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 describ-
ing those features of these bodies that are important for understanding orbital
mechanics about them. Accordingly, the book does not discuss the many inter-
esting 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-Muñoa. A special thank you is given to
Aaron Rosengren for help in proof-reading the book.
Second, I must acknowledge my many colleagues from the scientific and engineering communities that have encouraged my research and continually asked the probing questions that force one to further refine and dig into this research. Primary among these is Steven Ostro, to whom I dedicate this book. It is not an understatement to say that Steve’s enthusiasm for my research on these problems, his probing questions that went far beyond science, and his continual encouragement have served as the foundations of my success in my professional life. Many others have also encouraged or enabled my research on these problems. Two who have provided such support during crucial periods of my career are Bobby G. Williams and Donald K. Yeomans.

Finally, and most importantly, I must acknowledge my wife, Susan Postema Scheeres, my children Annaka, Samuel and Eleanor, and my parents, Jacob and Ann, for their continual encouragement, support and confidence in me.

Boulder, Colorado, August 2011

Daniel J. Scheeres
Orbital Motion in Strongly Perturbed Environments
Applications to Asteroid, Comet and Planetary Satellite Orbiters
Scheeres, D.J.
2012, XVIII, 390 p., Hardcover
ISBN: 978-3-642-03255-4