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Managing Space as a Global Commons

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Abstract

To prepare for a changing space economy, stakeholders seek to establish 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. The landscape of outer space utilization and exploration is expanding from primarily scientific research to include economic outcomes, and private-sector space technology is experiencing exponential growth. The future of space exploration likely includes additional space stations, exploration of other planets, and in-situ resource utilization. Mismanagement of space could result in Kessler syndrome or monopolies of rare space resources. These changes in the space economy demand consideration of space as a global commons. However, perspectives on space as a global commons vary widely and have economic, legal, and political implications.

Beginning with Lloyd and Hardin, I examine commons criteria and apply them to terrestrial and extraterrestrial domains. Using a rivalry and excludability continua I show differences between three separate space domains (earth orbit, celestial bodies, and interplanetary space) and consider the present and predicted demand and capacity for these domains. I further compare space domains to common pool resources on earth including the oceans, atmosphere, and Antarctica.

I evaluate space domain management using Ostrom's eight design principles. Identifying management deficiencies, I show where additional policy is possible. Considering commons management strategies already in place like the Antarctic Treaty, UNCLOS, and climate agreements, I identify possible solutions and risks. I also consider governance concepts like the New Zealand Te Urewera Act as proposed by Tepper and Whitehead. Finally, I make the case for dynamic management strategies to accommodate a changing space economy.

Keywords: commons, policy, resources, global commons

1. Introduction

In 2022, the global number of successful orbital rocket launches totaled 180 for the first time in history, marking significant growth in the aerospace sector not seen in decades [1]. Historically, two nations dominated the launch list, but today's orbital rockets are launched by a variety of nations and private partners. Notably, of the 180 successful launches in 2022, over a third were launched not by a major government space agency, but by a single private corporation: Space Exploration Technologies Corp. (SpaceX). While SpaceX is the leading company in the aerospace industry in terms of orbital launch numbers, many other companies occupy the space economy. State-owned launches still dominate some nation's launch lists, but globally, commercial space activity shows no sign of slowing down. Technology currently used and tested is slated for new public and private missions in earth orbit, the moon, and beyond [2].

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 the space commons decision, policy leaders can make decisions about the role of private corporations in space.

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 [3], the most significant space-capable actors (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 largely avoid using the term "commons".

US leaders have made conflicting statements about the topic. President Obama referred to space as a global commons in his May 2010 National Security Strategy [4]. The Department of Defense reaffirmed this stance with statements made in the *Joint Operating Environment (JOE) 2035* [5], 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." However, President Trump's Executive Order 13914 on April 6, 2020, contradicted these statements. The same order 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. In 2019, NATO declared space an "operational domain" as part of their "deterrence and defense posture" [6]. Furthermore, the European Council recently concluded that "space is a global common that should be free for exploration and use by all states." [7]

Other nations, notably China, seem to 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* [8]. However, some of them have programs or policies in place to do the same space resource exploitation as the United States [9], calling into question whether these policy differences are substantive.

While many seem to consider space a global commons, there is no consensus even among space capable nations. The use of specific terms in space literature and agreements further clouds the understanding of space as a commons. Phrases including "…For the benefit of all peoples", "the province of all mankind", or "…common heritage of all mankind" are both subjective and poorly defined. However, these phrases have been the bases for an economic commons designation by some [10].

Furthermore, even nations that may consider space a global commons disagree on how to manage the domain. This imprecision hurts the cause for commonality, but it results from several factors. Space is not a homogenous domain and 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. This disadvantage is a special concern for private space corporations whose profits are linked to unlimited use of the domain. Nonetheless, effective space policy should benefit all space stakeholders 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 one must consider the earliest examples of the commons, and how the concept has changed over time.

3. History of the Commons

Looking at the earliest uses of the terms by William Foster Lloyd and its modern application by Garrett Hardin, we understand that an economic commons is both rivalrous and non-excludable [11]. The term *rivalrous* here means that a resource is finite and that its use or occupation by one person reduces its availability for another. The term *excludable* means that someone could control the use or access of a resource. Excludable goods are often private goods.

Traditional understanding displays these criterial as binary attributes, but modern scholars now see these categories as a continua [12,13]. This interpretation adds nuance to the commons discussion and explains why informed scholars can disagree about domain categories. The charts below show the benefits of a continua view of commons criteria. The first chart shows a rivalry and excludability matrix. The second chart shows relative rivalry and excludability along an x and y axis. The nuance of relative placement of a domain shows why some may disagree on a commons status.*

	Non-excludable	Excludable
Rivalrous	Common Pool Resource (commons): Fish stocks, atmosphere	Private Good: Personal goods and property
Non-Rivalrous	Public Goods: Roads, parks, radio stations	Club Goods: Country Club, Workout Gyms, Subscription media services

Fig. 1. Rivalry-excludability matrix

* 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.

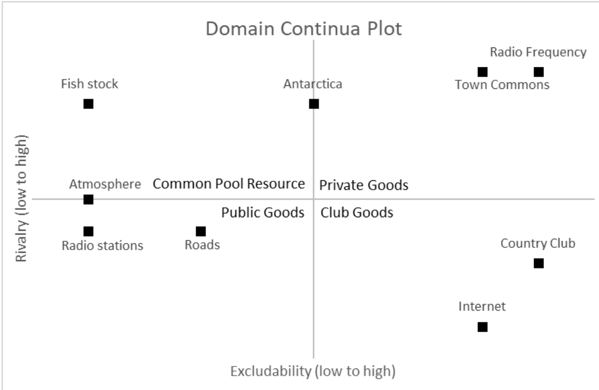

Fig. 2. Domain continua plot

Two legal terms provide a helpful distinction in commons discussions. First, *res nullius* [†] refers to something that no one owns. 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. 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*, the use of low earth orbit by many nations would qualify it as *res communis* [14].

A related term is *res extra commercium*[§]*:* a thing that is outside of commercial trade. 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 [14]. Space may have been considered *res extra commercium* in the early days of space exploration, but current activities show commercial feasibility and profitability [15].

4. Commons in Existing Space Law

Although it is not the only multinational organization with agreements impacting space policy,[**] guiding principles for international cooperation in and management of outer space by the United Nations (UN) come in three forms: Resolutions adopted by the General Assembly, principles adopted by the General Assembly, and 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) was 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 five treaties took decades to negotiate and sign, and apart from the Moon Agreement, have widespread adoption. The Bogota Declaration is a notable example of a declaration that the UN did not organize. The 1976 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.

The five UN treaties address some of the core principles for operating in space, but they are products of a time when space exploration was a national, not commercial, endeavor. While some see the language of these treaties to reinforce a space commons perspective, they do not specifically address commercial operations in space or the complexity of in-situ resource utilization (ISRU). In short, these treaties were written with the old model of aerospace companies. The apparent oversight is likely a result of the treaties' main goal of the non-armament of space. Written during the cold war, these treaties were aimed at avoiding national and nuclear conflict in space, so avoiding commercial exploitation of space may not have been considered [16]. Development of the Artemis Accords focuses on addressing some of the challenges including the new model of space companies, but two major space nations: China and Russia, have not signed the accords.

5. 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 rocket technology has been

† From Latin translating to nobody's thing

‡ From Latin translating to community or public thing

§ From Latin: a thing outside of commerce

** START and SALT nuclear arms control treaties have significant implications for space.

an excludability mechanism[††]. As this technology has become more widely used 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 is more ubiquitous, understanding space as a collection of domains is 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 air sports 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 km [17]. Still others like the U.S. Space Command continue to use 100 km for the ease of use [18].

5.1 Earth Orbit (LEO, MEO, elliptical, and geostationary

Once in outer space from Earth, the first region encountered is now commonly known as low earth orbit (LEO). This domain sits between 100km and 2000km above earth. LEO is the most easily accessible space domain, and users have a variety of communication, position, and imaging satellites. 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 International Space Station 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. The current number of LEO satellites total 4700 and make up 86% of the total satellites in orbit [1].

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. Kessler Syndrome is the term for this process of cascading collisions, named after one of the scientists who first identified it [19]. Kessler Syndrome can lead to increased costs of operating satellites in LEO. At some point, those costs may get high enough that certain actors or missions are unfeasible 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 [20]. We do not only find debris in LEO. Distribution 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 through LEO.

Medium earth orbit (MEO) is the region between 2,000km and 35,786km, 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 only 140 total satellites [1]. The demand for MEO satellites and positions available make it less rivalrous than other domains.

Geosynchronous orbit (GSO) is the region near 35,786km above the Earth, with geostationary earth orbit (GEO) being a special case of an orbit at exactly 35,786 km, 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 [1].

Space debris is also a risk for GSO. While the total number of items tracked by NASA and DoD are far fewer in GSO, the relative distance 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 [20].

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 [1]. 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 categories, meaning that if LEO becomes inaccessible due to

[††] 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 technology. Because weaponization of this technology poses particularly high risk to national and international security, the US still enforces ITAR even when a growing number of nations possess launch capability.

Kessler Syndrome, debris will likely impact HEO as well.

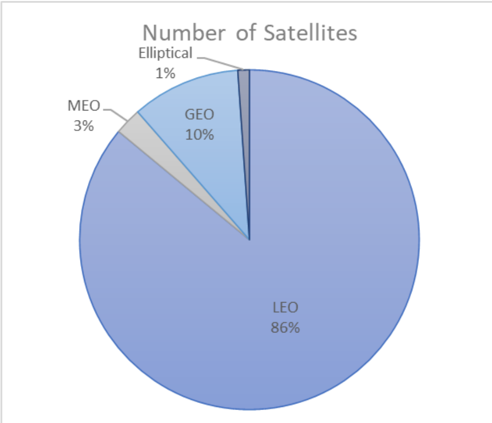

Fig. 3. Satellites in earth orbit

5.2 Celestial Bodies

Although geocentric orbits remain the most utilized space domains, celestial bodies have received increased attention. 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 fourteen planetary bodies since Luna 1 crashed into the Moon.

Moon is the body with the most human contact. 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 the space. Research indicates that the lunar poles likely contain the most valuable lunar resources [22,22]. These areas are the most likely selections for in-situ resource utilization (ISRU). The potential value of this resource 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 [22]. 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 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 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.

5.3 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.

6. Limitations in Domain Analysis

If we see space as a collection of sub-domains we can analyze their respective rivalry and excludability with the same continua plot shown earlier.

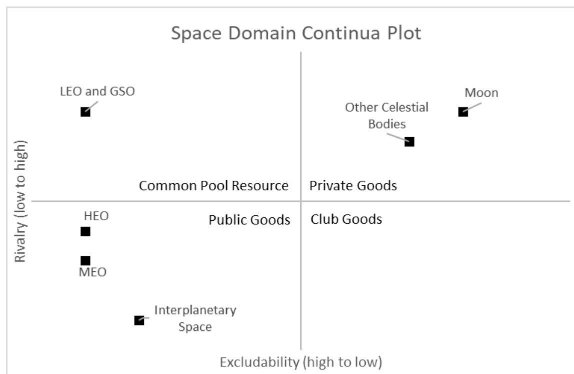

Fig. 4. Space domain continua plot

As indicated in figure 4, space domains are not all definitionally common pool resources‡‡. However, some sub-domains (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.

In understanding space as a commons, investigating the current management of the domain is key to understanding its vulnerabilities. Analysis of the

‡‡ 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.

subdomains may be performed with existing institutional frameworks.

Elinor Ostrom described eight design principles used to define the strength of a commons management mechanism: clearly defined boundaries, congruence between appropriation and provision rules and local conditions, collective-choice arrangements, monitoring, graduated sanctions, conflict-resolution mechanisms, minimal recognition of rights to organize, and nested enterprises [23]. Applying these principles to the subdomains of space allows for the identification of potential deficiencies in existing mechanisms.

Table 1. Sub-domains of space and design principles

Site	Clear boundaries & memberships	Congruent rules	Collective-choice arenas	Monitoring	Graduated sanctions	Conflict-resolution mechanisms	Recognized rights to organize	Nested units
Earth Orbit	Yes	Yes	Yes	Yes	Weak	Weak	Yes	No
Celestial Bodies	Weak	Weak	Yes	Weak	No	No	Weak	No
Interplanetary Space	Yes	Weak	Yes	Weak	No	No	Yes	No

The unique attributes of space make performing a robust institutional analysis impossible, but Ostrom's design principles can help identify current gaps in space management. These potential gaps include nested units and conflict resolution mechanisms.

As noted previously, space domains are not definitional commons, and the lack of effective commons management may partially be a sign that stakeholders do not want to categorize space as a commons. This perspective would be particularly advantageous to private space companies. A *res nullius* view of the domain would open its newly accessible resources to commerce. Such a determination would mirror that of early European settlers in the Americas.[§§]

7. Novel Governance Concepts

Considering these management gaps, some have proposed novel mechanisms like the New Zealand Te Urewera Act (2014) [24] as possible strategies for space commons management. 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.

Non-regulatory management mechanisms like the Artemis Accords are currently being tested [25]. This agreement relies upon incentivizing cooperation and formalizing a set of operating parameters through shared science and exploration missions, thus eliminating the need for sanctions. However, the success of this approach is limited to its adopters and could harm the cause for a unified global space policy as groups of nations agree to their own sets of space principles.

A single approach is not likely to be successful 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.

8. Conclusion

Findings from this research reveal that the questions of commons status are often complex, but looking at space as a global commons can help policy makers and stakeholders better understand the risks and opportunities inherent to the domain. Individual parts of space, like geocentric orbits, may be an economic commons by way of their rivalry and excludability, but other parts like celestial bodies and interplanetary space may not qualify by the same criteria. Stakeholders may choose to designate space domains as legal commons with treaties and agreements, but this decision must come by consensus of participants. As Ostrom's design principles show, existing agreements have management gaps, however policy analysis shows opportunities for more robust mechanisms by both mirroring successful management of terrestrial commons and testing novel governance mechanisms. The research, defense, and commercial use of space is still developing, so consideration of the present and future use of the domain is essential to avoiding irreversible impacts.

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