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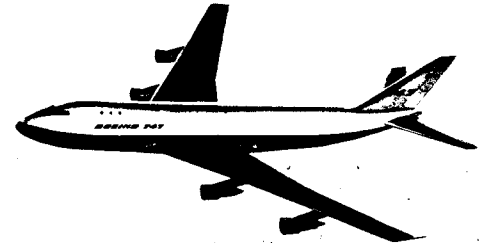
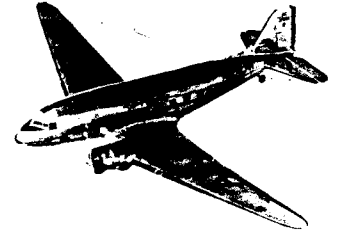
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# aircraft performance and design



AIRCRAFT PERFORMANCE  
AND DESIGN

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# AIRCRAFT PERFORMANCE AND DESIGN

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*University of Maryland*

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*To Sarah-Allen, Katherine, and Elizabeth  
for all their love and understanding*

John D. Anderson, Jr.

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## ABOUT THE AUTHOR

John D. Anderson, Jr., was born in Lancaster, Pennsylvania, on October 1, 1937. He attended the University of Florida, graduating in 1959 with high honors and a Bachelor of Aeronautical Engineering Degree. From 1959 to 1962, he was a lieutenant and task scientist at the Aerospace Research Laboratory at Wright-Patterson Air Force Base. From 1962 to 1966, he attended the Ohio State University under the National Science Foundation and NASA Fellowships, graduating with a Ph.D. in aeronautical and astronautical engineering. In 1966, he joined the U.S. Naval Ordnance Laboratory as Chief of the Hypersonic Group. In 1973, he became Chairman of the Department of Aerospace Engineering at the University of Maryland, and since 1980 has been professor of Aerospace Engineering at Maryland. In 1982, he was designated a Distinguished Scholar/Teacher by the University. During 1986–1987, while on sabbatical from the university, Dr. Anderson occupied the Charles Lindbergh chair at the National Air and Space Museum of the Smithsonian Institution. He continues with the Museum in a part-time appointment as special assistant for aerodynamics. In addition to his appointment in aerospace engineering, in 1993 he was elected to the faculty of the Committee on the History and Philosophy of Science at Maryland, and is an affiliate faculty member in the Department of History.

Dr. Anderson has published seven books: *Gasdynamic Lasers: An Introduction*, Academic Press (1976), *A History of Aerodynamics and Its Impact on Flying Machines*, Cambridge University Press (1997), and with McGraw-Hill, *Introduction to Flight*, 3d edition (1989), *Modern Compressible Flow*, 2d Edition (1990), *Fundamentals of Aerodynamics*, 2d edition (1991), *Hypersonic and High Temperature Gas Dynamics* (1989), and *Computational Fluid Dynamics: The Basics with Applications* (1995). He is the author of over 120 papers on radiative gasdynamics, re-entry aerothermodynamics, gas dynamic and chemical lasers, computational fluid dynamics, applied aerodynamics, hypersonic flow, and the history of aerodynamics. Dr. Anderson is in *Who's Who in America*, and is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA). He is also a Fellow of the Washington Academy of Sciences, and a member of Tau Beta Pi, Sigma Tau, Phi Kappa Phi, Phi Eta Sigma, The American Society for Engineering Education (ASEE), The Society for the History of Technology, and the History of Science Society. He has received the Lee Atwood Award for excellence in Aerospace Engineering Education from the AIAA and the ASEE, and the Pendray Award for Aerospace Literature from the AIAA.

## PREFACE

There are a number of books on airplane performance, and a number of books on airplane design. Question: Where does the present book fit into the scheme of things? Answer: Overlapping and integrating both subjects. On one hand, this book gives a presentation of airplane performance at the college level. It covers both static and accelerated performance topics. On the other hand, this book also gives a presentation of airplane design, with an emphasis on the *philosophy* and *methodology* of design. Some emphasis is also placed on historical material and design case studies in order to illustrate this philosophy and methodology.

This book is not a handbook for airplane design. It is intended to be used in courses in airplane performance as a main text, and in courses in airplane design as an introduction to the philosophy of design, and hence in conjunction with an existing detailed text on airplane design. To paraphrase a popular television commercial, this book is not intended to make a course in handbook engineering design—rather it is intended to make a course in handbook engineering design **better**. This author hopes that such intentions are indeed achieved in the present book.

The major features of this book are as follows.

1. This book is unique in that it is the first to provide an integrated introductory treatment of both aircraft performance and aircraft design—two subjects that are so closely connected that they can be viewed as technological Siamese twins.
2. This book is intentionally written in a conversational style, much like the author's previous texts, in order to enhance the readers' understanding and enjoyment.
3. The book is divided into three parts. Part I contains introductory material that is important for an understanding of aircraft performance and design. Chapter 1 deals with the history of aircraft design. It is important for students and practitioners of aircraft design to understand this history because the design of a new airplane is usually evolutionary; a new airplane is frequently an evolutionary extension of one or more previous designs. Even the most revolutionary of new airplane designs contain some of the genes of almost all previous aircraft. Hence, Chapter 1 is an essential part of this book. Other historical notes appear elsewhere in the book. Chapters 2 and 3 are overviews of aerodynamics and propulsion, respectively. These chapters focus on only those aspects of aerodynamics and propulsion that are necessary for an understanding and application of both aircraft performance (Part II) and aircraft design (Part III). However, they serve a secondary function; they provide a self-contained overview of theoretical and applied aspects of aerodynamics and propulsion that help the reader obtain a broader perspective of these subjects. So Chapters 2 and 3, in addition to being essential to the material in Parts II and III, have intrinsic educational value in and of themselves, no matter what may be the reader's background.
4. Part II deals with static and accelerated aircraft performance. The basic equations of motion are derived in Chapter 4. These equations are then specialized for the study of static performance (no acceleration) in Chapter 5, and are used in Chapter 6 in their more general form for performance problems involving acceleration. The material is presented in two parallel tracks: (1) graphical solutions, and (2) closed-form analytical solutions. The value of each approach is emphasized.

5. Parts I and II provide the material for a complete one-semester course on aircraft performance at the junior-senior level.

6. Parts I and II are sprinkled with “design cameos”—boxed discussions of how the material being discussed at that stage is relevant to aircraft design. These design cameos are a unique feature of the present book. They are part of the overall integrated discussion of performance and design that is a hallmark of this book. In addition, many worked examples are included in Parts I and II as a means to support and enhance the reader’s understanding of and comfort level with the material. Homework problems are included at the end of most of the chapters, as appropriate to the nature of each chapter.

7. Part III is all about aircraft design, but with a different style and purpose than existing airplane design texts. Chapter 7 lays out an intellectual, almost philosophical road map for the process of aircraft design. Then the methodology is applied to the design of a propeller-driven airplane in Chapter 8, and jet-propelled airplanes in Chapter 9. In addition, Chapters 8 and 9 are enhanced by important case histories of the design of several historic airplanes—another dose of history, but with a powerful purpose, namely to drive home the philosophy and methodology of aircraft design. Part III is not a design handbook; rather, it provides an intellectual perspective on design—a perspective that all airplane designers, past and present, exhibit, whether knowingly or subconsciously. Part III is intended for the first part of a senior design course. The complete book—Parts I, II, and III—is intended to provide a unique “pre-design” experience for the reader. I wanted to create a book that would work synergistically with existing main-line design texts. As mentioned earlier, this book is not intended to constitute a complete course in aircraft design; rather, its purpose is to make such a course a *better* and *more rewarding* experience for the student.

8. Although “history” is not in the title of this book, another unique aspect is the extensive discussions of the history of airplane design in Chapter 1 and the extensively researched historical case studies presented in chapters 8 and 9. In this vein, the present book carries over some of the tradition and historical flavor of the author’s previous books, in particular some of the historical research contained in the author’s recent book, *The History of Aerodynamics, and Its Impact on Flying Machines* (see Reference 8).

9. There are carefully selected homework problems at the end of most of the chapters—not an overpowering number, but enough to properly reinforce the material in the chapter. There is a Solutions Manual for the use of instructors. Permission is granted to copy and distribute these solutions to students at the discretion of the instructor. In addition, the answers to selected problems are given at the end of the book.

10. Computer software for aircraft performance and design calculations is intentionally not provided with this book. This may be seen as bucking current trends with engineering textbooks. But I want this book to provide a comfortable intellectual experience for the reader, unencumbered by the need to learn how to use someone else’s software. The reader’s experience with software for these subjects will most likely come soon enough in the classroom. However, much of the material in this book is ideally suited to the creation of simple computer programs, and the reader should enjoy the creative experience of writing such programs as he or she wishes.

I wish to acknowledge the author Enzo Angelucci and his wonderful book *Airplanes From the Dawn of Flight to the Present Day*, published in English by McGraw-Hill in 1973. The airplane drawings that appear in Chapter 1 of the present book are taken from his book.

I wish to thank the many colleagues who have provided stimulating discussions during the time that this book was being prepared, as well as the reviewers of the manuscript. I also

thank Sue Cunningham, who has provided some expert word processing for the manuscript. And most of all I thank Sarah-Allen Anderson for being such a supportive and understanding wife during the long time it has taken me to finish this project.

So here it is—this integrated treatment of aircraft performance and design. Try it on for size. I hope that it fits comfortably and serves you well. If it does, then all my labors will not have been in vain.

John D. Anderson, Jr.  
September 1998

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