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Introduction to Space Dynamics John Wiley & Sons Spacecraft attitude maneuvers comply with Euler's moment equations, a set of three nonlinear, coupled differential equations. Nonlinearities complicate the mathematical treatment of the seemingly simple action of rotating, and these complications lead to a robust lineage of research. This book is meant for basic scientifically inclined readers, and commences with a chapter on the basics of spaceflight and leverages this remediation to reveal very advanced topics to new spaceflight enthusiasts. The topics learned from reading this text will prepare students and faculties to investigate interesting spaceflight problems in an era where cube satellites have made such investigations attainable by even small universities. It is the fondest hope of the editor and authors that readers enjoy this book.

Quaternion-Based Approach Springer

One of the major challenges of modern space mission design is the orbital mechanics -- determining how to get a spacecraft to its destination using a limited amount of propellant. Recent missions such as Voyager and Galileo required gravity assist maneuvers at several planets to accomplish their objectives. Today's students of aerospace engineering face the challenge of calculating these types of complex spacecraft trajectories. This classroom-tested textbook takes its title from an elective course which has been taught to senior undergraduates and first-year graduate students for the past 22 years. The subject of orbital mechanics is developed starting from the first principles, using Newton's laws of motion and the law of gravitation to prove Kepler's empirical laws of planetary motion. Unlike many texts the authors also use first principles to derive other important results including Kepler's equation, Lambert's time-of-flight equation, the rocket equation, the Hill-Clohessy-Wiltshire equations of relative motion, Gauss' equations for the variation of the elements, and the Gauss and Laplace methods of orbit determination. The subject of orbit transfer receives special attention. Optimal orbit transfers such as the Hohmann transfer, minimum-fuel transfers using more than two impulses, and non-coplanar orbital transfer are discussed. Patched-conic interplanetary trajectories including gravity-assist maneuvers are the subject of an entire chapter and are particularly relevant to modern space missions.

Modern Astrodynamics
Springer

This is a short course covering advanced topics in state estimation and Kalman filtering. It focuses on the Orbit Determination problem. This course is structured to present the basic concepts without the in-depth theoretical background and mathematical derivations that commonly accompany an academic presentation of the subject. My intention is to introduce state estimation in a simplified manner to those with no previous background in the field, or to provide a review to those who have studied the subject previously. Readers should have a familiarity with differential and integral calculus and differential equations to help understand some equations presented. The form of this short course is like the many short courses I've taught at government agencies and private corporations during my thirty-five-year

career as an aerospace engineering professor at Auburn University. It presents the material in a simplified outline / bullet format using many understandable figures, rather than using lengthy, detailed explanations with complex mathematical derivations and proofs. It provides the practical equations that are useful to the practicing engineer. The objectives of this short course are to: - Introduce the concepts and fundamentals of state estimation, with applications to the orbit determination problem. - Present the concepts of batch estimation using least squares, weighted least squares, minimum variance, and ridge-type estimation methods. - Introduce the fundamentals of sequential estimation using the Kalman filter, the Extended Kalman filter, and the Unscented Kalman filter. - Discuss the sources of error in orbit determination and present methods of improving accuracy in the solution process- - Present practical considerations of orbit determination involving observational data, update intervals and fit spans, the results of differential correction, and the use of smoothers and GPS. The material presented is usually covered in graduate level course in estimation theory except that there's no required homework, quizzes, projects, computer programs to write, or examinations. I believe that even a novice reading through this material will gain an in-depth understanding of state estimation. My former students should recognize everything in this presentation, and if they didn't learn it the first time, they can learn it now through this simplified short course with much less work. State estimation and Kalman filtering is not easy, but it's my goal to make it enjoyably simple once the fundamentals are understood. To do so, I've attempted to present the difficult concepts as clearly as possible to facilitate that understanding. Completion of this short course should enhance the knowledge base of all those who read through its content. This short course is part of a series I've developed as a Professor at Auburn University. Others in this series include: Orbital Mechanics, Part I: The Two-Body Problem Orbital Mechanics, Part II: Satellite Perturbations Fundamentals of Inertial Navigation and Missile Guidance David A. Cicci, Auburn, Alabama, ciccida@auburn.edu

Fundamentals of Spacecraft Attitude Determination and Control McGraw-Hill College Comprehensive, classic introduction to space-flight engineering for advanced undergraduate and graduate students provides basic tools for quantitative analysis of the motions of satellites and other vehicles in space.

Space Flight Dynamics Cambridge University Press This is a long-overdue volume dedicated to space trajectory optimization. Interest in the subject has grown, as space missions of increasing levels of sophistication, complexity, and scientific return - hardly imaginable in the 1960s - have been designed and flown. Although the basic tools of optimization theory remain an accepted canon, there has been a revolution in the manner in which they are applied and in the development of numerical optimization. This volume purposely includes a variety of both analytical and numerical approaches to trajectory optimization. The choice of authors has been guided by the editor's intention to assemble the most expert and active researchers in the various specialities presented. The authors were given considerable freedom to choose their subjects, and although this may yield a somewhat eclectic volume, it also yields chapters written with palpable enthusiasm and relevance to contemporary problems.

Space Vehicle Dynamics and Control John Wiley & Sons

Fundamentals of Astrodynamics and Applications is rapidly becoming the standard astrodynamics reference for those involved in the business of spaceflight. What sets this book apart is that nearly all of the theoretical mathematics is followed by discussions of practical applications implemented in tested software routines. For example, the book includes a compendium of algorithms that allow students and professionals to determine orbits with high precision using a PC. Without a doubt, when an astrodynamics problem arises in the future, it will become standard practice for engineers to keep this volume close at hand and `look it up in Vallado'. While the first edition was an exceptionally useful and popular book throughout the community, there are a number of reasons why the second edition will be even more so. There are many reworked examples and derivations. Newly introduced topics include ground illumination calculations, Moon rise and set, and a listing of relevant Internet sites. There is an improved and expanded discussion of coordinate systems, orbit determination, and differential correction. Perhaps most important is that all of the software routines described in the book are now available for free in FORTRAN, PASCAL, and C. This makes the second edition an even more valuable text and superb reference.

Space Vehicle Design Springer Science & Business Media

Spacecraft Dynamics and Control: The Embedded Model Control Approach provides a uniform and systematic way of approaching space engineering control problems from the standpoint of model-based control, using state-space equations as the key paradigm for simulation, design and implementation. The book introduces the Embedded Model Control methodology for the design and implementation of attitude and orbit control systems. The logic architecture is organized around the embedded model of the spacecraft and its surrounding environment. The model is compelled to include disturbance dynamics as a repository of the uncertainty that the control law must reject to meet attitude and orbit requirements within the uncertainty class. The source of the real-time uncertainty esti mation/predictio n is the model error signal, as it encodes the residual discrepancies between spacecraft measurements and model output. The embedded model and the uncertainty estimation feedback (noise estimator in the book) constitute the state predictor feeding the control law. Asymptotic pole placement (exploiting the asymptotes of closed-loop transfer functions) is the way to design and tune feedback loops around the embedded model (state predictor, control law, reference generator). The design versus the uncertainty class is driven by analytic stability and performance inequalities. The method is applied to several attitude and orbit control problems. The book begins with an extensive introduction to attitude geometry and algebra and ends with the core themes: state-space dynamics and Embedded Model Control. Fundamentals of orbit, attitude and environment dynamics are treated giving emphasis to state-space formulation, disturbance dynamics, state feedback and prediction, closed-loop stability. Sensors and actuators are treated giving emphasis to their dynamics and modelling of measurement errors. Numerical tables are included and their data employed for numerical simulations. Orbit and attitude control problems of the European GOCE mission are the inspiration of numerical exercises and simulations. The suite of the attitude control modes of a GOCE-like mission is designed and simulated around the so-called mission state predictor. Solved and unsolved exercises are included within the text - and not separated at the end of chapters - for better understanding, training and application. Simulated results and their graphical plots are developed through MATLAB/Simulink code.

An Introduction to the Mathematics and Methods of Astrodynamics Cambridge University Press

Statistical Orbit Determination presents fundmentals of orbit determination--from weighted least squares approaches (Gauss) to today's high-speed computer algorithms that provide accuracy within a few centimeters. Numerous examples and problems are provided to enhance readers' understanding of the material. Covers such topics as coordinate and time systems, square root filters, process noise techniques, and the use of fictitious parameters for absorbing unmodeled and incorrectly modeled forces acting on a satellite. Examples and exercises serve to illustrate the principles throughout each chapter.

Fundamentals and Applications AIAA

Beginning from an understanding of Hamiltonian dynamics, Modern Astrodynamics blends the modern methods of dynamical system theory with the classical perturbation methods. Emphasizing earth satellite motion, the work also explores planetary motion. The text concludes with nonlinear resonance and relative motion of satellites. A Windows PC program disk suppliments the text.

Understanding Space Oxford University Press, USA

This essential book is the first comprehensive exposition in the area of optimal low-thrust orbit transfer using non-singular variables.

Fundamentals of Astrodynamics and Applications Springer Science & Business Media

A lively study of orbital mechanics by the writer responsible for the computer simulations and systems analysis for the Saturn V moon rocket, Project Skylab and many others. Provides thorough coverage of all background theories, including unusual concepts and paradoxes that will enhance appreciation of this field. Includes discussion of rocket propulsion and optimization of techniques for maximizing payload and minimizing fuel consumption, plus complete coverage of the interaction of space vehicles and space bodies.

An Introduction to Celestial Mechanics

Springer Science & Business Media

This textbook provides details of the derivation of Lagrange's planetary equations and of the closely related Gauss's variational equations, thereby covering a sorely needed topic in existing literature. Analytical solutions can help verify the results of numerical work, giving one confidence that his or her analysis is correct. The authors—all experienced experts in astrodynamics and space missions—take on the massive derivation problem step by step in order to help readers identify and understand possible analytical solutions in their own endeavors. The stages are elementary yet rigorous; suggested student research project topics are provided. After deriving the variational equations, the authors apply them to many interesting problems, including the Earth-Moon system, the effect of an oblate planet, the perturbation of Mercury's orbit due to General Relativity, and the perturbation due to atmospheric drag. Along the way, they introduce several useful techniques such as averaging, Poincaré's method of small parameters, and variation of parameters. In the end, this textbook will help students, practicing engineers, and professionals across the fields of astrodynamics, astronomy, dynamics, physics, planetary science, spacecraft missions, and others. “An extensive, detailed, yet still easy-to-follow presentation of the field of orbital perturbations.” -Prof. Hanspeter Schaub, Smead Aerospace Engineering Sciences Department, University of Colorado, Boulder “This book, based on decades of teaching experience, is an invaluable resource for aerospace engineering students and practitioners alike who need an in-depth understanding of the equations they use.” - Dr. Jean Albert Kéchichian, The Aerospace Corporation, Retired “Today we look at perturbations through the lens of the modern computer. But knowing the why and the how is equally important. In this well organized and thorough compendium of equations and derivations, the authors bring some of the relevant gems from the past back into the contemporary literature.” - Dr. David A Vallado, Senior Research Astrodynamicist, COMSPOC “The book presentation is with the thoroughness that one always sees with these authors. Their theoretical development is followed with a set of Earth orbiting and Solar System examples demonstrating the application of Lagrange ' s planetary equations for systems with both conservative and nonconservative forces, some of which are not seen in orbital mechanics books. " - Prof. Kyle T. Alfriend, University Distinguished Professor, Texas A&M University

Advances in Spacecraft Attitude Control Springer Science & Business Media This volume is designed as an introductory text and reference book for graduate students, researchers and practitioners in the fields of astronomy, astrodynamics, satellite systems, space sciences and astrophysics. The purpose of the book is to emphasize the similarities between celestial mechanics and astrodynamics, and to present recent advances in these two fields so that the reader can understand the inter-relations and mutual influences. The juxtaposition of celestial mechanics and astrodynamics is a unique approach that is expected to be a refreshing attempt to discuss both the mechanics of space flight and the dynamics of celestial objects. " Celestial Mechanics and Astrodynamics: Theory and Practice " also presents the main challenges and future prospects for the two fields in an elaborate, comprehensive and rigorous manner. The book presents homogenous and fluent discussions of the key problems, rendering a portrayal of recent advances in the field together with some basic concepts and essential infrastructure in orbital mechanics. The text contains introductory material followed by a gradual development of ideas interweaved to yield a coherent presentation of advanced topics.

Fundamentals of Orbit Determination

Elsevier

This modern textbook guides the reader through the theory and practice of the motion and attitude control of space vehicles. It first presents the fundamental principles of spaceflight mechanics and then addresses more complex concepts and applications of perturbation theory, orbit determination and refinement, space propulsion, orbital maneuvers, interplanetary trajectories, gyroscope dynamics, attitude control, and rocket performance. Many algorithms used in the modern practice of trajectory computation are also provided. The numerical treatment of the equations of motion, the related methods, and the tables needed to use them receive particular emphasis. A large collection of bibliographical references (including books, articles, and items from the "gray literature") is provided at the end of each chapter, and attention is drawn to many internet resources available to the reader. The book will be of particular value to undergraduate and graduate students in aerospace engineering.

Spacecraft Trajectory Optimization

Springer Science & Business Media

Newton's laws

of motion and his universal law of gravitation described mathematically the motion of two bodies undergoing mutual gravitational attraction. However, it is impossible to solve analytically the equation of motion for three gravitationally interacting bodies. This book discusses some techniques used to obtain numerical solutions of the equations of motion for planets and satellites, which are of fundamental importance to solar-system dynamicists and to those involved in planning the orbits of artificial satellites. The first part introduces the classical two-body problem and solves it by rigorously developing the six integrals of the motion, starting from Newton's three laws of motion and his law of gravitation and then using vector algebra to develop the integrals. The various forms of the solution flow naturally from the integrals. In the second part, several modern perturbation techniques are developed and applied to cases of practical importance. For example, the perturbed two-body problem for an oblate planet or for a nonsymmetric rotating planet is considered, as is the effect of drag on a satellite. The two-body problem is regularized, and the nonlinear differential equation is thereby transformed to a linear one by further embedding several of the integrals. Finally, a brief sketch of numerical methods is given, as the perturbation equations must be solved by numerical rather than by analytical methods.

Statistical Orbit Determination Springer

Teaching text developed by U.S. Air Force Academy and designed as a first course emphasizes the universal variable formulation. Develops the basic two-body and n-body equations of motion; orbit determination; classical orbital elements, coordinate transformations; differential correction; more. Includes specialized applications to lunar and interplanetary flight, example problems, exercises. 1971 edition.

Models, Methods and Applications Courier Corporation

Want to know not just what makes rockets go up but how to do it optimally? Optimal control theory has become such an important field in aerospace engineering that no graduate student or practicing engineer can afford to be without a working knowledge of it. This is the first book that begins from scratch to teach the reader the basic principles of the calculus of variations, develop the necessary conditions step-by-step, and introduce the elementary computational techniques of optimal control. This book, with problems and an online solution manual, provides the graduate-level reader with enough introductory knowledge so that he or she can not only read the literature and study the next level textbook but can also apply the theory to find optimal solutions in practice. No more is needed than the usual background of an undergraduate engineering, science, or mathematics program: namely calculus, differential equations, and numerical integration. Although finding optimal solutions for these problems is a complex process involving the calculus of variations, the authors carefully lay out step-by-step the most important theorems and concepts. Numerous examples are worked to demonstrate how to apply the theories to everything from classical problems (e.g., crossing a river in minimum time) to engineering problems (e.g., minimum-fuel launch of a satellite). Throughout the book use is made of the time-optimal launch of a satellite into orbit as an important case study with detailed analysis of two examples: launch from the Moon and launch from Earth. For launching into the field of optimal solutions, look no further!

Introduction to Orbital Perturbations Courier Dover Publications Provides the basics of spacecraft orbital dynamics plusattitude dynamics and control, using vectrix notation Spacecraft Dynamics and Control: An Intro ductionpresents the fundamentals of classical control in the context ofspacecraft attitude control. This approach is particularlybenefi cial for the training of students in both of the subjects ofclassical control as well as its application to spacecraft attitudecontrol. By using a physical system (a spacecraft) that the readercan visualize (rather than arbitrary transfer functions), it iseasier to grasp the motivation for why topics in control theory areimportant, as well as the theory behind them. The entiretreatment of both orbital and attitude dynamics makes use ofvectrix notation, which is a tool that allows the user to writedown any vector equation of motion without consideration of areference frame. This is particularly suited to the treatment ofmultiple reference frames. Vectrix notation also makes a very cleardistinction between a physical vector and its coordinate representation in a reference frame. This is very important inspacecraft dynamics and control problems, where often multiplecoordinate representations are used (in different reference frames)for the same physical vector. Provides an accessible, practical aid for teaching andself-study with a layout enabling a fundamental understanding ofthe subject Fills a gap in the existing literature by providing ananalytical toolbox offering the reader a lasting, rigorousm ethodology for approaching vector mechanics, a key element vitalto new graduates and practicing engineers alike Delivers an outstanding resource for aerospace engine eringstudents, and all those involved in the technical aspects of designand engineering in the space sector Contains numerous illustrations to accompany the written text.Problems are included to apply and extend the material in eachchapter Essential reading for graduate level aerospace engine eringstudents, aerospace professionals, researchers and engineers.

Fundamentals of Astrodynamics AIAA

Roger D. Werking Head, Attitude Determination and Control Section National Aeronautics and Space Administration/ Goddard Space Flight Center Extensiye work has been done for many years in the areas of attitude determination, attitude prediction, and attitude control. During this time, it has been difficult to obtain reference material that provided a comprehensive overview of attitude support activities. This lack of reference material has made it difficult for those not intimately involved in attitude functions to become acquainted with the ideas and activities which are essential to understanding the various aspects of spacecraft attitude support. As a result, I felt the need for a document which could be used by a variety of persons to obtain an understanding of the work which has been done in support of spacecraft attitude objectives. It is believed that this book, prepared by the Computer Sciences Corporation under the able direction of Dr. James Wertz, provides this type of reference. This book can serve as a reference for individuals involved in mission planning, attitude determination, and attitude dynamics; an introductory textbook for stu dents and professionals starting in this field; an information source for experimen ters or others involved in spa cecraft-related work who need information on spacecraft orientation and how it is determined, but who have neither the time nor the resources to pursue the varied literature on this subject; and a tool for encouraging those who could expand this discipline to do so, because much remains to be done to satisfy future needs.

Essential Spaceflight Dynamics and Magnetospherics

Fundamentals of Astrodynamics and Applications Widely known and used throughout the astrodynamics and aerospace engineering communities, this teaching text was developed at the U.S. Air Force Academy. Completely revised and updated 2013 edition.