Review of Spacecraft Dynamics and Control: A Practical Engineering Approach

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Spacecraft Dynamics and Control: A Practical Engineering Approach

Marcel J. Sidi

Cambridge University Press, 1997, xvii + 409 pp., $85.00.

This new addition to the spacecraft dynamics and control literature joins a fairly short list of texts that treat control of both orbit and attitude dynamics, including Bryson's *Control of Spacecraft and Aircraft* (1994), Kaplan's *Modern Spacecraft Dynamics and Control* (1976), and Wiesel's *Spaceflight Dynamics* (1996). As the subtitle indicates, a novel aspect of this text is its emphasis on the "practical engineering" details of the subject, and the book succeeds in its stated goal of introducing "the basic engineering notions of controlling a satellite." The author's experience in the field is clearly demonstrated through his extensive use of examples illustrating the fundamental concepts; in fact, the cover features an image of one of the author's projects – the Amos 1 satellite. The essence of the book is the development and linearization of the appropriate equations of motion, followed by the solution of typical automatic control problems using the basic tools of linear control theory. The author assumes that his readers are familiar with these tools, so that Bode plots, Nichols charts, and so forth are used with minimal explanation. Although the author uses some matrix and vector notation throughout the text, many equations which could be expressed

succinctly in vector notation are given in scalar notation. While this may make the book more readable for some, the use of scalar notation obscures some of the advantages which come with the use of state space methods.

The book has ten chapters and three appendices. The first chapter introduces the subject matter with a brief look at the life of a spacecraft from the dynamics and control analyst's viewpoint, and provides an overview of the rest of the text. There are two chapters on *Orbit Dynamics* and *Orbital Maneuvers.* Most of the usual topics are included; however, there are notable exceptions. The time-of-flight problem and the design of interplanetary missions using patched conics are both absent. The latter omission is especially noteworthy, since many students want to do projects in this area, and the AIAA-sponsored student design competitions typically involve interplanetary mission design. On the other hand, this is the only book I have seen that emphasizes the importance of attitude control during orbit transfers.

The remaining seven chapters cover a variety of key topics in attitude dynamics and control. The first of these develops the basic equations of motion for a rigid body, including kinematics in terms of both Euler angles and quaternions. Part of the kinematics analysis is removed to an appendix, which should not trouble a careful reader. Two things about the development are troublesome. The first involves a lack of rigor that will not impede the practical

application of the equations of motion. Namely, the development of angular momentum passes directly from a *summation* over a finite number of mass particles to an *integral* over a continuum, without mentioning whether this is an appropriate move or not. (For the interested reader, Truesdell's essay "Whence the Law of Moment of Momentum?" in his 1968 *Essays in the History of Mechanics* is recommended.) The second item also involves moments of inertia. The author claims that the "engineer generally prefers a satellite in which there are negligible products of inertia." While the experienced reader will understand the meaning here, newcomers to the subject may get the mistaken idea that products of inertia are satellite properties rather than reference frame properties.

The second of the attitude dynamics and control chapters treats *Gravity Gradient Stabilization*. This chapter begins with an introduction to all of the subsequent chapters, and defines "the basic attitude control equation" based on a linear PID (proportional plus integral plus derivative) control law, whose gains are to be developed as appropriate for each problem. The discussion of gravity gradient stability is thorough and includes examples with passive, active, and magnetic damping. The discussion of the DeBra-Delp region is misleading in its statement that the region "is seldom used owing to practical structural difficulties." The fact is that this region is unstable in the presence of damping (See for example, § 9.3 of Hughes' 1986 *Spacecraft Attitude Dynamics*).

The remaining chapters cover *Spin and Dual-Spin Stabilization*, *Attitude Maneuvers in Space*, *Momentum Bias Attitude Stabilization*, *Reaction Thruster Attitude Control*, and *Structural Dynamics and Liquid Sloshing*. All of these are unusually thorough in the sense of providing useful information on the effects of real-world difficulties such as sensor noise and actuator limitations. The chapter on *Attitude Maneuvers* includes excellent coverage of the use of momentum wheels as momentum exchange devices for maneuvers; control moment gyros are not covered. The author restricts attention to control synthesis based on linear dynamics models, and for large-angle rotational maneuver refers readers to Junkins and Turner's 1986 text *Optimal Spacecraft Rotational Maneuvers*, which remains the only textbook treatment of this topic.

One especially useful feature of the book is the extensive use of specific examples illustrating the various topics. While some of these examples do not include all of the data necessary to reproduce the results exactly, it is usually possible to deduce the missing information, at least approximately. If the book is used as a text for a course, these examples will serve as good starting points for homework problems. This is especially important, as the book does not include any exercises. Another useful feature of the book is the inclusion of specific hardware data in two appendices on attitude determination and attitude control hardware.

I am confident that anyone working in the field of spacecraft dynamics will find plenty of useful material in this book. The book will also be useful as a text for a one or two semester course at the senior or first-year graduate student level.

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