Rigid Body Dynamics for Space Applications

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This is a timely book dealing with a very important emerging application area for rigid body dynamics – namely space systems engineering – and is written by one of the world's foremost experts in space systems engineering.

In this book, Professor Aslanov has covered several major topics, specifically re-entry attitude dynamics, dynamics and control of co-axial satellite gyrostats, the deployment, dynamics, and control of a tether-assisted return mission of a re-entry capsule, the removal of large space debris by a tether tow and, finally, some original tasks of space mechanics.

Interestingly, the book starts with an initial chapter entitled 'Mathematical Mechanical Preliminaries'. This very neatly sets the reader off on a useful (and interesting) exploration of certain mathematical methods, many of which the reader will have some prior knowledge of, but this chapter also offers a nicely targeted and relevant refresher tutorial and enables the rest of the book to be digested more quickly and efficiently. This chapter provides neat tutorial reading on elliptic integrals, rigid body kinematics, rigid body dynamics and chaotic dynamics, but some wider reading may also be required to fill in gaps in understanding.

Chapter 2 presents a brief review of the literature on re-entry dynamics and then moves straight into the aerodynamics of re-entry vehicles. This is based around a three-dimensional portrayal of the components of aerodynamic forces and moments, which takes some studying, but the persistent reader will fairly quickly be rewarded with a spatial understanding of the components as stated in the accompanying equations. This is important as it allows the reader to then build up to a model for re-entry of a typical capsule and some attendant examples for specific spacecraft, all cast in non-dimensionalised form. An analytical solution is given for aspects of the case of Vostok using elliptic functions, with an interesting addendum to this relating to the build-up of error due to numerical control of the elliptic function modulus. The undisturbed and disturbed equations of motion for conical capsules with spherical bottoms are examined in considerable detail and then different forms of restoring moment are considered, with later sections exploring the effects of bifurcation and its elimination for the descent of spacecraft in rarefied atmospheres. There is very considerable analytical information available towards the end of this chapter, and the determined reader will learn a great deal from it, as long as s/he is prepared

to undertake the principal calculations and explore them in context. This is one of the benefits of this book in that it informs and teaches by example, but it certainly requires the reader's proper involvement in order for the full benefit to be realised and is not the sort of book that one should skim lightly. It would be particularly interesting to use the book as a manual when trying to solve one's own specific re-entry problem. Chaotic motions are treated very comprehensively for interesting problems such as vehicles with a moving centre of mass and for pragmatic vehicles with past mission exemplars given. In summary, there is little left to the reader's imagination here despite some serious effort required of the reader to extract the full benefit of the studies presented. There is very little doubt that a proficient reader will find most of what s/he needs to know here to model the descent dynamics for a realistic mission scenario. The chapter also ends with a comprehensive list of references from which to delve deeper, as may be required.

Chapter 3 offers a full treatment of the dynamics and control of co-axial satellite gyrostats, with detailed canonical analysis of a generic axial gyrostat in the form of a typical satellite configuration. A full analysis is performed, and the stability of possible solutions is examined in full and presented as phase trajectories. Analytical solutions are examined in detail for oblate and prolate bodied satellites, for different modes of motion and control options and another comprehensive list of references is supplied at the end of the chapter.

Chapter 4 deals with space tethers, and many of the principal references for this intensively researched application area are given. The chapter deals with a specific tether application, but many of the general steps needed for modelling a momentum exchange tether are stated. The determined reader will be able to customise the analysis given for the return mission that is examined specifically to get insight into another mechanical configuration. Separation of variables is used to obtain an analytical solution for both the unperturbed and perturbed motions of the centre of mass of a tethered satellite mission, and this culminates in a section on numerical simulations for oscillatory behaviour and the interesting case when there are microaccelerations onboard the satellite. Stability and chaos analyses are also provided, then the chapter moves on to examine the swinging release scenario from a tether. This is an important case as it emerges in many different tether designs, and it is treated in depth here with practical numerical data to test the controllability of the system. The chapter concludes with a very interesting section on tether assisted return with atmospheric re-entry analysis, and the all-important starting points for this problem are carefully covered.

The penultimate chapter treats the contemporary problem of large debris removal by means of a tether tow, starting with a short but very compelling introduction to the large debris problem. The analysis begins with generalised space tug, tether and passive satellite configuration and then the specific equations of motion are derived. The model is neatly validated by calculating the time rate of change of the angular momentum and then comparing that quantity with the same quantity obtained from the equations of motion. Although the line-type on the numerical plots is a little hard to distinguish, the relevant

point is certainly well made. Four different dynamical cases are studied in depth for this system, effectively taking different pragmatic sets of initial conditions and then ascertaining the performance characteristics. The problem is then placed in the context of the Earth's gravitational field, and seven different cases are examined for this realistic problem. This section concludes with a useful discussion of accuracy and exactness, again with practically significant conclusions for the reader interested in realistic mission analysis and design. The chapter proceeds to take the cases studied in the earlier parts of the chapter and introduce flexible appendages, with three different mounting conditions examined in a comparative manner. Fuel residuals within orbiter debris and prevailing atmospheric disturbances are also included in final sections, terminating in an investigation of the chaotic dynamics of this important system. A very comprehensive list of references completes this authoritative chapter.

The book ends with a chapter entitled, 'Original Tasks of Space Mechanics', an interesting miscellany of interesting studies, which the author includes for the reader's further education and interest.

To summarise, this is a really outstanding book that will complement the bookshelf of satellite and tether researchers, in particular; however, it will also be of wider interest, and mission design and analysis engineers will undoubtedly find it of help. The initial mathematics chapter is quite useful, and one way to approach this book would be to read that chapter, then delve more deeply into some of the references to that chapter to be sure of one's mathematical ground. Then have a quick initial look at Chapter 6 to get a wider perspective of the author's vision and to understand the context of the book, and after that start to work through the chapters of specific relevance. This book will indeed appeal to the communities that the author suggests, but the reader will have also to be prepared to do some serious work to keep up properly with the narrative. If the reader follows this advice, then I believe they will be very richly rewarded indeed.

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