Space Law and Policy

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Maria A. Pozza
Joel A. Dennerley *Editors*

Risk Management in Outer Space Activities

An Australian and New Zealand Perspective

Springer

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Series Editor
Maria A. Pozza, Gravity Lawyers, Christchurch, New Zealand

Space activities across the Asia-Pacific, specifically in Australia and New Zealand, are increasing and diversifying. Over the last decade, countries in this region have seen significant growth within their national space industries and economies which in turn benefit their wider societies due to the downstream application and use of, space-related technologies, products, and services. This phenomena presents not only a great opportunity for these countries, but also represents a situation necessitating considered and fit-for-purpose space law and policy. Robust yet flexible regulatory regimes are needed if countries in the Asia-Pacific, such as Australia and New Zealand, are to benefit from the strategic and commercial advantages associated with a presence in outer space and functioning domestic space sector. These regulatory regimes must respond to, and address, numerous challenges ranging from adherence to international legal obligations to issues of geo-political space security and military concerns through to questions about how best to regulate and support commercial space endeavours. These myriad factors will have an impact upon how countries develop, implement, and refine their space laws and policies. This series offers a unique perspective from this region and intends to act as a source of knowledge and guidance for space actors across government, the private sector and academia in the pursuit and furtherance of their respective space activities and operations. The contributors to this series are all experts in their field who share a common interest in strengthening space governance via the promotion and development of space law and policy.

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Editors
Maria A. Pozza
Gravity Lawyers
Christchurch, New Zealand

Joel A. Dennerley
Management Consultant
Canberra, Australia

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During June 2020, our co-author Professor Hearnshaw lost his son Dr Edward Hearnshaw during a fatal tramping accident crossing the Hawke's Bay's Makaroo River. Edward, who was my good friend and someone who I fondly referred to as to "Teddy", left this life far too early. It is with great privilege, and on behalf of the editing team and authors of this book, that I would like to dedicate this work to the memory of Dr Edward Hearnshaw.

Foreword

Risk Management in Outer Space Activities: An Australian and New Zealand Perspective

When asked to prepare this foreword, I gladly accepted this challenging task due to the relevance and innovative character of the topic under consideration, namely risk management in space activities.

While often unaddressed in legal literature, risk management represents a key element in the study, preparation, and implementation of any space project, not only from a theoretical/academic perspective but, most importantly, from the point of view of actors and investors. Indeed, when one takes a moment to consider space activities, it is rather intuitive to realize the variety of risks associated with them and the danger that these risks pose to the successful completion of space-related endeavors. First and foremost, space activities are inherently dangerous due to the technological challenges that they face and the hazardous nature of the materials used; in fact, despite the great progress made in the past decades, space launches are far from being "routine," and technical failures occur often. Human factors can also lead to accidents and therefore can compromise the safe realization of a space project. Secondly, due to the increased number of space actors and the growing level of pollution in Earth orbits, the likelihood of un-intentional collisions among space objects (active and non-active) increases on a yearly basis. Finally, due to their strategic relevance, satellites might become objects of attack (either by means of traditional or non-traditional/cyber means) in the context of military confrontation.

Taking the above elements into account, one should easily understand not only the importance of assessing risk in the context of a space project but also the need to bring these risks within acceptable levels or thresholds. From this point of view, the present book represents a useful, and rather unique, "tool" to perform this task. What makes the book unique is the approach that it endorses, one that focuses on practical considerations rather than theoretical ones. In particular, the book emphasizes the importance of determining "context" when assessing risk; in this respect, the authors suggest recourse to the Layers of Control Framework, a structure that enables a better understanding of the types of risk controls that a risk manager is likely to implement based on their situation. An additional value that this book provides are the varied case studies that it presents, each examining risk and risk management in relation to different space-related contexts; indeed, each chapter focuses on one specific issue, such as insurance, space debris mitigation, and cyberattacks, and analyzes how risk is managed therein. Such a choice enables the book to tackle some of the most pressing issues in the space domain and to bring a "fresh" approach to them.

Overall, I am extremely confident that the book will represent an important contribution to the space law literature and, most importantly, will become an essential reading for those with an interest in the subjects of both risk management and space activities. The experience and the level of the authors provide a further guarantee of the quality of the manuscript.

Institute of Space Law and Strategy
Beihang University, Beijing, China

Fabio Tronchetti

Editor's Acknowledgements

Writing and editing a book of this nature during a first-of-a-kind global pandemic was certainly not an easy task and presented us with unique challenges. However, the challenges that COVID-19 presented did not phase the authors or editing team working on this book. Both the authors and the editing team demonstrated an incredible work-ethos which was built on a foundation of support for one another, good humour, and positive encouragement. To the authors of this book, I want to express my heartfelt thanks for your incredible contributions to this work, especially during a very challenging time.

I have been privileged to work alongside an incredible editing team that banded together despite the global challenges that COVID-19 presented. The effort, dedication, and time given to the reviewing process, even before going out to external reviewers, was truly extraordinary. It is impossible to find the appropriate words of gratitude that one might extend to a group of individuals that, without any hesitation, willingly gave up their time and energy because they believed in the importance of this book. My thanks to Tyson, Joel, Andreas, and Sarah, for being truly wonderful to work with.

I would also like to thank my authors and editorial teams' families (as well as my own family) for allowing their loved ones to dedicate so much of their time and energy away from them to the culmination of the work produced in this book.

A book of this nature required many of us to consult with industry professionals in order to gage our respective theories and test analysis. The advice, time, and willingness given to us by individuals who are highly admired in their respective fields was truly phenomenal. In this regard we, would like to thank Dr Fabio Tronchetti both for the book's foreword and his ongoing support during the writing process. We would like to thank Dr Brett Biddington AM, Dr Malcolm Davis, Morten Pahle, and Professor William B. Boothby for providing their guidance, expertise, and wisdom in the creation of this book. A special thanks is extended to Brad Robb, MD of ALARP Solutions (a boutique management consultancy, specialising in governance, risk, assurance, and system safety solutions), for giving us permission to use the *Layers of Control Framework* as a contextual aid for this book.

Encouragement, support, and wisdom are fundamental key elements that every editor requires when producing a work of this nature. I owe a great deal of thanks to Lucie Bartonek, the Springer Commissioning Editor of Business, Economics, Law, and Space Studies, for her ongoing support of us in producing this work.

Finally, I owe a debt of gratitude to my assistant editor Joel A. Dennerley. Joel is not only a rising star in the field of space law and policy, he is truly a gifted intellect in the complex and evolving field of space studies. As a collaborative work colleague, good friend, and fellow space professional, not only do I have the utmost admiration for Joel, I hold him in the highest esteem. To Joel I owe the greatest thanks of all.

Gravity Lawyers, Christchurch, New Zealand Maria A. Pozza

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About the Contributors

Eric L. Dahlstrom, BA, MS. Mr. Eric Dahlstrom is co-founder of SpaceBase Limited, New Zealand, and co-founder of International Space Consultants.

Joel A. Dennerley, BA, LLB (Hons). Joel is a management consultant and is currently undertaking a Master of Applied Data Analytics.

John Hearnshaw, MA, PhD, DSc, FRSNZ, FRASNZ, MNZM, NZOM. Dr Hearnshaw is Emeritus Professor of Astronomy at the University of Canterbury, New Zealand.

Tyson Lange, BA, JD (Hons), GDLP. Tyson Lange is a lawyer based in Canberra, Australia, specialising in the Australian regulation of outer space activities.

Blair McNamara, LLB (Hons), BBus, Dip Fin Ser. Blair is the principal lawyer at Brockhill and Usherwood Lawyers, Melbourne, Australia.

Sarah O'Connor, B Int R (Hons), LLM. Sarah is a former researcher with the Australian Strategic Policy Institute's International Cyber Policy Centre. Sarah is currently undertaking the Master of Applied Cybernetics course.

Maria A. Pozza, LLB (Hons), BVC (ICSL), PG Dip Legal Research & Skills, M Inst, PhD. Dr Pozza is the director and principal lawyer of Gravity Lawyers, New Zealand, which specialises in the international regulation, and New Zealand regulation, of space activities.

Andreas K. E. Sherborne, BA, LLB (Hons). Andreas is a practising lawyer in Canberra, Australia, and has experience advising on commercial and contract law, international law, and space law.

Heloise Vertadier, LLM, MSc. Heloise is currently undertaking a PhD (supervised by Dr Pozza) at the University of Otago, New Zealand, and works as a project coordinator with Breaking Ground Trust.

Aaron Young, MSc Oceanography, BSc Physics, Grad Dip Meteorology. Aaron is the director of operations and the governance risk and assurance discipline lead at ALARP Solutions.

Chapter 1
An Introduction to Risk Management in Outer Space Activities

Joel A. Dennerley, Aaron Young, and Maria A. Pozza

1.1 Introduction

Outer space has a special connection to humankind. For millennia, the night sky has instilled in us a sense of awe and curiosity. In the twenty-first century, it is now a domain which we explore and conduct activities within. Nevertheless, however human activities are conducted in outer space, there will always be a series of associated risks. Having evolved in a terrestrial Earth-bound setting, the foreign environment of outer space exposes humans to a set of hazards primarily associated with survivability and wellbeing. Therefore, when conducting space activities, we must constantly and consistently strive to improve the safety, certainty and security of all our space endeavours. This requires space actors to consider, understand and manage the risks that are inherit to their space activities. The purpose of this book is to serve as a step toward this objective.

The breadth of human activities conducted in, having an effect in, or intended to have an effect in outer space, ranges from the manufacturing of satellite components, to the launching of space objects, through to the operation of ground stations that receive data transmissions from spacecraft. All these endeavours represent vastly different contexts in which risks can and do occur, and as such they must be managed accordingly. There is no universal panacea that will manage, treat or solve

The views of the authors are the authors' alone and are intended to provide commentary and general information, and do not represent the views of any organisation. This chapter should not be relied upon as a substitute for professional legal advice or for any other purpose.

J. A. Dennerley · A. Young (✉)
Canberra, Australia
e-mail: info@gravitylawyers.co.nz

M. A. Pozza
Gravity Lawyers, Christchurch, New Zealand

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all risks associated with every space activity. Drafting a work that either comprehensively examines every risk related to outer space activities, or which proposes a universal approach to the management of all risks would be nearly impossible to do. Such a tome would likely be out of date from the day it is published due to the dynamic and constantly changing nature of space activities. Instead, this book sets out to examine a variety of space related risks as well as risk management concepts and practices that may be more broadly understood and applied. The mix of topics found within this work has been selected to highlight some important factors associated with risk management in respect of outer space activities. It does so from an Australian and New Zealand perspective. This points to the fact that risk management as a concept and practice will be understood and applied differently by different countries, corporations and individuals. Despite these differences, a commonality to successful risk management is the ability to situate risk within its unique context. Context in this sense is the different circumstance(s) that cohere to form the place(s), setting(s) or surrounding(s) in which an event(s) will occur or unfold. Identifying and understanding the specific context in which risks manifest, and to which risk management will apply (for instance in outer space), is critical to the success of risk management.

This introductory chapter, therefore, establishes a framework for the remainder of the book by providing a structure to establish the risk context and situate risk management considerations in outer space and its associated activities. To do this, this chapter will explore what risk is, what risk management is, what constitutes space activities and what defines the outer space context. The chapter will finish by describing a conceptual framework designed to help situate the various risk contexts in relation to the space domain. This will assist the reader locate those chapters that are of special interest to them.

Each subsequent chapter in this book then examines, from an Australian and New Zealand perspective, certain risks associated with selected space activities and operations, and discusses how these risks have, or might be, appropriately managed. As a whole, this book is not intended to provide a detailed guide to risk assessment techniques. Rather it provides an overview through the use of specific case studies, which examine the potential risks and how Australia and New Zealand manage those risks.

With the above in mind, the intended readers of this work is potentially quite broad. There may be many readers with an interest in risk management and space activities. These may include members of international organisations, national and state governments, employees of companies involved in space operations, to academics in disciplines such as astronomy, engineering, law and finance. This book can be read cover to cover as a high-level overview of certain risks associated with selected space activities. Alternatively, a reader may choose to read a specific chapter that is of particular interest to them. To assist readers do this, a table is included in Sect. 1.7 of this chapter.

1.2 What Is Risk and What Is Risk Management?

Douglas Hubbard highlight's in his book, 'The Failure of Risk Management', the controversy surrounding the word 'risk' and how it is interpreted (Hubbard, 2020, p. 9). In short, the term 'risk' is not universally accepted by all to mean the same thing. Rather than addressing the various controversies surrounding the term, this book will start with Hubbard's definitions of risk and risk management as a good basis for discussing risk considerations in the context of outer space activities. These definitions are as follows:

DEFINITION OF RISK

> Long definition: 'A potential loss, disaster, or other undesirable event measured with probabilities assigned to losses of various magnitudes' (Hubbard, 2020, p. 9).
> Shorter (equivalent) definition: 'The possibility that something bad could happen' (Hubbard, 2020, p. 9).

DEFINITION OF RISK MANAGEMENT

> Long definition: 'The identification, analysis, and prioritization of risks followed by coordinated and economical application of resources to reduce, monitor, and control the probability and / or impact of unfortunate events' (Hubbard, 2020, p. 11).
> Shorter definition: 'Being smart about taking chances' (Hubbard, 2020, p. 11).

The practical application of risk management is easier to discuss if risk itself is broken into its component parts. That is, the first component is the potential loss, disaster or other undesirable event. This could also be called a hazard or a potential source of harm. The second component constitutes those threats leading to, or causes of, the undesirable event, and the third component consists of the consequences resulting from the undesirable event occurring. The relationship between a cause and an undesirable event is typically represented as a discrete probability, or likelihood over a given time period (e.g., days, weeks, years etc) or over a given number of occurrences (e.g., number of launches). A risk statement typically expresses each of these components; for example, there is a chance that poor weather (cause) could result in a launch delay (undesirable event), resulting in a loss of forecast revenue (consequence).

The likelihood is a discrete probability because the cause either results in the undesirable event occurring over the specified time period (or number of occurrences) or it does not. It is common practice to define the likelihood of a given undesirable event occurring through qualitative descriptors such as very unlikely, unlikely, probable, almost certain etc. As noted by Hubbard, use of qualitative descriptors can lead to ambiguity and misrepresentation of information intended to support decision making. With respect to likelihood for example, consider an event that has historically occurred once a century. What is the likelihood of the event occurring? If you are interested in the likelihood of the event occurring on a given day, then you might say that it has a low chance of occurring. If you are interested in how likely the event is to occur over a 100-year period, then you might say that the event has a high or very high chance of occurring. Similarly, you may be interested in the likelihood of an event occurring over a given number of launches as opposed to a time period. Either way, it is clear that a statement that the event has 1% probability of occurring in a given year, is more meaningful than a statement that the likelihood is low.

The relationship between the undesirable event and the consequence is typically represented as a continuous probability, that is, if the launch is delayed, loss of revenue could range from $10,000 to $10,000,000. The combination of the likelihood of an event occurring, and the associated range of possible consequences is often assessed using simulations (such as Monte Carlos) and probability distributions. As noted in Hubbard's definition, risk management is the act of identifying, assessing and controlling the risks. So, the management of risk generally results in the application of one or more controls that either reduce the likelihood of the risk occurring or reduce the impact (consequences) if the risk does occur. For example, applying a control that reduces the likelihood of an undesirable event occurring from .01 (or 1%) per year to .001 or (0.1%) per year, can be meaningfully represented as reducing the likelihood of an event occurring from once every 100 years to once every 1000 years. Similarly, reducing the likelihood of an event occurring from 1% per launch to 0.1% per launch means that you would expect to see the event happen once every 1000 launches instead of once every 100 launches.

More often than not, a control that reduces the likelihood of the undesirable event occurring does not reduce the consequence and vice versa. Consider, for example, insurance. The act of taking out insurance in no way reduces the chance of launch failure, but it may reduce the financial impact resulting from dealing with other consequences (loss of life, environmental damage, fines from legal non-compliance etc). Similarly, multiple redundant systems may reduce the likelihood of launch failure in the first instance, however if the launch does subsequently fail, the consequences may still be the same. So, risk management aims to first understand the risk, second, to eliminate a given risk where possible, third to reduce the likelihood of a risk occurring to a level deemed acceptable and fourth, to reduce the impact of the risk, should it occur, to a level deemed acceptable. What is deemed as acceptable depends on numerous factors, including legal requirements and standards, the appetite for risk of the organisation's leaders and so on.

Actual tools and techniques used to assess risk depend greatly on the context of risk and will not be covered in this book. Typical pitfalls in risk[1] management are also suitably covered elsewhere (Hubbard, 2020; Cox, 2008; Kaplan & Mikes, 2012); and will not be addressed in this book, with one notable exception. An understanding of context is fundamental to all risk management and consequently, issues of context will be addressed.

[1] Issues include the use of inappropriate or ineffective techniques as well as not addressing cognitive biases etc.

A failure to establish the context for risk can lead to issues highlighted by Kaplan and Mikes (2012), where organisations have a tendency to manage risks in functionally independent silos (the function trap of risk management). For example, a company involved in the placement of satellites into outer space requires fit-for-purpose launch vehicles operated by competent people. This type of enterprise is exposed to many types of risks. Using the operation of a launch vehicle as an example, risk can be considered through multiple lenses. There are technical risks associated with poor rocket design, safety risk with crew members operating and maintaining the vehicle, environmental and reputational risk through potential fuel spill from faulty components, operational risk associated with delays to the launch schedule if the vehicle was unserviceable, and as the launch vehicle generates the company's revenue, there could be financial risk stemming from inability of the launch due to inoperable subsystems or through compensation pay-outs and fines due to legal non-compliance. In this scenario, the term risk is used in multiple contexts which represent "functional" lenses. However, although these "functional" views of risk can give an understanding of the areas of expertise required to manage risk, these areas should not be seen as independent from each other. Rather than developing independent technical, safety, environmental, reputational, operational and financial risk management systems; organisations would benefit from an overarching risk management system that understands where and when these functional considerations must be applied. In addition, the types of controls put in place to manage the risk will be dependent on context. To assess the various risk management contexts associated with space activities, we need to first define what we mean by space activities and subsequently, what we mean by outer space.

1.3 What Are Space Activities?

Space activities are any human activities conducted in, having an effect in, or intended to have an effect in the outer space domain. They typically encompass a range of governmental and non-governmental organisations, activities and processes that produce objects intended to go into an orbit around the Earth and which provide services that are accessed and consumed by end-users on Earth. Space organisations, activities, processes and objects are broadly categorized as either civilian or military in nature. In reality, however, the distinction between the two can sometimes become blurred. This is because the products and services derived from space industry technologies typically have use and application in both a civilian and military setting (European Commission [EC], 2018). This is known as dual-use, and a large majority of space technology could be characterised as being dual-use (Johnson-Freese, 2018, p. 435). Nevertheless, space objects will typically perform a function whilst in outer space, which will have an effect either in that domain, in the Earth's atmosphere or on and around the Earth's surface. Indeed, much of what occurs in outer space has direct relevance and significance in a terrestrial setting. This point is perhaps best demonstrated by the role played by satellites. A satellite is a human-made object placed in an orbit around the Earth which can serve a variety of different purposes. A satellite's purpose will usually be the provision of a specific service, application or capability. These include the facilitation of satellite internet, communications and telephony services, GPS navigation and tracking, satellite television and radio, weather forecasting services, information related to the management of natural disasters, insights relevant to minerals exploration, urban and land development services as well as astronomical observations and measurements. In addition, satellites capture and transmit a variety of data sets and data types related to Earth observation and remote sensing imagery, meteorology, epidemiology, hydrology, climate and environmental sciences as well as conducting vegetation and forestry assessments (National Aeronautics and Space Administration [NASA], 2017; Union of Concerned Scientists, 2015; Dennerley, 2018, p. 283). Taking a step back, space activities in the space industry have traditionally been divided into three main segments. These are:

(i) spacecraft, satellite and payload manufacturing, including associated equipment manufacturing, known as the space segment;
(ii) the launch of the aforesaid space segment's objects into orbits around the Earth, including all associated launching activities, known as the launch segment; and
(iii) the operation and support of the aforesaid space segment's objects via ground-based systems, known as the ground segment.

These three segments have historically comprised much of what would encompass space activities, and traditionally would only have been undertaken by a small group of space-faring States or corporations that had the scientific capability, political will and dedicated budgets and resources to undertake such activities. Today, however, new space actors, different types of space activities or new ways of conducting the traditional space industry segments have emerged and are now becoming the norm. This is largely driven by the increasing commercialisation, privatisation and governmental outsourcing of certain space activities. As of 2018, the global space industry was estimated to be worth approximately USD $360 billion (Bryce Space and Technology, 2018). Of this number, one quarter is attributable to governmental spending[2] and three quarters is attributable to the private sector commercial revenues that flow from satellites and their related products and services (Bryce Space and Technology, 2018). Indeed, the civilian or commercial space industry landscape largely comprises the products, services, applications and capabilities derived from satellites (Bryce Space and Technology, 2017, p. 5). Recently however, the civilian space industry landscape has become a more diverse arena comprising new and emerging space activities that don't neatly fall into one of the traditional space, launch or ground segments. Some of these new and emerging space industry activities include:

[2] As of 2017, approximately 50 States have resources and budgets dedicated to space activities (Bryce Space and Technology, 2017, p. 1).

(i) space support services, which comprise those services that support other space activities via the provision of professional and advisory services relevant to a particular discipline or field (for instance financial, legal, consultancy services);
(ii) space and satellite insurance, which comprise the provision of insurance products to space actors to protect them, and other parties, by way of certain guarantees and the accessing of compensation in the event of damage, harm or loss that arises in the course of conducting space activities;
(iii) space and satellite data, which comprise the acquisition, transfer, storage, processing, analysis, archiving, visualisation and consumption of data derived from instrumentation and equipment onboard spacecraft, satellites or payloads that are conducting on orbit operations;
(iv) space industry groups, which comprises those associations, consortiums or organisations that connect space actors and promote the development and growth of the global or a specific State's domestic space industry, or a subset of the industry;
(v) academic research and development, which comprise those companies or organisations (for instance universities) undertaking activities that seek to innovate and improve existing space activities or technologies, or introduce new scientific or commercial space-related products, services, applications and capabilities;
(vi) space cyber security, which comprise those activities designed to engineer and harden the electronic, network and computational elements of space systems (for instance spacecraft, satellites, payloads, ground stations and telecommunications links) and protect them from malicious attacks that seek to disable the space system and / or access its data;
(vii) space resource exploitation and space mining, which comprise those activities that seek to extract valuable minerals or materials from objects in the outer space domain (for instance from asteroids or the Moon);
(viii) space manufacturing, which comprises the manufacturing of goods in the outer space domain, which are undertaken there because of the unique physical and environmental conditions associated with outer space and celestial bodies; and
(ix) space tourism, which comprises those human spaceflight activities done for recreational or entertainment purposes.

It is important to remember that there is not always a strict separation between the aforesaid traditional, new and emerging space industry activities because in certain circumstances they may be undertaken in conjunction or may overlap. What is interesting about this collective grouping of space activities is that at present, many of these activities are conducted by, or involve, companies, universities, industry groups and even individuals (European Space Agency [ESA], 2016). These new and emerging space industry activities and trends fit into a phenomenon known as Space 4.0 (ESA, 2016). Space 4.0 is a term used to describe the current space epoch. It is characterised by the aforesaid new and emerging space industry activities, and also features increasing interaction between governmental and non-governmental space actors (ESA, 2016), as well as increased international and multi-disciplinary cooperation. The new and emerging space activities of Space 4.0 present us with novel contexts in which risks can and will arise. Therefore, understanding the concept of, and undertaking the practice of, risk management in these novel contexts is more important than ever.

1.4 What and Where Is Outer Space?

As mentioned above, risk management as a concept and practice will apply differently in different contexts. Context in this sense includes the specific circumstances that cohere to form the places, settings or surroundings in which an event will occur or unfold. Identifying and understanding the specific contexts to which risk management will apply is critical to its overall success. Therefore, the concept of risk management and space activities will logically include reference to the outer space domain as a context in which risk management can apply. Yet pinpointing what, and where, the outer space context is has proved to be a difficult and contentious issue. The core of the issue relates to both the definition of outer space, and its demarcation from airspace. Both issues are linked, but we will first turn to the latter.

The Earth is surrounded by a blanket of gasses called the atmosphere. The atmosphere is generally thickest at the Earth's surface and becomes thinner the farther one moves away from the planet's surface. Due to the fact that the Earth's atmosphere is adjacent to the planet's surface, it has been broadly assumed historically that this region fell within the control of those who inhabited the subjacent surface. Indeed, this belief has found its way into international law where a State's territory and the airspace above it, both fall within the power or authority of that sovereign State (Cheng, 1983, p. 91). This point is articulated by Article 1 of the Chicago Convention on International Civil Aviation[3] which details that those States party to the Convention recognise that other States have 'complete and exclusive sovereignty over the airspace above [their] territory' (International Civil Aviation Organization, 2006).[4] A logical question follows; to where, or how far, does this sovereignty extend?

One line of reasoning purports that, in-line with the legal status that airspace holds under international law, a State's sovereignty extends to the point or boundary at which airspace is no more. This would presumably be a location at which the Earth's atmosphere is no longer present or detectable. From this, we glimpse the

[3] This point of law was first articulated by Article 1 of the 1919 Paris Convention on the International Regulation of Aerial Navigation, which was later superseded by the Chicago Convention on International Civil Aviation (Cheng, 1983, p. 91).

[4] The Chicago Convention on International Civil Aviation came into force on 4 April 1947, and at the time of writing this chapter it has 193 parties that have either ratified it, or who have agreed to adhere to it.

possibility of identifying, at least from a legal perspective, where airspace might end. However, locating where airspace ends has proved difficult to ascertain. Scientific estimates suggest that the outermost layer of the Earth's atmosphere is approximately 965 km away from the planet's surface (National Oceanic and Atmosphere Administration [NOAA], 2016). For several important reasons, concluding that *this* distance includes within it a State's airspace raises various objections. These include that States may not agree upon an upper limit to their sovereign airspace, the lowest record perigee of an orbiting satellite is approximately 160 km (Diederiks-Verschoor & Kopal, 2008, p. 17) meaning that certain objects orbiting at altitudes lower than 965 km may violate or infringe upon a States' airspace, and finally that fixing a boundary line as high as this might constrain spatial activities, such as commercial spaceflight (McDowell, 2018, p. 668).

Turning elsewhere, another candidate distance that has been suggested as a possible boundary line between the Earth's atmosphere and outer space is the Kármán Line.[5] The Kármán Line is situated 100 km above the Earth's mean sea level. At this height, the atmospheric gasses surrounding the Earth become too thin to support aerodynamical lift in most aircraft (NOAA, 2016). It has been noted that current, and likely future, civil aircraft will not be able to operate at altitudes higher than approximately 100 km (United Nations Committee on the Peaceful Uses of Outer Space [UNCOPUOS], 2020, p. 4). This means that from an engineering point of view, most aviation activities will occur in the region below 100 km in altitude. There is a lack of international agreement, however, as to whether this region correlates to the airspace above a State's territory, so as to place an upper limit or cap on a State's sovereignty. What the term airspace refers to, and what lies within its extension, are critical questions that air law has not defined or settled upon (Diederiks-Verschoor & Kopal, 2008, p. 15). It is reasonable to assume that airspace has some sort of connection to outer space, but the quest to discover how outer space should be defined and demarcated by way of a reference to airspace has thus far not proved to be effective.

At this point it is important to reaffirm that there is no international agreement as to the demarcation of airspace from outer space, nor is there a definition of outer space under general international law or space law, as a specialised regime of international law (United Nations Committee on the Peaceful Uses of Outer Space [UNCOPUOS], 2012, p. 2). In all five United Nations (UN) multilateral space treaties (UN space treaties),[6] which are the primary sources of international space law,

[5] The Kármán Line derives its name from the Hungarian-American aerospace engineer Theodore von Kármán.

[6] The UN space treaties include: Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty) 1967, 610 UNTS 205; Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Rescue Agreement) 1968, 672 UNTS 119; Convention on International Liability for Damage Caused by Space Objects (Liability Convention) 1972, 961 UNTS 187; Convention on Registration of Objects Launched into Outer Space (Registration Convention) 1975, 1023 UNTS 15; Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement) 1979, 1363 UNTS 3.

the term ‘outer space’ is not defined, nor is outer space differentiated from airspace.[7] Nevertheless, a State’s sovereignty, whilst present in the airspace above its territory, does not extend into outer space because outer space constitutes a different legal regime (Diederiks-Verschoor & Kopal, 2008, p. 16). This definitional lacuna has not prevented States, and more recently corporations, from conducting activities, like operating satellites, in a region broadly considered to be outer space. The characteristics of this domain such as its boundaries, extent and content, from a scientific and legal perspective, are less than certain. Nevertheless, by identifying the various characteristics of airspace and outer space, specifically their boundaries or edges, it has been hoped that a definition of these domains might emerge. It could be argued that by identifying the boundary separating airspace from outer space, via scientific or legal consensus, a definition of outer space could be crafted. Outer space in this sense would be the antithetical to airspace. Both are mutually incompatible and the definition of one, necessarily excludes the other. However, perhaps identifying the demarcation of airspace from outer space is not the most effective way to determine what and where outer space is. Rather, a possible solution might just focus on those activities considered to *be* in outer space. International air and space law expert Professor Bin Cheng highlights that by conducting spatial activities such as the operation of satellites at certain perigee altitudes, space-faring States have willed that certain activities do indeed take place in outer space, despite lacking a precise definition of this location (Cheng, 1983, p. 95). Explained another way, the place where certain objects reside, such as human-made satellites in orbit around the Earth, are considered as occurring in outer space. This entails the notion that where these sorts of spatial activities take place, airspace, and therefore air law, will not enter into, interfere with, or exceed in height (Cheng, 1983, p. 95). This conclusion, that by their very nature, certain activities take place in outer space, has seemed acceptable to most States (UNCOPUOS, 2020, p. 4).

Regardless of whether one attempts to define and delimit airspace from outer space based on some boundary distance line or derived from the location of objects or activities that are considered to take place in outer space, both of these lines of reasoning are imperfect. Contrasted to this, another possible way forward is to ask what the function and purpose of the object or activity is. From a legal point of view this seems to make sense, considering that space law, either international or domestic, serves to create a legal regime that regulates objects and activities that do, or that are intended to have, an effect in outer space, or which relate to this domain. This approach, termed the functional approach, redraws the ‘boundary line’ of outer space, so as to include the ‘circumstances [that surround …] activities in outer space’ (Diederiks-Verschoor & Kopal, 2008, p. 18). Like all approaches that attempt to tackle these issues, the functional approach is not without criticism (see, McDowell, 2018, p. 668). Unlike the boundary distance line approach, which if definitively identified and agreed upon would enable the clear and unambiguous

[7] The UN space treaties do not derogate from the primary rule of international law that State’s maintain sovereignty over the airspace above their territory, per Article 1 of the Chicago Convention on International Civil Aviation (Cheng, 1983, p. 92).

determination of when an object or activity was in outer space, the functional approach suffers by inarticulately scoping what is meant by the function, purpose or circumstances associated with space objects and activities. For example, an essential component of a spacecraft or satellite system is the ground segment. The elements of a ground segment are built, operated and managed on the Earth's surface, despite it having certain effects on objects in outer space. Under the functional approach, it could be argued that ground segments fall within the 'circumstances' that surround, support and enable space-based objects to function and space activities to occur. However, it is difficult to know whether all the elements of a ground segment, such as terrestrial telecommunications networks present at the ground segment, fall entirely within the relevant 'circumstances', and whether an element can have multiple different functions or purposes, or whether the nature of the object or activity must solely relate to outer space.

After assessing the divergent viewpoints that relate to the definition and demarcation of airspace from outer space, a reasonable conclusion might be that obtaining a single agreed upon definition of what and where outer space is will not be achievable. Indeed, different professions and disciplines, such as aerospace engineers or international lawyers may simply need to define and delimit these two domains based upon their own specific set of circumstances and needs (McDowell, 2018, p. 669). For the purposes of this book, the definition and demarcation of air space from outer space can be looser and more inclusive than the aforesaid approaches might seek to mandate. This is because the focus of this book is risk management and space activities. From this book's point of view, outer space is a broad context to which the concept and practice of risk management can apply. As explained above (Sect. 1.3), space activities include any human activities conducted in, having an effect in, or intended to have an effect in the outer space domain. This includes activities like the design, manufacture, launch, operation and retirement of an object like a satellite. In essence, the entire space project or mission lifecycle, from the terrestrial activities to the spatial, creates and contains places, settings or surroundings in which risks can and do occur or unfold, therefore necessitating the need for risk management. This book will not attempt to define outer space, but instead focus on explaining how risk management relates to specific space activities and more broadly to outer space.

1.5 How Does Risk Management Relate to Space Activities and Outer Space?

Clearly there are numerous activities relating to outer space in which risks can manifest. The remaining chapters of this book will provide a more detailed overview of risk considerations from some of these activities. Let us start by looking at six broad categories consistent with space activities: getting into outer space, being in outer space, removing objects from outer space, use of spaceborne capabilities, losing the spaceborne capability, and the study of outer space.

Risks considerations associated with getting into space could include anything from poor design of launch vehicles, through to the build, launch and placement of payloads into orbit, such as weather satellites. Both the Challenger Space Shuttle disaster in 1986 and the Columbia disaster in 2003, provide sobering reminders of the types of consequences of getting risk management wrong in the design, build, test and launch of space vehicles.

Risk considerations associated with being in outer space, could include the management of possible collisions between two or more objects (particularly relevant when considering space debris), or even the loss of useable space itself as certain areas of the outer space domain are becoming congested and contested. The latter point may seem counter intuitive given the size of outer space, however, like most natural and freely available resources, long-term pressures and over utilisation can cause scarcity which can lead to conflict. Whilst the space around the Earth is a vast region, certain areas are more valuable than others. Geostationary Orbit (GEO) has the most desirable orbital characteristics for the placement and operation of certain types of satellite, for instance communications and weather satellites (Howell, 2015). GEO is a prime example of over utilisation and the potential overcrowding of regions in outer space as it already contains a large number of satellites which inhabit and use a finite number of orbital slots. Orbital slots are regions in GEO allotted for satellites. Currently, there are 560 satellites in GEO (Union of Concerned Scientists, 2019). GEO as an orbital location, however, can sustain roughly 1800 satellites which must remain within their assigned orbital slot (Howell, 2015). Whilst this upper limit may seem large, it is not infinite. As a result of the rising levels of risk associated with overcrowding, positioning and potential collisions that may lead to loss of service and revenue, Low Earth Orbit (LEO) has become more attractive as an alternative to GEO in certain circumstances.

Removal of objects from space could occur through, for example, the orbital decay of a satellite (for instance when the space station Skylab returned to the Earth in 1973), or the intentional removal of space debris in an attempt to remediate the space environment. Either way, there are potential consequences associated with objects falling back to Earth or with attempting to remove objects such as space debris from an increasingly overcrowded domain. Conversely, not removing objects like space debris could itself present risk to future space operations. This underscores the fact that risk management is essentially about trade-offs, and that there is often not a straightforward answer about what should be done to manage risk.

The way in which spaceborne capability is used reveals a vast array of possible risks dependent on one's context. For example, a spy satellite provides advantages to the country launching and operating it but may not be seen in a favourable light by other nations. Privacy could be put at risk intentionally or even unintentionally through the use satellite imagery, which is ever increasing in resolution (consider what you can see in your neighbour's backyard on Google Maps). Even more concerning is the potential for cyber attack on communications satellites, which carries the potential of far reaching consequences for individuals, organisations and nations