

# Preface

In my more than forty years working as an engineer on a variety of increasingly difficult problems in the aerospace industry, I have come to appreciate the strong computer-assisted design and analysis skills of many of my younger colleagues. Many recent engineering graduates are now quite adept at using, or modifying existing complex computer codes to design and to analyze engineering systems in those particular disciplines where they have previously obtained substantial education and hands-on experience.

To stay fully employed in the aerospace engineering business, working on challenging and rewarding problems, an engineer must always be able to learn and to utilize the technical skills needed to support the latest engineering contract goals.

The ability to quickly adapt to and master a new engineering challenge or design problem is a very important survival skill for today's engineers. Most importantly, one must revive certain basic technical skills or concepts that one learned long ago and subsequently forgot in the stressful day-to-day working environment.

A critical survival skill is the ability to conceptually work out in one's own mind, and on paper, the basic technical underpinnings (or the physics) of a complex real-world problem that may involve several new analysis and design elements. To be able to quickly comprehend a new engineering problem or goal and to set forth on a new design effort, an engineer needs the skills to conceptualize and develop *simplified* mathematical and/or empirical models for a range of complex physical processes using a number of different engineering approximations; and the ability to quickly calculate *quantitative* estimates of the problem's key design parameters and to interpret their meaning, even if there is little or no supporting data at hand.

Another way of restating these points is:

*An engineer must have strong "Back-of-the-Envelope" engineering estimation skills.*

It is said that a good system designer is usually skilled in the *art of estimation*. However, I have observed that many of today's aerospace engineers are *unable* to estimate key engineering dimensions and requirements without the aid of an already existing engineering model or software code. Because they do not know the basics of estimation, engineers often cannot quickly select the most important physical scales and parameters to characterize real aerospace engineering systems. It follows that they have difficulty identifying those design variables that can be safely neglected, or bypassed, when tackling a new problem. The ability to estimate can be quite useful in limiting the extent of a major analysis effort or the range of testing needed to advance a new design.

To be able to develop quick design concepts and to estimate the important geometric, performance, and design dimensions for a new problem, an engineer needs to learn how to effectively utilize Back-of-the-Envelope (BotE) estimation skills. These provide important rough quantitative guidelines and/or answers to real-world problems, particularly for projects with enormous complexity and very limited resources.

In the six chapters of this book, we illustrate the importance and use of BotE techniques by primarily applying them to two major real-world engineering case studies, the Space Shuttle and the Hubble Space Telescope. We also examine a few less-well-known engineering systems.

The goal of this book is not to try to cover all of the major design issues for these case studies, but rather to illustrate how an engineer might use BotE skills to obtain a first-order quantitative “feel” for the magnitudes and sensitivities of several of the key system variables driving the design and performance metrics that characterize these two complex aerospace systems. We show, by example, how an engineer can quickly use BotE techniques (and perhaps a #2 pencil) to obtain initial *quantitative* estimates of the sizes and performance measures of key components for the Space Shuttle and Hubble Space Telescope projects.

Such engineering estimates can often be used to guide the development of more complex computer modeling studies and initial test programs so that engineers can confidently advance to the next step in a project's system design.

*Irwin Alber*  
Irvine, California

Aerospace Engineering on the Back of an Envelope

Alber, I.E.

2012, XXII, 326 p., Hardcover

ISBN: 978-3-642-22536-9