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Book Reviews

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Flight Dynamics

Robert F. Stengel, Princeton University Press, Princeton, NJ, 2004, 752 pp., $99.50

A famous airfoil designer once described flight dynamicists to this reviewer as "the folks in the aerodynamics office who can't do integral calculus." Any flight dynamicist who has been stung by similar accusations now need only point out the extraordinary range of computational and analytical techniques brought to bear on the subject in this excellent 845-page book. Today, it seems that flight dynamicists require a thorough knowledge of modern and classical control theory, Monte Carlo analysis, neural networks and many, many other techniques that are described, discussed, and applied to flight dynamics examples in this tour de force of a text.

The intended audience of this book is the usual "upper-level undergraduate and first-year graduate students, as well as practicing engineers," but the practicing engineer category will include many practitioners of other disciplines. They will find this book interesting and stimulating and will find very useful the succinct and clear descriptions of analytical methods that have far wider application. Specialists who already own other books on the general topic will want to add this book to their library for all of this and for its new insights into old topics: the neat analysis of the controllability and observability of the phugoid mode is just one of this book's satisfying, updated insights into traditional topics.

The book begins with an introduction to aircraft and their components and descriptions of a wide range of flight vehicles, and by the completion of the analysis of the paper airplane on page 27, the reader should have no doubt that mathematical and computational rigor will be a foundation of this book. Most readers will welcome the inclusion of MATLAB code and references to MATLAB functions for this and other examples in the book.

Following an introductory chapter on the atmosphere, static forces and moments, propulsion, and performance, the treatment of airplane dynamics begins. The material covers the usual topics like the different axis systems and rigid-body equations, plus treatments of some welcome less-traveled topics like round-Earth equations, quaternions, and unsteady derivatives. Numerical integration methods are described rigorously but in the context of available MATLAB routines. Here as elsewhere in the book, the author does not encourage such routines as "black boxes" but instead places a premium on insight.

Engineering authors must tackle the question of whether to refer to separate texts on methodology—in this case differential equations, stability, control theory, etc.—or whether to include the material in their present text. Given this book's early emphasis on computational methods, it is no surprise that the author elected to include the material, which is succinctly done in many definitions and derivations throughout the text, and especially in a 170-page dedicated chapter, Methods of Analysis and Design. This chapter adds to the usual material some relatively unusual topics including unsteady aerodynamics, linear aeroelasticity, and flying qualities. With its broad interpretation of methodology, this chapter's especially large number of references will be especially valuable to the reader.

Some elements of flight dynamics are inescapable, and the treatment of longitudinal and lateral-directional dynamics (in separate chapters in this volume) is an example. This very traditional approach is very helpful to the reader's insight; however, the author brings a fresh view to these well-worn topics. Less traditional, and very welcome, is the book's inclusion of a chapter on coupled longitudinal and lateral-directional motions, including a relatively thorough treatment of inertial coupling and flight at high angles of attack. The book's concluding sections include supporting computer code, description of downloadable methods, a valuable NASA report bibliography, an epilog, and the very thorough index expected in today's texts. This reviewer could find only the smallest of quibbles with the content. In particular, though treatment of frequency domain methods is otherwise very complete, there is no mention of fast Fourier analysis, which today is a popular system identification approach.But the omission of this rather specialized analysis does not diminish the book's value.

This is an ambitious and important work, which begs an attempt to put it into context. In particular, readers might ask what this volume adds to a field that is arguably well covered already. There are other books on flight dynamics, of course, and many books with different titles contain flight dynamics information. Or the reader may wonder whether perhaps the technology has been relatively quiescent for a few years.

One way to put the volume into context is to consider the evolution of books on this topic using a few examples (with no claims by the reviewer for completeness). It is interesting to compare the present volume with Bairstow's 1919 text on the broader technology of applied aerodynamics.[1] Bairstow's book contained a

chapter titled, The Stability of the Motions of Aircraft (cf. the present volume's Stability and Modes of Motion), to remind us that the physics do not change. However, mere computation of the roots of the characteristic equation was clearly a significant obstacle in those days. In contrast, Prof. Stengel presents examples of root loci, both deterministic, quasilinear (utilizing a describing function) and stochastic (utilizing a Monte Carlo simulation), to remind us that our computational power has very much changed. And the technology did stagnate between the World Wars; Bairstow did not change his stability chapter in his 1939 edition because in the intervening 20 years "the experimental investigation of the more complex motions of aircraft has been less thoroughly pursued."

Around midcentury, however, the technology had accelerated greatly, as evidenced by the so-called BuAer reports[2,3] and Etkin's *Dynamics of Flight: Stability and Control*.[4] These volumes, along with several other fine texts, became standard on the North American continent, with their emphasis on equations of motion, aerodynamic effects on modes of motion, and feedback control. The present book includes much material on all of these. The two BuAer reports evolved into the later McRuer et al.,[5] whose extraordinarily complete coverage of the technology will be compared by many readers with the more modern approach of the present book.

Roskam's volumes,[6] with their clear goal of teaching the technology, later occupied almost 5 in. of shelf space in most flight dynamicists' offices. More recently there have been other books with a pedagogic emphasis (for example, Refs. 7–9), and Refs. 7 and 9 are justly among the standard teaching and reference texts in English-speaking areas. We could summarize this history as periods of arcane inaccessibility followed by inactivity,[1] hyperactivity,[2–4] consolidation,[5] and more recently, a focus on accessibility and comprehension.[6–9] This present volume is an example of the latter, but its computational thrust makes it considerably more than that.

As the very latest of this genre, Prof. Stengel's hefty volume brings the material up to the minute, tackles more topics with more depth, buttresses its analysis with MATLAB examples, and still does a superb job of stimulating and informing the reader. And again, its push toward computational synthesis does open a new door for this type of text.

Finally, the author, in a thoughtful epilog that should be required reading for any teacher of the subject, unapologetically advocates the strong computational emphasis of his approach. He confronts the widely discussed concern that "Computational tools can be employed without requiring the user to develop intuition, the ability to approximate and to visualize, or an awareness of the validity of results," but he states, "Unlimited computation alone is not the answer; however, intelligent use of large-scale computation is a central feature of the new synthesis," *and* integral calculus.

References

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