
NEW
SPACE
VENTURES
Space Mining and Its Regulation
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Springer
PRAXIS

Astronautical Engineering

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More information about this series at http://www.springer.com/series/5495

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Springer

Published in association with
Praxis Publishing
Chichester, UK

PRAXIS

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ISSN 2365-9599 ISSN 2365-9602 (electronic)
Springer Praxis Books
ISBN 978-3-319-39245-5 ISBN 978-3-319-39246-2 (eBook)
DOI 10.1007/978-3-319-39246-2

Library of Congress Control Number: 2016943086

Cover illustration: Courtesy of Deep Space Industries.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Foreword

Simply put, the authors of *Space Mining and Its Regulation* provide in this rather concise book a comprehensive view of the history, technical challenges, current status, and future probabilities of mining off-Earth space resources. This they do in breadth, depth, and in very accessible detail. They discuss the evolution toward space mining as a natural flow of the human use of space. As presented, the accurate history and analysis makes the author's views and presentations invaluable. It thus provides critical information both to those responsible for formulating space resource mining policies and those formulating and following laws designed and intended to implement the policies in a relatively global-interest context.

The book is thus an extraordinarily useful—perhaps even rare—resource, not just for the daily practitioner of space law relating to the mining of space resources but also to the broad spectrum of relevant policy makers, programmers, and project implementers. In many respects, the subject matter of the book is presented in an intriguingly simplistic as well as highly professional fashion that will attract an average interested and nontechnically oriented reader. The subject matters addressed specifically and in detail cover issues and positions that need to be taken regarding the present and long-term importance of off-Earth natural resources, i.e., exactly why they are needed for the current and future challenges of the world population.

Included in the discussions are the various transportation systems and locations for mining a variety of usable space resources; the use of robotic systems for mining purposes; the role of governmental activities and applicable policies in current and future resource mining; the involvement of private sector initiatives, principally by emerging US companies seeking to take advantage of the unfolding accessibility to a variety of different space and space-related resources; the past and current activities of the USA, the former Soviet Union, and now Russia in exploring and developing space resource mining capabilities, as well as those practices and planning pursuits in Japan, China, India, and also in Europe, Canada, and certain other nations located in the western hemisphere. All of these activities are explored by the authors in the context of the existing and potential international and various national regulatory environments. A close look is taken by the authors at existing and potential national space laws relating to resource exploitation.

Normally, daily or otherwise routine adoption of laws for domestic and even international purposes is simply the implementing of underlying policies already formulated and either existing or soon to come into effect. There has to be a

reasonable understanding of the underlying philosophic construct driving all components of human space migration before the mining of space resources can be carried out in a responsible fashion. Otherwise, the sporadic and disparate mining of space resources will affect that migration in perhaps an irretrievably negative fashion. The mining and underlying costs must be for globally shared purposes and conducted with that overall aim or construct as a constant guiding principle. The cost effect of off-Earth mining may well be prohibitive without the broader objective of species migration and survival serving as a significant motivating factor. The book's authors have shown clearly, carefully, and unmistakably that the absence of pressingly definitive policies regarding the use of off-Earth space resources has forced the traditional law makers and space-related law practitioners to assume much responsibility normally left to the policy formulators. Bringing people together globally for a pressingly common, but little understood, objective is one of the greatest challenges historically faced by constantly evolving cultures, societies, and civilizations. The authors bring much of the global population together in a very pragmatic fashion to focus on the details of mining space resources for the benefit of humans living and working in space, as well as on Earth's surface.

The authors have identified a number of the different start-up, evolving, and established companies across the globe with programs or dedicated activities to explore usable space resources and exploit them financially to the greatest reasonable extent practicable. In addition to describing the flight potential objectives of these companies, the applicability of current space-related mining laws to these objectives is set forth. But some of the real issues emphasized by the authors with respect to identifying potentially usable space resources are the applicability of existing laws and the need to develop and fine-tune not only these laws and regulations but address the need for potentially unique laws as resource identification and usability unfold. In this context, and as relevant dependency on rapidly developing technologies necessary for space resource extraction and practical applications becomes clear and available, the need for an overall jurisprudence underlying resource extraction and applications, both on Earth and off, will become clear.

This book presents the underlying policies and available technologies, present and future, necessary for supporting migration off Earth. This is particularly clear in the context of learning how to use space resources, once they are mined successfully, for space habitation to support those mining efforts in situ. With respect to mining lunar resources, the authors are keenly aware of the need to know for what purposes the resources are being mined, and indeed have as thorough a knowledge as possible, for example, of the Moon's origin and composition, and whether and under what circumstances expanding mining undertakings might or will disturb its physical relationship with Earth and, indeed, orbiting habitats such as the current International Space Station (ISS). The flow of information set forth in the book is orderly, logical, and historically accurate, particularly with respect to the variety of space systems that have existed and currently exist for the retrieval, transportation, and delivery of mined space resources. Again, the book carefully sets forth the underlying policies and technologies necessary for migration off Earth and learning

how to use space resources, once mined successfully, for space habitation and production of resources usable on Earth as well as in space.

In the context of space resources available, or becoming available, for commercial mining purposes, the authors address the rise of new companies resulting, often uniquely, by contracting and partnering with established companies, such as Northrop Grumman and the birth of commercial space industries over the past 15 or so years. These companies rely primarily on relatively modest start-up capital and bottom-up decision making using constantly evolving technology based on software development that is transforming the way space business is and will be conducted. In a revealing and fascinating fashion, the authors address the issues raised by these new companies and their management style, e.g., flatter and more flexible organizations that are consumer focused, innovative, and with owner-management willingness toward risk-taking. The companies by-and-large are organized in a way that focuses on new technology-oriented problem solving.

The authors document a zealous management impatience among all the new space mining companies with restrictive regulations. They are constantly pressing to move ahead rapidly. The authors focus primarily on the United States as the principal source of these new types of business formats and operational infrastructures that reflect activities emphasizing private sector pursuits in addressing space resources mining. They also present a marvelous hint of currently existing companies that could clearly identify and exploit usable resources offered by "potentially mineable" asteroids and Earth's moon.

Finally, the authors bravely tackle how they believe the national, international, and global communities will react to the developing manner of the evolving variety of interests, technologies, and methodologies for capturing and using space resources. In addition to presenting excellent and very readable histories of pursuits to capture and use space resources through often unique methodologies, the authors pose and address the final question for the moment, i.e., "How Is the World Likely to React to these Developments?" The book serves both as a fascinating read and particularly as a very usable text to which space lawyers and policy makers can easily resort for accurate and relevant information in furtherance of their respective professional responsibilities.

Dr. George S. Robinson

Preface

This book is designed as a "one-stop shopping" guide to the newly emerging field of space mining. The chapters that follow seek to provide a review of the past, current, and planned activities of various national space agencies of the world—as well as new commercial enterprises—in their relevant efforts to explore and exploit the resources of the Solar System. This review covers the Moon, Mercury, Venus, Mars, Jupiter and its Moon as well as asteroids and even comets. It includes an overview of the exploratory and scientific activities of the United States, USSR/Russia, Europe, Japan, China, India, Canada, and others in terms of space initiatives of national space agencies.

This book also provides a review of the current activities of the new space mining ventures, including Planetary Resources, Deep Space Industries, Moon Express, and Shackleton Energy. The book describes the international and national legal and regulatory frameworks (or the absence thereof) within which space mining is being and will be developed or undertaken. Special attention is paid to the legal issues related to existing and evolving international liabilities, property rights, and national licensing systems applicable to private entities aspiring to engage in space mining.

Clearly there are great technological, ecological, and legal and policy challenges to be met and resolved before space mining can make the transition from aspiration to reality. This book attempts to provide useful background as to past and current activities as well as to offer a guide to that future as well.

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Acknowledgements

This book is a significantly expanded and updated version of a study that was carried out in 2013 by Ram S. Jakhu and Yaw O. M. Nyampong for the Canadian Space Agency (CSA). The CSA, which holds copyright to the original study, has authorized and encouraged the authors to publish the study under their names. We are indebted to the CSA for its generosity and support.

Tanveer Ahmed helped us in the collection of data for some chapters of this book. We express our gratitude to Tanveer. Dr. Joseph Pelton, the former dean of the International Space University, has added a significant amount of new text with regard to the technical challenges that space mining faces in the years ahead and has participated fully in the complete rewriting of the original study and providing updated materials throughout.

However, as always and notwithstanding the above-mentioned invaluable help and support, the authors remain exclusively responsible for any errors contained in this book.

The Arthur C. Clarke Foundation was established in 1983 in Washington, D.C., as part of World Communications Year celebrations at the United Nations, an international event sponsored by the United Nation's International Telecommunication Union (ITU). The Foundation was created to recognize and promote the extraordinary contributions of Arthur C. Clarke to the world and to promote the use of space and telecommunications technology for the benefit of humankind.

The Foundation is dedicated to enhancing Sir Arthur Clarke's legacy and to share that opportunity with like-minded institutions and especially sister organizations such as the Arthur C. Clarke Center for the Human Imagination and the Arthur C. Clarke Institute for Space Education.

The Foundation draws its inspiration from an individual whose range of creativity is unimaginably wide. At one extreme is Clarke the physicist who, at age 28, envisioned a time wherein geosynchronous platforms—extraterrestrial relays—could be used for global communication. At the other is Clarke as the most inspiring science fiction writer of his age, and his relentless and profound faith in humanity's ability to meet, even to elevate, its moral obligations to the planet upon which we live.

To the world, Arthur C. Clarke was a visionary, known not only for his science fiction novels such as Childhood's End, Rendezvous with Rama, and 2001: A Space Odyssey, but also for his scientific publications on space, energy, and the oceans. He is perhaps most famous for envisioning a global network of geosynchronous telecommunications satellite in 1945, as well as conceptualizing the "space elevator"—an elevator from Earth's surface to orbit, and ocean thermal energy conversion (OTEC).

The Arthur C. Clarke Foundation regards Sir Arthur's work as an unparalleled synthesis of science, literature, and social concern. History will list him among the few whose insights ranged most broadly in our comprehension of the universe we live in, the way we live in it, and the responsibility we have to improve our world. The scope of his vision is presented in the book *The Oracle of Colombo: How Arthur C. Clarke Revealed the Future*.

The Foundation exists to

- Stimulate creative use of communications technologies and social resources to improve health, education, and the quality of life for people everywhere, with emphasis on the needs of developing countries.
- Integrate science and technology with literature, film, and other means of outreach to enhance recognition of our increasingly complex, interconnected world.
- Deepen public understanding of science and technology and their impact on humanity and our world.

To carry out its mission, the Foundation has created and oversees annual awards, educational programs, video productions, lectures, fellowships, travel grants, and endowments to commemorate the life and works of Arthur C. Clarke who died in 2008.

The Global Space Institute was formed in 2014 and has offices in the United States and Canada, but is organized and committed to support the outer space community worldwide. It has served a growing list of clients in Europe, Mexico, South Africa, the Middle East, Israel, India, Canada, and the United States with training, research, and educational projects and has provided specialized courses in space development for the International Astronautical Congress.

- GSI is an international education and research institute dedicated to the future development of space and especially new applications serving humankind.
- GSI was founded by space professionals with decades of international experience within national and regional space programs, the private sector, and world-class universities.
- GSI is designed to provide a wide range of services to the international space community whether in the form of on-site training, targeted research and development of space-related products or services, or consulting support.
- GSI is available to assist with specialized space training and especially "new space" entrepreneurial initiative training, education, and analysis needs.

The International Association for the Advancement of Space Safety (IAASS) was legally established on April 16, 2004, in the Netherlands, as a nonprofit organization dedicated to furthering international cooperation and scientific advancement in the field of space systems safety. In 2004 IAASS became a member of the International Astronautical Federation (IAF). In 2010 IAASS was granted Observer status at the United Nations COPUOS (Committee on the Peaceful Uses of Outer Space).

In accordance with the Association charter, the IAASS membership is open to anyone having a professional interest in space safety. Members can be physical persons, corporations, agencies, universities, institutions, and other professional associations.

The Association exists to help shape and advance an international culture of space safety (technical, organizational, and socio-political), which would contribute to make space missions, vehicles, stations, extraterrestrial habitats, equipment, and payloads safer for the general public, ground personnel, crews, and flight participants. The Association also pursues the safeguarding and sustainability of the on-orbit environment to allow unimpeded access to space by future generations as well as to address cosmic hazards of all types—including asteroids, comets, and solar storms.

The mission of the IAASS is to advance all forms of space safety study, research, and practical implementation. The association is committed, through the knowledge and dedication of its members, to advance space safety internationally. Goals include:

- Avoiding risk badly measured or willingly underestimated;
- Providing education and training in the field and providing necessary knowledge concerning space safety especially that not made available by others;
- Avoiding and preventing a lack of management commitment and attention to all aspects of space safety;
- Seeking to avoid a lack of personal accountability in the field of space safety, which can make people negligent;
- Advancing the science and application of space safety;
- Improving the communication, dissemination of knowledge, and cooperation between interested groups and individuals in this and related fields;
- Improving understanding and awareness of the Space Safety discipline;
- Promoting and improving the development of Space Safety professionals and standards;
- Advocating the establishment of safety laws, rules, and regulatory bodies at national and international levels for the civil use of space.

At its central campus in Strasbourg, France, and at various locations around the world, the ISU provides graduate-level training to the future leaders of the global space community. The university offers a 2-month Space Studies Program, a 5-week Southern Hemisphere Program, and a 1-year Masters program related to space science, space engineering, systems engineering, space policy and law, business and management, and space and society.

These programs give international graduate students and young space professionals the opportunity to learn while solving complex problems in an intercultural environment. Since its founding in 1987, the International Space University has graduated more than 3000 students from 100 countries (as noted in red in the map below), creating an international network of professionals and leaders. ISU faculty and lecturers from around the world have published hundreds of books and articles on space exploration, applications, science, and development.

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