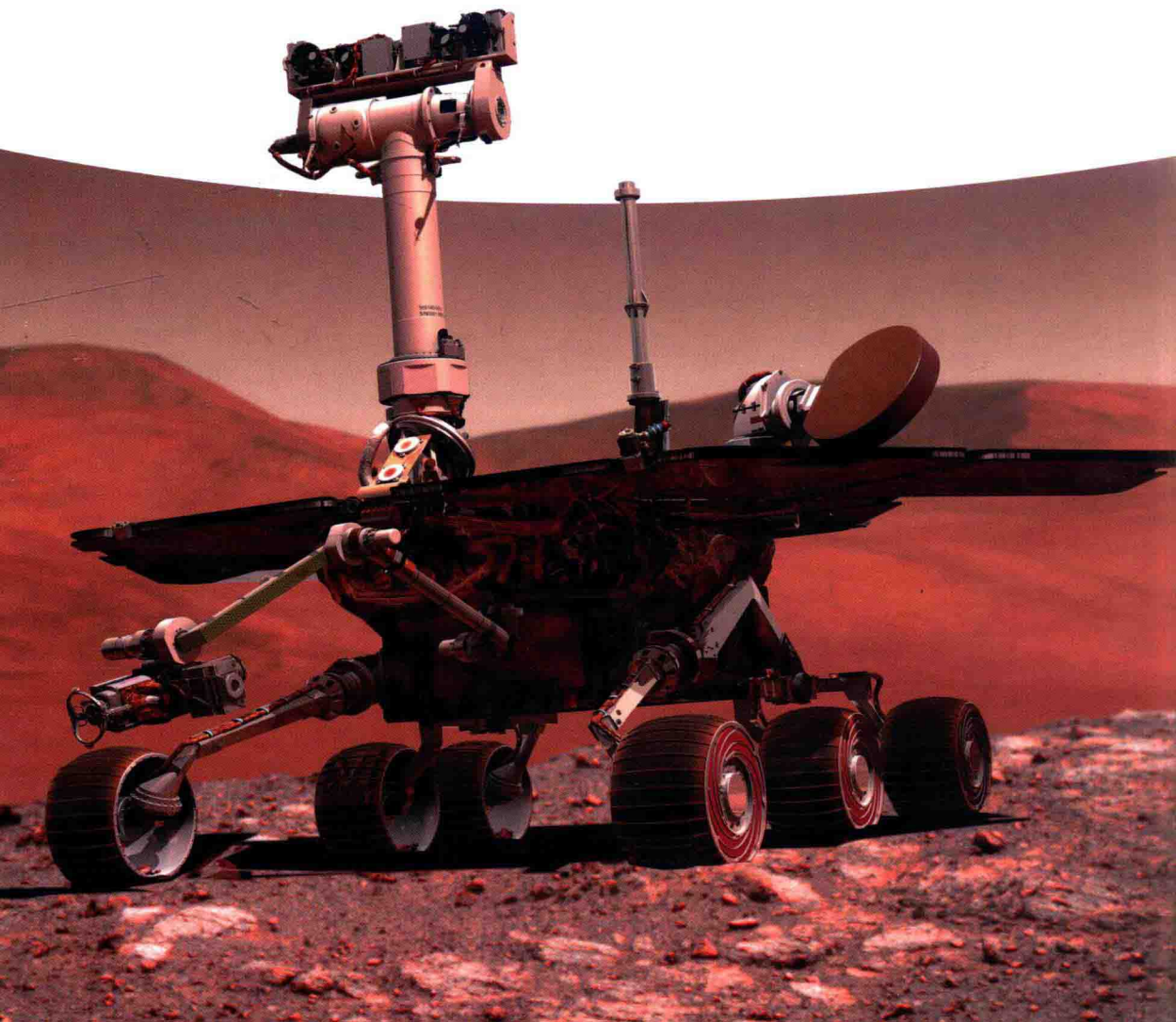


Edited by Yang Gao

# Contemporary Planetary Robotics

An Approach Toward Autonomous Systems



*Edited by Yang Gao*

# **Contemporary Planetary Robotics**

An Approach Toward Autonomous Systems

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## Editor

**Professor Yang Gao**

University of Surrey  
Surrey Space Centre  
STAR Lab, Stag Hill  
GU2 7XH, Guildford  
United Kingdom

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*Edited by*  
*Yang Gao*

**Contemporary Planetary Robotics**

## List of Contributors

### *Elie Allouis*

Airbus Defence and Space Ltd.  
Future Programmes  
Gunnels Wood Road  
SG1 2AS Stevenage  
United Kingdom

### *Abhinav Bajpai*

University of Surrey  
Surrey Space Centre  
STAR Lab, Stag Hill  
GU2 7XH Guildford  
Surrey  
United Kingdom

### *Guy Burroughes*

University of Surrey  
Surrey Space Centre  
STAR Lab, Stag Hill  
GU2 7XH Guildford  
Surrey  
United Kingdom

### *Robert G. Deen*

California Institute of  
Technology  
Instrument Software and Science  
Data Systems Section  
Jet Propulsion Laboratory  
4800 Oak Grove Drive  
Pasadena  
CA 91109  
USA

### *Alessandro Donati*

European Space Agency  
ESOC, OPS-OSA  
Robert-Bosch-Strasse 5  
64293 Darmstadt  
Germany

### *José de Gea Fernández*

DFKI GmbH  
Robotics Innovation Center  
Robert-Hooke-Str. 1  
D-28359 Bremen  
Germany

### *Simone Fratini*

European Space Agency  
ESOC, OPS-OSA  
Robert-Bosch-Strasse 5  
64293 Darmstadt  
Germany

### *Yang Gao*

University of Surrey  
Surrey Space Centre  
STAR Lab, Stag Hill  
GU2 7XH Guildford  
Surrey  
United Kingdom

**Peter Iles**

Neptec Design Group  
Space Exploration  
302 Legget Drive  
Ottawa  
ON K2K 1Y5  
Canada

**Frank Kirchner**

DFKI GmbH  
Robotics Innovation Center  
Robert-Hooke-Str. 1  
D-28359 Bremen  
Germany

*and*

University of Bremen  
Faculty of Mathematics and  
Computer Science  
Robert-Hooke-Str. 1  
D-28359 Bremen  
Germany

**Jan-Peter Muller**

Imaging Group  
Mullard Space Science  
Laboratory  
UCL Department of Space &  
Climate Physics  
Holmbury St Mary  
RH5 6NT Surrey  
United Kingdom

**Jorge Ocón**

GMV Aerospace and Defense  
Avionics On-board Software  
Division  
Space Segment Business Unit  
Isaac Newton, 11 (PTM)  
Tres Cantos  
28760 Madrid  
Spain

**Gerhard Paar**

JOANNEUM RESEARCH  
Institute for Information and  
Communication Technologies  
Machine Vision Applications  
Group  
Steyrergasse 17  
8010 Graz  
Austria

**Nicola Policella**

European Space Agency  
ESOC, OPS-OSA  
Robert-Bosch-Strasse 5  
64293 Darmstadt  
Germany

**Karol Seweryn**

Space Research Centre of the  
Polish Academy of Sciences  
(CBK PAN)  
18a Bartycka str.  
00-716 Warsaw  
Poland

**Affan Shaukat**

University of Surrey  
Surrey Space Centre  
Department of Electrical &  
Electronic Engineering  
GU2 7XH Guildford  
United Kingdom

***Nuno Silva***

Airbus Defence and Space Ltd.  
Department of AOCS/GNC and  
Flight Dynamics  
Gunnels Wood Road  
Stevenage  
SG1 2AS Hertfordshire  
United Kingdom

***Matthias Winter***

Airbus Defence and Space Ltd.  
Department of AOCS/GNC and  
Flight Dynamics  
Gunnels Wood Road  
Stevenage  
SG1 2AS Hertfordshire  
United Kingdom

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## 1

## Introduction

*Yang Gao, Elie Allouis, Peter Iles, Gerhard Paar, and José de Gea Fernández*

Planetary robotics is an emerging multidisciplinary field that builds on knowledge of astronautics, terrestrial robotics, computer science, and engineering. This book offers a comprehensive introduction to major research and development efforts for planetary robotics, with a particular focus on autonomous space systems, which will enable cost-effective, high-performing, planetary missions. Topics covered in this book include techniques and technologies enabling planetary robotic vision processing, surface navigation, manipulation, mission operations, and autonomy. Each topic or technological area is explained in a dedicated chapter using a typical space system design approach whereby design considerations and requirements are first discussed and followed by descriptions of relevant techniques and principles. Most chapters contain design examples or use cases that help demonstrate how techniques or theoretical principles can be implemented in real missions. Since any space engineering design or development is a system engineering process, this book also dedicates one chapter to planetary robotic system design – from mission concepts to baseline designs. As a result, this book can be used as a text or reference book for relevant engineering or science courses at the undergraduate and postgraduate level, or a handbook for industrial professionals in the space sector.

This chapter introduces the book by offering a chronicle on how planetary exploration and robotics have evolved to date, a systematic overview of planetary robotics, as well as an explanation on the organization and scope of the book.

### 1.1

#### Evolution of Extraterrestrial Exploration and Robotics

The need for humans to explore beyond the realm of Earth is driven by our inherent curiosity. Throughout our history, new worlds have been discovered by daring explorers who set out to discover new lands, find riches, or better understand these little-known territories. These journeys were fueled by the technological advances of the times such as the compass, maritime maps, or plane, and in return contributed tremendously to the scientific knowledge of humankind. For all

the good provided by these exploratory endeavors, history also reveals that *exploration* is difficult, perilous, and can be fraught with unforeseeable consequences. For examples, within early maritime exploration, only a fraction of all the ships that aimed for the new worlds eventually achieved their goals. There have also been countless instances where the discovery of the new lands was detrimental to the indigenous populations. The past and lessons learned serve as a stark reminder to all new exploration endeavors.

Outer space has provided real, new exploration frontiers for mankind since the 1950s. With the capability and the irresistible attraction to go beyond our planet Earth, minimizing the impact of mankind on other extraterrestrial bodies (be it a planet, a moon, a comet, or an asteroid) is paramount. Strong with the hindsight and knowledge provided by humans' own history, we are continuously learning about these new space frontiers and taking precautions to avoid repeating mistakes learned from the past exploration activities.

The onset of space exploration in the late 1950s to early 1960s focused on sending humans into space and the Moon, a key priority for the two main adversaries of the Cold War. However, it was true then as it is now, in parallel to the expensive development of manned space programs, the use of cheaper robotic proxies was deemed important for understanding the space environment where the astronauts will be operating. The USSR had the first set of robotics missions, successfully launching a series of Luna probes starting from 1959. Within a year, the Luna 1 managed a flyby of the Moon, Luna 2 crash landed on the Moon, and Luna 3 took pictures of the Moon's far side. It took another 7 years before both the USSR and the United States, within a few months from each other, performed soft landing on the Moon with their respective probes, Luna 9 and Surveyor 1. These missions paved the way for the first human landing on the Moon in 1969 by the United States. Building on these earlier successes, robotic exploration missions have extended their reach to Mercury, Venus, Mars (known as the *inner solar system*), and subsequently the *outer solar system* where tantalizing glimpses of the volcanic Io, the frozen Europa, or the methane rains of Titan have been obtained.

Planetary missions can use various ways to explore an extraterrestrial body, often starting with reconnaissance or remote sensing using orbiting satellites. More advanced approaches (such as landing, surface operation, and sample return) enabled by sophisticated robotic systems represent a giant leap in terms of mission complexity and risk, but more importantly scientific return. Not surprisingly, advanced extraterrestrial exploration is littered with unsuccessful missions bearing witness to serious technical challenges of such endeavors. Table 1.1 presents statistics of successful surface missions aimed for the solar system (excluding manned missions). The relatively low success rate is a clear reflection on the technical difficulties involved in designing, building, and operating the required robotic spacecraft. It is worth noting that space engineers and scientists have created the landscape of what we know today. With sheer determination, they continue to address countless challenges, failing often, but regrouping until they succeed.

Within the existing successful unmanned missions, various types of robotic systems have played significant roles, including **robotic platforms** (such as the