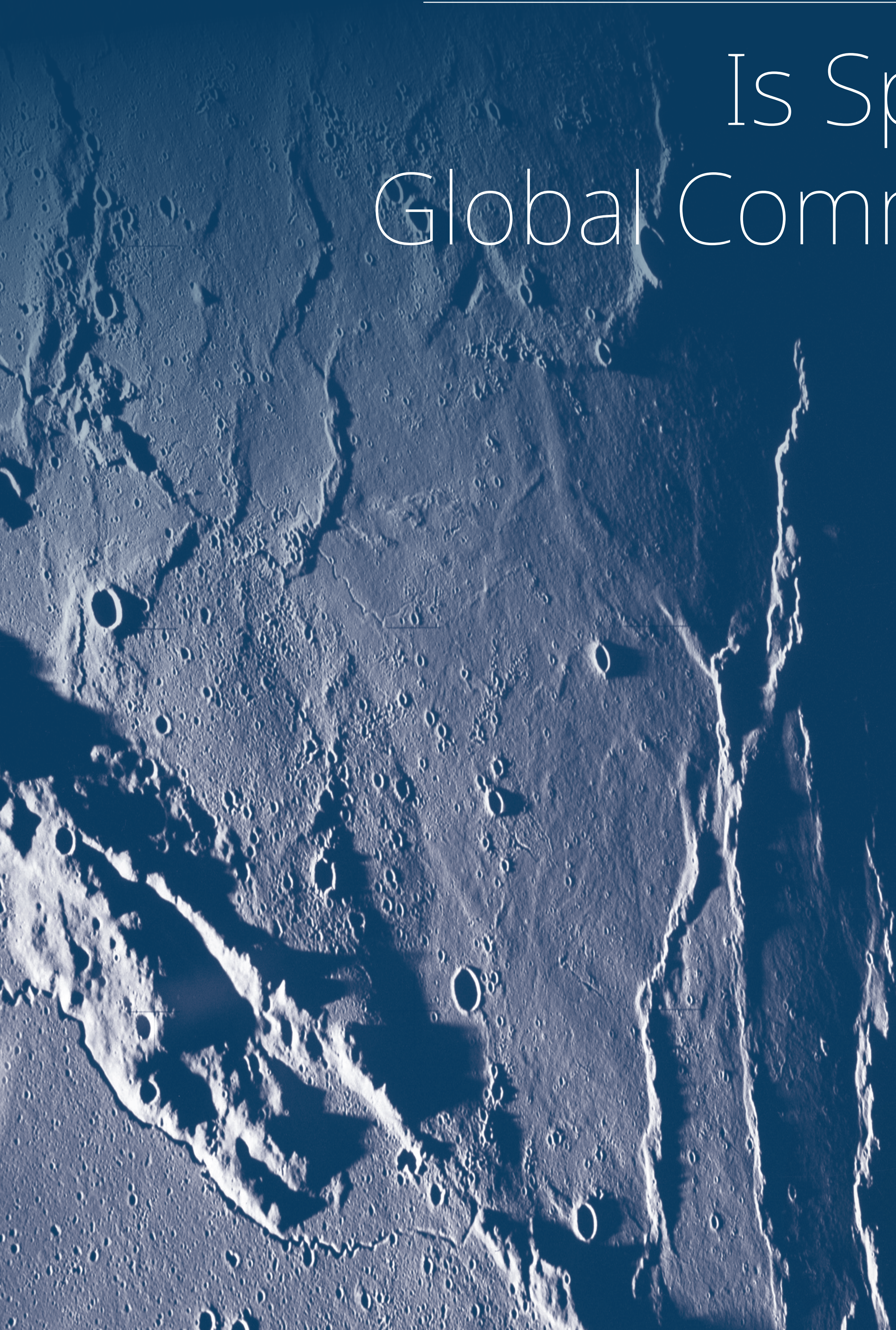
Secure World Foundation
Space Sustainability Briefs

2022/1

Is Space a Global Commons?



SECURE
WORLD
FOUNDATION

About Secure World Foundation

The Secure World Foundation strives to be a trusted and objective source of leadership and information on space security, sustainability, and the use of space for benefits on Earth. We use a global and pragmatic lens to study and evaluate proposed solutions to improve the governance of outer space. While recognizing the complexities of the international political environment, SWF works to encourage and build relationships with all willing stakeholders in space activities, including government, commercial, military, civil society, and academic actors. Central to this approach is increasing knowledge about the space environment and the need to maintain its stability, promoting international cooperation and dialogue, and helping all space actors realize the benefits that space technologies and capabilities can provide.

Cover Imagery

This view of Montes Agricola on the lunar surface was taken by Apollo 15 command and service modules pilot Alfred Worden.

Image Credit: NASA

Is Space a Global Commons?

TABLE OF CONTENTS

1. Introduction ... 1
2. Perspectives on Space as a Commons ... 2
3. The Commons and Economic Goods ... 3
4. Resource Categories ... 6
5. Mechanisms for Commons Management ... 6
6. Rivalry and Excludability ... 8
7. The Subdomains of Space ... 9
   7.1 Earth Orbit ... 10
   7.2 Celestial Bodies ... 11
   7.3 Interplanetary Space ... 13
8. Analogous Domains ... 14
   8.1 Antarctica ... 15
   8.2 The Oceans ... 16
   8.3 The Atmosphere ... 20
9. Historic and Existing Space Agreements ... 24
   9.1 Outer Space Treaty ... 25
   9.2 Rescue Agreement ... 26
   9.3 Liability Convention ... 27
   9.4 Registration Convention ... 27
   9.5 Moon Agreement ... 28
   9.6 Bogota Declaration ... 28
10. Governance Regime Success ... 29
11. Potential International Action to Address Management Deficiencies ... 30
12. Conclusion ... 32
References ... 34

Disclaimer

The research, writing, and publication of this report was conducted as part of the Secure World Foundation's Space Sustainability Research Fellowship program, which invites scholars to explore fundamental questions underpinning space sustainability.

The views and opinions expressed in this publication are those of the authors. They do not necessarily reflect the opinions or views of the Secure World Foundation, or any other organization referred to in this publication.

Secure World Foundation
Space Sustainability Briefs

Is Space a Global Commons?

Daniel Patton

2022 SWF Space Sustainability Fellow

1. INTRODUCTION

In 2021, the global number of successful orbital rocket launches totaled 135. The previous record was set in 1984 with 129 launches (McDowell J., 2022). Scheduled launches in the coming years show that the record will likely be broken again, perhaps by orders of magnitude. When the previous launch record was set in 1984, two nations—the United States and Soviet Union—dominated the launch list. The 2021 list includes six nations or groups of nations—the United States, European Union, Russia, China, India, and Japan—and many private companies and partners. The governmental and private commercial space activities that make up the space sector show no signs of slowing down. Plans for missions to the Moon, Mars, and new space stations in the coming decades signal a more complex, diverse, and crowded space economy.

To prepare for a changing space economy, many stakeholders recognize a need for policies to manage various resources. The question "is space a global commons" is fundamental to these policy decisions. If space is a global commons or a domain containing common pool resources (CPRs), policies and cooperative agreements may be necessary to preserve resource use. If space is not a common resource, other models involving private rights and sovereignty may come into play, which could lead to increased competition and risk of conflict. In exploring this issue, we look to answer the following essential questions:

- What does the phrase "Space as a Global Commons" mean?
- Is outer space a global commons or common pool resource?
- Can outer space be classified as a single economic good or model?
- Which actors refer to outer space using these terms?
- How can concepts from the governance of the commons and common pool resources productively inform various space policy discussions?
- Are there approaches from the governance of other shared domains (Antarctica, sea, air, and environment) that might be usefully transposed to space governance?
- What concepts from those shared domains do not translate well to outer space?
- What happens when some actors see space as a commons, while others do not?

To answer these questions about the commons, we must first look at the history of the term and create a set of conditions against which to judge domains: rivalry and non-excludability. Next, we compare the subdomains of space—Earth orbit, celestial bodies, and interplanetary space—to these criteria. Establishing that at least some of these subdomains are definitionally commons, we investigate other commonly designated global commons and compare them to space domains. Similarly, we can compare terrestrial and space CPRs. Finally, we consider existing legal mechanisms regulating space and Earth commons, identifying possible risks and tools for protecting the commons beyond Earth's atmosphere.

2. PERSPECTIVES ON SPACE AS A COMMONS

Major space stakeholders disagree on whether space is truly a global commons. Although many academic references to the global commons specifically mention space along with the oceans, the atmosphere, Antarctica, and telecommunications (Buck, 1998), the most significant space-capable actors—the United States, European Union, Russia, China, India, and Japan—have made conflicting statements on commons status. International treaties such as the Partial Test Ban Treaty of 1963 lump space in with other global commons, but actual space treaties contain no explicit reference to the "commons." [1] Even US leaders have made conflicting statements about the topic with then President Obama referring to space as a global commons in his May 2010 National Security Strategy (National Security Strategy, 2010). The Department of Defense reaffirmed this stance with statements made in the Joint Operating Environment (JOE) 2035 (US Navy, 2016), which identifies outer space (particularly Earth orbit in the range of 60 to 22,300 miles above the surface) among other domains as essential to the prosperity of the nation. The same document claims that "[o]pen and accessible global commons are the pillars of the current international economy and empower states that use them to conduct commerce, transit, scientific study, or military surveillance and presence." Then President Trump's Executive Order (EO) 13914 (April 6, 2020) contradicted these statements:

> Americans should have the right to engage in commercial exploration, recovery, and use of resources in outer space, consistent with applicable law. Outer space is a legally and physically unique domain of human activity, and the United States does not view it as a global commons. Accordingly, it shall be the policy of the United States to encourage international support for the public and private recovery and use of resources in outer space, consistent with applicable law.

The same EO also rejects the 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement) giving insight into the possible motivations to not consider space a global commons.

Some members of the US Congress expressed an opinion in H.R. 2809: American Space Commerce Free Enterprise Act, which stated that "[n]otwithstanding any other provision of law, outer space shall not be considered a global commons." The bill, introduced in 2017, passed the House of Representatives but did not become law. Still, stakeholders debate the perspective that space (or at least portions of space) is a global commons and clearly the perspective has ideological implications for some policy makers.

In 2019, NATO declared space an "operational domain" as part of its "deterrence and defense posture" (NATO, 2022). Other nations, notably China, take the perspective that space is a global commons, calling it a "global public space" in a document from the Chinese Aerospace Studies Institute from 2013 titled *In Their Own Words: Foreign Military Thought.* However, some of these

[1] The word "commons" does not appear even once in the UN Treaty booklet. What we find is "common interest" (five times); "common heritage" (once); "common understanding" (once); and "common procedures" (once). None of these terms relate to the concept of the commons.

nations have programs or policies in place to do the same space resource exploitation as the United States (Kadam, 2022), calling into question whether or not these policy differences are substantive.

While many nations seem to consider space a global commons, there is no consensus even among space-capable nations. The subtle differences in terms used complicate the matter. Furthermore, even nations that may consider space a global commons disagree on how to manage the domain. Compare the following three actions aimed at space management.

- The Outer Space Treaty (1967) codifies that space exploration and use is the "province of all mankind."
- Only 18 states are parties to the Moon Agreement (1979), which uses the term "common heritage of all mankind." The Bogota Declaration makes a claim that at least parts of space are private goods but only eight states signed the 1976 agreement.

This imprecision hurts the cause for space as a commons, but it results from several factors. Space is not a homogenous domain, and it contains distinct categories of economic goods. Commons designations impact policy decisions, and policy that requires sharing a resource is likely to be a disadvantage to major stakeholders that have the benefit of early access. The separation between space-capable nations and space-incapable nations has created an apparent conflict in perspectives on the management of space activities (Laver, 1986). Nonetheless, effective space policy should benefit all nations in the long term, so understanding effective commons management is essential to protecting space for future use. Knowledge of the development of the commons concept is key to understanding effective commons management, so first we must consider the earliest examples of the commons, and how the concept has changed over time.

3. THE COMMONS AND ECONOMIC GOODS

The tragedy of the commons is not a new concept, and although William Foster Lloyd coined the term in the 19th century, the idea likely predates his lecture. Aristotle famously said, "what is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest" (Barker, 1905). However, seeing as Lloyd's words have become the standard term, understanding the true definition of the "commons" is essential. Although absent from modern cities and towns, "commons" were a standard centerpiece of towns and villages around the world and especially in Lloyd's England. Villagers used the multipurpose green space for grazing of village livestock. Because the town surrounded the commons, the grazing space was limited. This limitation was not a problem for a small city, whose carrying capacity was beyond the needs of the livestock, but cities encountered a "tragedy of the commons" as the grazing population grew beyond the commons' capacity. [2]

Lloyd points out that the tragedy arises when users consume a shared resource beyond its capacity; that is to say, unlimited utilization would exhaust the resource before natural processes can replace it. Consider the problem taken from the perspective of an individual user.

Ten farmers share a commons that can sustain 100 sheep. If each user has 10 sheep, no "tragedy" occurs. The commons can operate in this scenario indefinitely. However, additional farmers (or sheep) would exhaust the commons if allowed to graze unrestricted. Each user, being fully aware of the commons' capacity, knows that they can graze 10 sheep. If an individual decides to graze an additional animal, only they experience the benefit, but all users experience the cost

---

[2] As Garrett Hardin points out in his 1968 essay of the same name, Lloyd's use of the word "tragedy" is reflective less of sadness and more of the unfortunate reality of the natural world.

(i.e., less grass) equally. This imbalanced cost and benefit mounts for each additional animal. Each user—acting in their own self-interest—continues to add sheep until they deplete the commons beyond use.

In economic terms, in the utilization of a shared domain where users share the cost but individuals benefit, each member will act in their own self-interest, to the destruction or spoilage of the resource.

An important distinction exists between a commons and a common pool resource (CPR). A CPR is the *resource* that is subject to depletion (e.g., grazing grass in Lloyd's original example, fish, timber), while a commons is the *domain* containing these resources (e.g., Lloyd's common pasture, the atmosphere, the ocean, Antarctica). Global commons are commons containing global CPRs. This distinction is complicated by commons that are valuable for their position instead of their resources.

Lloyd's commons has two distinct traits. No one privately owns or restricts the resource (i.e., no person or group of people owns exclusive rights to the resource), and the space possesses a shared expendable resource. In economic terms, the resource is both non-excludable and rivalrous. These two resource descriptors set up four distinct resource categories as shown in

Figure 1. The Four Different Types of Goods

	NON-EXCLUDABLE	EXCLUDABLE
RIVALROUS	Common Pool Resources "the Commons" • Fish stocks; the atmosphere	Private Goods • Personal goods and property
NON-RIVALROUS	Public Goods • Roads • Parks • Radio stations	Club Goods • Country clubs • Gyms • Subscription media services

The term "rivalrous" here means that a resource is finite and that its use or occupation by one person reduces its availability for another.

Fish stocks are an example of a rivalrous resource because the more fish that are caught, the less are available for other people. The same holds for timber stocks: as trees are cut for timber, fewer are available for the next timber company. Importantly, a resource can be both rivalrous and replaceable. As with both examples above, the resource can rebound if the rate of consumption is less than the replacement rate. Conversely, sunlight is a non-rivalrous resource. If one person places solar panels on their roof, it does not decrease the amount or intensity of sunlight available for their neighbor, assuming both have space to set up separate sets of panels.

The term "excludable" means that someone could control the use or access of a resource.

Excludable goods are often private goods. A toll road is an excludable good because owners control access, and owners allow entry with a fee. For a good to be non-excludable, it must be accessible to everyone and not controlled by a person, business, or government. Air is a non-excludable good, because its access is not controllable.

A domain is a commons if it is rivalrous and non-excludable, and only overcrowded domains experience the tragedy of the commons. If our 100-sheep pasture has 100 or fewer sheep, users avoid the tragedy even though the domain is a commons.

Lloyd illustrated the tragedy to argue for sustainable population growth, but in 1968 Garrett Hardin referenced the tragedy of the commons to illustrate climate degradation, expanding the commons from a small resource shared by a community to a global resource used by all of humanity. Hardin argued that certain domains like the atmosphere and the oceans were commons on a global scale (Hardin, 1968). This perspective was a shift in the understanding of global resources and the commons, both because of the scale of the resource and the fact that parts of these domains were subject to external motivators for cooperation. Portions of the ocean were in fact claimed by individual nations for both fishing rights and shipping routes. These nations took responsibility for the management and protection of these areas and held exclusive jurisdiction. Hardin thus introduced the idea of domains held in common while still being privately or publicly owned.

However, the economic goods framework is only one way to look at a resource. If one user says an excludable resource is a CPR but another does not, the user who sees the good as private will use their powers to claim and exclude the other party. Users and governments can also choose to apply legal frameworks to resources independently of, and sometimes in conflict with, the characteristics of a resource. Agreement on commons status, especially on the global scale, often relies on legal mechanisms like agreements and treaties. Therefore, we can draw a distinction between an economic CPR and a legal CPR. An economic CPR is a resource that is both rivalrous and non-excludable, but a legal CPR exists only if its users agree to regard it as such. Antarctica is a legal commons but not an economic commons. The continent is technically excludable, meaning that states could choose to divide the continent and claim sovereignty, but stakeholders have agreed to a shared ownership method of management.

Hardin's more developed definition of the commons now also included non-participatory stakeholders. In other words, an individual not contributing to the degradation of the atmosphere or waters would still suffer the consequences of the polluted resource. Lloyd's commons metaphor showed that a responsible user would suffer the consequences of another over-user, but the existence of these non-participatory stakeholders expands this idea to include a broader definition of resource consumption. Because atmospheric pollution or ocean acidification affects everyone, decisions made to protect or conserve these resources are decisions that affect all people. This dynamic sets up potential conflict between acting for economic or national benefit and acting for global human benefit.

Hardin's commons differs from the classic commons metaphor in one essential attribute: the reason it is excluded from private ownership. Here the distinction between voluntary and involuntary non-excludability is clear. Participants share the metaphorical commons by collective agreement. An individual or group could own the land as others own land. A state could regulate the resource as it does other resources. The community shares grazing land by continued agreement, whether explicit or implicit. In contrast, a community shares Hardin's commons by nature of its size and attributes.

Two legal terms provide a helpful distinction in commons discussions. First, res nullius refers to something that no one owns. [3] A *res nullius* resource may be either inaccessible or simply yet unclaimed. *Res communis* is the concept of something that everyone or an entire community owns.[4] Both terms stem from Roman law, and they highlight an important distinction. Roman law considered things like the ocean to be res communis but considered the sky to be *res nullius*. In Roman law the difference stems from use. If people use but do not own a resource, it is *res communis.* If they neither own nor use the resource, it is *res nullius*. While Roman law may have considered outer space to be *res nullius*, its current use by many nations would qualify it as *res communis* (Cheng, 1998).

[3] From Latin, translating to "nobody's thing."

[4] From Latin, translating to "community or public thing."

A related term is *res extra commercium:* a thing that is outside of commercial trade. [5] As mentioned regarding the commons, res extra commercium may include things that are outside of trade for practical reasons, or a person or group could designate them as such. For example, if a state attempts to ban the use of a product, it may designate it res extra commercium, prohibiting its trade, sale, or taxation (Cheng, 1998).

4. RESOURCE CATEGORIES

Traditional interpretations of the term "resource" imply consumable utilization. Lloyd's and Hardin's works both referred to consumed resources. However, modern interpretations also consider occupied but unconsumed resources. This distinction hinges on the ability for an actor to make a resource immediately available upon a change in use. In Lloyd's original framework, removing the grazing livestock does not replace the used resource, but when considering occupational resources like radio frequencies, we see the opposite. Occupational resources include domains that are important for several uses including technological (e.g., ratio frequencies, geostationary orbit), scientific (e.g., Antarctica), or military (e.g., Guam). While space does have consumptive resources that states or companies may use in the future (Ross, 2001; O'Leary, 1977), most of the resource categories currently utilized by stakeholders are non-consumable. In other words, the location itself is the resource. This paradigm is present in terrestrial domains. While fish stocks and timber stands are valuable for their consumable resources, remote islands like Guam and inhospitable lands like Antarctica are valuable for their strategic position and scientific value respectively.

5. MECHANISMS FOR COMMONS MANAGEMENT

When Hardin wrote on the commons in his article in *Science*, he declared the consequences of the tragedy as inevitable given a limited world, self-interested participants, and a free commons. "Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons" (Hardin, 1968). In other words, humans will most often fail to find a way to cooperatively use a CPR.

Early economists saw one of two paths out of the tragedy: a coercive external force, or privatization (Ostrom, 1990). Hardin defends the first path in a 1978 article. Seeing no possibility of cooperation, some external force must act on participants with sufficient force to overcome their self-interested action. "If ruin is to be avoided in a crowded world, people must be responsive to a coercive force outside their individual psyches, a 'Leviathan,' to use Hobbes's term" (Hardin, 1978). The Leviathan motivates commons regulations through a deterrent or punitive system. However, as Elinor Ostrom points out in *Governing the Commons: The Evolution of Institutions for Collective Action,* the Leviathan—or central agency, as she identifies it—is only effective if it has complete knowledge of the commons and its participants (Ostrom, 1990). While possible in small commons, comprehensive knowledge of a large common domain, like those discussed here later, is almost impossible.

As an alternative, privatization moves the domain out of shared ownership. Transferring the commons or its resource to a private good can lead to effective management by leveraging the self-interest of users, but the process of privatization is the challenge and, in some cases, can destroy the "commonness" that makes the resource valuable in the first place. This mechanism is highly successful in small community commons, but exercising sufficient control to claim ownership is impossible for larger commons.

[5] From Latin, translating to a thing "outside of commerce."

Stakeholders can use privatization to manage a commons without privatizing the entire domain. Both the atmosphere and the oceans are global commons, but states incorporate a degree of privatization for each domain. Nations control the airspace above their borders, and similarly nations control the territory up to 12 miles from their shores (they assume exclusive economic control up to 200 miles).

Neither the privatization nor Leviathan mechanisms are sufficient to fully manage a global CPR, but groups practice effective commons management outside coercive external force or privatization on both the small and large scale. Voluntary self-regulation is an alternative previously considered impossible by Hardin and others. If stakeholders recognize the tragedy and organize to act as their own Leviathan, they can avoid tragedy. On a global scale, states accomplish this self-regulation through treaties and conventions.[6] As the central international organizing body, the United Nations can be a forum for states to negotiate these treaties. However, not all treaties are equal. Limits and consequences for exceeding them vary widely.

In her seminal work, *Governing the Commons: The Evolution of Institutions for Collective Action,* Elinore Ostrom (1990) explored the idea of long-lasting commons management and analyzed examples of effective self-governance of the commons. Ostrom examined communities and institutions across the globe, including communal tenure in high mountain meadows and forests and multiple irrigation communities and institutions. Despite the substantial differences between these CPRs and how users manage them, Ostrom identified several shared traits. These eight "design principles" show key criteria for effective and long-lasting commons management. They are:

1. Clearly defined boundaries:

   Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.

2. Congruence between appropriation and provision rules and local conditions:

   Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money.

3. Collective-choice arrangements:

   Most individuals affected by the operational rules can participate in modifying the operational rules.

4. Monitoring:

   Monitors, who actively audit CPR conditions and appropriate behavior, are accountable to the appropriators or are the appropriators.

5. Graduated sanctions:

   Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.

6. Conflict-resolution mechanisms:

   Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.

---

[6] Often predating a treaty or convention, a declaration is distinctly different. A declaration is a statement of a shared view or opinion on an international issue.

7. **Minimal recognition of rights to organize:**

   The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

For CPRs that are parts of larger systems:

8. **Nested enterprises:**

   Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

Ostrom then scored the institutional performance of various management cases using these design principles. Based on the number of principles that the site met, Ostrom rated them as "robust," "fragile," or "failure." Table 1 illustrates this scoring scheme with two examples from the book (Ostrom, 1990).

Table 1. Examples of institutional performance of management schemes according to Ostrom's design principles for two commons. *Source: Ostrom (1990)*

SITE	Clear boundaries & memberships	Congruent rules	Collective-choice arenas	Monitoring	Graduated sanctions	Conflict-resolution mechanisms	Recognized rights to organize	Nested units	Institutional performance
TÖRBEL, SWITZERLAND	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a	Robust
ALANYA, TURKEY	No	Yes	Weak	Yes	Yes	Weak	Weak	n/a	Fragile

These design principles are evident as we explore common pool resource management across other domains, but as Ostrom was quick to note, these principles are not guarantees for effective management. Even small community management has complex relationships. Attempts to scale these principles up to management of global commons is even more complex, and the inclusion of these design principles does not assure effective commons management. However, we can apply the scoring system established in *Governing the Commons* to global commons to categorize their performance.

6. RIVALRY AND EXCLUDABILITY

The discrete categories of rivalrous vs. non-rivalrous and excludable vs. non-excludable provide a helpful framework for categorizing resource domains. By examining the traits of the domain, one can fit it into one of four distinct categories as shown in Figure 1.

However, some domains do not fit so neatly into the four categories. For example, some domains are theoretically but not practically excludable (e.g., the internet). Many consider Antarctica a commons, but space on the continent is limited and theoretically excludable. Other domains are rivalrous to varying degrees. Furthermore, rivalry and congestion are closely related. While a certain good may be rivalrous, low demand may mean that management is unnecessary.

Some consider the atmosphere to be rivalrous, while others define it as a public good. The blurring lines of the rivalry/excludability matrix have led many scholars to see these categories as opposite ends of a continuum instead of as binary attributes (Leach, 2004; Henry, 2022). This interpretation adds nuance to the commons discussion and explains why informed scholars can disagree about domain categories. Considering domain placement as a continuum instead of as discrete categories, we can chart specific domains as shown in Figure 2.[7]

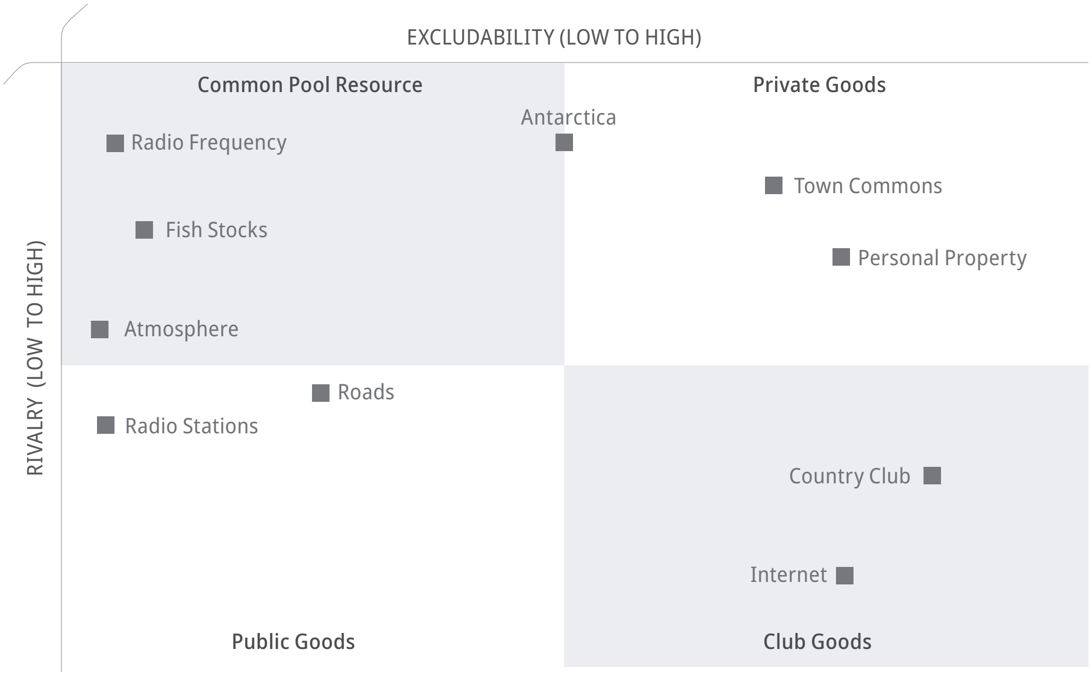


Figure 2. Continuum of Domains. Different types of goods expressed as a continuum, rather than just four discrete categories, as in Fig. 1.

In this framework, we place excludability ranging from completely non-excludable to easily excludable domains. We place domains that are feasibly excludable based on their relative cost of exclusion. Both a town commons and Antarctica are excludable, but their scale makes the relative cost of exclusion for Antarctica much higher.

Similarly, we score rivalry on a supply/demand ratio. The internet has virtually no limit to its supply (supply being the number of users it could be available to), so the limited demand places it lower on the rivalry scale. Radio frequency has a limited supply (limited frequencies and two sources cannot occupy one frequency), but demand is high, so it scores much higher on rivalry.

Using the continuum framework, we can score space differently depending on what part of space we examine. Therefore, we must look at each of these parts separately.

7. THE SUBDOMAINS OF SPACE

Stakeholders often refer to space as a single domain, but the vastness and diversity of outer space opposes this assumption. States and companies use orbital segments, celestial bodies, and interplanetary space differently, and their regulation may also differ. Therefore, for this analysis, **it is more useful to consider space as a collection of distinct subdomains grouped only by their access pathway.** This pathway has been the limiting factor for space domains in the past as few nations possessed rocket launching technology. Consequently, controlling

[7] While a quantitative analysis of resource domains is possible and would yield more precise positions, this chart is merely an illustration of the concept. Domain placement is approximate.

rocket technology has been a mechanism of excludability.[8] As this technology has become more widely available and a growing number of nations and private companies have demonstrated launch capabilities, this mechanism is less effective. The limited availability of rocket technology unified space domains, but as this technology becomes more ubiquitous, understanding space as a collection of domains is a more practical approach.

Universal agreement on the boundary between atmosphere and space is lacking, but many suggest it should be the so-called von Kármán line at 100 kilometers (62 miles) above mean sea level. This is the position taken by the *Fédération Aéronautique Internationale* (FAI), which is a long-standing aeronautical organization. The von Kármán line was based on physical limitations of air density as it relates to airplanes and balloons. However, recent arguments based on historical, physical, and technological criteria push for the boundary to be closer to Earth at 80 kilometers (McDowell J., 2018). Still others, such as the US Space Command, continue to use 100 kilometers for ease of use (US Space Command, 2022).

7.1 Earth Orbit

Once in outer space from Earth, the first region encountered is now commonly known as low Earth orbit (LEO). This domain sits between 100 and 2000 kilometers above Earth. LEO is the most easily accessible space domain, and users have a variety of communication, position, and imaging satellites in this area. In addition to satellites owned by states, many commercial entities own satellites in LEO ruling out a *res extra commercium* view of the domain. This orbit is also the home of long-duration human spaceflight activities, including the International Space Station (ISS) and the Chinese Space Station. The combination of ease of access and technological benefit makes LEO a high-demand space domain. Consequently, LEO is also the most congested domain. As of January 2023, there were more than 7,300 active satellites, the vast majority of which were in LEO (McDowell J., 2023).

LEO is also the domain at highest risk of increased costs from congestion. As the number of space objects increases, so does the likelihood of a collision between objects that in turn could create even more objects at a rate faster than they fall out of LEO through natural decay into the atmosphere. The Kessler Syndrome is the term for this process of cascading collisions, named after one of the scientists who first identified it (Kessler & Cour-Palais, 1978). A Kessler Syndrome situation in LEO would lead to increased costs of operating satellites in LEO. At some point, those costs may get high enough that certain actors or missions become infeasible to do in LEO.

NASA and the US Department of Defense (DoD) track over 27,000 pieces of orbital debris, but they are not able to track a significant portion of space debris. NASA estimates there are half a million pieces of debris one centimeter or larger, and approximately 100 million pieces of debris about one millimeter and larger (NASA, 2021). We do not only find debris in LEO. The distribution of orbital debris is roughly proportional to the number of satellites in each orbital segment, but debris in LEO poses a particular risk as all space activity must pass though LEO.

Medium Earth orbit (MEO) is the region between 2,000 and 35,786 kilometers, and currently its main use is for satellite navigation constellations. These satellites' high orbit and slow orbital period make them ideal for moving slowly over a large portion of the Earth, providing widespread coverage. This orbit category is far less crowded than LEO with approximately only

[8] International Traffic in Arms Regulations (ITAR) largely enforces the control of space technology in the US. Part 121 regulates launch vehicles, guided missiles, ballistic missiles, and rockets among other technologies. Because weaponization of this technology poses particularly high risk to national and international security, the US still enforces ITAR, even though a growing number of nations possess launch capability.

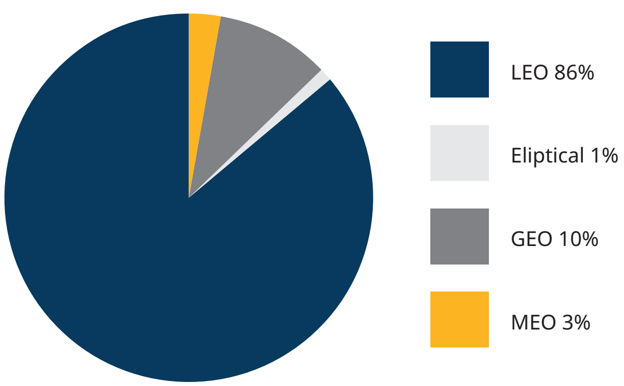
140 satellites (McDowell J., 2022). The demand for MEO satellites and the positions available make it less rivalrous than other domains.

Geosynchronous orbit (GSO) is the region near 35,786 kilometers above the Earth, with geostationary Earth orbit (GEO) being a special case of an orbit at exactly 35,786 kilometers, zero inclination, and zero eccentricity. Satellites in GEO orbit the Earth at exactly the same rate as the Earth rotates and appear to remain fixed in the sky over a particular part of the Earth. These traits make GEO most useful for telecommunication and Earth observation. However, the GEO region is the most limited in size of all orbital regions, particularly considering the need to prevent radiofrequency interference between nearby satellites in GEO broadcasting signals at the same frequency. As a result, despite the relatively limited number of satellites currently in GEO, it remains highly rivalrous (McDowell J., 2022).

Space debris is also a risk for GSO. While the total number of items tracked by NASA and DoD are far fewer in GSO than in LEO, the greater distance to GSO means that they can only track larger objects. The Space Surveillance Network tracks objects five centimeters in diameter and larger in LEO, but NASA and DoD only track objects one meter and larger in GSO (NASA, 2021).

Considered to be a subset of MEO, the least utilized Earth orbit is highly elliptical orbit (HEO). With only 60 satellites in this category, a diverse set of satellites ranging from scientific projects to Earth observation to communications occupy HEO (McDowell J., 2022). This domain is the least crowded, but it does pose potential challenges for accurate tracking due to uncommon orbits. Satellites in HEO also cross each of the other orbital regimes, meaning that if LEO becomes inaccessible due to Kessler Syndrome, debris will likely impact HEO as well.

Figure 3. Relative fractions of satellites in the different orbital regions around the Earth.



7.2 Celestial Bodies

Although geocentric orbits remain the most utilized space domains, celestial bodies have received increased attention in recent years. As constant ornaments of the night sky, humans have seen moons, planets, asteroids, and comets as eventual destinations. Beginning with Luna 1 launched by the Soviet Union in 1959, scientists and engineers were able to explore these distant bodies. Although humans have only stood on one celestial body, numerous probes, landers, and rovers have explored not only planets and moons of our solar system but also asteroids and comets. Spacecraft have landed, contacted, or collided with 14 planetary bodies since Luna 1 crashed into the Moon in 1959.

Table 2. Landers and impactors on other celestial bodies in the solar system. Fly-by missions are not included in this list.

PLANETS	
Mercury	One lander in 2015
Venus	Fifteen probes and landers between 1966 and 1985
Mars	Sixteen probes, rovers, landers, and one helicopter between 1971 and 2021
Jupiter	One probe with two parts (atmospheric probe in 1995 and main craft in 2003)
Saturn	One orbiter crashed in 2017
MOONS	
Earth's Moon	47 landings from 1959 to 2020 including 6 manned missions
Phobos (Mars)	One failed landing attempt in 1989
Titan (Saturn)	One floating lander in 2005
ASTEROIDS	
Eros	One orbiter crash in 2001
Itokawa	One sample return mission in 2005
Ryugu	One rover and sample collection mission in 218-2019
Bennu	One sample return mission in 2020
Dimorphos	One intentional collision in 2022
COMETS	
Comet 9P/Tempel 1	One impactor in 2005
Comet 67P/ Churyumov–Gerasimenko	One lander and intentional orbiter crash in 2014/2016

As shown in Table 2, the Moon is the most visited body in the solar system. While this fact is no doubt due to the proximity of the Moon, we can see the Moon as a bellwether for other celestial bodies. These domains are potentially more rivalrous than orbital domains due to each body likely only having limited resources or regions that are of commercial or scientific interest. Areas of special interest on planets and the Moon in particular are some of the most rivalrous domains in outer space. Research indicates that the lunar poles likely contain the most valuable lunar resources (Elvis et al., 2020; Open Lunar Foundation, 2021). These areas are the most likely locations for *in-situ* resource utilization (ISRU). The potential value of lunar resources for life support, research, and base building makes these locations of special interest. For example, there may be water ice in some deep craters near the lunar South Pole that are also adjacent to elevations that can provide constant sunlight for solar power (Open Lunar Foundation, 2021). The limited area of these so-called "peaks of eternal light" may make them highly rivalrous but also theoretically excludable from a technological and logistical perspective (although excluding access to these resources would violate the Outer Space Treaty). While not every planet or moon has a similarly valuable resource, ideal locations for research make rivalrous domains much more common on celestial bodies. Rivalry has not been a major concern in past decades because the number of nations with lunar landing capabilities has been few. However, as more nations and organizations possess launching and landing technology, groups may push to occupy the areas or resources to exclude competitors.

7.3 INTERPLANETARY SPACE

While celestial bodies are both highly rivalrous and excludable, interplanetary space occupies the opposite corner of the chart. With low excludability and low rivalry, interplanetary space is functionally infinite. There is no risk of spoilage of the whole domain by high use or demand.

Figure 4. Goods continuum for interplanetary space.

As indicated in Figure 4, space domains are not all definitionally CPRs.[9] However, some subdomains—like LEO or GSO—are. Even absent the existing legal framework, these domains are economic commons by nature of their inherent rivalry and excludability. Consequently, they are particularly susceptible to the tragedy of the commons. As these domains become more congested, their rivalry will only increase.

As indicated by the works of Hardin and Lloyd, the fact that only some domains are economic commons does not mean that other subdomains cannot be held in common. If all or enough stakeholders agree to hold some of these domains in common, they can use commons management strategies. In some cases, holding a domain in common requires formal agreement, but for some vast and non-congested domains governance regimes may be impractical. When there are few stakeholders, each one has little motivation to hold a domain in common. Still, early commons designations may be more advantageous in the long term, as they set precedence for resource sharing. Stakeholders also have other motivations for holding a resource in common for its preservation and conservation. In these situations, stakeholders must enact legal contracts to regulate the use of the commons. Such a mechanism is in place to regulate activity in Antarctica and to a limited extent in space. Similar agreements regulate the oceans and the atmosphere, but as we will explore in the next sections, no Earth-based domain is sufficiently analogous to space to act as a regulatory or contractual template. Instead, stakeholders must identify the part of existing treaties that may be effective if applied to space domains.

[9] While a quantitative analysis of space resource domains is possible and would yield more precise positions, this chart is merely an illustration of the concept. Domain placement is approximate.

8. ANALOGOUS DOMAINS

The list of "global commons" often includes Antarctica, the oceans, the atmosphere, and the electromagnetic spectrum. We can apply the commons framework to any shared domain, but the fit is often not perfect. For example, despite private ownership of each part, the internet still has some traits of the commons (Raymond, 2012). Although in the case of the internet, the danger is not of resource exhaustion, but of resource dilution, disruption, or corruption. Users can apply some of the same principles for preserving the commons to ensure utility. Similarly, consider Antarctica. Users hold the domain in common, and regulate it with the 1959 Antarctic Treaty. Nations share responsibility and agree to use the continent only for scientific research, but the decision to manage the domain as a commons was likely due to poor resource availability and the inhospitable climate. But to compare the resources of Antarctica to those of space reveals that similar management strategies would likely fail. In exploring each of the following terrestrial domains, we can glean helpful tools that we can apply to the management of space domains.

International law recognizes a nation's acquisition of land via five methods: [10]

1. Subjugation/annexation: the forcible taking of land by actual or threat of military force. This method is historically the most common but has become less common over time, although instances still occur today, such as Russia's annexation of Crimea in 2014.

2. Natural geographical accretion: Natural processes like river deposits or volcanic eruptions expand existing territory, as occurs when lava flows create new land on the island of Hawaii.

3. Cession of territory by one country to another: The mutual agreement to transfer territory, as occurred with the Louisiana Territory (France to US) or Alaska (Russia to US).

4. Prescription: This process occurs when one nation conducts open and notorious use of land claimed by another over a prolonged period of time. In these cases, actors may recognize the occupant as the owner despite previous claims.

5. Occupation of previously uninhabited land: This "finders' keepers" method of claiming territory is usually the first method applied, but claimants often utilize other acquisition methods in competitive territory (Jennings, 1963).

While many of the human spaceflight goals of the last 50 years have concentrated on short-term return type missions, space programs are now setting their sights on permanent occupation of celestial bodies (NASA, 2022). Astronauts currently occupy the ISS year-round, with new astronauts and supplies arriving periodically. NASA now plans this same mission for lunar orbital and surface stations. NASA has also announced the goal of establishing a long-term presence on Mars (NASA, 2022). These missions use terms like "base" and "colony," which suggests some similarity to the colonial organization of the post-Columbian Americas.

Europeans acquired land in the Americas primarily through subjugation, although they also used other methods. The first wave of European colonization in the Americas was an enormous economic and strategic opportunity of European nations. Europeans saw the native peoples as easily conquerable, and the land was full of valuable mineral resources and agricultural opportunity. While many nations made claims to different parts of the continent (notably Portugal, Spain, France, Britain, and the Netherlands), no agreements on land sharing were

[10] Many consider long-term leasing of land as with Hong Kong and China another method of land acquisition, but it is excluded here as it is definitionally temporary.

struck until each kingdom had taken as much as they could. The age of exploration predates Lloyd and his idea of the commons, and the concept of a global commons was far in the future.

8.1 Antarctica

Although many long suspected the existence of a southern continent, the first European voyages set on exploring the southern extremes included Jacob Roggevean (financed by the Dutch East India Company) in 1721, Bouvet de Lozier (financed by the French East India Company) in 1739, and British explorer James Cook in the 1770s. While these missions would fail to discover *terra firma,* they did reveal the rich biological resources (i.e., seals and whales) that would drive ships to the region for the next 200 years. This discovery would bring American, Australian, Argentinian, and French hunters and whalers in the late 1700s and early 1800s.

By the 1880s Germany and New Zealand had joined the thriving whaling industries. Strangely, although Antarctic resources were known, no one would discover the actual continent until 1820 by Edward Bransfied (Fuchs, 1983). [11] In 1840, French explorer Jules Dumont d'Urville planted the French flag to claim the land for his country.

Activity on the continent increased slowly over the following decades. A British expedition from 1907–1909 would be the first to reach the magnetic south pole, and Roald Amundsen would famously beat Robert F. Scott to the geographic pole by five weeks in 1911. Despite whaling and hunting activity in the Southern Ocean around the continent, activity on Antarctica was primarily scientific, researching the climate, geology, and limited ecology. The United States dominated Antarctic activity in the early 20th century.

Historical and modern claims of Antarctica utilized many of the acquisition methods including prescription, natural accretion, and most often, occupation of uninhabited land. Currently, Argentina, Australia, Chile, France, New Zealand, Norway, and the UK, claim portions of the continent. All but Norway claim a portion of the continent in line with their longitudinal boundaries. These claims are "wedges" that originate at the far southern boundaries of their national borders and converge at the south pole. These wedges do not carve out a perfectly portioned pie, as some claims overlap. While the only activity on the continent is scientific research, claimant nations strategically place their research stations within their claim. Further complicating matters, two of the most active nations on the continent, the United States and Russia, make no territorial claim, and have research stations throughout the continent. [12] With so many overlapping claims and the potential for territorial conflict, states saw the need for an international agreement on Antarctic activity.

Following the formation of the Special Committee on Antarctic Research (SCAR)[13] in 1958, the Antarctic Treaty (1959) went into force in 1961. All 12 nations (the seven claimant parties plus Belgium, Japan, Russia, South Africa, and the United States) that were active on the continent at the time signed the treaty. The treaty currently has 54 participating parties. The key aspects of the treaty are as follows:

- States shall use Antarctica for peaceful purposes only (Art. I);
- Researchers shall make scientific observations and results from Antarctic research available to the public and exchanged freely (Art. II);
- The treaty does not require the renunciation of "previously asserted rights or claims of territorial sovereignty" (Art. IV);

[11] Accounts differ; some claim that Nathanial Palmer sighted the continent first. Others claim that Fabian Gottieb von Bellingshausen saw land two days before Bransfied.

[12] Although the US and Russia have no territorial claims, they both reserve the right to make a claim in the future.

[13] SCAR was renamed the Scientific Committee on Antarctic Research in 1961.

- States cannot make additional claims or expand existing claims while the treaty is in force. (Art. IV); and
- No nuclear explosions or disposing of radioactive waste (Art. V).

While the treaty was one of the first of its kind to designate a global commons, the article that addresses competing territorial claims is notoriously vague. The treaty allows existing claims to remain while prohibiting expansion of those claims or addition of new claims. Simultaneously, the treaty restricts activity on the continent to peaceful scientific research, while stating that states shall exchange information and observations freely. Parties agree in Article III that states shall exchange scientific personnel between expeditions and stations.

Evaluating Antarctica against Ostrom's design principles, we find that the lack of graduated sanctions and conflict resolution mechanisms weaken the institutional performance. Yet, the treaty has been successful in managing these commons thus far (Table 3). This success may be due to the unique attributes of the continent as a domain such as its remoteness and inhospitable climate.

Table 3. Management of Antarctica according to Ostrom's principles for a commons.

SITE	Clear boundaries & memberships	Congruent rules	Collective-choice arenas	Monitoring	Graduated sanctions	Conflict-resolution mechanisms	Recognized rights to organize	Nested units	Institutional performance
ANTARCTICA	Yes	Weak	Yes	Yes	No	No	Yes	Yes	Fragile

The Antarctic treaty demonstrated that effective global commons management is possible, but the differences between Antarctica and space domains are obvious barriers to implementing an identical agreement for outer space.

The relatively rapid development of the space economy compared to Antarctica is evidence of the resource value of each domain. While valuable resources exist in Antarctica, none of these resources are unique to the continent, and the grade and size of mineral deposits preclude them from significant economic interest (Watt, 2022). The relative remoteness of Antarctica makes the region most valuable for scientific research. In terms of remoteness and climate, Antarctica and the Moon are the most similar. Both locations have lower economic and strategic military value, but have significant scientific value. Conversely, some space resources, especially geocentric orbits, have great economic value that is unavailable elsewhere. When compared to Antarctica, space is a relatively resource-rich domain. The relative rate of development of these domains supports this difference.

Additionally, the existence of competing claims separates the two domains. Existing territorial claims can act as a barrier to cooperative agreements as parties would have to cede territory as it would become a commons. However, competing claims also act as an incentive to cooperative agreements as these agreements avoid conflict while preserving the right to access and utilize the *res communis* domain.

Resource type also differentiates the domains. As previously noted, the primary resource application for Antarctica is scientific research and observations. Space has unique scientific value, which is the central goal of most human spaceflight up to this point in time. However, satellites and future space use are increasingly non-scientific. The commercialization potential of space is far greater than that of Antarctica, so holding space domains in common comes at a much greater opportunity cost than that of Antarctica.

8.2 The Oceans

Perhaps the most universally agreed commons is the ocean. As a land-based species, humans have long seen the sea like modern humans see outer space, as both a pathway towards and a barrier to new lands. But unlike space, the ocean holds vast resources that have sustained humans for millennia. Fish and ocean mammals have been a dominant food source for all human history. As a geographic feature, seas and oceans have been important defensive mechanisms. The countless battles fought from the decks of ships testify to the important role that the sea plays in territory protection and acquisition. In the modern era, the ocean became valuable for something beyond biological resources or military defense. The discovery of vast oil reservoirs meant that some parts of the ocean may hold buried treasure in the form of energy potential. Thus, oil and mineral resources became another factor in managing the ocean. Protection of these three resource uses—biological, territorial, and energy/mineral—have been the driving force behind international ocean regulation. Furthermore, each resource use requires a specific regulatory framework to effectively manage the commons. Essential to managing the commons is first establishing the limits of that commons. In the ocean domain, this process necessarily includes categorizing part of the domain as private territory (and therefore not a commons).

Implicit territorial agreements certainly existed prior to the first recorded ocean treaties, but as with many legal concepts, scholars trace the history of sea law to the Roman Empire. Romans labeled the seas as communes omnium naturali jure or common to all mankind in the second century by jurist Marcianus. The Digest of Justinian, by then Emperor Justinian I (483–565), references Marcianus' work and scholars recognize it as the first recorded statement on maritime law.

Despite centuries of normative development of maritime law, we know of few written records on the matter. The arrival of Columbian exploration in the 15th, 16th, and 17th centuries brought with it the need for sea territory agreements. With so many nations entering the naval exploration economy, differing opinions on what territory states could claim was inevitable. Disagreements between Spain and Portugal are particularly notable as they considered the Pacific Ocean a closed sea *(mare clausum)*. Dutch jurist Hugo Grotius (1583–1645) took the opposing position *(mare liberum)* in his On the Law of Spoils (De jure praedae).

In a later work, Grotius would assert that the issue of sea territory was a question of control of a coastline. This assertion would be the basis for the cannon-shot rule, limiting territorial claims to the distance a cannon could shoot from the shore. First limited to 4,200 feet (0.8 miles), advances in technology and the dominance of British naval fleets would extend this measure to three miles, which courts upheld by several cases in the early 18th century. Still, some nations claimed different standards such that even post-WWI attempts to reach an agreement were unsuccessful. The Hague Conference for the Progressive Codification of International Law (1930) could not agree upon territorial range.

The three United Nations Convention on the Law of the Sea (UNCLOS) would successfully establish standard territorial limits to ocean domains. After first meeting in 1958 and in 1960 without reaching agreement on territorial limits, UNCLOS III in 1982 would finally establish the maritime zone we know today. This treaty codified the extent of territorial water under sovereign control to 12 miles from the coast. The contiguous zone, the distance at which a state can enforce domestic laws, extends a further 12 miles (24 miles total). UNCLOS II also established the Exclusive Economic Zone (EEZ), extending 200 miles from the shore. The treaty also allowed for economic activity on the continental shelf if it extended beyond the EEZ. We can divide the agreement into four regulatory focuses: national territory, biological resources, pollution, and mineral resources.

Within the territorial boundary set by UNCLOS at 12 miles from the shore, states have exclusive jurisdiction and sovereignty. States treat this area like an extension of the land territory, which precludes its commons status. Importantly, this zone applies not only to the surface of the water, but also extends down to the seabed and up into the atmosphere. This 12-mile zone also constitutes national airspace.

Biological resources include fish and mammals but may also include aquatic plant life. Living organisms have been a challenging domain for international cooperation for two primary reasons: biological resources often move in and out of territorial boundaries, and demand for biological resources is highly inconsistent between nations. These two factors have led major fishing nations like Japan to refuse past agreements.

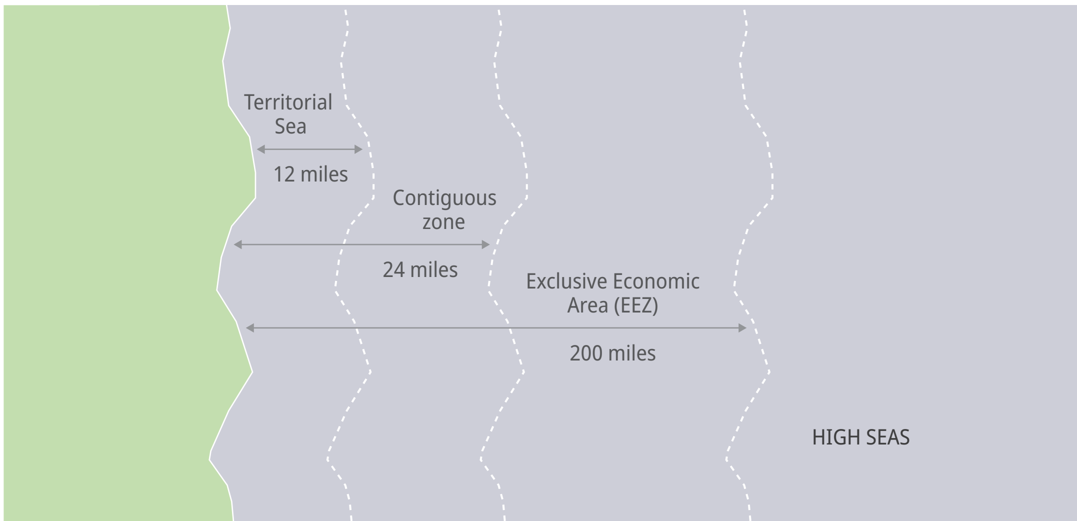


Figure 5. Demarcation of territorial waters, the contiguous zone and exclusive economic zones in maritime law.

The EEZ set at 200 miles in UNCLOS III allows for exclusive fishing and whaling within the boundary. Fishing beyond the EEZ has been the topic of many additional treaties throughout the 20th and 21st centuries. Relevant regulations include:

- International Convention for the Regulation of Whaling (ICRW), 1946
- Geneva Conventions on the Law of the Sea, 1958
- The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR Convention), 1980
- Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, 1993
- The UN Fish Stocks Agreement, 1995
- Food and Agriculture Organizations of the United Nations Code of Conduct for Responsible Fisheries, 1995
- Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem, 2001
- Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, 2009
- Four separate International Plan of Action (IPOA) under the UN's Food and Agriculture Organization: Seabirds, Sharks, Fishing Capacity, and Illegal, Underreported and Unregulated Fishing (IUU)

These treaties, agreements, and plans range in scope, numbers of parties, and compliance mechanisms. The topic of sea law certainly merits its own in-depth discussion, but the number of agreements that are currently in force to regulate biological resources shows the complexity of this domain. Beyond these specific agreements, portions of the Declaration of the UN Conference on the Human Environment (the Stockholm Declaration), 1972; Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973; Convention on the Conservation of Migratory Species (CMS), 1979; and other instruments also apply to ocean biological resources.

In contrast to living resources which people have used for millennia, deep seabed mineral resources only recently became a usable resource. Advances in technology have allowed for use of this new domain, but also created an imbalance in access. While even less developed nations can fish, only the most advanced states can access deep sea mineral resources. Because UNCLOS grants exclusive economic rights within a nation's EEZ or continental shelf region, national laws regulate mineral and oil mining within this region. However, valuable mineral resources exist outside of these regions necessitating the regulation of this domain. States formed the International Seabed Authority (ISA) parallel to UNCLOS to manage seabed mining. The ISA acts to ensure equitable allocation of mining sites and resources so the few developed nations that are currently able to access them do not claim a monopoly on the resources. Under the earliest form of the ISA, private or state-sponsored mining organizations would apply for two mining sites. The ISA would grant one site to the mining organization, and the ISA would keep the second. The agreement would also force the mining industry to share technology, personnel, and money. The ISA would use the resources and mining sites to ensure equitable access and distribution of deep-sea mineral resources.

States restructured seabed mining rules in the 1990s to eliminate the requirement to share technology, grant more control to technologically advanced nations, and establish an economic assistance fund for developing nations. Additionally, the 1994 agreement would designate the seabed as *res communis*. The ISA has also adopted exploration regulations for polymetallic nodules (2000 and revised in 2013), polymetallic sulfides (2010), and cobalt-rich ferromanganese crusts (2012).

Like space domains, the ocean is susceptible to degradation from resource exhaustion and from resource spoilage. In the case of LEO, spoilage may include orbital debris. In the case of oceans, spoilage is often physical and chemical pollution or ocean acidification. Attempts to address ocean pollution date back as early as 1926 and 1935 when states drafted conventions that never entered force. The UN established the International Marine Organization (IMO) [14] in 1948 and it entered into force in 1958. Early attempts at regulating ocean pollution like the 1958 International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL), would prove ineffective.[15]

The key IMO conventions in force include:

- International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended, which established the minimum safety standards of ships. Contracting governments enforce SOLAS by inspecting ships.
- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997 (MARPOL), which aims at minimizing accidental and intentional pollution from ships.

---

[14] Originally named the Inter-Governmental Maritime Consultative Organization (IMCO) the name changed in 1982 as the organization's role extended beyond consultation.

[15] OILPOL was updated several times before being subsumed by MARPOL in 1973.

- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) as amended, including the 1995 and 2010 Manila Amendments.[16]

The individual resource use categories (biological, territorial, and energy/mineral) make evaluating the ocean by Ostrom's eight design principles tricky. Some of the resource uses have stronger management mechanisms than others. Considering the entire domain, we can consider the ocean to have a robust institutional performance (Table 4).

Table 4. Management of the maritime domain according to Ostrom's principles for a commons.

SITE	Clear boundaries & memberships	Congruent rules	Collective-choice arenas	Monitoring	Graduated sanctions	Conflict-resolution mechanisms	Recognized rights to organize	Nested units	Institutional performance
OCEAN	Yes	Yes	Yes	Yes	Weak	Yes	Yes	Yes	Robust

As with the Antarctic domain, the ocean treaties demonstrate that management of a global commons is possible. However, the multitude of existing treaties, the variety of resources and number of stakeholders, adds considerable complexity to effective agreements. Like space, the ocean has a variety of uses and resources, so managing those resources or regions separately may prove an effective strategy. As with Antarctica, significant differences between space and the ocean bear consideration. Most obviously, the number of members participating in the ocean commons is much higher than that of space.

The technological requirements and financial cost to access space resources (whether consumable or positional) is much higher. In this case we may look to regulation of deep-sea mineral mining as a possible analogy. Like space, this domain has high economic and technological requirements prohibiting its access by most developing states. Establishing an enterprise like the ISA funded by private and state-sponsored organizations to act on behalf of developing nations is a possible solution. However, space-capable nations have been reluctant to share technology and resources for activities beyond scientific research.

Historic access to the oceans as a resource also separates them from space. Because boats and coastlines are widely available, controlling a coastline is much more challenging that controlling space technology. In the early days of space exploration, the limited potential stakeholders meant that the ocean was a much more likely candidate for a global commons. Like early participants in the age of European Exploration, current participants in the space economy are more likely to see it as a *res nullius* than a *res communis.*

8.3 The Atmosphere

From the perspective of astronauts aboard the ISS, Earth's atmosphere appears as a thin blue and violet border between the terrestrial and the dark backdrop of space. Easy to ignore in relation to the vibrant sphere within, the atmosphere is essential to life on Earth. The atmosphere provides protection from harmful radiation, regulates the temperature change between day and night, facilitates the movement of water and energy around the globe, and holds the air that all living things need to survive. Protection of the atmosphere is a critical part of protecting life on Earth.

---

[16] STCW code has two parts. Part A includes mandatory requirements for training and certification; part B includes recommended guidance and examples.

Prior to the 20th century, many did not consider the atmosphere at risk of the tragedy of the commons. However, a series of events throughout the century brought the atmosphere to the forefront of the commons discussion. First, was the advent of the airplane. As airplane travel developed and improved, the sky became another medium through which to travel. This change meant that states considered the sky a territory that they or their rivals could claim, protect, or infringe upon. Second, researchers began to understand the effect of acid rain and the vast amount of greenhouse gasses that humans emitted to the atmosphere as a result of fossil burning and other anthropogenic sources. With this understanding, scientists realized that human action could have a significant impact on Earth's climate. Third, development of nuclear technology in the middle of the century brought with it the threat of dangerous global radioactive contamination of the air. This threat to global human health—a shift from regional impact like smog from coal plants—brought pollution to a personal level, and as a result forced consideration of the entire atmosphere. These three developments represent the three critical management areas: airspace, pollution, and climate change. Consequently, many of the global commons agreements focus on at least one of these areas.

Airspace is doubtless the most straightforward of these management areas. States considered the question of airspace territory almost as soon as humans were capable of flight. Some asserted that air travelers had a right to free passage, while others asserted that territorial sovereignty extended upward into airspace (Lay & Taubenfeld, 1968). The International Conference on Air Navigation in 1910 decided to allow free overflight, but only nine years later in 1919, article one of the Convention Relating to the Regulation of Aerial Navigation, signed at Paris stated the opposite, saying, "The High Contracting Parties recognize that every Power has complete and exclusive sovereignty over the air space above its territory…." This change in policy is likely due, at least in part, to the use of aircraft in military conflict. At the conclusion of WWI, the combat potential of aircraft was obvious, so protecting sovereign airspace was a key component of national security. The expansive use of planes during WWII only bolstered this claim. Nearing the end of the war, the Chicago Convention on Civil Aviation (1944) strengthened this assertion. Article one of that agreement states: "The contracting States recognize that every State has complete and exclusive sovereignty over the airspace above its territory." These decisions, much like UNCLOS, privatize a portion of the domain. However, territorial privatization does not isolate those regions, and actions that impact the atmosphere impact private airspace and open air alike.

Discussion around human impacts to the atmosphere often include both pollution and climate change: pollution, including chemical changes to the atmosphere that impact living things (like acid rain or smog); and climate change, including changes to the atmosphere's greenhouse effect. These two types of pollution are certainly interrelated, but we separate them for the purpose of this discussion because atmospheric pollution has both more regional and more immediate impacts to human life. Climate change has global impacts and a noticeable impact on human life has taken much longer to occur, although researchers have predicted these impacts for decades.

The impact of atmospheric pollution like smog is much more localized than other pollution, so even though its negative impact on human health and the environment has been known since the mid-1800s (Fourier, 1827), states did not deem it necessary to address the issue with a global treaty. Nations could simply address it with their own laws. However, in the middle of the 20th century, another form of atmospheric pollution was becoming a concern. Isolated lakes and waterways that were free from surface pollutants were dying. A form of acidification puts the delicate ecosystem out of balance. The culprit was acid rain, and it also impacted crop production, eggshell formation, and other biological processes (Rosenbaum, 1987). Like climate change, this chemical process and its connection to fossil fuels had been long known (Smith, 1872). NO_2 and SO_2 emitted into Earth's atmosphere[17] form acid rain when they react with water and oxygen in the atmosphere to form nitric and sulfuric acid, respectively. In response to the risk that acid rain posed to the environment, states proposed several agreements to curb its impact. Scandinavian nations were proponents of international controls on NO_2 and SO_2, but other developed nations opposed measures that may increase energy costs. The first major agreement to address atmospheric pollution was the Convention on Long-Range Transboundary Air Pollution (CLRTAP) (1979), which includes eight protocols:

- Protocol on Long-Term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) (1984)
- 1985 Helsinki Protocol on the Reduction of Sulphur Emissions
- Nitrogen Oxide Protocol (1988)
- Volatile Organic Compounds Protocol (1991)
- 1994 Oslo Protocol on Further Reduction of Sulphur Emissions
- Protocol on Heavy Metals (1998)
- Aarhus Protocol on Persistent Organic Pollutants (1998)
- 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone

CLRTAP is an important step in regulating air pollution, but the signatories are mainly European countries. Notably, the US has only signed four of the eight protocols. Furthermore, some criticize CLRTAP for its lack of adequate enforcement measures or its setting standards too low. Still, recent research suggests that states have made significant progress in reducing emissions. "Emissions of all key air pollutants have been reduced significantly and for the most important acidifying compound, sulfur dioxide, emissions in Europe have decreased by 80% or more since the peaks around 1980–1990" (Grennfelt et al., 2020). Whether we can attribute this reduction to CLRTAP or other state and regional restrictions is unclear.

Separating atmospheric pollution from climate change is impossible. Air pollutants and greenhouse gasses have significant overlap in terms of effects and sources, but the process and policy differ significantly. Climate change is the change in global temperature and weather patterns due to increased atmospheric greenhouse gasses. Although Svante Arrhenius linked climate change to fossil fuel burning as early as the 1890s (Dressler, 2021), global treaties regulating greenhouse gasses took a century to develop. In 1992, 154 states signed the United Nations Framework Convention on Climate Change (UNFCCC) agreeing to further study, future meetings, and policy discussions on climate change. The Kyoto Protocol signed in 1997 would extend the UNFCCC and commit to reducing greenhouse gasses.[18] As climate action pressure mounted in the 2010s, nations drafted the Paris Agreement, which states signed and which went into force in 2016 with the following long-term goals:

- Substantially reduce global greenhouse gas emissions to limit the global temperature increase in this century to 2 degrees Celsius while pursuing efforts to limit the increase even further to 1.5 degrees;

[17] Some NO_2 and SO_2 are emitted by natural processes like volcanos, but the vast majority is anthropogenic.

[18] Annex A of the Kyoto Protocol specifically mentions carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Negotiators added nitrogen trifluoride for the second compliance period.

- Review countries' commitments every five years;
- Provide financing to developing countries to mitigate climate change, strengthen resilience and enhance abilities to adapt to climate impacts.

Decreasing levels of atmospheric ozone, which protects the Earth from ultraviolet radiation, measured in the 1980s and 1990s only added to the climate problem. Researchers linked the thinning or disappearance of the ozone to the use of chlorofluorocarbons (CFCs). A damning report from the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) in 1986 showed that CFCs in the atmosphere were rising even without increased use of the compounds (World Meteorological Organization et al., 1986). Models warned of significant reduction of ozone and the impact of CFCs on climate change. In response to this and other studies, climate activists pushed for the UN to act. In 1987, 24 nations signed the Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol). This agreement took aggressive action to regulate and phase out CFCs. The UN has revised the agreement several times, but researchers have measured the resulting ozone rebound and an update to the status of the Montreal Protocol by Canada states that, "Results from continuing global observations have confirmed that atmospheric levels of key ODS are decreasing, and it is believed that, with continued, full implementation of the Protocol's provisions, the ozone layer should return to pre-1980 levels by 2050." Although greenhouse gas emissions have not achieved the same progress, the effectiveness of the Montreal Protocol is a demonstration of the potential of effective agreements. Unfortunately, researchers have shown that the compounds designed to replace CFCs, hydrochlorofluorocarbons (HFCs), are dangerous greenhouse gasses as well (Velders et al., 2007).

Managing the atmospheric domain exhibits some of the most challenging potential barriers to regulation. Complex social and political issues lie at the center of these barriers. Existing fossil fuel companies represent large portions of the global economy, so large oil exporters, generators, and users react to any restrictions that limit their activities with resistance. The economic implications are only part of the issue. Existing infrastructure for energy and transportation prioritizes fossil fuel use. Changing these systems would require a massive rebuilding effort that would take time and money. Furthermore, these costly changes are only barely within reach of developed nations. Less developed and developing countries can only access the most affordable energy. Even large nations like China and India resist fossil fuel restrictions, because oil and gas are fueling the rapid economic growth. Many nations see restrictions imposed on developing nations by the US and Europe as hypocritical. The US and Europe relied on unrestricted fossil fuel throughout the 20th century and experienced tremendous growth at the same time. The main goal of CPR regulation is to ensure sustainable and equitable use of a resource. In the case of the atmosphere, current and historic use is neither, but even if states achieve sustainable use, it will not be equitable because the earliest industrialized nations enjoyed unrestricted use for over a century.

As with the ocean, evaluating the performance of atmospheric regulation by Ostrom's design principles is challenging due to the various mechanisms in place. Monitoring this domain is notoriously difficult as measuring atmospheric pollution is straightforward but showing where the pollution originated is less obvious. Furthermore, sanctioning and conflict resolution have been constant challenges as major stakeholders are often unwilling to submit to sanctions for non-compliance. At best, the atmosphere has fragile institutional performance, although some may consider existing mechanisms a failure.

Table 5. Management of the atmosphere according to Ostrom's principles for a commons.

SITE	Clear boundaries & memberships	Congruent rules	Collective-choice arenas	Monitoring	Graduated sanctions	Conflict-resolution mechanisms	Recognized rights to organize	Nested units	Institutional performance
ATMOSPHERE	Yes	Yes	Yes	Weak	Weak	Weak	Yes	Yes	Fragile

States adopted space commons regulations much earlier compared to the atmosphere, but the same risk of inequitable use exists. If the few space capable nations have unrestricted access to a domain until a crisis point is reached, later parties of the space domain will never have the same type of use and would therefore be less willing to restrict their use. In this regard, the atmosphere is a warning sign for space policy. No policy decision will eliminate the advantage (or risks) of domain pioneers, but we should avoid allowing these pioneers to deplete a resource at the expense of the future. The role of unsustainable actors is another warning sign. If high economic drivers also pose a threat to the CPRs through unsustainable use, their influence is likely to impact policy decisions. As a result, space regulators should carefully consider stakeholders in terms of their impact, not just their influence.

9. HISTORIC AND EXISTING SPACE AGREEMENTS

Although it is not the only multinational organization with agreements impacting space policy, the UN is the preeminent body for international discussions on space governance. Certain bilateral agreements also touch on activities in outer space. Guiding principles for international cooperation in and management of outer space[19] by the UN come in three forms: (i) Resolutions adopted by the General Assembly, (ii) principles adopted by the General Assembly, and (iii) UN Treaties. These first two categories are not enforceable actions, but merely express the view of the UN as voted by its members. Treaties have legal authority and often include specific requirements or prohibitions. The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) is the forum where states negotiated the five treaties related to outer space. These treaties include the Outer Space Treaty, the Rescue Agreement, the Liability Convention, the Registration Convention, and the Moon Agreement. These treaties took years to negotiate and sign, and apart from the Moon Agreement, have widespread adoption.

As with other global commons, the development of international outer space law has evolved gradually, and policy makers established many of the principles enshrined in these treaties years before they were signed. While space may be the most recently accessed domain, space law developed at the same time and even before some of the multinational agreements previously discussed. UN General Assembly Resolution 1721 A and B (XVI) of 20 December 1961: *International cooperation in the peaceful uses of outer space* was the first action by the UN on outer space policy. [20] This resolution introduced the key concepts found in future declarations eventually treaties such as:

---

[19] For example, the START and SALT nuclear arms control treaties have significant implications for space.

[20] Decades later, four additional resolutions would be passed, including: Paragraph 4 of resolution 55/122 of 8 December 2000: International cooperation in the peaceful uses of outer space; Resolution 59/115 of 10 December 2004: Application of the concept of the "launching State;" Resolution 62/101 of 17 December 2007: Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects; and Resolution 68/74 of 11 December 2013: Recommendations on national legislation relevant to the peaceful exploration and use of outer space.

- Actors should only use outer space for the betterment of humankind;
- Outer space should benefit states irrespective of their economic status or scientific capabilities;
- The UN should be an agent of space cooperation; and
- States launching objects should share information about those launches with the UN and other states.

The resolution also invited COPUOS to study and report on the potential legal problems regarding space. This initial resolution would soon lead to *The Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space*, which the UN adopted in 1963. This declaration further lays out the foundation for space as a commons.

The declaration addresses the commons problem directly stating the belief "…that the exploration and use of outer space should be carried on for the betterment of mankind and for the benefit of states irrespective of their degree of economic or scientific development…"

The declaration goes on to establish guiding principles including:

1. The exploration and use of outer space shall be carried on for the benefit and in the interests of all mankind.

2. Outer space and celestial bodies are free for exploration and use by all States on a basis of equality and in accordance with international law.

Borrowing concepts from the Antarctic Treaty, the UN recognized the risks of sovereignty claims in outer space and addressed them accordingly.

3. Outer space and celestial bodies are not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

The remainder of the declaration includes statements on responsibility for outer space activities and objects, cooperation and mutual assistance in space activities, and liability for damage by space objects.

The declaration seeks to preserve equitable access by asking states to act with regard to the interest of other states and parties, which may include states not yet capable of spaceflight. Four additional principles would soon follow this declaration including:

- Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting

- Principles Relating to Remote Sensing of the Earth from Outer Space

- Principles Relevant to the Use of Nuclear Power Sources in Outer Space

- Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries

As mere principles, these statements had normative value, but not legal authority. As such, a more comprehensive agreement would be necessary to detail what steps and behaviors are necessary to meet this goal, but the earliest actions to manage space show an undeniable view of outer space and celestial bodies as a global commons.

9.1 Outer Space Treaty

Throughout the 1940s and 1950s the development of space technology was intrinsically tied to military application. In 1944, German military scientists and engineers launched the first man-made object to enter outer space, an A-4 test rocket that reached an altitude of 176 kilometers. American and Soviet space programs used this technology to develop their own rockets. With postwar technology and resources, a global arms race started to form. As states developed intercontinental ballistic missiles (ICBMs) and nuclear payloads, the need for international agreements on the use of space was critical (Jankowitsch, 2015). With the central goal of limiting space to peaceful purposes, nations developed the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, also known as the Outer Space Treaty. States signed the treaty, and it went into force in 1967, and its main provisions are as follows:

- the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;
- outer space shall be free for exploration and use by all States;
- outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
- States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;
- the Moon and other celestial bodies shall be used exclusively for peaceful purposes;
- astronauts shall be regarded as the envoys of mankind;
- States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;
- States shall be liable for damage caused by their space objects; and
- States shall avoid harmful contamination of space and celestial bodies.[21]

Article IX also states that exploration and use of space shall be “guided by the principle of cooperation and mutual assistance.” The treaty has been ratified by 112 states, which is an indication of its wide support, but it has also been criticized for lack of specificity in those aspects where the drafters left some language vague—either intentionally or as a result of undeveloped technology. Like the Declaration of Legal Principles, the Outer Space Treaty borrowed concepts from existing agreements like the Antarctic Treaty.

Among these concepts was that of common management. While the treaty does not say that space belongs to all humankind, Article I states that, “The exploration and use...shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.” Article II adds by prohibiting claims of sovereignty, a non-appropriation measure like that of Antarctica.

This non-appropriation perspective was key to one of the central goals of the treaty: to limit military activity in space.[22] The Outer Space Treaty is one of a collection of “nonarmament” treaties, but because states created it partly in response to the threat of military conflict in or

[21] As stated by the United Nations Office for Outer Space Affairs (UNOOSA).

[22] The treaty does not impose a complete ban of military activity in space. It allows for military personnel in space for “scientific research or for any other peaceful purposes.” Furthermore, the treaty does not prohibit military satellites if they do not carry weapons of mass destruction.

from space, it does not address many of the non-military issues that arise from space utilization (Jankowitsch, 2015). The treaty is notably silent on commercial use of space. Perhaps negotiators did not anticipate the commercialization of space to the extent that we are witnessing today, an oversight that states may need to address in the future.

9.2 Rescue Agreement

The Outer Space Treaty includes specific requirements for assisting astronauts in the event of an accident in Article V:

> States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render to them all possible assistance in the event of accident, distress, or emergency landing on the territory of another State Party or on the high seas. When astronauts make such a landing, they shall be safely and promptly returned to the State of registry of their space vehicle.
>
> In carrying on activities in outer space and on celestial bodies, the astronauts of one State Party shall render all possible assistance to the astronauts of other States Parties.
>
> States Parties to the Treaty shall immediately inform the other States Parties to the Treaty or the Secretary-General of the United Nations of any phenomena they discover in outer space, including the Moon and other celestial bodies, which could constitute a danger to the life or health of astronauts.

Although addressed in the Outer Space Treaty, as crewed spaceflight became a regular occurrence, stakeholders recognized the need for a more specific agreement on the rescue of people and equipment. In 1968, states signed the *Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched in Outer Space* (Rescue Agreement). Prior to this treaty, disagreement existed on a specific rescue protocol. Some argued to follow the precedent set by maritime law, where sea rescuers were obligated for the return of stranded sailors, but they were also allowed to salvage equipment and cargo (Grotius, 1583–1645; Buck, 1998). However, negotiators did not carry over this principle into the domain of outer space, likely because space-race era technology was protected information. The agreement also includes rules for reimbursement, damages, and other costs for returning equipment.

9.3 Space Liability Convention

In the same way that the Rescue Agreement bolstered Article V of the Outer Space Treaty, stakeholders crafted the Convention on International Liability for Damage Caused by Space Objects (Liability Convention) to bolster Article VII:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies.

All spacefaring nations and over 100 other countries have signed this treaty. While the Outer Space Treaty set the liability precedent, the Liability Convention provided the actual mechanism for presenting claims against offenders. The convention does have shortfalls. As written, it only states and certain international organizations are liable for space accident damage and cleanup. This leaves private companies immune from liability claims.

In 1977, the Kosmos 954 accident put the Liability Convention to the test. This incident saw the failure of a four-ton Soviet reconnaissance satellite. The satellite and its onboard nuclear reactor reentered Earth's atmosphere, scattering nuclear debris over northern Canada. Under the Liability Convention, the Soviet Union should have covered the cost of remediation. Canada billed the Soviet Union over six million dollars but only received three million in the end (Brearly, 2008).

9.4 Registration Convention

Article XI of the Outer Space Treaty states:

> In order to promote international co-operation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the Moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving the said information, the Secretary-General of the United Nations should be prepared to disseminate it immediately and effectively.

Another elaboration on a requirement stated in the Outer Space Treaty, the 1974 Convention on Registration of Objects Launched into Outer Space (Registration Convention) requires parties to notify the UN of space-related activities. The Registration Convention requires states to provide detailed information that allows more accurate tracking of space objects. Required information includes:

- (a) name of launching State or States;
- (b) an appropriate designator of the space object or its registration number;
- (c) date and territory or location of launch;
- (d) basic orbital parameters, including:
  - (i) nodal period;
  - (ii) inclination;
  - (iii) apogee;
  - (iv) perigee;
- (e) general function of the space object.

The Registration Convention and the Liability Convention work in tandem to hold nations accountable for the objects they launch into space.

9.5 Moon Agreement

The only one of the five UN space treaties that has failed to achieve widespread adoption is the 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement). Despite the Outer Space Treaty specifically mentioning the Moon in its language, many states that have ratified the Outer Space Treaty have refused to ratify the Moon Agreement, largely because of its clauses around common heritage and benefits sharing. Article 11 of the treaty, which begins by stating that, "The Moon and its natural resources are the common heritage of mankind…" goes on to prohibit national appropriation by any means, and mandates the equitable sharing of all lunar resources.

Article Fifteen goes even further stating,

> Each State Party may assure itself that the activities of other States Parties in the exploration and use of the Moon are compatible with the provisions of this Agreement. To this end, all space vehicles, equipment, facilities, stations and installations on the Moon shall be open to other States Parties….

Many states saw this treaty as a step too far, especially considering the scientific and strategic value of the Moon. The Moon Agreement's small number of parties is an indication that states see the lunar domain as distinctly different from outer space.

9.6 Bogota Declaration

Although the existing treaties and declarations appear to show international consensus on the status of space as a commons, some nations have made attempts to designate certain portions of space subject to exclusive claims by a state. The Declaration of the First Meeting of Equatorial Countries (Bogota Declaration) is another attempt to limit the commons designation in outer space.

In 1976, representatives of Colombia, Congo, the Democratic Republic of the Congo (DRC; named Zaire at the time), Ecuador, Indonesia, Kenya, and Uganda met in Bogota to discuss geostationary orbits as natural resources. The collection of these countries and their position on the equator was essential to this declaration as the only orbital category where satellites are stationary with respect to Earth is geosynchronous orbit (GEO). As discussed above, roughly 10 percent of satellites are in this orbit and they are all positioned in the plane of the equator. Unsurprisingly, equatorial countries were in favor of considering segments of GEO above their national borders as natural resources despite the fact none of the signing countries have satellites in GEO.[23] The agreement plainly states that "...the segments of geostationary synchronous orbit are part of the territory over which Equatorial states exercise their national sovereignty." These statements are in direct contradiction to UN declarations and treaties to which some of these equatorial nations are parties. These territorial claims are like the Antarctic claims made prior to the Antarctic Treaty, and like the Antarctic claims, they are not legally recognized.

10. Governance Regime Success

With a high-level understanding of space policy and the history of its implementation, we can evaluate domains of outer space for institutional performance, and the success or failure of the governance regime applicable there, based on Ostrom's eight design principles.

As discussed, we must examine the subdomains of space individually. However, specific and widely accepted treaties only exist for space generally. These treaties include the Outer Space Treaty, the Rescue Agreement, the Liability Convention, and the Registration Convention. While some states have attempted to govern specific areas (Bogota Declaration and Moon Agreement), other spacefaring nations do not widely accept these agreements.

Table 6. Management of the space subdomains according to Ostrom's principles for a commons.

SITE	Clear boundaries & memberships	Congruent rules	Collective-choice arenas	Monitoring	Graduated sanctions	Conflict-resolution mechanisms	Recognized rights to organize	Nested units	Institutional performance
EARTH ORBIT	Yes	Yes	Yes	Yes	Weak	Weak	Yes	No	Fragile
CELESTIAL BODIES	Weak	Weak	Yes	Weak	No	No	Weak	No	Likely to Fail
INTERPLANETARY SPACE	Yes	Yes	Yes	Yes	Weak	Weak	Yes	No	Likely to Fail

[23] At the date of publication (2023), Colombia, Ecuador, Indonesia, and Uganda do have satellites in LEO. Congo, DRC, and Kenya do not have any satellites in orbit.

Despite unified management mechanisms, the space subdomains have some differences in institutional performance.

In terms of clear boundaries and memberships, each subdomain has well defined boundaries and membership principles. Definitional distinctions separate each subdomain, but as evidenced by the Moon Agreement, some disagreement exists on the extent of the commons on the Moon and other celestial bodies. As such, this design principle scores "weak" for celestial bodies.

In terms of congruent rules, because multiple treaties exist for space generally, congruent rules do exist, however, only Earth orbit scores highly in this category because multiple states have national laws and policy that buttress the international agreements.

Collective choice arenas exist for all domains because the UN, which operates by collective choice, has organized all the successful treaties mentioned above. Of course, while all members have voting power, wealthier and more powerful nations leverage economic and political pressure making the organization less than equitable.

Monitoring for space domains becomes more challenging with distance from the Earth. NASA and DoD track most satellites from Earth's surface, and the registration convention allows for effective monitoring. However, knowledge of specific actions on a distant planet or far from Earth's orbit is difficult. No agreements currently exist that require detailed reports of activity on celestial bodies or interplanetary space.

Graduated sanctions do not exist in any robust form. While treaty parties agree to terms, stakeholders have not reached agreement on how they would handle non-compliance. Instances when states violated agreements (e.g., the *Kosmos 954* accident) have not resulted in sanctions. Theoretically, the UN or individual states could enact sanctions against a violating party, but the process to do this has not been codified.

Similarly, the UN or another international organization could act as a mediator for conflict resolution, but they have not agreed on this process. However, as the subdomain with the most international agreement, states are more likely to protect Earth orbit with sanctions and conflict resolution mechanisms.

Recognized rights to organize exist for all subdomains of outer space, but the failure of the Moon Agreement cast some doubt on lunar organization.

Nested units are not currently present for space subdomains individually. The Outer Space Treaty does mention specific domains or subdomains by name, but stops short of individualized management mechanisms.

Overall, each space management mechanism scores "fragile" or even "likely to fail." The major gaps include monitoring, graduated sanctions, conflict resolutions, and nested units. While Ostrom's institutional analysis is a helpful tool for predicting the success of a particular mechanism, the strength of the governance regime (i.e., the "institution") is not the only principle at play.

The demand for a particular domain also impacts how likely a commons is to fail. While interplanetary space management may be likely to fail according to Ostrom, the vastness and low demand make it less likely to become spoiled or overcrowded. Furthermore, although Earth orbit scores higher on the analysis, its demand is currently the highest. Spoilage of Earth orbit would also mean spoilage of the other domains if the Kessler Syndrome became a reality.

11. POTENTIAL INTERNATIONAL ACTION TO ADDRESS MANAGEMENT DEFICIENCIES

Humans have been active in space for decades, but managing and regulating space is still a developing field. As shown in previous sections, the existing mechanisms are not robust enough to serve as effective mechanisms for commons management. However, this approach is not the only potential solution. Stakeholders could accomplish effective management through commons management, novel legal tools, privatization, or a combination of all three.

To strengthen commons management mechanisms, establishing nested units is essential. Along with defining domains, this strategy would allow for specific mechanisms for the fundamentally different space domains. States may need to establish specific monitoring, graduated sanctions, and conflict resolution strategies to further strengthen these mechanisms. Effective management must also address the different functions that space serves. Just as UNCLOS addressed territorial and economic challenges for the ocean, agreements crafted for space must move beyond non-armament to address commercial use of space.

Nested units beyond the subdomains already mentioned may also be necessary. Just as stakeholders manage specific ocean and atmosphere CPRs with individual treaties, so might space stakeholders address CPRs with individual agreements. Despite fisheries and mineral resources both being in the ocean, states manage them with distinct strategies. The different uses for satellites around Earth might require specific management methods for each use. ISRU on the Moon may also require individual management.

Some terrestrial domain mechanisms could be helpful frameworks for space domains. The Antarctic Treaty could be a helpful framework for lunar activity. A lunar treaty based on the Antarctic Treaty would prohibit territorial claims, and it would reserve the Moon for scientific research. However, stakeholders could still use lunar resources to some extent. Additionally, this treaty would encourage international cooperation in the name of scientific research. Resource use could also draw from existing management mechanisms. For example, stakeholders could use a structure like that of deep seabed mining to manage celestial body ISRU. Like the International Seabed Authority, which acts as an agent for developing nations, states could create an international space mining authority to act as an agent for nations not yet capable of this technology.

To protect Earth orbit from overcrowding, states could establish cooperative agreements to limit the number of active satellites or require deorbiting inactive ones. Nations that dominate the satellite economy would likely react to these agreements with resistance. In a system where each participating state receives a number of satellite credits, developing states could sell/lease their credits or hold them for future use. This would generate wealth while still protecting the orbital domains as a commons. This approach might also encourage safely deorbiting satellites once they are obsolete so that another satellite can take its place without increasing the total number. This management strategy may help avoid the Kessler Syndrome.

The likely failure of existing management mechanisms may mean that these methods are not suited to space domains. The unique attributes of space may require novel management methods. Tepper and Whitehead present the New Zealand Te Urewera Act (2014) as an example of alternative governance models potentially suited for space. This model is a hybrid between Common Law and the indigenous legal traditions of the Māori. Te Urewera was formerly a national park on New Zealand's Northern Island. However, the act asserted nonhuman legal person status. The act recognizes that "the rights, powers, and duties of Te Urewera must be exercised and performed on behalf of, and in the name of, Te Urewera ... by Te Urewera Board." A diverse set of stakeholders representing both legal traditions comprises the board. While the stakeholders for space domains represent different interests, granting nonhuman legal person status to space domains—particularly celestial bodies—could be an effective management method. This strategy coupled with a board protecting the interest and integrity of the domain may prove more effective than traditional treaties. Tepper and Whitehead show in their paper that this strategy still satisfies most of Ostrom's design principles for commons management.

Critics condemn privatization in commons discussions because it monopolizes a resource. This action obviates resource use by others, but in some cases it is the only effective strategy for sustainable use. The legal structures in place at a national level allow for many of Ostrom's design principles to be satisfied, but they also prevent true collective choice or right to organize. Stakeholders can only implement privatization on excludable resources, so some Earth orbits and interplanetary space are not candidates for this method. However, some degree of privatization may be an effective management strategy on the Moon and other celestial bodies.

A single approach is not likely to be sufficient for each domain just as a single treaty is not effective to protect space. A successful approach to commons management will likely require each of these methods to some degree. Additionally, static mechanisms are likely to fail in a rapidly changing space economy. Hybrid and dynamic mechanisms, while challenging to create, are potential solutions to manage space commons.

12. CONCLUSION

Returning to the original question: "Is space a global commons?", we now see the complexity of the situation. World leaders disagree on the answer, and various international legal instruments seem to contradict some national policies and the rhetoric of some administrations. The question does not have a single clear answer, but we see it better as a range of questions with a range of answers.

With a more nuanced view of space, commons, economics, and international law and policy, we can answer what is perhaps the more important question: "how do we protect space from the tragedy of the commons?"

We examine what is meant by "space." Some see space as anything beyond 80 kilometers above sea level (McDowell J., 2018). Others draw the line higher at 100 kilometers. Some see space as only the empty area between Earth and other celestial bodies, but others consider those stars, planets, moons, and asteroids as space. In answering this question, we see space as a collection of distinct subdomains with one common means of access: upward through Earth's atmosphere. At a general level, we can categorize the various subdomains of outer space as follows: Earth orbit, celestial bodies, and interplanetary space. As unique realms, we must ask the commons question of each subdomain individually.

Next, we must answer what is meant by "global commons." We look to the earliest references to the commons by Lloyd and its modern application by Hardin to categorize a CPR as both rivalrous and non-excludable. Considering these attributes, we understand that they exist not in binary form, but as a range of qualities (Henry, 2022). Two domains may both be rivalrous or excludable to different degrees. Seeing these two qualities as linear ranges, we can set them as x and y axes and plot the domains on the corresponding chart. Such a graph allows for examination of the domain as a commons and reveals why disagreement on this designation exists (Leach, 2004).

Ostrom's work in this field shows that early ideas of commons management, the Leviathan and privatization, are not the only effective mechanisms. Self-governance is possible if the community establishes a robust enough system. Using Ostrom's eight design principles we can evaluate the strength of a commons management mechanism (Ostrom, 1990).

Other global commons exist and may provide a helpful framework for space governance. The governance structures for Antarctica, the sea, and the atmosphere provide both useful examples and cautionary tales. Applying Ostrom's design principles reveals the institutional performance of these structures, showing their strengths and deficiencies. However, global CPRs on Earth are distinctly different from space, and while some of these mechanisms may be helpful tools, none translate exactly to space domains. The combination of problems of access, resource availability, resource use, and economic potential make space unlike any single Earth-based commons. We must acknowledge the unique attributes of space domains in our management strategies.

Existing space law and policy is critical to understanding space as a commons. Resolutions, declarations, and especially treaties negotiated in the UN show where there is international consensus, and where disagreement exists. Areas without consensus are particularly vulnerable to the tragedy of the commons. In these domains, we can expect unrestricted resource exploitation. Here, there is no guarantee of access to these resources by less developed nations or continued use at all. Without international agreement, and with each state acting in its own self-interest, to borrow Hardin's phrase, "Ruin is the destination" (Hardin, *The Tragedy of the Commons,* 1968).

By looking at existing space law and policy, we find the institutional performance of space domains is fragile or likely to fail. In some cases, the current minimal usage of space domains is the only thing protecting them from the tragedy of the commons. In each of these domains, we can see what action is necessary to make these institutions more robust. In some cases, we can look to terrestrial commons for possible effective management mechanisms. We also see the potential of novel management methods and limited privatization (Tepper & Whitehead, 2018). However, no single solution is a panacea, and success likely requires a combination of methods.

In 1957, the Soviet Union launched the first artificial satellite into space. Since that time, the area around the globe has become increasingly crowded with debris and thousands of satellites. If orbital congestion is not properly managed, a series of cascading collisions could render certain orbits unsafe for space operations and this would be an orbital manifestation of the tragedy of the commons. Even if we avoid this danger, we may still compete for orbital positions leading to conflict far above national borders. The earliest users may completely claim or consume the limited resources on moons and planets before other actors are able to access them. The use of space and celestial bodies is at risk of spoilage, where it would no longer be available for the benefit of all mankind. These dangers are avoidable. With international cooperation and robust management mechanisms, humans can use space in perpetuity. These mechanisms require leaders, states, and industries to acknowledge space as a global commons. With these principles as a foundation, space can truly be a resource for the good of all humanity.

Daniel Patton
December 2022

REFERENCES

Aristotle. (1905). *Aristotle's Politics.* Oxford: Clarendon Press.

Brearly, A. (2008). Reflections upon the notion of liability: The instances of Kosmos 954 and space debris. *Journal of Space Law,* 291.

Buck, S. J. (1998). *The Global Commons an Introduction.* Washington, DC: Island Press.

Cheng, B. (1998). *Studies in International Space Law.* United Kingdom: Clarendon Press.

China Aerospace Studies Institute. (2013). *In Their Own Words: Foreign Military Thought.* Montgomery, AL: China Aerospace Studies Institute.

Dressler, A. E. (2021). *Introduction to Modern Climate Change*. Cambridge University Press.

Elvis, M., Krolikwski, A., & Milligan, T. (2020). Concentrated lunar resources: imminent implications for governance and justice. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 379(2188).

Executive Order 13914, *Encouraging International Support for the Recovery and Use of Space Resources,* 85 FR 20381 (04 10, 2020).

Food and Agriculture Organizations of the United Nations Code of Conduct for Responsible Fisheries. (1995).

Fourier, J.-B.-J. (1827). *Mémoire sur les températures du globe terrestre et des espaces planétaires.* Mémoires de l'Académie Royal de Science de l'Institut de France.

Fuchs, V. (1983). Antarctica: Its History and Development. *Antarctic Resources Policy: Scientific, Legal, and Political Issues*, 13-14.

Geneva Conventions on the Law of the Sea. (1958).

Grennfelt, P., Engleryd, A., Hov, Ø., Rodhe, H., & Cowling, E. (2020). Acid rain and air pollution: 50 years of progress in environmental science and policy. *Ambio,* 849-864.

Grotius, H. (1583-1645). On the Law of Spoils.

H.R.2809 - 115th Congress (2017-2018): American Space Commerce Free Enterprise Act. (2018, April 25). http://www.congress.gov/.

Hardin, G. (1968). The Tragedy of the Commons. *Science,* 1243-1248.

Hardin, G. (1978). Political Requirements for Preserving our Common Heritage. *Wildlife and America,* 310-317.

Henry, E. G. (2022, April 7). Private Good. Encyclopedia Britannica. Retrieved from https://www.britannica.com/topic/private-good

International Convention for the Regulation of Whaling (ICRW). (1946).

Jankowitsch, P. (2015). Handbook of Space Law. In F. von der Dunk, & F. Tronchetti (Eds.). Edward Elgar.

Jennings, R. (1963). The Acquisition of Territory in International Law. Manchester: University of Manchester Press.

Justinian I. (483-565). The Digest of Justinian.

Kadam, T. (2022, June 1). *Lunar Research Station: Russia, China Almost Ready To Ink Pact On 'Moon Base' That Will Rival Artemis Accords – Rogozin.* Retrieved from Eurasian Times: https://eurasiantimes.com/russia-china-almost-ready-to-ink-pact-on-moon-base/

Kessler, D. J., & Cour-Palais, B. G. (1978). Collision Frequency of Artificial Satellites: The Creation of a Debris Belt. *Journal of Geophysical Research,* 2637-2646.

Kyoto Protocol. (n.d.). 1997.

Laver, M. (1986). Public, Private and Common in Outer Space: Res Extra Commercium or Res Communis Humanitatis beyond the High Frontier? Political Studies. *Political Studies,* 359-373.

Lay, S. H., & Taubenfeld, H. J. (1968). *The Law Relating to Activities of Man in Space.* University of Chicago Press.

Leach, J. (2004). A Course in Public Economics. Cambridge University Press.

Lloyd, W. F. (1833). Two Lectures on the Checks of Population.

McDowell, J. (2018). The edge of space: Revisiting the Karman Line. *Acta Astronautica,* 668-677.

McDowell, J. (2022, October 20). Launch Log. Retrieved from Jonathan's Space Report: https://planet4589.org/space/gcat/data/derived/launchlog.html

NASA. (2021, May 26). *Space Debris and Human Spacecraft.* Retrieved from NASA: https://www.nasa.gov/mission_pages/station/news/orbital_debris.html

NASA. (2022). *Future.* Retrieved from NASA Science, Mars Exploration Program: https://mars.nasa.gov/mars-exploration/overlay-humans/

NASA. (2022). *Moot to Mars Overview.* Retrieved from Explore Moon to Mars: https://www.nasa.gov/topics/moon-to-mars/overview

(2010). *National Security Strategy.* Washington, DC: The White House.

NATO. (2022, January 17). *NATO's overarching Space Policy.* Retrieved from North Atlantic Treaty Organization: https://www.nato.int/cps/en/natohq/official_texts_190862.htm#:~:text=In%20November%202019%2C%20NATO%20declared,Air%20Command%20in%20Ramstein%2C%20Germany.

O'Leary, B. (1977). Mining the Apollo and Amor Asteroids. Science, 363-366.

Open Lunar Foundation. (2021). *Res Luna: Resource Systems and Governance Approaches.* Open Lunar Foundation.

Ostrom, E. (1990). *Governing the Commons: The evolution of institutions for collective action.* Cambridge University Press.

Paris Agreement. (n.d.). 2015.

(1987). *Protocol on Substances That Deplete the Ozone Layer* (Montreal Protocol).

Raymond, M. (2012, October 26). *The Internet as a Global Commons?* Retrieved from CIGI: https://www.cigionline.org/publications/internet-global-commons/

Rosenbaum, W. (1987). *Energy, Politics, and Public Policy.* Washington DC: Congressional Quarterly Books.

Ross, S. D. (2001). Near-Earth Asteroid Mining. California Institute of Technology.

Smith, R. A. (1872). *Air and Rain, the beginnings of a chemical climatology.* London: Longmans, Green, and Company.

Tepper, E., & Whitehead, C. (2018). Moon Inc.: The New Zealand Model of Granting Legal Personality to Natural Resources Applied to Space. *New Space,* 288-298.

The Declaration of the First Meeting of Equatorial Countries (Bogota Declaration) . (1976).

The Hague Conference for the Progressive Codification of International Law. (1930).

The United Nations Antarctic Treaty. (1959, December 1).

U.S. Navy. (2016). *Joint Operating Environment 2035.* U.S. Navy, Joint Force Development.

United Nation. (1961, December 20). Resolution 1721 A and B (XVI) of 20 December 1961: International cooperation in the peaceful uses of outer space.

United Nations. (1963). The Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space.

United Nations. (1967). 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).

United Nations. (1968). Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched in Outer Space (Rescue Agreement).

United Nations. (1972). Convention on International Liability for Damage Caused by Space Objects (Liability Convention).

United Nations. (1974). Convention on Registration of Objects Launched into Outer Space (Registration Convention).

United Nations. (1979). Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement).

United Nations. (1979). Convention on Long-Range Transboundary Air Pollution (CLRTAP).

United Nations Conferences on the Law of the Sea (UNCLOS) . (1958).

United Nations Conferences on the Law of the Sea II (UNCLOS II) . (1960).

United Nations Conferences on the Law of the Sea III (UNCLOS III) . (1982).

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.). 1992.

US Space Command. (2022). *Frequently Asked Questions.* Retrieved from U.S. Space Command: https://www.spacecom.mil/About/Frequently-asked-questions/

Velders, G. J., Andersen, S. O., Daniel, J. S., Fahey, D. W., & McFarland, M. (2007). The importance of the Montreal Protocol in protecting climate. *Proceedings of the National Academy of Sciences*., 4814-4819.

Watt, L. v. (2022, August 19). Antarctica. *Encyclopedia Britannica.* Retrieved from https://www.britannica.com/place/Antarctica

World Meteorologial Organization et al. (1986). Atmospheric Ozone 1985: *Assessment of Our Understanding of the Process Controlling Its Present Distribution.* Geneva: World Meteorlogical Organization.

ACKNOWLEDGEMENTS:

Advisor and editor: Christopher Johnson

Feedback: Ian Christensen, Peter Martinez, and Brian Weeden.

525 Zang Street, STE. D
Broomfield, CO 80021 USA
v : + 1 303 554 1560
e : info@swfound.org

1779 Massachusetts Ave. NW
Washington, DC 20036 USA
v : + 1 202 568 6212
e : info@swfound.org

swfound.org

SWF Publication: 23.01
Published: 23.03