Preface

If you do a casual search for books that contain the word attitude in their title, you'll find yourself drowning in a sea of over 500 volumes. Of course, most of those books relate more to personal self-improvement than to spacecraft dynamics, but even when the subject is limited to the areas of aerospace and astrodynamics you'll still find a fair number of items from which to choose. So, what distinguishes this text from those many other candidates? This book attempts to de-emphasize the formal mathematical description of spacecraft onboard attitude and orbit applications in favor of a more qualitative, concept-oriented presentation of these topics (whether or not we ultimately achieved that goal is something we'll have to leave to you, dear reader, to decide). As such, it would most likely be described by an attitude control analyst as a (hopefully) amusing light read rather than an essential reference bible. And it certainly would not be the first text an Attitude Control Subsystem (ACS) flight software (FSW) designer would grab if he needed a specification of a Kalman filter algorithm. ACS Without an Attitude is instead intended for programmers and testers new to the field who are seeking a commonsense understanding of the subject matter they're coding and testing in the hope that they'll reduce their risk of introducing or missing the key software bug that causes an abrupt termination in their spacecraft's mission and their careers.

ACS Without an Attitude is organized in four major sections. Section One (Chaps. 1–3) contains the attitude, orbit, and dynamics background material required to understand the downstream spacecraft applications. Section Two (Chaps. 4 and 5) is a survey of the spacecraft sensors and actuators used to measure and control the spacecraft attitude and orbit. Section Three (Chaps. 6–11) examines how sensor data is combined with reference data to measure attitude and orbit, and how desired or commanded attitude parameters are compared with measured attitude parameters to determine what should be done to maintain the current pointing, or modify it to satisfy future needs. Finally, Section Four (Chap. 12) is a survey of mission characteristics and how attitude and orbit geometries are selected to accomplish mission objectives.

The information presented in these sections was originally collected to support an informal set of lectures in 1999 and 2000 instigated by my Branch Chief, Elaine

Shell (Flight Software Branch, NASA Goddard Space Flight Center), who also realized that bullet charts are an ineffective means to document information, hence this book. The following is a list of textbooks and documents I drew on (hopefully not too blatantly) while preparing for my talks, as well as additional references used when writing this book:

1. Spacecraft Attitude Determination and Control, edited by James R. Wertz, Kluwer Academic Publishers (1978).
2. Space Mission Analysis and Design, edited by Wiley J. Larson and James R. Wertz, Microcosm, Inc. and Kluwer Academic Publishers (1992).
3. Reducing Space Mission Cost, edited by James R. Wertz and Wiley J. Larson, Microcosm Press and Kluwer Academic Publishers (1996).
4. Satellite Technology and Its Applications, by P.R.K. Chetty, TAB Professional and Reference Books (1991).
5. An Introduction to the Mathematics and Methods of Astrodynamics, by Richard H. Battin, AIAA Education Series (1987).
6. Modern Inertial Technology Navigation, Guidance, and Control, by Anthony Lawrence, Springer (1998).
7. Modern Control Systems, by Richard C. Dorf and Robert H. Bishop, Addison-Wesley Publishing Company (1995).
8. Feedback Control of Dynamic Systems, by Gene F. Franklin, J. David Powell, and Abbas Emami-Naeini, Addison-Wesley Publishing Company (1991).
9. Modern Control Engineering, by Katsuhiko Ogato, Prentice-Hall (1997).
10. Goddard Trajectory Determination System (GTDS) Mathematical Theory, Revision 1, edited by A.C. Long, J.O. Cappellari, Jr., C.E. Velez, and A.J. Fuchs, NASA/GSFC Flight Dynamics Division Code 550 (1989).
11. Fundamentals of Astrodynamics, by Roger R. Bate, Donald D. Mueller, and Jerry E. White, Dover Publications, Inc. (1971).
12. Classical Mechanics, by Herbert Goldstein, Addison-Wesley Publishing Company (1950).
13. Fundamentals of Spacecraft Attitude Determination and Control, by Landis F. Markley and John L. Crassidis, Springer Science and Business Media (2014). (An excellent book for both subject history and in-depth mathematical analysis.)

In addition, here are some references targeted to specific topics discussed in the later chapters:

1. Hermite Polynomials, Legendre polynomials, and spherical harmonics: Mathematical Methods for Physicists (seventh edition), by G. Arfkin, H. Weber and F. Harris, Academic Press, Inc. (2013), Sect. 18.1.
2. Runge-Kutta integrator: Numerical Methods for Scientists and Engineers by R.W. Hamming, McGraw-Hill (1962).

One of the strengths of my original set of lectures was the participation of several of my NASA/GSFC Guidance, Navigation, and Control (GN&C) colleagues who supplemented (and often, and graciously, corrected) my presentations with material

drawn from their extensive experience here at GSFC. And when my pitches started to drag a bit, they also helped liven things up by recounting some of their many war stories accumulated during their years of applying clean-cut mathematical algorithms to uncooperative real-life spacecraft. My crew of semi-regular experts included

1. Gary Welter
2. Landis Markley
3. Dave Quinn
4. Dave McGlew
5. Bruce Bromberg

As the years have rolled by since the first version of the manuscript, the material in the book has been updated many times, stimulated by new missions and new ACS technologies, as well as new teaching experiences gained repeating the course. Finally, as I reached the point I could no longer bear to edit the material again, Gary Welter, Dave Simpson, and Chris Rouff have ridden to the rescue to co-author with me this final version.

Lou Hallock—2010

Well … life goes on, including delays from other obligations. Lou passed the torch to us, his three amigos, when he retired in 2011, along with encouragement to put our own stamp on the book (sometimes with a "you broke it, you bought it" response to editorial suggestions). We've also corralled a couple of colleagues (Scott Starin and Tim McGee) to provide some review and feedback on the near-final text. (Our thanks to you both.) So, here is the multi-chef result, we think well-flavored—though some of you may find certain sections more "in your face" than "without an attitude". Time to let it go. Enjoy.

Gary Welter, Dave Simpson and Chris Rouff—2016

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