# Table of Contents

List of Authors and Editors xv

Preface xxi

1 An Introduction to Human Spaceflight 1

1.1 Humans in Space 3
1.2 The Life Cycle of Human Space Missions 8
1.3 The Space Mission Concept and Architecture 10
1.4 The Challenges 15

2 Designing Human Space Missions 17

2.1 Define Mission Objectives 19
2.2 Define Mission Requirements and Constraints 21
2.3 Develop Alternative Mission Concepts and Architectures 24
2.4 Identify System Drivers and Critical Requirements 48
2.5 Baseline a Mission Concept and Architecture 50

3 The Space Environment—Hazards and Effects 53

3.1 Operating in a Vacuum 55
3.2 Effects of the Nonionized Atmosphere 58
3.3 The Plasma Environment—Spacecraft Charging 62
3.4 Effects of Radiation 65
3.5 Micrometeoroids and Orbital Debris 73
3.6 Interplanetary Space 74
3.7 Design Example—Lunar Base 74

4 Surface Environments 77

4.1 The Moon 79
4.2 Mars 88

5 Physiology of Spaceflight 103

5.1 Setting Environmental Parameters 104
5.2 Metabolic Parameters and Related Inputs and Outputs 121
5.3 Other Physiological Factors 125
5.4 Lunar Base Example 130
## 18 Crew Accommodations

- **18.1** Designing Crew Accommodations for Space Missions  
- **18.2** Mission Requirements and the Design Process  
- **18.3** A Resource Model for Crew Accommodations  
- **18.4** Crew Accommodations Subsystems  
- **18.5** Tailoring the Model for the Shuttle, International Space Station, Moon, and Mars

## 19 Attitude Determination and Control

- **19.1** Designing the Attitude Determination and Control Subsystem (ADCS)  
- **19.2** Establishing Control Modes and Requirements  
- **19.3** Quantifying the Disturbance Environment  
- **19.4** Selecting and Sizing ADCS Hardware  
- **19.5** Defining the Control Algorithms

## 20 Designing Power Systems

- **20.1** Overview of Power Systems  
- **20.2** Primary Power  
- **20.3** Energy Storage  
- **20.4** Power Management and Distribution (PMAD)  
- **20.5** Design Example

## 21 Structures

- **21.1** Requirements for Space Structures  
- **21.2** Establishing a Verification Plan  
- **21.3** Special Considerations for Space Structures that House People  
- **21.4** Design Options  
- **21.5** Preliminary Layout and Sizing of Structures  
- **21.6** Example: Sizing a Crew-Module Structure

## 22 Extravehicular Activity (EVA) Systems

- **22.1** Requirements for EVA Systems  
- **22.2** EVA Systems and Operations Concepts  
- **22.3** Interfaces  
- **22.4** Developing a Design  
- **22.5** Case Study: Providing EVA at a Lunar Base

## 23 Space Robotics

- **23.1** Basic Concepts of Robotics  
- **23.2** Humans vs. Robots  
- **23.3** Analyzing Functional and Operational Requirements
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Space Logistics Support</td>
<td>907</td>
</tr>
<tr>
<td></td>
<td>28.1 Logistics Support in the Design Process</td>
<td>909</td>
</tr>
<tr>
<td></td>
<td>28.2 Determining the Overall Logistics Support Concept</td>
<td>912</td>
</tr>
<tr>
<td></td>
<td>28.3 Establishing Objectives, Requirements, and Constraints</td>
<td>915</td>
</tr>
<tr>
<td></td>
<td>28.4 Preliminary Logistics Support Concepts and Scenarios</td>
<td>917</td>
</tr>
<tr>
<td></td>
<td>28.5 Design Example and Early Supportability Assessment</td>
<td>929</td>
</tr>
<tr>
<td>29</td>
<td>Estimating the Cost of Crewed Space Systems</td>
<td>933</td>
</tr>
<tr>
<td></td>
<td>29.1 Overview of Cost Estimating</td>
<td>933</td>
</tr>
<tr>
<td></td>
<td>29.2 Parametric Cost Estimating</td>
<td>941</td>
</tr>
<tr>
<td></td>
<td>29.3 Other Cost Issues</td>
<td>951</td>
</tr>
<tr>
<td></td>
<td>29.4 Example—Rover Design for the Lunar Base</td>
<td>957</td>
</tr>
<tr>
<td>30</td>
<td>International Crewed Missions</td>
<td>961</td>
</tr>
<tr>
<td></td>
<td>30.1 The Need for International Cooperation</td>
<td>961</td>
</tr>
<tr>
<td></td>
<td>30.2 General Principles of Cooperative Missions</td>
<td>971</td>
</tr>
<tr>
<td></td>
<td>30.3 Development Processes for International Cooperation</td>
<td>972</td>
</tr>
<tr>
<td></td>
<td>30.4 Requirements and Constraints on International Crewed Missions</td>
<td>976</td>
</tr>
<tr>
<td></td>
<td>30.5 Elements of Agreements and International Management</td>
<td>977</td>
</tr>
<tr>
<td></td>
<td>30.6 Case Study</td>
<td>979</td>
</tr>
<tr>
<td>31</td>
<td>Mars Design Example</td>
<td>981</td>
</tr>
<tr>
<td></td>
<td>31.1 Designing the Mars Mission</td>
<td>983</td>
</tr>
<tr>
<td></td>
<td>31.2 Transfer Vehicle—Designing the Habitation and Lander</td>
<td>991</td>
</tr>
<tr>
<td></td>
<td>31.3 Estimating Mass and Power</td>
<td>998</td>
</tr>
<tr>
<td></td>
<td>31.4 The Next Iteration</td>
<td>999</td>
</tr>
<tr>
<td>Appendix A</td>
<td>Inertias of Geometric Primitives</td>
<td>1003</td>
</tr>
<tr>
<td>Appendix B</td>
<td>Explanation of Earth Satellite Parameters</td>
<td>1007</td>
</tr>
<tr>
<td>Index</td>
<td></td>
<td>1013</td>
</tr>
</tbody>
</table>

Glossary of Acronyms