

Tactical Missile Design
Second Edition



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Second Edition

Eugene L. Fleeman
Lilburn, Georgia



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To my family, especially my grandchildren Nicholas and Christopher



Foreword

We are delighted to present the second edition of *Tactical Missile Design* by Eugene Fleeman formerly of Georgia Tech. The first edition was very well received in the aerospace community. This new edition has updated material and expanded coverage, and we anticipate that it will be equally well received. The current volume has nine chapters and six appendices in more than 450 pages covering all of the topics relevant to this subject. One appendix has good homework problems and another contains an extensive bibliography. In addition, a CD with PowerPoint slides suitable for a short course is included.

Eugene Fleeman is superbly qualified to write this book because of his long and productive career in the tactical missile area. His command of the material is excellent, and he is able to organize and present it in a clear manner.

The AIAA Education Series aims to cover a very broad range of topics in the general aerospace field, including basic theory, applications, and design. The philosophy of the series is to develop textbooks that can be used in a university setting, instructional materials for continuing education and professional development courses, and also books that can serve as the basis for independent study. Suggestions for new topics or authors are always welcome.

Joseph A. Schetz
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Preface

The material in this book is oriented toward the needs of aerospace engineering students, missile engineers, and missile program managers. One objective is to provide a reference text for the aerospace engineering curriculum of universities. Although the tactical missile community is large, receives a significant amount of funding, and has many technical and system problems to address, few universities offer courses in missile design. This introduction to tactical missiles will hopefully spark the interest of young engineers to make a career in the missile community. Also, the text is a reference for missile engineers and missile program managers.

The text is a summary of information that I have collected during my 40-plus years of experience in the development of tactical missiles and their technologies. It distills the technical knowledge that I have gathered into an integrated handbook method for missile design. Generally used are simple, closed-form, analytical, physics-based equations to provide insight into the primary driving parameters. Closed-form analytical equations are a throwback to the way missile design was conducted more than thirty years ago. The text also provides example calculations of rocket-powered and ramjet-powered baseline missiles, typical values of missile parameters, examples of the characteristics of current operational missiles, discussion of the enabling subsystems and technologies of tactical missiles, and the current/projected state-of-the-art of tactical missiles.

In recent years we have seen increased usage of tactical missile systems for military operations. Tactical missiles are expected to have an even larger share of military operations in the future. A key contributor to the increased effectiveness is the advancement in technology. Examples of advancement in missile system effectiveness include improved range, firepower, maneuverability, accuracy, lethality, and adverse weather capability.

A historical example of the value of guided weapons is the attack on the Thanh Hoa Bridge in Vietnam. For more than six years, a total of 871 aircraft sorties dropped unguided bombs but failed to close the bridge. However, the first operational application of laser-guided bombs on 13 May 1972 resulted in direct hits on the supporting piers, dropping the center span and closing the bridge. Eleven aircraft had been lost in the 871 previous sorties. No aircraft were lost in the four sorties using precision guided munitions. A more recent example is the use of precision strike weapons in Desert Storm, Kosovo, and Enduring Freedom. In the year 1991 Desert Storm operation, 9% of the strike weapons were guided weapons. In Kosovo 35% of the strike weapons were guided weapons. In the

year 2002 Enduring Freedom operation, 69% of the strike weapons were guided weapons.

The organization of the material in this text is as follows: Chapter 1 gives an overview of the missile design process. Chapter 2 discusses aerodynamic design methods and the technologies of low aspect ratio wing and wingless configurations. Conceptual design methods and technologies for rocket, ramjet, and turbojet propulsion are included in Chapter 3. Chapter 4 addresses conceptual design weight considerations. Topics include weight prediction, aerodynamic heating prediction, technologies for lightweight materials and subsystems, and low-cost manufacturing processes. Conceptual design methods for predicting flight range, velocity, time to target, maneuverability, and off boresight are given in Chapter 5. Chapter 6 provides measures of merit and launch platform integration considerations. It includes conceptual design methods and technologies in the areas of robustness, warhead lethality, miss distance, carriage and launch observables, other survivability considerations, reliability, cost, fire-power, store separation and carriage, and storage environment. Conceptual design sizing examples and computer-aided sizing tools are presented in Chapter 7. Sizing examples are for a rocket-powered missile, a ramjet-powered missile, and a soda straw rocket. An example of an electronic spreadsheet sizing tool based on the methods of this textbook is presented. Chapter 8 discusses the missile development process. A summary of this text and lessons learned in missile development are given in Chapter 9.

The appendices in the back of the book have a set of homework problems/classroom exercises, an example of a request for proposal for a missile design study, a list of nomenclature, a list of acronyms, a table for conversion of English to metric units, selected figures from the text that are in color, and an example of a syllabus for a course curriculum in Tactical Missile Design. I wish to express my appreciation to the Boeing Company for providing the funding to print the color figures.

References for the data and methods used in this text and a bibliography of other reports and Web sites that are related to tactical missiles are provided in the back of the book.

A compact disk (CD) is included with this book. It includes a Microsoft PowerPoint presentation of a short course based on this book. The slides are in color and have embedded tabular data. Embedded in the slides are 29 videos illustrating missile design considerations, development testing, manufacturing, and technologies. The CD includes a tactical missile design spreadsheet in Microsoft Excel format. The spreadsheet models the configuration sizing methods of this text. Also on the CD are six tactical missile design case studies. These were conducted by Georgia Tech students over the years 1999 to 2005. Finally, the CD includes a presentation entitled Soda Straw Rocket Science. It is an aerospace engineering outreach program for elementary and middle school students.

I would like to thank the faculty and students at the Georgia Institute of Technology for their support for this textbook. Special appreciation is expressed to Dr. Dimitri Mavris, Director of the Georgia Tech Aerospace Systems Design Laboratory.

I would like to also express my appreciation to the following persons who have supported my work in the areas of missile design, advanced weapon

concepts, and advanced weapons technologies: Bill Lamar and Charles Westbrook of the United States Air Force Research Laboratory and Thad Sandford of the Boeing Company Phantom Works. Again, I wish to thank the Boeing Company for sponsoring the color figures at the back of the book.

Finally, I would appreciate receiving your comments and corrections on this text, as well as any data, examples, or references that you may offer. E-mail to: GeneFleeman@msn.com, or visit the Web site: <http://genefleeman.home.mindspring.com>.

Eugene L. Fleeman

April 2006

