in these countries has been an elusive goal. Secondary schools teach natural science and mathematics in ways that emphasize the learning of principles, and these schools and most universities and colleges require nontechnical students to have some exposure to these subjects. But engineering is usually taught to students who plan to become engineers. More recently, at the secondary level, many schools have begun giving students classes in simple engineering design, and science curricula include some engineering ideas. But engineering is usually perceived to be a technical skill or is used as a way to teach science, rather than taught as a set of major innovations that illustrate a kind of insight independent of science.

An informed public should know how key engineering ideas are embodied in the most important objects and systems that are basic to modern life. In research going back

to the 1970s, the author's father found that most of the major technical innovations of the last two centuries could be explained in the language of engineers–mathematics–at a numerical level that most American students learn in the first two years of secondary school. In this book, the first three chapters contain boxes that explain engineering ideas in terms of entry-level algebra or geometry. Owing to the greater complexity of the ideas, boxes in the rest of the book explain engineering ideas visually with simple graphics. The main narrative text does not require mathematics to follow.

Engineers also need this kind of overview. Modern engineering knowledge consists mostly of principles and applications that aim to inculcate "best practices" or standards of excellence in design. However, modern engineering is also a sequence of "best works" that began as major innovations and that set new ideals and standards. Scientists, architects, artists, lawyers, and physicians learn the canonical ideas and works in their fields along with their creators. In their training, engineers tend to learn what they know as an abstract body of knowledge in which landmark ideas that are still relevant belong in the form of timeless general principles and applications. In fact, modern engineering also has a body of key ideas exemplified in best works that engineers should also know. This book shows how, in a basic way, engineers can also communicate these ideas and works to a wider public.

At their inception, each key innovation usually came from the insight of one or two engineers, and the accounts in this book mostly describe what these people did. In recent decades, historians have highlighted how larger and often neglected social groups contributed to the rise of new technologies. Scholars have also explored the wider context of engineering choices and the social consequences of these choices. Although it

describes some of these consequences, and includes several engineers who overcame barriers of race and gender, the present book is not intended to be a broader history of this kind. Its main purpose is to provide a basic engineering literacy to a general audience through accounts of innovative, ideas, and works. Learning what these innovators thought and did should be of interest to future engineers as well.

The book presents several key innovations in one volume in order to see how they resembled each other and how they differed. A comparison also allows a wider perspective on two issues: the role of science and the role of national government. Perceptions of modern technology tend to treat science and engineering as a single category. While they have much in common, there are important differences between the two that need to be better understood. Public debate over how to stimulate innovation and economic growth has been driven by advocacy in support of a preferred role for government. Although not a study of public authority, the book tries briefly to show what government actually did across a range of key technologies.

This book completes a trilogy on engineering ideas that shaped American civilization over nearly two and one-half centuries. In the first volume, the author's father introduced the modern engineering that connected the United States from 1776 to 1883.[1] In the second volume, the author and his father described the engineering breakthroughs that industrialized the country from 1876 to 1939.[2] The first five chapters in the present volume describe the major works of U. S. public engineering in the twentieth century, from great dams and highway programs to the Moon landing in 1969. The remaining three chapters give the main breakthroughs in electronics: the transistor, the microchip, the personal computer, and the Internet. The book combines narrative,

technical description, and illustrations to make these insights and works more accessible. Each chapter has a key breakthrough as its focus but also describes some of the more important ancillary innovations.

The title of this book, *From Insight to Innovation*, refers to ideas and events that transformed modern life. Less dramatic developments are also part of technical development, and the difference between these and the more radical innovations is not always clear. However, other accounts of the most significant twentieth century innovations include most of those in this book. Two excellent studies by Vaclav Smil give a comprehensive overview of the technical advances of the last two centuries, and an end-of-century volume commissioned by the National Academy of Engineering identifies twenty of the most important breakthroughs of the twentieth century.[3] The present book focuses on the engineering behind a smaller number of these and concludes with an overview and brief look into the future.

Any errors of fact or interpretation are the author's and are not the fault of either the publisher or people consulted in the research and writing of this book. The author welcomes comments sent care of the publisher.

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[1] David P. Billington, *The Innovators: The Engineering Pioneers Who Made America Modern* (New York NY: John Wiley and Sons, 1996).

[2] David P. Billington and David P. Billington Jr., *Power Speed and Form: Engineers and the Making of the Twentieth Century* (Princeton NJ: Princeton University Press, 2006).

[3] See Vaclav Smil, *Creating the Twentieth Century: Technical Innovations of 1867 to 1914 and Their Lasting Impact* (New York NY: Oxford University Press, 2005), and by the same author, *Transforming the Twentieth Century: Technical Innovations and Their Consequences* (New York NY: Oxford University Press, 2006). For the survey commissioned by the National Academy of Engineering, see George Constable and Bob Somerville, *A Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives* (Washington DC: Joseph Henry Press, 2003).