

Preface

Flexible Spacecraft Dynamics, Control and Guidance is a text conceived as a guide to the design of attitude and orbit control systems (AOCS) for modern space vehicles.

In addition to the various classic topics which we have reviewed from a modern perspective, this text deals with new issues of AOCS such as spacecraft flexibility, agility and guidance.

Attitude and orbit control (AOC) is a discipline where engineers can study the equations governing attitude, orbital, and deformation dynamics of a satellite, methods to measure the status of the satellite and to determine the control actions to be implemented on board the satellite in order to get the desired dynamics, and technologies that allow the production of these control actions from measurements.

The author's intention is to provide a manual that allows a satellite designer or a student to learn a theoretical and practical engineering approach to the design of attitude and orbit control systems, providing a panorama of applications of practical and theoretical interest.

The experience of the author in designing AOC systems was useful in defining the road map of the text, introducing topics that are important for current and future applications; these systems include various satellites for low orbit (Radarsat 2, Cosmo, Sentinel 1, and Cosmo Second Generation) and for geostationary orbit (Artemis, Sicral 1, Sicral 1-B, Sicral 2, and Atlantic Bird), participation to the design of new low orbit constellations (Globalstar 1 and 2) and study phases for future satellites generations (Neosat and Galileo Second Generation).

The AOC topic, due to its utility for industrial applications, has been the subject of many books. The reader will find an elementary bibliography in Chap. 1.

Most of these texts are focused on rigid body and spinning body dynamics: Kaplan [1], Thomson [2], and Hughes [3], while few others introduce examples dealing with the flexible spacecraft as Rimrott [4] and Sidi [5]. Sidi [5] provides also a good presentation of synthesis of AOC mode design in frequency domain.

Only Kane et al. [6] and Likins et al. [7] deal with the issue of a complex satellite with appendages and flexibilities, but these texts are mainly focused on providing a

global approach to the dynamics, without discussing the applications to attitude control.

Among the available literature, Wertz [8] (1978) is surely the more complete and was reprinted several times up to 2002. It provides a wide treatment of orbital and attitude control including space environment interactions, attitude determination, control system architectures, frequency design techniques, and a review of the sensor and actuators technologies, but this text is now four decades old.

We have to say that today satellites are rarely based on spin stabilization. They are mostly three axes stabilized, which is why we have not treated the spinning body among the applications, preferring to highlight new topics such as the satellite's flexibility effect due to large appendages, the ability of fast repointings, the so-called agility and the optimal guidance, which, for various reasons, look more interesting for modern applications.

Today, the design techniques have evolved into more complex methods, like, synthesis of multi-input multi-output (MIMO) systems with use of optimal robust control theory. This is why, even if we have provided a description of the satellite AOCS's operating modes in terms of SISO (single-input single-output) models, discussing them in terms of frequency methods, in order to have an immediate and simple understanding, we have treated the control synthesis subject focusing on optimal control theory and MIMO systems.

In more recent years, many textbooks have reviewed the classic table of content of the old textbooks, introducing new subjects.

We mention a few of them: Tewari [9] who dealt with satellite attitude control and orbit control and guidance, starting from the perspective of the optimal control theory, Noton [10] who dealt with optimal orbital guidance with low thrust, and Bryson [11] who dealt with some classic AOC problems using the optimal linear control theory.

A recent book by Landis and Crassidis [12] presents the AOC topic focusing on the many new algorithms for attitude determination based on modern sensor technology and optimal estimation theory.

My primary motivation to write a new book is the fact that the classic texts are quite old today, AOC architectures have considerably changed, and even though rigid body motion and stability of spinning bodies are still very important, some new issues of dynamics and control need to be treated in a form suitable for immediate application.

For instance we propose in this text the following subjects: AOC modes design methods, flexibility theory, optimal control theory, optimal navigation and guidance, a modern description of sensors and actuators, attitude agility, and plasmic low thrust propulsion; all of these are important new topics for AOCS.

I have tried to be as general as possible on the theory that these notions can be used not only to convey an understanding of the problems but also for practical use.

My approach was to present the study of attitude control along with that of orbital control. This type of presentation can be useful to AOC designers as satellites are becoming more and more autonomous and implement orbital control tasks directly on board.

Two important chapters (Chap. 4 on attitude control and Chap. 9 on sensor and actuator technologies) were written by my colleague and friend G. Campolo. Giovanni has provided an invaluable specific contribution to make the text more usable for real engineering practice.

Ostuni, Porta Nova
August 2015

Leonardo Mazzini

References

1. M.H. Kaplan, *Modern Spacecraft Dynamics and Control* (Wiley, New York, 1976)
2. W.T. Thomson, *Introduction to Space Dynamics* (Dover Publications, New York, 1986)
3. P. Hughes, *Spacecraft Attitude Dynamics* (Dover Publications, New York, 2004)
4. F.P.J. Rimrott, *Introductory Attitude Dynamics* (Springer, New York, 1989)
5. M.J. Sidi, *Spacecraft Dynamics and Control* (Cambridge University Press, New York, 1997)
6. T.R. Kane, P.W. Likins, D.A. Levinson, *Spacecraft Dynamics* (McGraw-Hill, New York, 1983)
7. P.W. Likins, R.E. Roberson, J. Wittenburg, *Dynamics of Flexible Spacecraft, Department of General Mechanics* (Springer, Dubrovnik, 1972)
8. J.R. Wertz, *Spacecraft Attitude Determination and Control* (D. Reidel Publishing Company, Dordrecht, 2002)
9. A. Tewari, *Advanced Control of Aircraft, Spacecraft and Rockets* (Wiley, New York, 2011)
10. M. Noton, *Spacecraft Navigation and Guidance* (Springer, London, 1998)
11. A.E. Bryson, *Control of Spacecraft and Aircraft* (Princeton University Press, London, 1994)
12. F. L. Markley, J.L. Crassidis, *Fundamentals of Spacecraft Attitude Determination and Control* (Springer, New York, 2015)



<http://www.springer.com/978-3-319-25538-5>

Flexible Spacecraft Dynamics, Control and Guidance
Technologies by Giovanni Campolo

Mazzini, L.

2016, XXI, 363 p., Hardcover

ISBN: 978-3-319-25538-5