

Preface

The main purpose of writing this book is to present a unified approach for automatic control of atmospheric and space flight vehicles. Such an outlook has become more necessary now than ever, with the advent of aerospace vehicles whose single mission covers operation as aircraft, rocket, and spacecraft at various instants. The automatic control system for such a craft must therefore have the entire gamut of flight control techniques in its repertoire.

This book is primarily designed as a textbook for senior undergraduates as well as graduate students in aerospace engineering/aeronautics and astronautics departments. As an acquaintance with control theory is not necessary, the book can be used as a first course in flight control systems. However, a familiarity with the basic mathematical concepts of calculus, linear algebra, and Laplace transform is required. The contents have evolved from the lecture notes of several 3rd–4th year undergraduate, and graduate-level courses I have taught in my career. The material in the book has been especially selected to be useful in modern courses on flight control systems, where the artificial distinctions among aircraft, rockets, and spacecraft are removed. Suggestions for the usage of the material by course instructors is given later. The chapters and sections are designed to follow in a sequence such that their concepts evolve logically, and are introduced in an easy-to-read manner, while retaining mathematical rigor.

It is easy for a reader to be lost in the theorems and proofs commonly found in textbooks on control systems, without realizing their practical significance. For this reason, the basic control theory concepts are covered in a manner accessible to a beginner in the topic. At the same time, understanding of relevant flight dynamic principles is highlighted while designing a flight control system. More emphasis is placed on realistic examples and exercises that require some programming, rather than those of the analytical type.

Each chapter begins with a list of clearly defined aims and objectives. At the end of each chapter, short summaries and a limited number of exercises are provided for consolidation. A primary feature of the book is the ready and extensive use of

MATLAB[®] and Simulink[®].¹ The codes are supplied with the examples in order to readily illustrate control design and analysis. MATLAB/Simulink is standard, easy-to-use software that most engineering students learn in the first year of their curriculum. In giving the reader a hands-on experience with practical problems, the book is useful for a practicing engineer, apart from being an introductory text for the beginner. The use of the supplied MATLAB/Simulink codes as instructional tools (rather than as “black-boxes”) is encouraged. The reader is required to write his/her own codes for solving many of the problems contained as exercises. All the codes used in the book are available for free downloading at the following web-site: <http://home.iitk.ac.in/~ashtew>.

The coverage of flight control topics in the book is basic rather than exhaustive, with a greater emphasis on single-variable control for a fundamental understanding of the relevant concepts. However, some advanced topics – such as linear, optimal control, nonlinear orbit plane control, and two-point boundary value problem solution for de-orbiting spacecraft – are included for imparting a flavor of the variety found in automatic flight control.

A reader is assumed to have taken basic undergraduate courses in mathematics and physics – particularly calculus, complex variables, linear algebra, and fundamental dynamics – and is encouraged to review these concepts at several places in the text. I will now briefly discuss the organization and highlights of the topics covered in each chapter in order to provide a ready guide to the reader and the classroom instructor.

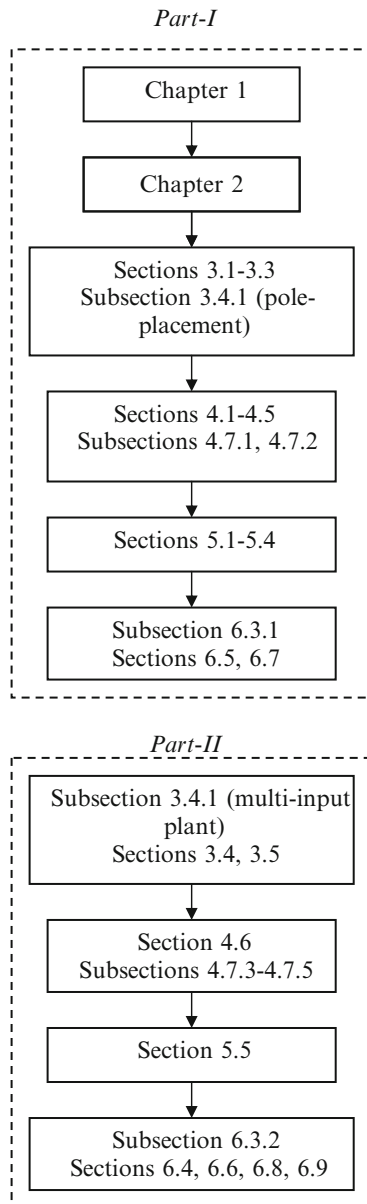
The undergraduate curriculum in an aerospace engineering department traditionally includes separate courses on introduction to automatic flight control of aircraft and spacecraft, depending upon the interest of students to pursue either atmospheric or space flight in further study and research. These basic courses are supplemented by advanced elective courses in the same respective areas. I think the time has come to move away from this tradition, and allow courses that cover aircraft, rockets, and spacecraft control systems at both introductory and advanced levels. It is envisaged that the contents of this book are followed in a single introductory course taught in the senior year. The fourth-year undergraduate courses, (a) 16.30 titled *Estimation and Control of Aerospace Systems*, taught by the Department of Aeronautics and Astronautics at Massachusetts Institute of Technology (MIT), and (b) AE-620 *Aircraft and Spacecraft Automatic Control Systems I*, of the Ohio State University (OSU) are likely examples. The following is a suggested coverage of material by course instructors.

The first part of the course would cover basics of control systems, with focus on single-variable control design for aircraft, rockets, and spacecraft. This part should cover material given in Chaps. 1 and 2, Sects. 3.1–3.3, 3.4.1 (only pole-placement), 4.1–4.5, 4.7.1, 4.7.2, 5.1–5.4, 6.3.1, 6.5, and 6.7, as shown in the accompanying

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flowchart. Such a range of topics includes basic stability and control of flight vehicles, thus also replacing the traditional aircraft/spacecraft stability and control courses (e.g., 16.333/16.335 of MIT and AE-720 of OSU).

The second (and shorter) part of the course would begin probably after the second midsemester examination, covering multivariable and nonlinear flight



control systems for aircraft, rockets, and spacecraft. This includes the design of regulators and observers by eigenstructure assignment and linear, optimal control (LQR) methods. The coverage can be selected from Sects. 3.4 (including 3.4.1 for multi-input plant), 3.5, 4.6, 4.7.3–4.7.5, 5.5, 6.3.2, 6.4, 6.6, 6.8, and 6.9 (see the accompanying flowchart). This material can also be used to supplement an advanced undergraduate course, such as (a) 16.31 *Feedback Control Systems* of MIT's Department of Aeronautics and Astronautics, and (b) AE-621 *Aircraft and Spacecraft Automatic Control Systems II* of Ohio State University.

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