An Introduction to Space Systems

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1 Welcome

2 Introduction

Welcome to *An Introduction to Space Systems*. This book is a personal journey through the principles, mathematics, and technologies behind satellite missions.

You may start reading from any chapter, but we recommend beginning with Orbital Mechanics. If you want to learn about ADCS, then we recommend ADCS

See Equation Equation 2.1 and Section Section 2.1 for examples of references.

2.1 The Structure of This Book

This book is divided into two parts:

- **Orbital Mechanics**: Basics of orbits, coordinate systems, and orbital elements.
- **Satellite Subsystems**: ADCS, power, communication, and more.

2.2 A Demo Equation

A simple math example for reference:

$$E = mc^2 \tag{2.1}$$

Part I

Orbital Mechanics

3 Geocentric Coordinate Systems

4 Overview

Geocentric coordinate systems are centered at the Earth's center. This chapter introduces the geocentric equatorial frame and related systems.

See also the orbital elements in Section **?@sec-orb-elements**.

4.1 Coordinate Frames

We define a right-handed coordinate system with:

- X-axis pointing toward the vernal equinox
- Z-axis along the Earth's rotation axis

4.2 Example Equation

The position vector $\vec{r}$ can be expressed as:

$$\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k} \tag{4.1}$$

5 Orbital Elements

6 Orbital Elements

Orbital elements define the shape and orientation of a satellite's orbit.

The six classical elements are:

1. Semi-major axis (a)
2. Eccentricity (e)
3. Inclination (i)
4. Right ascension of ascending node (RAAN)
5. Argument of perigee (ω)
6. True anomaly (ν)

6.1 Equation Example

The equation for orbital period:

$$T = 2\pi\sqrt{\frac{a^3}{\mu}}$$

{#eq:orbital-period}

where μ is the standard gravitational parameter.

Refer to Equation @eq:orbital-period for orbital period.

Part II

Satellite Subsystems

7 Attitude Determination and Control

8 Introduction

The ADCS subsystem is responsible for controlling a satellite's orientation.

We build on the orbital reference frames defined in Geocentric Coordinate Systems.

8.1 Euler Angles

Attitude can be described using Euler angles (ϕ, θ, ψ).

The transformation matrix is:

$$R = \begin{bmatrix} c_\psi c_\theta & c_\psi s_\theta s_\phi - s_\psi c_\phi & c_\psi s_\theta c_\phi + s_\psi s_\phi \\ s_\psi c_\theta & s_\psi s_\theta s_\phi + c_\psi c_\phi & s_\psi s_\theta c_\phi - c_\psi s_\phi \\ -s_\theta & c_\theta s_\phi & c_\theta c_\phi \end{bmatrix}$$

{#eq:rotation-matrix}

where c and s denote cosine and sine functions respectively.

Refer to Equation @eq:rotation-matrix for attitude rotation.