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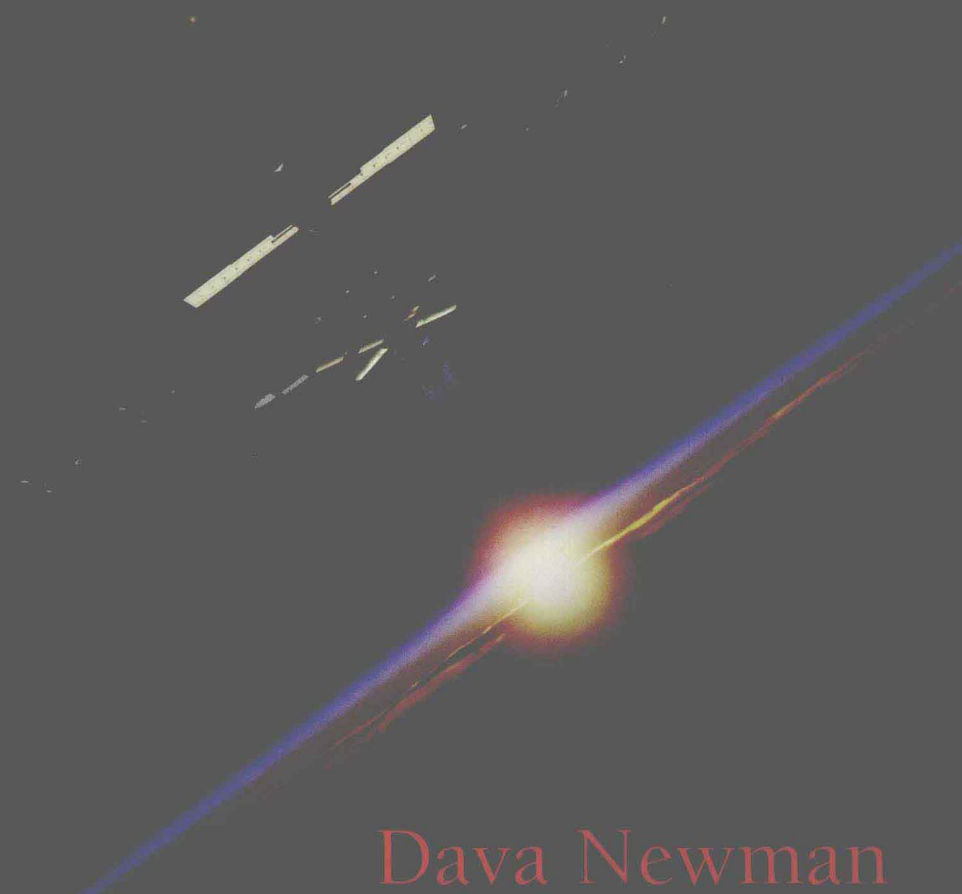

Dava Newman

Interactive Aerospace Engineering and Design

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Dedicated to:

Guillermo Trotti, for all of the love and thrills he has brought to my life and for all that is to come.

My family, the Newmans and Macks whom I love across the country.

PREFACE

I have written *Interactive Aerospace Engineering and Design* for all students and learners who imagine flying a human-powered aircraft, being the first to step on the planet Mars, or have an insatiable curiosity about the governing physics underpinning the theory of flight. My inspiration began with the Apollo Program, the first human footsteps on the Moon, and with a desire to see peaceful human exploration of the solar system and beyond. My heartfelt thanks to Buzz Aldrin for contributing the Foreword. The purpose of this book is to provide a stimulating introduction to aerospace engineering and design. The two main themes I embrace for delivering my introduction to engineering thoughts are:

- hands-on design—where engineering becomes real, albeit challenging and thrilling.
- diversity in learning styles—where concepts and engineering laws can be understood through analytical, visual, and immersive techniques that are delivered through multimedia.

Chinese humanitarian Wei Jingsheng said, "To write, you must work methodically, forming your thoughts and prompting other people to think as they read. Writing requires work at both ends. That's what makes it special."

It has been a very special adventure for me, writing this book, reflecting on engineering education, and attempting to provide information and knowledge not only to assist the reader in thinking about the written words, but also to invite all readers to actively participate in their own education as well as to engage in a design process and build and fly their own lighter-than-air vehicle. I hope that you enjoy the material as much as I have enjoyed its creation.

Information technology (IT) is now revolutionizing the amount of knowledge disseminated worldwide. For the past few years, I have been contemplating how IT can best enhance engineering education, and I offer the following perspective: Multimedia and web-based tools provide students with an opportunity. The educational opportunity is for students to learn through analysis, visual animation, and interactive simulations at our own discretion. In other words, students are empowered to take charge of their own learning by using well-crafted IT tools that complement traditional knowledge dissemination via lectures and printed materials. This text describes the fundamentals of engineering and design in printed material enriched by a multimedia CD-ROM with animations, simulations, movie illustrations, and a web interface for electronic access and interactive demonstrations. Engineering students will find that this book augments their undergraduate core curriculum (i.e., physics, mathematics, and science). The hands-on lighter-than-air vehicle design project and accompanying

design materials are intended for first- or second-year students to experience hands-on engineering.

For motivation during the wee hours while writing and editing, I kept these words of wisdom in mind:

> "Writing is humandkind's most far-reaching creation, its forms and designs endless."
>
> "Time is a luxury, thought a sanctity, and education a true gift. Respect them, honor them, and cherish them most of all."

Dava Newman

ACKNOWLEDGMENTS

First, I would like to thank my students who are truly my inspiration. I wish to acknowledge many friends and coauthors of much of the material for this book. It has truly been a team effort to bring what started out as my initial attempt at a web-based introductory aerospace engineering course to fruition in this manuscript. Professor Jack Kerrebrock, it was with your notes that I began teaching introductory aerospace engineering that first semester—thank you. Amir Amir has been my "left hand" throughout much of the writing of this manuscript and deserves inordinate kudos for his efforts.

To all of the coauthors, my heartfelt thanks, you made it happen: Amir Amir and Dr. Stan Weiss for Chapter 1; Professor Richard Bannerot and Dr. Jean Luc Herbeaux for material included in Chapter 2, Sections 2.1–2.2; Jason Carrillo and Sharmi Singh for their assistance with Chapter 3; Thomas Benson for authoring much of the stimulating aerodynamics material and Amir for his contribution to Chapter 4; Professor Edward Crawley for content included in Chapter 5; Thomas Benson, again, for the wonderful portrayal of propulsion fundamentals and to NASA Glenn Research Center for numerous graphics and illustrations of concepts included in Chapter 6, and Charles Toye for assistance with homework questions for this chapter; Amir Amir for coauthoring Chapter 7 and Joseph Saleh for assistance with homework questions for this chapter; Joseph Saleh for coauthoring Chapter 8 and Tyra Rivkin for assistance editing the chapter; Professor Richard Battin for his insightful review and loan of figures, Natasha Neogi and Bryant King for writing assistance, and Christopher Carr for his orbital mechanics program and homework questions for Chapter 9; Cory R. A. Hallam for coauthoring Chapter 10, Keoki Jackson for initial material, Joseph Saleh for assistance with the Case Studies and Christopher Carr for developing the homework questions; Dr. Michael Barratt for writing an earlier book chapter on humans in space with me, which served as inspiration for Chapter 11; Professor Richard Bannerot, Dr. Jean Luc Herbeaux, Lance Newman, Marion Carroll, Gui Trotti, Esther Dutton, Bradley Pitts, Elizabeth Walker, and Grant Schaffner for contributing to Chapter 12. Amir Amir is the author of the Appendices: Unit Systems and Unit Conversion Factors and Physical Constants and Miscellaneous Values.

Other MIT students who have made valuable contributions include Hector Ayuso, Louis Breger, Esther Dutton, Nathan Fitzgerald, Lisa Gerard, Lisa Hughey, Gary Li, Vanessa Li, Shannon Russell, Brian Wong, and all the 16.00 LTA vehicle teams in general—thank you. Thank you to all those mentioned in the credits for photos and art. There are numerous others who have kindly participated in the creation of this publication perhaps without even knowing. Thanks to: Arthur Ganson for design inspiration and use of materials; Professor Mark Drela, Dr. Matthew

Wall, and Steve Finberg for Decavitator and Daedalus human-powered vehicle knowledge and materials; Professor Larry Bucciarelli for sharing the Delta Design experience; Professor David Wallace for insights into product design and web-based education; and my colleagues Professors John Hansman, Earll Murman, Chuck Oman, and Larry Young for technical conversations. I would also like to thank Professor John Leinhardt of the University of Houston who has greatly inspired me and whose wisdom is reflected in his "Engines of Ingenuity" transcripts that are so often quoted and referenced throughout this publication.

Acknowledgement is also directed to the MIT Classes of 1951 and 1955 Funds for Educational Excellence and the National Science Foundation's ECSEL coalition (Engineering Coalition of Schools for Excellence in Education and Leadership), in particular, MIT Professor Herbert Einstein. Gratitude and thanks are extended to the National Aeronautics and Space Administration (NASA) for the numerous images and reflections of spaceflight contained in this book and CD-ROM. A huge thank you to the folks that are always there to assist me: Jennie Leith, Ping Lee, and Marion Carroll—your support and wonderful images are crucial to this final publication.

An important factor to reach fruition of this educational project is the support I received from MIT senior administrators. Professors Charles Vest, President; Robert Brown, Provost; Lawrence Bacow, Chancellor; Thomas Magnanti, Dean of Engineering; and Edward Crawley, Head of Aeronautics and Astronautics. I have found amazing moral support and encouragement among my MacVicar Faculty Fellows community, thank you.

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Stephen Batill, *Notre Dame University*
Frank Redd, *Utah State University*
David Scott Eberhardt, *University of Washington*
Martin Dunn, *University of Colorado at Boulder*
Bruce Carroll, *University of Florida*
Robert H. Bishop, *University of Texas at Austin*

Also, I am grateful to friends, not named, whose ideas I have implemented from conversations and sharing. Professor Thomas McMahon who taught me so much—how to truly teach and mentor based on creativity and sensitivity—I miss you. Finally, Guillermo Trotti has been my beacon from the first word to the closing image and last multimedia clip.

FOREWORD

Professor Dava Newman has written an exciting introductory book for students of aerospace engineering and design. We are all students in our universe, and her interactive illustrations take us from the earliest engineering feats to the Wright brothers' airborne flight to my spaceflight on Apollo 11 to future missions to Mars. Dr. Newman's *Interactive Aerospace Engineering and Design* makes engineering principles and the design process become intuitive components in our learning. Her landmark book offers the combination of text, animations, and simulations, utilizing information technology to motivate, illustrate, and demonstrate physical phenomena such as the principles behind flight, the fundamentals of the space environment, and artistic insight into creative design. The learning process culminates in *Interactive Aerospace Engineering and Design* with the lighter-than-air (LTA) vehicle design chapter. Through active, hands-on learning, blimps become operational and engineering principles are fully demonstrated in the team design.

This book is for those curious about engineering and design. I recommend it to college engineering students and teachers, advanced high school students, or members of the general public who want to think and be challenged to solve problems and learn technical fundamentals.

My Apollo 11 spaceflight to the Moon was the pinnacle of an engineering education, but my lifelong work is to continue answering technical problems for future aerospace endeavors, as seen in my collaboration with Professor Newman and colleagues to analyze novel Mars mission trajectories. In *Interactive Aerospace Engineering and Design,* Professor Newman invites us as a community of learners to take flight. This multidisciplinary, multimedia approach is how engineering should be taught.

Buzz Aldrin

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The emphasis of this book is to inspire students new to the aerospace field to become actively challenged by this text, the CD-ROM, and the Internet resources. These various types of media will stimulate students with different learning styles to the excitement of aerospace engineering. While reading through the chapters, you will be exposed to animations, simulations, movies, and problems, all of which are easily identifiable by the following symbols:

Throughout the book, the image of the **thinker** in the margin is used to indicate that the problems presented are general thought-type questions. These problems do not require a quantitative answer, but require creative, qualitative contemplation.

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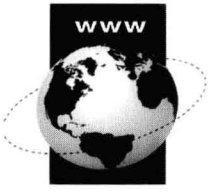

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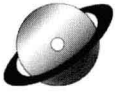

A **CD-ROM** icon with a resource description is used to direct the reader to specific material on the accompanying *Interactive Aerospace Engineering and Design* CD-ROM. The CD-ROM contains animations, QuickTime™ movies, simulations, multimedia projects, design templates, and the complete e-text.

Interactive Aerospace Engineering and Design

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