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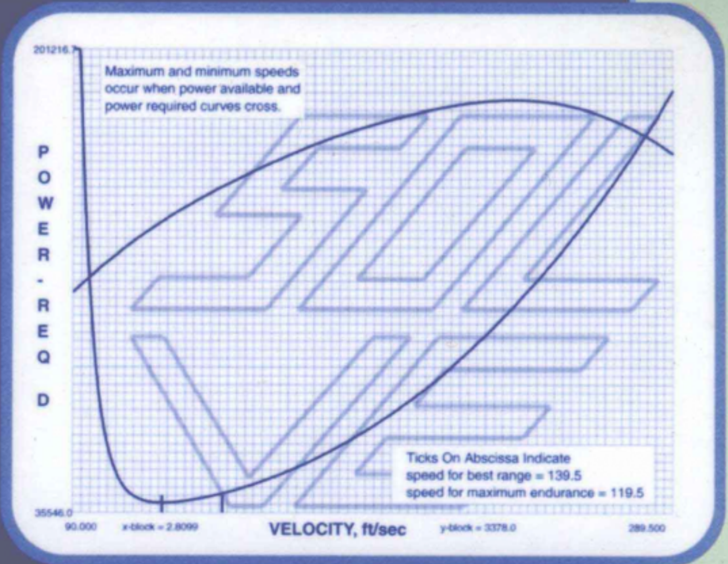

飞行器性能与气动力操纵

FLIGHT VEHICLE PERFORMANCE AND AERODYNAMIC CONTROL

（美）斯麦塔那（Smetana F. O.） 著
詹 浩 译注／杨 永 审

航空工业出版社

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本书为普通高等院校航空航天双语教学用书，其原版教材供（美国）大学二年级水平航空工程专业的学生使用，目的是让学生了解飞行器各组成部分的一般特性和在亚声速状态下各个部分是如何结合起来对飞行器的总体性能产生影响的。本书描述了确定飞行中气动操纵面操纵所需的力的方法，以及这些力是如何与飞行器的静稳定性联系起来的。本书所附光盘还提供了源代码和可执行的软件，可以做性能和操纵力的分析。在某种意义上，它在减少学生的错误的同时提高了结果的准确性。软件可以被用作教学的工具而不仅仅是个计算的工具。这个独有的特点增加了本书的价值。本双语版教材适合相关专业院校师生使用，以及作为专业技术人员的参考用书。

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内 容 提 要

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出版说明

双语教材的引进与使用，是我国高等院校双语教学课程建设的重要内容之一。航空工业出版社作为国内航空航天领域的专业出版社，针对目前我国高等院校推广的双语教学课程建设项目，与国内各航空航天院校积极探索，根据各院校教学的实际教学需求，对国外成熟的、优秀的航空航天教材进行了甄选，形成了独具特色的航空航天类双语版专业教材系列丛书，其中部分优选出的权威的、经典的教材已经在国内部分院校的教学实践中进行了试用，不但获得了教师和学生的肯定，而且取得了业内专家和学者的一致认同。

考虑到引进教材系列的完整性和专业的覆盖范围，以及国内院校教材使用的具体情况，航空工业出版社与美国航空航天学会（AIAA）建立了长期的战略合作关系，计划在几年内分批次引进出版 AIAA 的专业教科书。这套《AIAA 教育系列丛书》就是美国航空航天学会出版的航空航天类专业教科书的双语版本，“丛书”中的每一种教材都是国外高等院校航空航天专业教材中的经典作品，为多所院校采用，并经多次再版修订。考虑到直接使用原版教材在我国实际的教学中存在一定的不适应性，为了更加适合国内高校对于双语教学使用的需要，由既熟悉原版教材，又具备丰富的双语教学经验和扎实专业基础的任课教师，对原版教材中的要点进行了注释，这样可以使学生在学习过程中更容易理清知识脉络，抓住重点。经过增加注释的双语版教材基本保持了英文原版教材的结构和篇幅。此外，“丛书”基本保留了原版书的量和单位符号，如单位使用“ft”（1ft=0.3048m）等，马赫数（Ma）符号使用“M”等，为便于结合英文原文使用，公式中的矢量和标量等也沿用了原书的符号系统。

本套双语版教材的出版是我国航空航天专业教材出版领域的创新之举，得到了中国航空工业集团公司的大力支持。西北工业大学航空学院对教材的出版做出了重要贡献，承担译注和审校工作的各位老师在百忙之中完成了大量的工作，在此对他们的辛勤付出表示感谢！

由于出版工作繁杂，本书难免会有疏漏、差错及不妥之处，敬请读者指正。

A Thought To Consider–

...Some books are to be tasted, others to be swallowed, and some few to be chewed and digested; that is, some books are to be read only in parts; others to be read, but not curiously; some few to be read wholly, and with diligence and attention ... Reading maketh a full man; conference a ready man and writing an exact man. And therefore, if a man write little, he had need have a great memory; if he confer little he had need have a present wit: and if he read little, he had need have much cunning, to seem to know, that he doth not. Histories make men wise; poets witty; the mathematics subtle; natural philosophy deep; moral grave; rhetoric able to contend ....

—from "Of Studies" in *Essays*, 1597—1625
Sir Francis Bacon, Viscount St. Alban

书有可浅尝者，有可吞食者，少数则须咀嚼消化。换言之，有只需读其部分者，有只须大体涉猎者，少数则须全读，读时须全神贯注，孜孜不倦。书亦可请人代读，取其所作摘要，但只限题材较次或价值不高者，否则书经提炼犹如水经蒸馏，淡而无味。

读书使人充实，讨论使人机智，笔记使人准确。因此不常做笔记者须记忆力特强，不常讨论者须天生聪颖，不常读书者须欺世有术，始能无知而显有知。 读史使人明智，读诗使人灵秀，数学使人周密，科学使人深刻，伦理学使人庄重，逻辑修辞之学使人善辩……

——培根《论读书》（摘自王佐良先生译文）

原版前言

本书的目的之一是向航空工程专业的初学者介绍一些评测飞行器性能的典型方法及这些方法的理论基础。目的之二是解释从飞行器几何外形所导出的参数如何用于估计飞行器的垂直和水平操纵面的大小、形状及安装位置，以及驱动这些操纵面所需的气动力。这些方法及与此相关的种种方式，被各界人士使用了50多年。本书的独特之处在于包含了经过长期检验的计算机程序，这些程序经过运行分析，可以减少学生出错，从而提高数据结果的准确性。

这些计算机程序不只是简单的计算工具，也是教学工具。因此，鉴于本书的目的是让使用者懂得他们在干什么，该程序的一些特征，比如用于训练工程师的内容就不在此赘述了。基于同样的教学目的，本书还将介绍一些商业软件程序所不具备的内容。

飞行器性能的传统课程设置中通常包括讲解有关飞行器稳定性的内容，尤其是机体动力学的内容。而作者在本书中几乎没有介绍这方面的内容，这主要出于两点考虑：第一，这一领域在最近几年经历了知识爆炸，一个学期的时间无法介绍足够的信息量；第二，也是比较重要的一点是，在飞行器稳定性的设计和分析上要求有很强的数学能力，而只有工程专业高年级的学生才具备这些知识。如果只考虑飞行器静稳定性和操纵性，就无须顾及飞行器动力学及其影响因素。尽管如此，本书依然涵盖了全面、初步的布局方案设计。只有当一个方案满足设计要求之后，我们才需要进一步考虑其动力学特性。

通常来讲，飞行器性能课程是航空工程专业学生在本学科领域接触到的第一门主干课程。学生所面临的压力主要是掌握大量基础专业术语和理解本学科领域内的专业人员所从事的工作内容。因此本书第一章配以插图，讲解飞行器的各种零件，演示60年来飞行器设计者们在解决各种问题过程中探索出来的方案。附加的符号和概念在后面的章节中将陆续被定义，这是对以往教材的改进。以前的航天器和导弹设计是以航空学为背景的，很多航空术语自第一架飞行器设计成功后就沿用至今。

CLCDDATA 程序为读者提供了基于试验性升力—阻力数据的输入文件的生成方法。这些数据可以用 CLCD 程序基于以下公式来得出一个阻力极曲线：

CD=CD0+K1*CL**2+K2*CL**K3

如果使用者需要一个更精确的描述，可以使用这一扩展的公式，一个完整的升力—阻力的特征可以用来作为性能计算的基础。

POINT 程序利用由 CLCD 程序生成的数据和在飞行中的动力数据来计算各种飞行器静态性能的最大值和最小值。PATHPE 程序采用相同的输入数据再加上两种时间历程来计算飞机重心的运动。PATHPE 程序可以用来测定飞行器是否能在短时间内超过 POINT 程序得出的最大的静态性能值。PATHPE 程序的 TAKOFF 版本是用来计算起飞、爬升和着陆性能的。

ECON 程序用来确定活塞式飞机和喷气式飞机的最经济爬升性能数据。ECON 采用了一种粗略的数值积分技术来求解简单的微分方程式。而用于 PATHPE 程序和 TAKOFF 程序的数值积分方法相对来说更精确和复杂一些。

STADER97 的部分程序决定稳定性导数，它是各种气动力进行泰勒级数展开后的系数。这些气动力表达式可用于估测飞行中飞行器控制面的偏转所需力的大小。使用 STADER97 的子程序 FORCE 和 FORCEL 来完成这些任务。它们也可作为评估飞行器静稳定性的一般标准。在某些情况下，飞行器既具有静稳定性同时也具有动稳定性。除了一些附加的图形放在 STABLE 里，STADER97 是 STADER91 的一个子集。STADER91 还包括用来计算控制面偏转时线性化机体动力学响应的代码，但 STADER97 不包括这些内容，本书对这些代码作了详细论述。

本书围绕上述七个程序展开，利用这些程序对飞行器性能分析方法和操纵力确定方法作了最详细的讨论。

本书的主旨不是介绍空气动力学。虽然用于提供气动力系数值的程序所采用的方法在性质上通常是半经验的，但是这些方法在航空业已有长期成功使用的记录。这些数据的来源在书中都有注释。空气动力学处理方法也可以是完全利用空气动力学基础原理来确定那些气动力系数值。

包含在 STADER97 之内的子程序 STABLE97 以问题的形式显示在屏幕上，从用户键入的答案中得到有关几何和惯性数据来作

为 STADER97 所需的数据输入文件。这些文件接着被写入子程序 STABLE97 中。因为所要求的信息量很大，使用者有必要将这些问题的内容写入一个文件中，这样所有需要的信息都会事先集中存进将要生成的输入数据文件中。

试验性飞行器的制造者通常采用简便方法预测性能，本书也对此进行了讨论。但是我们必须明白，阻力极曲线公式中如果没有类似于 K2*CL**K3 这样的附加项，是不可能准确预测到飞行器失速速度，或与迎角对阻力曲线的变化影响相关的非常重要的其他性能参数。在个人计算机普及之前，这些简便方法被流程化，并可以用计算尺进行简单的加减运算来完成求解。但随着高性能个人计算机的广泛使用，这些方法就不需要了，取而代之的是更详尽的升力—阻力特性。推进器特性中的情况也是如此。简便方法也许在一定程度上能计算出这些特性，但通常不够确切，只是功能性地给出这些特性。如果能确切地得到推进器的性能，POINT、PATHPE、TAKOFF 等程序就可以在性能计算方面取得重大成果。

这些程序一般都将计算结果以列表的形式给出。以最大爬升率与飞行高度关系为例，数据可以绘制成图形以便更直观，但是目前这些程序还不包括数据图绘制的程序。具有一定编程技术的使用者可以通过重组输出数据的方式来满足他们所中意的图形绘制程序的输入数据要求。

本书作者以前就发表过上面提到的大部分程序，其中有些是 28 年前为 NASA 准备的程序。为适应目前的需要，对这些程序进行了修订更新，以便于更专业的初学者能轻松使用。程序中包括 FORTRAN 源代码和执行程序。FORTRAN 源代码是为那些有冒险精神的学生准备的，便于他们根据自己的需要对程序进行修改，或根据需要添加图形程序。

这些程序的早期版本只包含相当简要的关于相关理论基础的分析，这是作者认为这些程序集会作为其他已有的教科书在计算方面的补充。然而，这种情况并没有出现。对该专业的初学者来说，这些程序的原先版本中的解释都过于简单了，以至于他们根本无法理解。因此，作者发现这些程序集的使用者通常都是专业人士，他们都是对该学科十分熟悉的，他们只需要获取那些程序所提供的好用的分析工具。因此本书是按照教材标准编写的，并致力于为工程专业的初学者提供更易入门的程序信息。另外，与以往不同的是，教材中没有完整的程序源代码，这些代码在教材所附光盘中。

由于计算机平台的多样性和FORTRAN源代码的可移植性，以前的程序版本只提供了源程序。最近随着跨平台二进制兼容技术的出现，更多的用户使用英特尔平台下的WINDOWS95、98、NT甚至2000操作系统。因此，本书提供了这些程序在英特尔平台下的执行文件版本，同时也为那些希望能对程序进行改进或是在英特尔平台以外的其他平台上编译使用的用户们提供了源程序。

作者殷切希望本书兼具可读性和趣味性，受到学习相关课程的学生的青睐。作者认为阅读书本是在最短预期时间内吸收理解知识最有效的方法。这些程序为学生们自己尝试对于典型的设计问题所新建立起来的理解，快速地解决问题，并将计算错误降低到最小程度提供了解决手段。然而世界上没有应对任何问题的万能程序，所以细心的学生通常会在使用一个程序之前先检查这个程序是基于哪些假设条件而编写的。

他们也许会发现某个程序并不适用于他们所期望解决的问题，如果仍试图用这个程序来求解，就只会得到一些毫无物理意义的结果。能够从无效的数据中得出有效数据是专业工程人员的基本功。这种能力源自对这些程序理论基础的学习和理解。

本书适合作为大学二年级第一学期的教材。学生应该具备一定的物理和微积分知识，应该熟悉泰勒级数展开和微分方程式。虽然不要求学生去作级数展开或解方程，但要理解其意义。因为大部分学生都能轻松地运行这些程序，所以要求他们去发展求解程序就比仅仅运用这些程序以获得关于给定问题的准确结果要有意义多了。需要强调的是这些程序都有其特定的适用场合，因此练习题的设置在于训练学生能否从计算结果中得出合理的推论。还有些练习题在于帮助学生判定这些程序的适用范围。以上举一反三的教学重点的直接目的在于将程序视为计算工具和学习工具的结合体。

根据作者的经验，学生在最初使用这些程序时需要在如何正确地输入数据和理解运算结果方面得到一些帮助，特别是告诉学生们演算结果的大致范围。当然我们不可能列举每个学生出错的个例，但至少结果的大概量级是确定的，因为对学生来讲，任何计算机演算出的数据都是毋庸置疑的。用这一方法引导学生至少要求教师对程序十分熟悉，并使学生不要产生太大的学习压力。

本书给出的练习题都是作者在课堂上向学生提出过的典型问题。教师应注明有些问题应以短文形式作答。虽然这些问题对本年级的学

生来说确实有些难，但学生对于问题的理解程度会使教师感到欣慰，教师也会愿意花时间为学生评分。此外，教师也可以按照自己的要求布置作业。非常希望使用者就本书的作用、问题设置、涵盖面以及程序的运行、适用性和缺陷等提出反馈意见。

对于广泛用于分析翼型气动特性的理论方法，本书不作讲解。关于典型翼型特性的试验结果会在第4章中提到。这样调整的原因有三个。第一，讲清这个问题需要很多时间和一定的数学基础，这个任务在第一阶段课程设置中无法完成。第二，大多数高校针对此问题在较高的层次上要求详细的分析。第三，一系列的由试验得到的翼型气动特性，足以使学生应用所有涵盖了此类飞行器所涉及的知识来从事飞行器性能分析。根据流体力学基础原理，一种特定形状的翼型的性能不一定能决定整个飞机的飞行性能。只有当性能计算结果不佳时，人们才会研究这一问题，寻找另一种性能更好的翼型。这样一来，关于几何参数的变化对翼型气动特性的影响这方面的知识就变得十分重要了。

一种类似的情形也存在于飞行器推力章节内容中。基于性能分析的需要，很有必要了解推力和动力之间的关系。此外螺旋桨转化动力的效率（发动机把气流转换为有用的动力）是螺旋桨每分钟转数、叶片角度、实际空速和螺旋桨直径的函数。激励盘理论或动量理论可充分说明螺旋桨的作用原理，而无需依赖任何桨叶剖面特性之类的知识。尽管叶素理论可准确描述螺旋桨的特性，但我们所需要的螺旋桨效率，也就是在不同的桨叶角度、轴的转速、桨叶的直径和实际气流速度下将发动机产生的轴马力转化为气流中有效的向前推力，而这些信息通常可以从螺旋桨制造商给出的性能图表中直接获得。叶素理论在没有制造商给出的性能图表，同时螺旋桨的气动特性又需要进行估算时特别有用。如果认为一种特定机翼翼型能够产生一定的升力系数和一定的阻力系数，第 3 章所介绍的叶素理论也可满足学生学习和估算螺旋桨动力系数和推力系数的需要。由于大部分高校在三年级或四年级设置了有关螺旋桨特性或喷气式发动机推力特性理论方法的相关课程，所以本书不在这方面作具体论述。作者期望本教材能激发学生参与到推进装置内容的学习中来，当学生在以后的学习中遇到更深层次的问题时，他们就能更好地认识到推进装置在全面的飞行器设计中的重要性。

第 5 章详细推导了物体在笛卡尔空间的运动方程。这部分内容不仅是向学生解释第 7 章的性能分析中所使用的方程式的来源，还要将描述飞行器性能的方程式和计算飞行器静稳定性和动稳定性的方程组

联系起来。其实静态和动态稳定性是基于同一物理原理的，只是时间尺度不同。

第 6 章简要说明关于飞行器气动力和稳定性特性的信息来源。文中描述了两架特殊的飞行器，展现了人类丰富的想象力，提示在某些情况下要对计算机程序做出重大调整。书中提到了一个简单的关于飞行试验技术的例子，即通常用飞行器在飞行中的胎压式速度测量和高度测量系统来确定飞行器的位置误差。

作者想说明，本书前 6 章都是基础知识，旨在为学生以后的进一步学习做好准备。前 6 章没有涉及全面的理论和方法，因为大多数航空宇航工程专业的教学大纲中都详细讲述了这部分内容，而且这些内容一般都会单独开课，所以本书不再重复。

有人提意见说以往版本缺少插图，故修订版附了 30 多张图片和表格，并且每张插图都有文字说明，注明了图片的重要特征。另外，本书还收集了各种飞机性能参数的详细情况，列成表格。有关飞机的更多信息可在注释中找到。这些插图及表格，旨在使学生了解第二次世界大战以来飞机在特征和性能方面是如何演变的，以及演变发生的原因。本书还修订增加了喷气式飞机的性能及计算机程序列表的内容。希望修订版能更加完善，更方便读者使用。

读者若发现书中有疏漏或错误之处，请发邮件至 smetana@eos.ncsu.edu。

作者想借此机会向 20 世纪 70 年代中期作者的研究生们表示感谢。Douglas E. Humphreys、Delbert C. Summey、W. Donald Johnson、Neill S. Smith 和 Ronald K. Carden 准备了计算机代码的最初版本以及 NASA 合同报告中的部分内容，并描述了代码的用途。这些原始资料加上两个学生的硕士论文结集而成了作者早期的两本书。每次重新出版之前作者都对代码进行了修改，添加了代码的部分功能或者是使其与不断发展的 FORTRAN 语言及操作系统相兼容。各版本代码都包含了若干新程序，并对部分已有程序进行了升级。本书也一样进行了修改和升级。

本书末附有术语表，不熟悉的术语可以到附录中查找。

弗雷德里克·O. 斯麦塔那
2001 年 3 月

Preface

One purpose of this book is to explain to beginning aerospace engineering students typical methods used to estimate aspects of the performance of aircraft and the theoretical basis of these methods. A second purpose is to explain how various parameters derived from the aircraft geometry can be used to estimate the size, shape, and location requirements of vertical and horizontal control surfaces and the aerodynamic forces required to actuate these surfaces. These methods, or variations thereof, have been used by various groups for more than 50 years. A unique feature of this volume is the inclusion of time-tested computer programs, which can perform the analyses in a manner that reduces student error and improves result accuracy.

The computer programs are intended to be pedagogical tools, not simply computational tools. Thus, some features one might include in programs developed for use by practicing engineers are not present because it is desired that users be required to understand what they are doing. For this same reason some features not present in commercial software may be included.

Classical courses on aircraft performance usually included material on aircraft stability, which today is concerned primarily with airframe dynamics. The author has chosen to exclude most such material from this book because 1) knowledge in this area has undergone a huge expansion in recent years, preventing one from covering it adequately in part of a semester, and, more importantly, 2) the mathematical maturity required to use and appreciate developments in design and analysis for aircraft stability has increased to the level of a typical fourth- or fifth-year engineering student. By restricting consideration to the static aspects of flight vehicle stability and control, one does not have to consider the vehicle dynamics and the factors contributing to it. Nevertheless, the analyses provided by this book are sufficient to perform a complete, preliminary configuration design. Only when such a configuration appears to meet design requirements need one consider its dynamics.

A performance course is usually the first course in the major area encountered by students in aerospace engineering. As such it has the burden of revealing to the student much of the basic jargon in the field and something of what practitioners in the field do. Chapter 1 attempts to address these needs by illustrating the various components of the airplane and by displaying some of the solutions designers have evolved to solve problems set before them over the past 60 or so years. Additional symbols and concepts are defined in later chapters somewhat more repetitively than one might see in more advanced texts. Because spacecraft and missiles were first designed by engineers with backgrounds in aeronautics, much of the aeronautical jargon was carried over when these vehicles were first being designed.

The program CLCDDATA provides a means for the reader to create an input file of experimental lift-drag data, which can be used by program CLCD to generate a drag polar of the type

$$CD = CD0 + K1*CL**2 + K2*CL**K3$$

This extended form is employed so that if the user desires a more exact representation, the complete lift-drag characteristics can be used as the basis for performance calculations.

The program POINT uses the data generated by CLCD as well as data for the power into the airstream to calculate the various static performance maxima and minima. The program PATHPE uses the same input data plus two input time histories to calculate the motion of the aircraft's center of gravity. This program can be used to determine whether there are short periods of time when the performance maxima determined by POINT can be exceeded. A version of PATHPE called TAKOFF is used to calculate takeoffs, climbouts, and landings.

Program ECON can be used to determine the most economical climb for either piston-powered or jet aircraft. ECON employs a crude numerical integration technique for the simple differential equation involved. The numerical integration technique used in PATHPE and TAKOFF is considerably more sophisticated.

Portions of program STADER97 are used to determine values of what are called aircraft stability derivatives, coefficients in Taylor-series expansions for various aerodynamic forces. The representations for various aerodynamic forces can then be used to estimate the forces required to deflect aircraft control surfaces during flight. Subroutines FORCE and FORCEL in STADER97 perform these tasks. They also evaluate the usual criteria for aircraft static stability. For many cases it has been found that aircraft that are statically stable also turn out to be dynamically stable. Except for some additional graphics and the inclusion of STABLE, STADER97 is a subset of STADER91. The latter also contains code to compute linearized versions of the airframe's dynamic response to control surface deflections, but those portions are not included in STADER97, the version of the code that is discussed in this book.

This book can be said to have been written around the seven programs just mentioned in the sense that the performance analysis and the control force determination methods discussed in the most detail are those that have been programmed.

Aerodynamics per se is not the subject of this text. The methods that have been programmed to provide aerodynamic coefficients values are often semi-empirical in nature, but they have long records of successful use by the airframe industry. Their sources are noted in the text. An aerodynamics treatment would attempt to determine these coefficient values entirely from fundamental principles.

Subroutine STABLE97, which is included within STADER97, uses questions written to the screen to elicit from the user typed answers containing the pertinent geometric and inertial data needed to prepare the input data files for STADER97. Those files are then written by subroutine STABLE97. Because quite a lot of information is required, the user may find it desirable to write the contents of these questions to a file so that all of the necessary information can be gathered prior to the run in which the input data file is to be produced.

Certain simplified methods for estimating aircraft performance often used by builders of experimental aircraft are also discussed. However, it must be understood that without additional terms in the drag polar such as K2*CL**K3 it it not possible to obtain an accurate estimate of aircraft stall speed or other performance parameters in which variations in profile drag with angle of attack become important. These simplified methods, developed before the general availability of the personal computer, were crafted so as to be solvable with slide rules and simple addition and subtraction. With the widespread availability of powerful personal computers, it is no longer necessary to resort to such simplifications, provided, of course, that more detailed lift-drag characteristics are available. A similar situation exists with regard to propeller characteristics. The simplified methods really assume certain, often unstated, functional forms for these characteristics. However, if the actual characteristics of real propellers are known, POINT, PATHPE, TAKOFF, etc., can use them to great advantage.

The programs themselves generally present the results of computations as listings. In cases such as the variation of maximum rate of climb with altitude, the data can be plotted to advantage, but plot-generating routines are not yet included with all of the programs. Users with some programming skills may wish to rearrange the output data format to accommodate input requirements of favorite plotting routines.

Most of the programs herein described have been published previously by the author, some as long as 28 years ago in reports prepared for NASA. For the present, more specialized audience of beginning students, the programs have been revised and updated with an eye toward ease of use by neophyte computer users. Both FORTRAN source code and executables are included, the former to permit more adventuresome students to modify the programs to suit their specific requirements or to add such additional graphic routines as may be desired.

Previous incarnations of these programs have accompanied rather abbreviated discussions of the theoretical foundations behind them, it being thought that the collections would serve as computational supplements to more established texts. However, that does not seem to have happened. By themselves, the explanations accompanying previous collections were considered too abbreviated to permit someone new to the subject to really understand them. Hence, the author found that users of these collections were generally professionals already familiar with the subject area who simply wanted to acquire the easy-to-use tools that the programs provide. The present volume is therefore an effort to make the information in the programs more accessible to the engineering novice by treating the subject in standard textbook fashion. Another difference from the author's previous practice is that complete program source code is not given in the text but rather only on the accompanying CD-ROM.

Because of the wide variety of computer platforms then in use and the portability of FORTRAN source code, earlier versions of the programs were supplied only in source form. Lately, however, with the emergence of more cross-platform binary compatibility, it would seem that most users could run executables made for Intel platforms running Windows 95, Windows 98, NT, and probably Windows 2000 as well. The programs are therefore supplied in this form as well as in source form for those who wish to make their own modifications to the programs or compile them for platforms that will not run binaries made for the various Intel platforms.

The author hopes that the text is sufficiently readable and interesting that students of the target course will want to read it. The author, at least, is convinced that reading from hard copy remains the most cost-effective method for transferring specific knowledge and understanding in the shortest possible time. The programs provide a means for students to try their newly found understanding on typical design problems and to affect solutions quickly and with a minimum of computational errors. The student is cautioned, however, that no program can treat every imaginable case. Thus, the prudent student will always examine the assumptions under which a specific program was created before applying it to a problem. Students may find that the program is not applicable to the case to which they wish to apply it and that attempting to apply it to that case will result in numbers without valid physical meaning. The ability to discern valid numbers from invalid ones is the essence of engineering. That ability develops from a study and understanding of the theoretical bases of the programs.

The present text is intended for use in a one-semester course in the sophomore year. It is assumed that the user has at least some facility with physics and calculus. In addition the reader should be familiar with the concepts of Taylor-series expansions and differential equations. The reader will not be expected to develop such series or to solve such equations but will be expected to understand what the series and equations purport to represent. Because it is assumed that most readers will be able to run the programs without difficulty, obtaining the correct numerical values to assigned problems is given somewhat less weight than if the reader were also required to develop solution procedures. More emphasis is devoted to ensuring that the programs are not used where they are not applicable. Some of the exercises are therefore intended to determine whether the reader can draw the proper inferences from the computed results. Several of the problems provided are also intended to help the reader assess the limits of applicability of the programs. These changes in pedagogical emphasis are a direct result of having the programs available both as computational tools and as learning tools.

If the author's experience is typical, students will initially require some assistance entering the data into the programs correctly and interpreting the computed results. In particular, students need to be advised as to the expected range of the results. Obviously, it is not possible to trap every conceivable type of student error, so at least a general indication of the magnitudes of the expected results is essential because, to many students, any number generated by a computer is sacred and need never be questioned. To provide the student with such guidance requires that the instructor or teaching assistant have at least some familiarity with the programs, hopefully not too great a burden.

The problems given in the text are typical of those that the author would assign to students in his class. Instructors will note that some require essay-type answers. Although such problems are certainly more difficult to grade, the student responses give the instructor a better feel for the degree of student understanding and thus make the time invested in grading them worthwhile. Instructors should also feel free to assign problems of their own devising. Feedback from users of the text regarding its utility, problem types, topics covered, and operation of, coverage of, or bugs discovered in the computer programs would be greatly appreciated.

One of the topics readers will not find in this book is an extensive treatment of the determination by theoretical means of the aerodynamic characteristics of airfoils. The experimental characteristics of some typical profiles are, however, provided in Chapter 4. There are three principal reasons for this choice: 1) to treat this topic adequately requires more time and mathematical maturity than are usually available in a first course; 2) at most universities the topic is covered in the required detail