

orbital mechanics for engineering students pdf

orbital mechanics for engineering students pdf is an essential resource for those pursuing aerospace, mechanical, or related engineering disciplines. This document provides a comprehensive understanding of the fundamental principles governing the motion of objects in space, critical for designing and analyzing spacecraft trajectories. The study of orbital mechanics combines physics, mathematics, and engineering, focusing on how satellites and other space vehicles move under gravitational forces. Engineering students benefit from a structured approach to topics such as Kepler's laws, orbital elements, transfer orbits, and perturbations. This article delves into the key concepts covered in orbital mechanics for engineering students pdf materials, detailing essential theories, mathematical models, and practical applications. Additionally, it outlines the importance of these resources in academic and professional contexts and highlights how students can maximize their learning through such PDFs. Below is an overview of the main sections discussed in this article.

- Fundamentals of Orbital Mechanics
- Key Mathematical Concepts and Equations
- Types of Orbits and Orbital Elements
- Orbit Determination and Transfer Techniques
- Applications of Orbital Mechanics in Engineering
- Accessing and Utilizing Orbital Mechanics PDFs

Fundamentals of Orbital Mechanics

Understanding the fundamentals of orbital mechanics is crucial for engineering students studying space systems. This section introduces the basic principles that govern the motion of bodies in space, primarily influenced by gravitational forces. Orbital mechanics, also known as celestial mechanics or astrodynamics, explains how objects like satellites, space probes, and planets move in orbits around celestial bodies.

Newton's Laws and Universal Gravitation

Newton's laws of motion form the foundation of orbital mechanics. Specifically, his law of universal gravitation explains the attractive force between two masses, which dictates orbital motion. Engineering students learn to apply these laws to derive the equations of motion for satellites and spacecraft, enabling calculations of trajectories and velocities.

Kepler's Laws of Planetary Motion

Kepler's laws describe the motion of planets and satellites in elliptical orbits. These laws provide insight into orbital periods, shapes, and areas swept by orbiting bodies. The orbital mechanics for engineering students pdf resources elaborate on how these laws are used to predict satellite positions and design mission trajectories.

Two-Body Problem

The two-body problem simplifies the dynamics of two interacting masses under mutual gravity, ignoring external influences. This idealized model is fundamental in orbital mechanics, serving as a stepping stone for more complex multi-body analyses.

Key Mathematical Concepts and Equations

Mathematics underpins the study of orbital mechanics, with differential equations, vector calculus, and coordinate systems playing significant roles. Engineering students must master these mathematical tools to accurately model and predict orbital behavior.

Equations of Motion

The equations of motion in orbital mechanics describe how a spacecraft's position and velocity change over time. These are typically derived from Newton's second law combined with gravitational forces. Solutions to these equations yield orbit trajectories and parameters.

Orbital Energy and Angular Momentum

Orbital energy and angular momentum are conserved quantities in an ideal two-body system. Understanding these concepts allows students to analyze orbit stability, transfer maneuvers, and spacecraft dynamics.

Coordinate Systems in Orbital Mechanics

Different coordinate systems, such as inertial, perifocal, and Earth-centered inertial (ECI), are used to describe spacecraft positions and velocities. Mastery of coordinate transformations is essential for interpreting orbital data and performing calculations.

Types of Orbits and Orbital Elements

Orbits are classified based on shape, altitude, and inclination, among other parameters. Engineering students studying orbital mechanics for engineering students pdf materials gain knowledge of various orbit types and the six classical orbital elements that define an

orbit uniquely.

Common Types of Orbits

Several orbit types are commonly studied in orbital mechanics:

- **Low Earth Orbit (LEO):** Orbits close to Earth, typically between 160 to 2,000 kilometers altitude.
- **Geostationary Orbit (GEO):** Circular orbit approximately 35,786 kilometers above Earth's equator, allowing satellites to remain fixed relative to the Earth's surface.
- **Polar Orbit:** Passes over the Earth's poles, enabling global coverage for observation satellites.
- **Highly Elliptical Orbit (HEO):** Characterized by a high eccentricity, useful for communications and scientific missions.

Orbital Elements Explained

The six classical orbital elements describe an orbit's size, shape, and orientation:

1. **Semi-major axis (a):** Defines the size of the orbit.
2. **Eccentricity (e):** Measures the orbit's deviation from circularity.
3. **Inclination (i):** Angle between the orbital plane and the equatorial plane.
4. **Right Ascension of the Ascending Node (Ω):** Specifies the horizontal orientation of the orbit.
5. **Argument of Periapsis (ω):** Specifies the orientation of the ellipse in the orbital plane.
6. **True Anomaly (ν):** Describes the position of the satellite along the orbit at a given time.

Orbit Determination and Transfer Techniques

Determining and manipulating orbits are critical skills in orbital mechanics. Engineering students use various methods to calculate satellite positions and execute orbital transfers to achieve mission objectives.

Orbit Determination Methods

Orbit determination involves using observation data to estimate a satellite's orbital parameters. Techniques include:

- Radar and optical tracking
- Radio ranging and Doppler measurements
- Least squares estimation and Kalman filtering

Orbital Transfer Maneuvers

Orbital transfers enable spacecraft to move from one orbit to another efficiently. Key maneuvers include:

- **Hohmann Transfer:** A two-impulse maneuver used to transfer between coplanar circular orbits.
- **Bi-elliptic Transfer:** An alternative transfer involving two elliptical orbits, sometimes more fuel-efficient than Hohmann transfers.
- **Plane Change Maneuvers:** Adjusting the orbital inclination to match mission requirements.

Applications of Orbital Mechanics in Engineering

The principles of orbital mechanics are applied widely in aerospace engineering and beyond. Understanding these applications helps engineering students grasp the practical significance of the subject.

Satellite Mission Design

Designing satellite missions requires in-depth knowledge of orbital mechanics to ensure satellites achieve desired orbits for communication, navigation, or Earth observation. Orbital mechanics PDFs provide detailed methodologies for mission planning.

Spacecraft Navigation and Control

Navigation systems rely on precise orbital calculations to maintain spacecraft trajectories and perform course corrections. Control systems integrate orbital mechanics models to stabilize and orient spacecraft.

Interplanetary Travel and Exploration

Beyond Earth orbit, orbital mechanics principles guide spacecraft traveling to other planets and celestial bodies. Transfer orbits, gravity assists, and trajectory optimization are vital topics covered in advanced engineering materials.

Accessing and Utilizing Orbital Mechanics PDFs

Orbital mechanics for engineering students pdf resources are widely available and serve as foundational educational materials. These PDFs include textbooks, lecture notes, problem sets, and software manuals.

Sources and Types of PDFs

Common sources for obtaining orbital mechanics PDFs include university course websites, academic publishers, and aerospace organizations. Types of PDFs include:

- Comprehensive textbooks covering theory and applications
- Lecture notes summarizing key concepts
- Worked examples and problem sets for practice
- Simulation and modeling software guides

Effective Study Strategies

To maximize learning from orbital mechanics PDFs, students should:

1. Follow a structured reading plan aligned with coursework
2. Work through example problems to reinforce understanding
3. Use supplementary materials such as simulation tools
4. Participate in study groups or discussion forums for collaborative learning

Frequently Asked Questions

Where can engineering students find a comprehensive PDF on orbital mechanics?

Engineering students can find comprehensive PDFs on orbital mechanics through university websites, online educational platforms like MIT OpenCourseWare, or repositories such as ResearchGate and Academia.edu.

What are the key topics covered in an orbital mechanics PDF for engineering students?

Key topics typically include Kepler's laws, two-body problem, orbital elements, spacecraft trajectories, transfer orbits, perturbations, and rendezvous techniques.

How can a PDF on orbital mechanics help engineering students in their studies?

A PDF on orbital mechanics provides theoretical foundations, mathematical derivations, example problems, and practical applications that help students understand spacecraft motion and mission design.

Are there any free downloadable PDFs on orbital mechanics suitable for engineering students?

Yes, many universities and instructors offer free downloadable PDFs on orbital mechanics, such as the lecture notes from MIT OpenCourseWare or NASA educational materials.

What prerequisites should engineering students have before studying orbital mechanics PDFs?

Students should have a good understanding of calculus, differential equations, classical mechanics, and basic physics concepts to effectively study orbital mechanics PDFs.

Can orbital mechanics PDFs include practical examples and problem sets for students?

Yes, many orbital mechanics PDFs include practical examples, numerical problems, and case studies to help students apply theoretical concepts to real-world scenarios.

How detailed are orbital mechanics PDFs for undergraduate versus graduate engineering students?

Undergraduate PDFs often focus on fundamental concepts and basic problem solving, while graduate-level PDFs delve deeper into advanced topics like perturbation theory and numerical methods.

What software tools are commonly referenced in orbital mechanics PDFs for engineering students?

Commonly referenced software includes MATLAB, STK (Systems Tool Kit), GMAT (General Mission Analysis Tool), and Python libraries like poliastro for orbital simulations and analysis.

Additional Resources

1. *Orbital Mechanics for Engineering Students* by Howard D. Curtis

This textbook provides a comprehensive introduction to the fundamentals of orbital mechanics, with clear explanations tailored for engineering students. It covers topics such as two-body problems, orbital maneuvers, rendezvous, and interplanetary trajectories. The book includes numerous examples and problems to reinforce concepts, making it an ideal resource for both coursework and self-study.

2. *Fundamentals of Astrodynamics* by Roger R. Bate, Donald D. Mueller, and Jerry E. White

A classic text in the field, this book offers a solid foundation in orbital mechanics and astrodynamics. It focuses on practical problem-solving techniques and provides detailed mathematical treatments of orbit determination, trajectory analysis, and spacecraft motion. The clear layout and step-by-step approach make it accessible for engineering students.

3. *Introduction to Space Dynamics* by William T. Thomson

This book introduces the principles of space dynamics with an emphasis on spacecraft motion and orbital mechanics. It combines theoretical concepts with practical applications, covering topics like attitude dynamics and orbital perturbations. The text is supplemented with diagrams and examples, helping students visualize complex ideas.

4. *Space Vehicle Dynamics and Control* by Bong Wie

While focusing on spacecraft control systems, this book also covers essential orbital mechanics concepts necessary for understanding vehicle dynamics. It includes topics such as orbital transfer, station-keeping, and guidance algorithms. The detailed treatment of control theory alongside orbital mechanics is beneficial for engineering students specializing in aerospace.

5. *Orbital Mechanics and Astrodynamics: Techniques and Tools for Space Missions* by Michael D. Griffin and James R. French

This book bridges theoretical orbital mechanics and practical mission design, offering insights into trajectory optimization and spacecraft navigation. It is designed for students and professionals interested in mission planning and spacecraft operations. The text includes real-world examples and software tools to aid learning.

6. *Astrodynamics: Orbit Determination, Space Navigation, Celestial Mechanics* by Samuel Herrick

Focusing on the computational aspects of orbital mechanics, this book covers orbit determination and celestial mechanics with clarity. It provides detailed explanations of algorithms used in space navigation and mission analysis. Engineering students will find

the practical orientation helpful for understanding spacecraft trajectory design.

7. *Spaceflight Dynamics* by William E. Wiesel

This comprehensive text covers the fundamentals of spacecraft motion, orbit theory, and mission analysis. It explains the mathematical basis of orbital mechanics and provides numerous worked examples and problems. The book is suitable for advanced undergraduate and graduate engineering students.

8. *Modern Astrodynamics* by Victor R. Bond and Mark C. Allman

Offering an updated perspective on astrodynamics, this book integrates classical orbital mechanics with contemporary topics such as low-thrust propulsion and spacecraft formation flying. It emphasizes computational methods and simulation techniques relevant for modern space missions. The clear presentation makes it accessible to engineering students.

9. *Space Mission Analysis and Design* by James R. Wertz and Wiley J. Larson

Although broader in scope, this book includes detailed sections on orbital mechanics critical for mission planning and spacecraft design. It covers trajectory design, orbit transfers, and mission constraints with practical examples. Engineering students will benefit from its holistic approach to space mission engineering.

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Orbital Mechanics for Engineering Students PDF

Ebook Title: Mastering Orbital Mechanics: A Practical Guide for Engineering Students

Contents Outline:

Introduction: What is Orbital Mechanics? Its Importance in Aerospace Engineering.

Chapter 1: Fundamental Concepts: Kepler's Laws, Newton's Law of Universal Gravitation, Two-Body Problem.

Chapter 2: Orbital Elements: Defining an Orbit, Orbital Parameters (e.g., semi-major axis, eccentricity, inclination).

Chapter 3: Orbital Maneuvers: Hohmann Transfers, Bi-elliptic Transfers, Delta-v Budget.

Chapter 4: Perturbation Theory: Influence of Non-Spherical Gravity, Atmospheric Drag, Solar Radiation Pressure.

Chapter 5: Orbit Determination: Tracking and Observation, Estimation Techniques.

Chapter 6: Spacecraft Attitude Dynamics and Control: Orientation, Stabilization, Maneuvering.

Chapter 7: Mission Design and Trajectory Optimization: Launch Windows, Interplanetary Trajectories.

Conclusion: Future Trends and Applications of Orbital Mechanics.

Mastering Orbital Mechanics: A Practical Guide for Engineering Students

Introduction: Unlocking the Secrets of Spaceflight

Orbital mechanics, the study of the motion of orbiting bodies, forms the very bedrock of aerospace engineering. Understanding how satellites, spacecraft, and even planets move through space is crucial for designing successful missions, predicting trajectories, and ensuring the safety and efficiency of space operations. This ebook serves as a comprehensive guide for engineering students seeking a solid understanding of this critical field. We'll move beyond simple textbook definitions and delve into practical applications, providing you with the tools to analyze and solve real-world problems. This is not just about memorizing equations; it's about gaining the intuition and problem-solving skills necessary to excel in aerospace engineering.

Chapter 1: Fundamental Concepts - The Building Blocks of Orbital Motion

This chapter lays the foundation for understanding orbital mechanics. We begin with Kepler's Laws of Planetary Motion, three elegant laws that describe the elliptical orbits of celestial bodies around a central mass. Kepler's laws, derived empirically from observations, paved the way for a deeper understanding of gravitation. We then introduce Newton's Law of Universal Gravitation, the cornerstone of classical orbital mechanics. This law quantitatively describes the attractive force between two masses, providing the mathematical framework for predicting the motion of objects under gravitational influence. Finally, we tackle the Two-Body Problem, a simplified model that assumes only two bodies interact gravitationally (e.g., a spacecraft and the Earth). While a simplification, solving the two-body problem provides valuable insights into orbital characteristics and forms the basis for more complex analyses. We will explore the derivation of Keplerian orbits and their properties within this context.

Chapter 2: Orbital Elements - Defining and Characterizing Orbits

An orbit is not simply a path; it's a precise mathematical description characterized by six orbital elements. This chapter details these elements: semi-major axis (a), eccentricity (e), inclination (i), right ascension of the ascending node (Ω), argument of periapsis (ω), and true anomaly (ν). We'll explain the physical meaning of each element and how they collectively define an orbit's shape, orientation, and position in space. Understanding these elements is vital for designing maneuvers, predicting satellite positions, and analyzing orbital perturbations. We will also explore different coordinate systems used in orbital mechanics and the transformations between them. This chapter will also touch upon the concept of osculating orbits, which are instantaneous approximations of a perturbed orbit.

Chapter 3: Orbital Maneuvers - Changing Your Course in Space

Once an orbit is established, it often needs modification. This chapter explores the techniques used to change an orbit, collectively known as orbital maneuvers. We'll cover Hohmann transfers, the most fuel-efficient method for transferring between two coplanar circular orbits. We'll also delve into bi-elliptic transfers, which, while requiring more time, can be more fuel-efficient than Hohmann transfers in certain situations. A critical concept introduced here is the delta-v budget, representing the total change in velocity required for a mission. Minimizing delta-v is paramount in spaceflight due to the limited propellant capacity of spacecraft. We'll present several examples illustrating the calculation of delta-v for various maneuvers.

Chapter 4: Perturbation Theory - Dealing with the Real World

The two-body problem provides an idealized model. In reality, many factors perturb an orbit, causing deviations from the perfectly elliptical path. This chapter introduces perturbation theory, the mathematical framework for analyzing these disturbances. We'll explore the effects of non-spherical gravity (due to the Earth's oblateness), atmospheric drag (for low-Earth orbits), and solar radiation pressure (especially for high-altitude satellites). Understanding these perturbations is essential for accurate prediction of satellite trajectories and for designing strategies to mitigate their effects. We will utilize both analytical and numerical methods to solve for perturbed orbits.

Chapter 5: Orbit Determination - Tracking and Estimating Orbits

Knowing where a satellite is located is crucial for communication, navigation, and mission success. This chapter explores orbit determination, the process of estimating a satellite's orbit based on observations. We'll examine various tracking techniques, including ground-based radar and radio

signals. We'll also discuss the estimation techniques used to process these observations and determine the best-fit orbit. This involves statistical methods to account for measurement errors and uncertainties. This chapter will touch upon the Kalman filter, a powerful tool used in orbit determination.

Chapter 6: Spacecraft Attitude Dynamics and Control - Keeping the Right Side Up

A spacecraft's attitude (its orientation in space) needs to be controlled to point instruments, antennas, and solar panels in the correct direction. This chapter explores spacecraft attitude dynamics and control. We will discuss different attitude representation methods (quaternions, Euler angles), the dynamics of rotating bodies, and control systems used to maintain a desired attitude. Topics covered will include reaction wheels, control moment gyroscopes, and thrusters.

Chapter 7: Mission Design and Trajectory Optimization - Planning Your Space Journey

This chapter focuses on the broader aspects of mission design, integrating the concepts discussed in previous chapters. We'll explore mission planning, including launch window selection (periods when a launch offers the most efficient trajectory), interplanetary trajectory design (transferring between planets), and the optimization of trajectories to minimize fuel consumption and mission duration. This often involves numerical optimization techniques.

Conclusion: The Future of Orbital Mechanics

Orbital mechanics is a constantly evolving field. This concluding chapter will briefly discuss future trends and applications, including the growing importance of orbital debris management, the challenges posed by asteroid deflection missions, and the increasing role of orbital mechanics in the development of space-based infrastructure. It will highlight the continuing relevance and importance of this field to engineers and scientists working in the space domain.

FAQs:

1. What mathematical background is required to understand this ebook? A solid understanding of calculus, differential equations, and linear algebra is recommended.

2. Are there any software requirements for using this ebook? While not strictly required, access to mathematical software (like MATLAB or Python with relevant libraries) will enhance the learning experience.
3. What types of problems are covered in the ebook? The ebook covers a wide range of problems, from simple two-body problems to complex maneuvers and perturbation analyses.
4. Is this ebook suitable for self-study? Yes, it is designed for self-study, with clear explanations and worked examples.
5. What are the practical applications of orbital mechanics? Applications include satellite communication, GPS navigation, space exploration, and Earth observation.
6. How does this ebook differ from other texts on orbital mechanics? This ebook focuses on practical application and problem-solving relevant to engineering students.
7. Are there any exercises or practice problems included? Yes, the PDF will include practice problems at the end of each chapter.
8. What level of detail is provided in the explanations? The explanations are comprehensive but avoid overly complex mathematical derivations.
9. Can this ebook help with preparing for aerospace engineering exams? Yes, the material covers key concepts and problem-solving techniques crucial for academic success.

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orbital mechanics for engineering students pdf: Orbital Mechanics for Engineering Students Howard D. Curtis, 2009-10-26 Orbital Mechanics for Engineering Students, Second Edition, provides an introduction to the basic concepts of space mechanics. These include vector kinematics in three dimensions; Newton's laws of motion and gravitation; relative motion; the vector-based solution of the classical two-body problem; derivation of Kepler's equations; orbits in three dimensions; preliminary orbit determination; and orbital maneuvers. The book also covers relative motion and the two-impulse rendezvous problem; interplanetary mission design using patched conics; rigid-body dynamics used to characterize the attitude of a space vehicle; satellite attitude dynamics; and the characteristics and design of multi-stage launch vehicles. Each chapter begins with an outline of key concepts and concludes with problems that are based on the material

covered. This text is written for undergraduates who are studying orbital mechanics for the first time and have completed courses in physics, dynamics, and mathematics, including differential equations and applied linear algebra. Graduate students, researchers, and experienced practitioners will also find useful review materials in the book. - NEW: Reorganized and improved discussions of coordinate systems, new discussion on perturbations and quaternions - NEW: Increased coverage of attitude dynamics, including new Matlab algorithms and examples in chapter 10 - New examples and homework problems

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orbital mechanics for engineering students pdf: Orbital Relative Motion and Terminal Rendezvous Jean Albert Kéchichian, 2021-04-12 This book provides a comprehensive analysis of time-fixed terminal rendezvous around the Earth using chemical propulsion. The book has two main objectives. The first is to derive the mathematics of relative motion in near-circular orbit when subjected to perturbations emanating from the oblateness of the Earth, third-body gravity, and atmospheric drag. The mathematics are suitable for quick trajectory prediction and the creation of computer codes and efficient software to solve impulsive maneuvers and fly rendezvous missions. The second objective of this book is to show how the relative motion theory is applied to the exact precision-integrated, long-duration, time-fixed terminal rendezvous problem around the oblate Earth for the general elliptic orbit case. The contents are both theoretical and applied, with long-lasting value for aerospace engineers, trajectory designers, professors of orbital mechanics, and students at the graduate level and above.

orbital mechanics for engineering students pdf: Python for Mechanical and Aerospace Engineering Alex Kenan, 2021-01-01 The traditional computer science courses for engineering focus on the fundamentals of programming without demonstrating the wide array of practical applications for fields outside of computer science. Thus, the mindset of “Java/Python is for computer science people or programmers, and MATLAB is for engineering” develops. MATLAB tends to dominate the engineering space because it is viewed as a batteries-included software kit that is focused on functional programming. Everything in MATLAB is some sort of array, and it lends itself to engineering integration with its toolkits like Simulink and other add-ins. The downside of MATLAB is that it is proprietary software, the license is expensive to purchase, and it is more limited than Python for doing tasks besides calculating or data capturing. This book is about the Python programming language. Specifically, it is about Python in the context of mechanical and aerospace engineering. Did you know that Python can be used to model a satellite orbiting the Earth? You can find the completed programs and a very helpful 595 page NSA Python tutorial at the book’s GitHub page at <https://www.github.com/alexkenan/pymae>. Read more about the book, including a sample

part of Chapter 5, at <https://pymae.github.io>

orbital mechanics for engineering students pdf: *Celestial Mechanics and Astrodynamics: Theory and Practice* Pini Gurfil, P. Kenneth Seidelmann, 2016-07-28 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.

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orbital mechanics for engineering students pdf: *Spacecraft Attitude Determination and Control* J.R. Wertz, 2012-12-06 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 students and professionals starting in this field; an information source for experimenters or others involved in spacecraft-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.

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