

Preface

The *in situ* exploration of small bodies, most typically asteroids and comets but also including planetary satellites, is an exciting endeavor currently at the forefront of planetary science. The science one can do at such bodies is as fundamental as it is important, as these bodies provide windows into the past of the Solar System. Found within the asteroid population are various stages of planetary formation, albeit in shards and tumbled with each other. Found within the comet population are the pristine chemicals that dominated the proto-planetary disk prior to the formation of the modern Solar System. Found within planetary satellites are whole snapshots of the formational epoch of the Solar System, and also miniature worlds that have evolved towards their own unique ends. Thus, justification for the exploration of these bodies is well-founded and has motivated large portions of the planetary science community over the last decades.

More recently, these small bodies, especially Near-Earth asteroids, have also become of interest for human exploration of the Solar System. Motivated by an eventual human mission to Mars, much debate and discussion in the space exploration community has swirled around what the appropriate pathway towards this eventual goal may be. As of this writing, the current pathway towards Mars is seen to lie through an initial human exploration mission to a Near-Earth asteroid. The topics covered in this book are fundamental for the design, evaluation and navigation of such missions. Human exploration of asteroids can also be envisioned as a useful endeavor for the identification and exploitation of extra-terrestrial resources. Indeed, there has been much serious scholarship focused on how asteroid materials can be utilized for sustaining human presence in outer space. Finally, the mitigation of hazardous asteroids and comets on potential impact trajectories with the Earth relies fundamentally on our exploration and understanding of spacecraft mechanics at these bodies.

Thus there is a cornucopia of well-motivated scientific and exploration activities at asteroids, comets and planetary satellites. While there have been countless studies, proposals and papers describing these activities, there has not been such a clear focus on the practicalities of what one can do with space vehicles when they arrive at these bodies. It is surprising to note that there are many more studies of

how to plan a spacecraft's path to such small bodies than there are what should be done once one arrives. Whereas the theory for plotting a course to an asteroid, comet or planetary satellite is well understood and has been implemented many times in recent decades, the fundamental mechanics of motion in the vicinity of a small body is not fully understood and cannot be understood based solely on a simple application of Kepler's laws. Thus, the opinion is frequently expressed that it is *impossible* for a spacecraft to orbit an asteroid smaller than, say, a few tens of meters in size. But, on closer inspection, this turns out to be fully feasible in many circumstances. Similar examples abound and, while not always discussed specifically, will be addressed through the content of this book.

The goal of this book is to remove some of this mystery, and to lay out the fundamental mechanics of what one *could* do with a spacecraft when visiting a small body. While this book is not the definitive summation of all the work that has been done on this subject, it can at least serve as a background for further study and analysis.

The text is divided into three parts. Part I reviews the basics of small bodies in the Solar System, their orbits, their spin states, their sizes, their morphological properties, and the force environment about them. The emphasis is on describing those features of these bodies that are important for understanding orbital mechanics about them. Accordingly, the book does not discuss the many interesting scientific aspects of these bodies nor does it discuss motivations for their explorations – such motivations are taken as fact. Part II presents the background dynamical theory that is necessary if one wishes to fully explore the dynamics of motion about these bodies. For an expert in dynamical systems, these chapters may seem a bit naive, while to a novice in astrodynamics they may seem relatively advanced. The material presented in these chapters is there mainly because I have found these results useful in my own research on this problem, and thus feel that they must be presented. Part III applies and analyzes a range of different types and situations that may exist at a variety of small bodies of the Solar System. The list is certainly not exhaustive, as small bodies have a penchant for presenting hitherto unforeseen dynamical situations. Indeed, this is what makes them so exciting. The intent of these chapters is to provide case studies that can be used as a reference for other small bodies considered for exploration, and to serve as a springboard for investigating new situations or configurations that may arise.

There are many people to whom I owe a debt of gratitude for the development of this book and the topics covered herein. First, I must acknowledge the many students who have worked with me on these topics. In a very real sense, all of the students I have worked with on research have shaped me and my approach to these topics – oftentimes the connections between their research and how it impacts topics in this book are not clear, yet they exist nonetheless. Of special note are several students whose thesis research is clearly and explicitly called out in this book. I list them here in order of their graduation: Weiduo Hu, Benjamin Villac, Marci Possner (nee Paskowitz), Stephen Broschart, Ryan Park, Julie Bellerose, Eugene Fahnestock and Oier Peñagaricano-Muñoz. A special thank you is given to Aaron Rosengren for help in proof-reading the book.

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