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Professor Taw – I am endlessly grateful for the slightly sporadic sequence of events that inspired this paper. It started in a classroom in Seoul, where your sophistication, kindness, and insightfulness sparked my interest in and enthusiasm for international relations—and it culminated in a global pandemic, throughout which your support and compassion have been one of few constants. Thank you.

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*That’s the paradox of today’s world, where peace comes from deterrence and weaponization; and even outer space, God’s sole preserve, has not been left out. [[1]](#footnote-1)*

–PN Tripathi

*There will be a lot of jobs on Mars! [[2]](#footnote-2)*

–Elon Musk

ɪɴᴛʀᴏᴅᴜᴄᴛɪᴏɴ

Apollo 11 launched from the Kennedy Space Center at 9:32 a.m. on July 16, 1969. At 10:56 p.m. on July 20, Neil Armstrong and Edwin “Buzz” Aldrin became the first humans to walk on the moon.[[3]](#footnote-3) They left a plaque on the lunar module *Eagle* inscribed, “Here men from the planet Earth first set foot upon the moon. July 1969 A.D. We came in peace for all mankind.”[[4]](#footnote-4)

Fifty-one years later, China’s *Chang’e 4* mission, named after the Chinese goddess of the moon, has successfully landed on the far side of the moon, equipped with science instruments including a terrain camera, a low frequency spectrometer, and a lunar biosphere experiment to investigate how silkworms, potato, and seeds of the small flowering plant *Arabidopsis thaliana* grow in lunar gravity.[[5]](#footnote-5) Japan’s *Hayabusa2* probe has successfully touched down on the surface of the asteroid Ryugu, a carbonaceous (C-type) asteroid—an asteroid composed of nickel, iron, cobalt, water, nitrogen, hydrogen, and ammonia, with a potential value of 82.76 billion USD and estimated profits of 30.08 billion USD.[[6]](#footnote-6) The National Aeronautics and Space Administration (NASA)’s first asteroid sampling spacecraft is scheduled to travel to the surface of the asteroid Bennu, a rare primitive and carbon-rich (B-type) asteroid composed of iron, hydrogen, ammonia, and nitrogen, with a potential value of 669.96 million USD and estimated profits of 185 million USD, on October 20, 2020.[[7]](#footnote-7)

In May 2019, Donald Trump tweeted, “Under my Administration, we are restoring @NASA to greatness and we are going back to the Moon, then Mars. I am updating my budget to include an additional $1.6 billion so that we can return to Space in a BIG WAY!”, directing NASA to accelerate plans to return to the lunar surface and land American astronauts on the South Pole Moon by 2024.[[8]](#footnote-8) NASA administrator Jim Bridenstine confirmed the agency’s commitment to landing the next man—and the first woman—on the moon by 2024.[[9]](#footnote-9) In September 2018, Elon Musk’s SpaceX program announced that Japanese fashion innovator Yusaku Maezawa will be the company’s first private passenger to the moon—in 2023.[[10]](#footnote-10)

International space law today lacks a regulatory framework, enabling a *laissez-faire* approach to space-based resource appropriation and exploitation—to date, the 1967 Outer Space Treaty (OST) is effectively the ‘constitution’ for all space activity. The OST establishes the principle of non-appropriation—that is, no state has the right to claim sovereignty over the moon or other celestial bodies—and designates outer space *res communis omnium* (a thing of the entire community) and celestial bodies *res extra commercium* (a thing outside commerce).[[11]](#footnote-11) China, Russia, and the U.S. are all party to the OST. None have signed, ratified, and/or acceded the 1979 Moon Agreement, which controversially declares the natural resources of the moon and other celestial bodies *res communis humanitatis* (the common heritage of mankind).[[12]](#footnote-12) If the resources of outer space are *res communis humanitatis*, then not only can celestial bodies not be appropriated, but their resources are the property of mankind at large. Consequently, only eighteen nations are party to the Moon Agreement, in contrast to the one hundred and eighteen party to the OST.[[13]](#footnote-13)

As space transitions from an intriguing concept to an accessible reality, unimaginable opportunities for wealth, power and prestige crowd out visions of space and its resources as the common heritage of mankind. Nations’ behavior in space will presumably be self-interested and competitive, resources will be allocated on a free-for-all, first-come, first-serve basis, existing tensions between spacefaring nations will be exacerbated, developing countries that are not currently capable of independently building and launching spacecraft will be at a serious disadvantage, and international conflict over the resources of the moon and other celestial bodies virtually inevitable. Insofar as the issue of how space resources will be allocated remains ambiguous and unresolved, asteroid and lunar mining can be anticipated to facilitate a contemporary gold rush, and consequently, foster insecurity in outer space. It is imperative to conceptualize (in)security in space and to analyze the feasibility and implications of space-based activities in order to develop a second generation of international space law that effectively promotes the regulation of space activities and preemptively reduces the likelihood of catastrophic outcomes.

Yet, despite man’s expansion into outer space becoming increasingly feasible—and arguably necessary—and the prospect of mining space for invaluable metals and water closer to a reality than merely the content of science-fiction, international space law has experienced a shocking lack of development. Given the Cold War context in which the OST was written, today’s growing dependency on space for both national and global purposes, a rapidly-increasing global population, a finite amount of resources on Earth, and the relentless, destabilizing effects of climate change, that space law has remained stagnant since the Cold War gives significant cause for concern. Furthermore, with the modern rise in nationalism and state-centered politics, the shifting balance of hegemonic power, the global pandemic, and the ubiquitous threat of climate change, international tensions and (in)security are growing. The international community is in dire need of comprehensive space law and regulations to mitigate (in)security and international cooperation both in and from outer space.

Section 1 of this paper discusses the multifaceted nature of space (in)security—an emerging, three-dimensional definition distinguishes between security *in* outer space, security *from* outer space, and *outer* space for security. Section 2 reviews the 1967 Outer Space Treaty, the 1963 Limited Test Ban Treaty, the 1968 Rescue Agreement, the 1972 Liability Convention, the 1975 Registration Convention, and the 1979 Moon Agreement, the six treaties that constitute the *corpus juris spatialis* (fundamental principles of public international space law). Section 3 details states’ incentives to mine the moon, asteroids, and other celestial bodies and considers the economic viability and security implications of mining in space.

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On October 4, 1957, the Soviet Union launched *Sputnik I*, the first satellite, into space. As of May 2020, there are 2,666 total operating satellites in orbit; 1,454 of these are commercial, 599 are government, 477 are military, and 136 are civil. [[14]](#footnote-14) 1,327 of these are U.S. satellites. China, Russia, the U.K., and Japan have 363, 169, 133, and 65 satellites in orbit, respectively.[[15]](#footnote-15) Satellite and space technology play a significant role in our everyday lives—they enable GPS and navigation, Earth and climate observation, electronic intelligence, communications, technology development, television coverage, the internet, and so on.

The Handbook of Space Security (HbSS) emphasizes “two dimensions of space security – security in space and security on Earth from space.”[[16]](#footnote-16) Eight indicators of space security are provided: *(i)* the space environment; *(ii)* space situational awareness; *(iii)* laws, policies, and doctrines; *(iv)* civil space and global utilities; *(v)* commercial space; *(vi)* space support for terrestrial military operations; *(vii)* space systems protection; and *(viii)* space systems negation.[[17]](#footnote-17) An emerging, three-dimensional definition of space security advances the aforementioned conception of space security in a way that encompasses the substantial role of satellites in space-related security:

*Outer space for security: the use of space systems for security and defense purposes*

*Security in outer space: how to protect space assets and systems against natural and/or human threats or risks and ensure a sustainable development of space activities*

*Security from outer space: how to protect human life and Earth’s environment against natural threats and risks from outer space.[[18]](#footnote-18)*

While the focus of this paper is on (in)security *in* space as it pertains to asteroid and lunar mining (and the security implications on Earth *from* mining in space), the size and scope of satellite-dependency and vulnerability is critical to understanding space (in)security. Every country has a right to access space, and an increasing number of countries are currently developing the means to launch satellites. As space becomes increasingly congested, it becomes more contested and competitive, and as nations continue to invest, exploit, and benefit from being active in outer space, they likewise grow increasingly dependent on space, and consequently, more vulnerable—and security threats to space activities, both naturally and man-made, are proliferating.[[19]](#footnote-19) Satellites are particularly assailable—they typically follow a specific orbital path, often lack “situational awareness” (they may not realize they have been attacked, or whom they have been attacked by) and the capacity to defend themselves from attack, and satellites are neither inexpensive nor easily replaceable.[[20]](#footnote-20)

There are four types of counterspace weapons: kinetic physical, non-kinetic physical, electronic, and cyber.[[21]](#footnote-21) Kinetic physical attacks, such as direct-ascent (DA) and co-orbital anti-satellite weapons (ASAT) attempt to destroy space assets and are easy to attribute to a specific attacker. Anti-satellite weapons (ASAT) pose a serious threat to the peaceful exploration and exploitation of space.[[22]](#footnote-22) In January 2007, China tested a DA-ASAT missile, destroying its own non-operational satellite and created 3,000 pieces of trackable debris—debris pose a major, indiscriminate threat to satellites in low Earth orbit (LEO)—and in April 2020, Russia executed a non-destructive test of a DA-ASAT.[[23]](#footnote-23) Non-kinetic physical attacks utilize electromagnetic pulses, high powered lasers, or high-powered microwaves to physically damage a satellite without making direct contact, making the attack more difficult to attribute than a kinetic physical attack.[[24]](#footnote-24) Electronic attacks, such as jamming and spoofing, temporarily impede satellite communications and mimic fake signals in order to inject false information, respectively.[[25]](#footnote-25) Cyber attacks can intercept and monitor a satellite’s data, infiltrate data systems to corrupt information, or seize control of a satellite.[[26]](#footnote-26) Nations’ behaviors towards one another’s satellites may offer insights regarding how countries will behave towards one another’s mining objectives and missions, and is therefore highly relevant to international cooperation and (in)security in outer space.

Furthermore, space is fundamentally intertwined with humanity’s future—any considerations of the survival of humanity must account for “potential cosmic catastrophes, such as impact by asteroid or comet.”[[27]](#footnote-27) NASA astronaut Ron Garan tweeted in June 2017, “If the dinosaurs had a space program they’d still be here”—a lighthearted joke, but not without a grain of truth.[[28]](#footnote-28) Tiny meteorites bombard the Earth’s atmosphere every day. Almost all of these burn up before reaching Earth’s surface. In February 2013, a superbolide—an extremely bright meteor that explodes in the Earth’s atmosphere—passed through the Earth’s atmosphere at 68,4000 kilometers-per-hour (42,5000 miles-per-hour) without burning up, over Chelyabinsk, Russia.[[29]](#footnote-29) Its blue glow indicated a temperature greater than the 6,000°C yellow glow of our sun. It broke apart at about twenty-seven kilometers, creating a blast of air pressure felt within 127 km (79 miles) of the superbolide. Scientists estimate the Chelyabinsk superbolide had the strength of 500 kilotons – or stronger – which is twenty-five times greater than the strength of the atomic bomb dropped on Nagasaki, Japan in 1945.[[30]](#footnote-30) The Chelyabinsk indicates a higher risk of future blasts from similar small asteroids in the future.[[31]](#footnote-31) In a 2010 interview, famed theoretical physicist Stephen Hawking said, “I believe that the long-term future of the human race must be in space…It will be difficult enough to avoid disaster on planet Earth in the next hundred years, let alone the next thousand, or million.”[[32]](#footnote-32)

While it may not be possible to know of or effectively plan for all future threats, the HbSS stresses the importance of undertaking multidimensional approaches to pursue space capabilities in order to achieve existential security for the human race, which only space can provide.[[33]](#footnote-33) (In)security is not an inevitable consequence of the international system—it is a consequence of unsustainable development, unpreparedness, and a lack of international cooperation. If the existential security of the human race is, as Hawking hypothesized, contingent upon humanity’s ability to become a multi-planetary species, then international space law that advances long-term, sustainable development and expansion into space is of paramount importance.

sᴇᴄᴛɪᴏɴ 2: ʜɪsᴛᴏʀʏ ᴏꜰ sᴘᴀᴄᴇ ʟᴀᴡ

*For a relatively ‘young’ field of human endeavor, outer space has already witnessed an impressive conglomeration of international law; according to some experts, "the USA and USSR have gone further to achieve arms control in space than in any other area.*[[34]](#footnote-34)

*The next generation of space law involves agreeing on specific norms. Is sovereignty necessary to establish property rights? Are space resources, as well as space itself, the province of all humankind? If so, how are they to be allocated? If not, why? How can non-spacefaring nations be assured use of outer space? How will the investments of spacefaring nations be honored? What is the appropriate relationship between the public and private sectors in space? How will private space activities be regulated? These questions, and more, are yet to be answered.[[35]](#footnote-35)*

2.1 *ᴄᴏʀᴘᴜs ᴊᴜʀɪs sᴘᴀᴛɪᴀʟɪs*

 The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) has finalized six multilateral treaties that are regarded as the *corpus juris spatialis* (fundamental principles of public international space law).[[36]](#footnote-36) These are: the 1967 Outer Space Treaty[[37]](#footnote-37), the 1963 Limited Test Ban Treaty[[38]](#footnote-38), the 1968 Rescue Agreement[[39]](#footnote-39), the 1972 Liability Convention[[40]](#footnote-40), the 1975 Registration Convention[[41]](#footnote-41), and the 1979 Moon Agreement[[42]](#footnote-42). With 110 nations party to the Outer Space Treaty (OST), it is undoubtedly the most important of the *corpus juris spatialis*, and with only eighteen nations party to the 1979 Moon Agreement, the most contended. It is critical to understand the implications of the Cold War context in which the OST and the other COPUOS treaties were negotiated, as the treaties reflect Cold War concerns of national rivalries evolving into space and, most unsettling, the potential use of nuclear and other weapons of mass destruction in space. As a consequence of the sustained threat of nuclear annihilation and the fear that the nuclear war could happen at any moment, international cooperation regarding arms control in space has been surprisingly productive.

However, despite the arguable success of space law in achieving states’ arms control objectives (there are some disconcerting ambiguities regarding the legality of conflict in space, the meaning of space weapons and peaceful purposes, etc.; discussed in Section 2.4), that international space law has remained stagnant since the Cold War provides significant cause for concern.[[43]](#footnote-43) Without the implementation of a modern regime, capable of regulating the exploitation, extraction, and appropriation of space resources, humanity’s expansion into space could easily become a source of (in)security, disagreement, and conflict—either in space, on Earth, or both—over the mining of the moon and other celestial bodies should be expected.

2.2 1967 ᴏᴜᴛᴇʀ sᴘᴀᴄᴇ ᴛʀᴇᴀᴛʏ

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies – the 1967 Outer Space Treaty – is the fundamental basis for international space law today. Articles I and II are indispensable to any contemporary discussion of space resource exploitation and allocation (and consequently the object of this paper); hence, both are provided in totality.

*Article I*

*The exploration and use of outer space, including the Moon and other celestial bodies, 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.*

*Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.*

*Article II*

*Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.*

110 countries are party to the OST.[[44]](#footnote-44) It designates space *res communis omnium* (a thing of the entire community) and celestial bodies *res extra commercium* (a thing outside commerce).[[45]](#footnote-45) Importantly, the OST is, for the most part, unconcerned with the allocation of space’s resources—the word ‘exploitation’ does not even appear.[[46]](#footnote-46) Taking into consideration the Cold War origins of the OST, this seems intuitive. The COPUOS treaties reflect “both the aspirations and fears of the [Cold War] times…Lacking complete knowledge of the other’s capability and concerned that they might give up an advantage, neither the Soviet Union nor the United States would agree to more”—and the most pressing objective of both the U.S. and the U.S.S.R. was to prohibit the weaponization of space.[[47]](#footnote-47) Article IV of the OST reads:

*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 by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall also not be prohibited”[[48]](#footnote-48)*

During the Cold War, states’ mutual interests in preventing wars from developing in outer space provided a significant basis for cooperation, as international cooperation was critical to preventing an arms race from occurring in space. To date, space is a *de facto* sanctuary—it is militarized, but not yet weaponized.[[49]](#footnote-49) The militarization and weaponization of space are “fundamentally at odds at with constructive commercial and scientific projects…war in space would destroy the intrinsic trust and cooperation necessary to maintain the systems deployed in space for peaceful purposes.”[[50]](#footnote-50) Yet projects for the militarization and weaponization of space have been on the increase, with the object of achieving military supremacy in outer space—a desire kindled by (i) apprehension regarding the ability of present missile defense systems to stall an incoming Inter-Continental Ballistic Missile (ICBM) armed with a nuclear warhead and (ii) to defend satellites against ASAT weapons.[[51]](#footnote-51) The future of space security is contingent upon the ability of states to negotiate a legal regime addressing property rights, resource allocation, etc. in space in a manner that practically resolves the issue of exploiting space-based resources and preemptively reduces the likelihood of conflict over such resources. Unfortunately, however, states have minimal mutual interests when it comes to exploiting space-based resources—exemplified by the inability of the 1979 Moon Agreement to gain international recognition.

2.3 1979 ᴍᴏᴏɴ ᴀɢʀᴇᴇᴍᴇɴᴛ

 The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies—the 1979 Moon Agreement—is regarded as “the last of the ‘first generation’ of space treaties.”[[52]](#footnote-52) It reinforces the OST, developing the principle of non-appropriation, and calls for the establishment of an international regime to govern the exploitation of natural resources. The Moon Agreement marked the first substantive effort to address contemporary issues with the *corpus juris spatialis*, *e.g.,* the security implications of asteroid and lunar mining, on an international scale, and it attempts to grapple with the issue of resource allocation, albeit extremely controversially.[[53]](#footnote-53) Most significantly, the Moon Agreement establishes that the moon and other celestial bodies are *res communis humanitatis* (the common heritage of mankind), thereby not only prohibiting national appropriation but asserting that the resources of space are the property of all mankind. Article XI asserts:

*Neither the surface nor the subsurface of the moon, nor any part thereof or natural resources in place, shall become property of any State, international intergovernmental or non- governmental organization, national organization or non-governmental entity or of any natural person. The placement of personnel, space vehicles, equipment, facilities, stations and installations on or below the surface of the moon, including structures connected with its surface or subsurface, shall not create a right of ownership over the surface or the subsurface of the moon or any areas thereof. The foregoing provisions are without prejudice to the international regime referred to in paragraph 5 of this article.[[54]](#footnote-54)*

Only eighteen countries—Armenia, Australia, Austria, Belgium, Chile, Kazakhstan, Kuwait, Lebanon, Mexico, Morocco, Netherlands, Pakistan, Peru, Philippines, Saudi Arabia, Turkey, Uruguay, and Venezuela—are party to the Moon Agreement; while the U.S., Russia, and China have all signed the OST, none have signed, ratified and/or acceded the Moon Agreement, and consequently, the Moon Agreement is essentially disregarded by significant spacefaring nations.[[55]](#footnote-55) A glaring obstacle to the evolution of space governance is that “incentives to trade off national interests and gains in return for collective action and international benefits are generally not present.”[[56]](#footnote-56) There is no international consensus regarding the exploitation of space resources, and the problem of motivating states to negotiate a framework for resource allocation continues to represent a substantial challenge.[[57]](#footnote-57)

2.4 ᴏᴛʜᴇʀ ʀᴇʟᴇᴠᴀɴᴛ sᴘᴀᴄᴇ ʟᴀᴡ

2.4.1 1963 ʟɪᴍɪᴛᴇᴅ ᴛᴇsᴛ ʙᴀɴ ᴛʀᴇᴀᴛʏ

 The Limited Nuclear Test Ban Treaty was the first international treaty on the legal regulation of space activities and is significant insofar as it renounces militarization and nuclearization of outer space.[[58]](#footnote-58) It prohibits nuclear weapons tests, or any other nuclear explosion, in the atmosphere, including outer space and under water.[[59]](#footnote-59) This treaty is “not concerned with outer space *per se*, but rather addresses activity in outer space as part of a more general subject—*i.e.*, the prevention of global nuclear contamination.”[[60]](#footnote-60) While the U.S. and the U.S.S.R., two major nuclear powers at the time, and 120 additional nations signed the Limited Test Ban Treaty, France and China refused to sign; as a consequence, the scope of the treaty is substantially limited.

2.4.2 1968 ʀᴇsᴄᴜᴇ ᴀɢʀᴇᴇᴍᴇɴᴛ

 The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects launched into Outer Space—the 1968 Rescue Agreement—was designed to further upon the duties provided in Article V of the OST, which declares astronauts “envoys on mankind in outer space” and requires parties to “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.”[[61]](#footnote-61) The Rescue Agreement obliges parties, in the case of a spacecraft suffering an accident, in conditions of distress, and/or having made an emergency or unintended landing in any place not under the jurisdiction of that state, to immediately notify the launching authority (or make a public announcement) and the Secretary-General of the United Nations.[[62]](#footnote-62)

2.4.3 1972 ʟɪᴀʙɪʟɪᴛʏ ᴄᴏɴᴠᴇɴᴛɪᴏɴ

 Articles VI and VII of the OST concern responsibility for outer space activities—states are internationally responsible for national activities in outer space, irrespective of whether activity is undertaken by governmental or non-governmental organizations, and states are internationally liable for any damages to another party caused by space objects.[[63]](#footnote-63) The 1972 Liability Convention reaffirms the importance of international cooperation and peaceful uses of outer space and further elaborates on the OST VI and VII. Article I defines *damages*[[64]](#footnote-64), *launching*[[65]](#footnote-65), *launching State*[[66]](#footnote-66), and *space object*[[67]](#footnote-67); Article II specifies the circumstances under which a launching state is liable to pay compensation for damages caused by its space objects.[[68]](#footnote-68)

2.4.4 1972 ʀᴇɢɪsᴛʀᴀᴛɪᴏɴ ᴄᴏɴᴠᴇɴᴛɪᴏɴ

 Sixty-nine states are party to the Convention on Registration of Objects Launched into Outer Space—the 1979 Registration Convention.[[69]](#footnote-69) It builds upon the OST, the Rescue Agreement, and the Liability Convention to “make provision for the registration by launching States of space objects launched into outer space with a view, inter alia, to providing States with additional means and procedures to assist in the identification of space objects.”[[70]](#footnote-70) Launching states are obligated to register space objects, providing information regarding the name of launching state(s), registration number, date and location of launch, basic orbital parameters, and the general function of the space object; as well as inform the Secretary-General of the United Nations of the establishment of such a registry.[[71]](#footnote-71) To date, however, states frequently delaying registering or fail to register their space objects altogether.[[72]](#footnote-72)

2.5 ᴀᴍʙɪɢᴜɪᴛɪᴇs/ɪᴍᴘʟɪᴄᴀᴛɪᴏɴs

Where, exactly, *does* outer space begin? The most widely recognized boundary, the Kármán line, lies hundred kilometers (sixty-two miles) above sea level; legally, however, there is no universally accepted boundary.[[73]](#footnote-73) In *The Legal Status of Outer Space and Relevant Issues: Delimitation Of Outer Space and Definition of Peaceful Use*, Bin Cheng writes, “Insofar as the legal status of outer space is concerned, there are two issues regarding which the present development of the law gives rise to grave anxiety. They are: (a) the delimitation of the boundary between airspace and outer space, and (b) the definition of the term "peaceful."[[74]](#footnote-74)

The preamble of the OST emphasizes “the common interest of all mankind in the…use of outer space for peaceful purposes”—without, however, providing any robust definition of peaceful.[[75]](#footnote-75) In the U.S., the 1958 National Aeronautics and Space Act commits to devoting the U.S. to peaceful space activities for the benefit of mankind, although the official U.S. position is that peaceful implies non-aggressive, but not non-military.[[76]](#footnote-76) Article III of the OST establishes that parties should “carry on activities in the exploration and use of outer space, including the Moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations,” insinuating that a more robust understanding of the term “peaceful” can be found in the UN Charter. [[77]](#footnote-77)  Chapter I, Article 2 (4) states that “All Members shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state,” although Chapter VII, Article 51 provides that “Nothing in the present Charter shall impair the inherent right of individual or collective self-defence if an armed attack occurs against a Member of the United Nations, until the Security Council has taken measures necessary to maintain international peace and security.”[[78]](#footnote-78)

Consequently, the definition of the term “peaceful” does not impose explicit rules or incentives to prevent, without exception, conflict in space.[[79]](#footnote-79) Tripathi expresses it eloquently:

*Even as space has been explored extensively for peaceful and commercial purposes for the benefit of all across the globe, the military planners, on the other hand, are focused on militarisation and weaponisation of space to establish their supremacy over the other military users of space. It is not only missiles that can traverse outer space or satellites that can spot targets and guide the missiles, but weapons could be permanently placed outside the Earth’s atmosphere, and then, on a signal from the earth, bombard target bases and cities. These two uses of outer space—one for the peaceful purpose of benefit for humans and the other as a venue for war and synchronised killings—coexist.[[80]](#footnote-80)*

In order to formulate effective policy that resolves the aforementioned problems with the term peaceful and the potential for conflict in space, robust, legal definitions of presently ambiguous concepts (*e.g,* space weapons, peaceful purposes, and military uses) are necessary. Second, the delimitation of the boundary of where space begins needs to be resolved, “so as to counter any arguments that outer space is, in fact, an area akin to the territory of a State for the purposes of national security.”[[81]](#footnote-81)

In summary, the major achievements of the *corpus juris spatialis* are the at least partial prohibition of nuclear and other weapons of mass destruction in outer space, the banning of the testing of weapons and establishment of military bases on the moon and other celestial bodies, and restricting the exploration and use of space for peaceful purposes. This does not imply, however, that weaponization and deterrence in outer space are of negligible concern to international peace and security. However, if the second generation of international space law is successful, it has the potential to become the beginning of an unprecedented increase in peace, security, and international cooperation for the human race.

sᴇᴄᴛɪᴏɴ 3: ᴍɪɴɪɴɢ sᴘᴀᴄᴇ

*It is estimated that Anteros, a 2-km-long asteroid that will pass within 7 million miles of Earth in 2038, contains $5.5 trillion of magnesium silicate, aluminum, and iron silicate “for anyone who can figure out how to mine it.”[[82]](#footnote-82)*

 *A forty-foot-long S-type asteroid… is likely to contain more than a million pounds of nickel, gold, platinum, rhodium, iron, and cobalt.[[83]](#footnote-83)*

3.1 ᴛʜᴇ ʀᴀᴄᴇ ᴛᴏ ᴍɪɴᴇ sᴘᴀᴄᴇ

The current known asteroid count is 994,384.[[84]](#footnote-84) An estimated 1.1 to 1.9 million total asteroids larger than ~1km in diameter, alongside millions of smaller ones, orbit within the asteroid belt between Mars and Jupiter; these constitute the majority of known asteroids.[[85]](#footnote-85) Near-Earth asteroids (NEAs) have orbits that pass close by Earth; as of August 2020, 23,463 NEAs of all sizes have been identified—901 of these NEAs are larger than ~1km in size and 9,290 are larger than ~140m.[[86]](#footnote-86) Russian-born scientist and mathematician Konstantin Tsiolkovsky wrote in 1903 that the exploitation of asteroid resources would be critical for humanity to conquer outer space—the “Final Frontier.”[[87]](#footnote-87) Now, in the 21st century, the prospect of humans mining space for its resources is becoming increasingly plausible.

China claims it will establish a manned space station by 2022, possess fully reusable launch vehicles by 2035, and achieve a major breakthrough in nuclear-powered space shuttles, which will enable mining of space-based resources, by 2040.[[88]](#footnote-88) The China National Space Administration (CNSA) has scheduled the time period between 2017 and 2022 to begin feasibility studies to pursue asteroid mining capabilities, with the ultimate object of landing on the NEA 1996 FG3, which has an estimated value of 1.33 trillion USD and estimated profits of 181.34 billion USD, begin probing samples of its minerals—nickel, iron, cobalt, water, nitrogen, titanium, and platinum—and establish a lunar presence to enable manufacturing in space.[[89]](#footnote-89) In December 2015, China’s *Chang’e 2* mission (precursor to *Chang’e 4*, mentioned in the introduction of this paper), captured photographs of the asteroid Toutatis—7 million kilometers away from Earth—making China the fourth nation to explore an asteroid from an unmanned spacecraft.[[90]](#footnote-90) NASA’s Asteroid Capture and Return (ACR) mission aims to return a 500,000 kg asteroid to a high lunar orbit by 2025.[[91]](#footnote-91) The feasibility of such a mission is contingent upon the capacity to *(i)* discover a sufficient number of small NEAs for capture and return, *(ii)* utilize powerful solar electronic propulsion systems to facilitate the transportation of the captured NEA, and *(iii)* “the proposed human presence in cislunar space in the 2020s enabling exploration and exploitation of the returned NEA.”[[92]](#footnote-92) If successful, placing an asteroid in high lunar orbit would create a cost-effective destination for future space exploration and exploitation missions and would enable longer missions to larger NEAs deeper in space.[[93]](#footnote-93)

In March 2019, U.S. Vice President Mike Pence stated, “The United States must remain first in space, in this century as in the last, not just to propel our economy and secure our nation, but above all because the rules and values of space, like every great frontier, will be written by those who have the courage to get there first and the commitment to stay.”[[94]](#footnote-94) Similarly, Ouyang Ziyuan, chief scientist of China’s Moon exploration program, asserted, “The Moon could serve as a new and tremendous supplier of energy and resources for human beings…This is crucial to sustainable development of human beings on Earth…Whoever first conquers the Moon will benefit first.” [[95]](#footnote-95) Both China and the U.S., then, seem to agree on the significance of ‘first presence’—that is, whichever state is first to utilize a space-based resource will reap the most economic and political benefits; as a consequence, early achievements in lunar and asteroid mining could significantly impact the existing balance of power in the international system, not to mention future dynamics and the existence of international cooperation in space.

The economic view of space as “a vast, untouched source of minerals and gases to be extracted” is not confined to China and the U.S—the European Space Agency (ESA), India, Japan, and Russia all likewise are pursuing ambitious space programs, and nations such as Canada, Germany, Italy, Luxembourg, the ROK, the U.A.E., and the U.K. are discussing their future as spacefaring nations.[[96]](#footnote-96) In November 2019, the ESA and the Luxembourg Space Agency signed a Memorandum of Cooperation, formally committing to a strategic partnership—with a primary focus on space resource extraction and processing.[[97]](#footnote-97)

Yet, despite all of these developments, international space law remains ill-equipped to regulate the mining of space and the allocation of resources.[[98]](#footnote-98) Early achievements in asteroid and lunar mining could easily become a source of disagreement, potential conflict, and (in)security without the prompt development of a legal and regulatory regime. Developing countries would be significantly disadvantaged, in terms of access to the moon and other celestial bodies, and the current lack of incentive for states to deprioritize national interests in outer space for the purposes of collective action and the interest of all countries, especially in an era of increasingly state-centered politics and rising nationalism, would exacerbate existing international tensions.[[99]](#footnote-99) Co-founder of Moon Express Inc., a Florida-based private company with a focus on lunar mining, Naveen Jain, expressed that the *corpus juris spatialis* is “going to change when the mining starts…No one owns international waters, but those who invest their money and effort to find fish are entitled to profit.”[[100]](#footnote-100)

3.2 ᴀsᴛᴇʀᴏɪᴅ ʀᴇsᴏᴜʀᴄᴇs

*Statistically, there should be approximately six metallic NEAs larger than 1 km in diameter that contain over 100 ppm of precious metals. Successful recovery of 400,000 tons or more of precious metals contained in the smallest and least rich of these metallic NEAs could yield products worth $5.1 trillion (US) at recent market prices.*[[101]](#footnote-101)

With a rapidly increasing global population, a finite amount of terrestrial resources, and the relentless, destabilizing effects of climate change, Earth’s resources are declining at an alarming rate and insecurity is multiplying. Sources of clean, renewable energy on Earth, like wind turbines and solar panels, for example, require rare earth metals—currently only available in terrestrial mines—for their construction. The demand for these metals is rising and their economical extraction increasingly difficult.[[102]](#footnote-102) Yet, the smallest known near-Earth metal asteroid contains “more metal than has been mined by humanity since the beginning of time”—and 901 NEAs larger than ~1km have been identified to date.

The utilization of asteroid resources may not provide a comprehensive solution to terrestrial problems, but as the exploitation of asteroids, the moon, and other celestial bodies becomes attainable, space resources may be utilized to provide supplemental resource reserves, both for the development of technologies on Earth and the exploration of the solar system.[[103]](#footnote-103) In space, for example, metals can be used for 3D printing; on Earth, they can be used for electronics, automobiles, medicines, and jewelry.[[104]](#footnote-104)

Certain NEAs contain precious metals, *e.g.,* platinum and gold, and semiconductors, *e.g.,* silicon and aluminum, can be found in relatively larger quantities on asteroids compared to terrestrial sources. It may be possible to extract “up to 187 parts per million (ppm) of precious metals, which includes Au [Gold], the Pt-group metals (Pt [Platinum], Ru [Ruthenium], Rh [Rhodium], Pd [Palladium], Os [Osmium], and Ir [Iridium]), Re [Rhenium], and Ge [Germanium]). More than 1000 ppm of other metals, semiconductors, and nonmetals may one day be extracted and imported by Earth from asteroids, such as Ag [Silver], In [Indium], Co [Cobalt], Ga [Gallium], and As [Arsenic].”[[105]](#footnote-105)

3.3 ᴘʀɪᴠᴀᴛᴇ ᴄᴏᴍᴘᴀɴɪᴇs ᴀɴᴅ ᴀsᴛᴇʀᴏɪᴅ ᴍɪɴɪɴɢ

In the U.S., the 2015 Commercial Space Launch Competitiveness Act, also cited as the Spurring Private Aerospace Competitiveness and Entrepreneurship (SPACE) Act, aims to incentivize private-sector investments in space by guaranteeing the right to possess, own, transport, use and sell any resources extracted from an asteroid or other space resource to any U.S. citizen.[[106]](#footnote-106) President Trump’s April 2020 Executive Order on Encouraging International Support for the Recovery and Use of Space Resources stresses the importance of recovering and using space resources for the successful and sustainable exploration of outer space, claims that the United States will “lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations,” and addresses the existing ambiguities regarding the right to recover and use the resources of the moon and other celestial bodies—expressing that the U.S does not view outer space as a global commons, will object should any state treat the Moon Agreement as customary international law, and accordingly plans to encourage the “public and private recovery and use of resources in outer spaces, consistent with applicable law.”[[107]](#footnote-107)

Planetary Resources, Deep Space Industries, Moon Express, the Shackleton Energy Company, SpaceX, Blue Origin and Bigelow are just a few of many private U.S. companies currently developing asteroid and lunar mining technologies.[[108]](#footnote-108) Planetary Resources is the leader in the asteroid mining industry in the U.S. and has been aiming to identity and target specific asteroids that would be the best candidates for profitable mining.[[109]](#footnote-109) In a comment on Planetary Resources’ founders and investors like Google’s Larry Page and Eric Schmidt, astrophysicist Michio Kaku stated, “I think private enterprise will boldly go where governments fear to tread…[W]e need private enterprise, especially people with deep pockets to help jump start the program and maybe mining the heavens is just the ticket.”[[110]](#footnote-110) Private companies are coming closer and closer to developing the capabilities necessary for the mining of asteroids, and international regulations and structure urgently need to be implemented prior to the first achievements in asteroid mining. If private companies undertake outer space missions, there need to be definite, legal answers for *(i)* who is responsible/accountable for such activities and *(ii)* if there can be private ownership of resources mined from space.[[111]](#footnote-111)

Irrespective of the tension and (in)security space mining could induce—both in space and on Earth—the social costs of mining on resource-based countries could be devastating. Will private companies *care* about the impacts of resource extraction? Who will regulate how much of resources can be brought back to Earth? Markets for the natural resources that will be mined on asteroids already exist on Earth, and flooding these markets with large quantities of resources could have a profound economic impact on the states and political systems that depend on terrestrial mining.[[112]](#footnote-112) It is important to stress, however, that “[t]he market response to the hypothetical introduction of such large quantities of precious metals is difficult to predict, because these metals historically have not obeyed normal economic laws of the market.”[[113]](#footnote-113) Production and prices of gold, for example, would likely only be marginally affected.[[114]](#footnote-114)

Furthermore, how might private companies and states interact in space, when mining asteroids and the lunar surface? If two private companies were to mine the same asteroid, what would constitute a valid reason to believe whether or not a state is causing potentially harmful interference? Article I of the OST calls for equitable access and use of outer space for all states—what penalties, if any, will there be for developed countries if they rush to mine the NEAs that are economically and financially feasible, leaving developing countries at significant economic and financial disadvantage?

3.4 ᴇᴄᴏɴᴏᴍɪᴄ ᴠɪᴀʙɪʟɪᴛʏ ᴏꜰ ᴀsᴛᴇʀᴏɪᴅ ᴍɪɴɪɴɢ

In a recent paper, Hein et al. develop a techno-economic analysis of asteroid mining in order to identify key criteria for economically viable asteroid mining, applied to the cases of supplying water in space and returning platinum to Earth.[[115]](#footnote-115) Their model accounts for the cost of return to Earth, development costs, assesses multiple mining missions as part of one asteroid mining venture, considers transfer time via a mission start and resource return date, and develops a supply-demand curve for platinum. It is limited insofar as only a single mining mission is considered, the cost of return to Earth is omitted, and development costs are not considered. From their Net Present Value (NPV) analysis, Hein et al. indicate the following as technical parameters for maximizing profit: use multiple spacecraft per mission in order to take advantage of learning curve effects and decrease development costs, increase the throughput rate and the reuse of spacecraft, reduce mission duration and other cost factors (e.g., operations and transportation).[[116]](#footnote-116) Vergaaij et al., in a similar article, assess the economic viability of asteroid mining and conclude that a positive NPV is feasible and can be increased if the mission entails multiple trips to the same asteroid.[[117]](#footnote-117) However, the economic viability of asteroid mining remains uncertain.

3.5 ʟᴜɴᴀʀ ᴍɪɴɪɴɢ ᴀɴᴅ ʀᴇsᴏᴜʀᴄᴇs

*Space may be vast, but many of the most valuable resources—especially those convenient to Earth—are limited. Our Moon may be one of the most promising sites for mining, energy capture, and spaceship refueling, but a limited amount of useable land exists, with an even more limited quantity of useable water. The problem is not limited to the Moon. Every resource is limited. The question then is who, if anyone, should have the right to the riches of space?[[118]](#footnote-118)*

The moon has a mass of 7.35 x 1022 kilograms—if one metric ton (one thousand kilograms) is removed from the moon each day, it would take 220 million years to deplete just one percent of its mass.[[119]](#footnote-119) Geological surveys demonstrate the moon contains three crucial elements—water, helium-3 (**3**He), and rare-Earth elements (REEs).[[120]](#footnote-120) Water is indispensable for supporting life and agriculture beyond Earth, and importantly, water can be electrolyzed to produce oxygen and hydrogen for rocket fuel.[[121]](#footnote-121) **3**He is a stable, non-radioactive isotope that could provide safe nuclear energy in a nuclear fusion reactor without yielding dangerous waste products.[[122]](#footnote-122) It is extremely rare on Earth but exists in abundance on the lunar surface—approximately one million metric tons—because the moon has no atmosphere or magnetic field and has been bombarded with large quantities of **3**He by the solar wind for billions of years.[[123]](#footnote-123) Simko et al. maintain that “the significant investment in lunar exploration can only be justified by the ultimate goal of mining lunar **3**He…the sole economically viable reason for returning to the moon.”[[124]](#footnote-124) While the economic viability of lunar **3**He mining is contingent upon (i) how much fusion reactors will cost and (ii) how much **3**He is worth, **3**He has tremendous potential as a fusion fuel:

*Just 44 tons of 3 He would meet the current annual electricity needs of the United States of about 4 TW h. Similarly, about 220 tons of 3 He could supply the world’s present annual electricity generation requirements of about 20 TW h. The total lunar resource of one million tons of 3 He could therefore meet current global electricity generation needs for about five thousand years. This assumes that all the helium can be easily extracted, which is unlikely as some regions could be unsatisfactory for mining. However, the effective supply would probably last over one thousand years.[[125]](#footnote-125)*

Based on current demand, technology, and mining operations, reserves of REEs on Earth are estimated to have approximately 2,500 years left for terrestrial utilization.[[126]](#footnote-126) While the lunar surface is a logical target for extraterrestrial REE resources, “lunar sample REE abundances are low compared to terrestrial ones…there is no geological, mineralogical, or chemical evidence to support REEs being present on the Moon in concentrations that would permit their classification as ores.”[[127]](#footnote-127)

3.6 sᴇᴄᴜʀɪᴛʏ ɪᴍᴘʟɪᴄᴀᴛɪᴏɴs

The size and scope of nations’ (inter)dependence on outer space encourages a sense of optimism regarding international cooperation in space, the peaceful use of outer space for the benefit of humanity, and a secure space environment. Yet the race to take advantage of the vast wealth of space-based resources has profound security implications—whichever state is first to utilize a space-based resource will reap the most economic and political benefits, not to mention power, influence, and prestige. Peace and security are fundamentally intertwined with the unabating threats of conflict, war, and insecurity—and derived from states’ capacities for weaponization and deterrence. It would be wildly idealistic to presume peace and security in outer space will not be intricately linked with conflict, war, and insecurity, and it follows that weaponization and deterrence cannot be absent from international space activities.

Namrata Goswami raises several compelling examples of the security implications of the inability of the existing *corpus juris spatialis* to effectively regulate nations’ activities in outer space, as asteroid and lunar mining become perpetually closer to becoming a reality. In *China in Space: Ambitions and Possible Conflict*, Goswami writes:

*What will be the likely strategic impact if China declares a “Zone of Non-Interference,” similar to an air defense identification zone, on the moon once it establishes a permanent base there? And if China passes an act similar to the 2015 US Asteroid Act that favors “first come, first served” with regard to mining rights and ownership of the mined resources, what would transpire if a US private company applies for landing and mining rights on an asteroid, but China rushes in and establishes its base first? What if both US and Chinese companies want to mine the same asteroid? Are there mechanisms that would help peacefully create shared rights?*[[128]](#footnote-128)

Economic theory implies that “property rights and claims thereto emerge when it is in someone’s self-interest to claim property…[i]n this context, one has to wait and see what will develop in this expensive but valuable exercise worth trillions of dollars.”[[129]](#footnote-129) As the private sector becomes increasingly involved in the exploitation of space resources, the ability to effectively regulate space activities will presumably become increasingly important to mitigating space insecurity.

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Outer space is fundamentally intertwined with humanity’s future; yet, despite the exploration of outer space and exploitation of space resources becoming increasingly technologically and financially feasible—and arguably critical for humanity’s long-term survival—international space law has remained stagnant. To date, six treaties—the 1967 Outer Space Treaty, the 1963 Limited Test Ban Treaty, the 1968 Rescue Agreement, the 1972 Liability Convention, the 1975 Registration Convention, and the 1979 Moon Agreement—constitute the *corpus juris spatialis* (fundamental principles of public international space law).

The “constitution” for all international space-based activity, the 1967 Outer Space Treaty, was “written at a time when Earth’s orbit was perceived as little more than a battlefield, rather than an untapped market,” and a corollary of this is that, while the *corpus juris spatialis* was arguably successful in prohibiting nuclear and other weapons of mass destruction in outer space, its capacities to regulate the exploitation of the moon and other celestial bodies is essentially negligible.[[130]](#footnote-130) Despite the size and scope of nations’ (inter)dependence on outer space, when it comes to exploiting space-based resources, states lack sufficient incentive to deprioritize national interests for the collective good. Without unambiguous international space law addressing property rights and regulating the exploitation and allocation of asteroid and lunar resources, current space powers will race to (i) be first to utilize a space-based resource and (ii) to achieve military supremacy in space.

It is unfortunate, albeit expected, that states have such little interest in international cooperation regarding the exploitation of space-based resources, exemplified by the failure of the 1979 Moon Agreement. While the (in)security implications of mining remain largely speculative, if mining begins prior to the negotiation of a treaty that *(i)* renounces the claim that space resources are *res communis humanitatis*; *(ii)* concedes that, while the non-appropriation principle still holds, those who invest their money and effort to exploiting resources are entitled to profit from those resources; and *(iii)* develops a definitive property law; it is difficult to imagine that the effects would be positive. Ultimately, every resource is limited—including those in outer space—and developing countries should be guaranteed the right to access and benefit from space-based resources. The activities of current space powers cannot be left unchecked, and resources cannot be allocated on a *laissez-faire*, first-come, first-serve basis, else the most accessible and valuable resources will be at the disposal of whichever present-day spacefaring nation is first to mine them.

Earth’s resource reserves are being rapidly depleted, and near-Earth asteroids contain vast quantities of these resources—gold, rhenium, germanium, platinum, palladium, iridium, osmium, rhodium, and ruthenium. The lunar surface contains water, rare-Earth elements, and most significantly, approximately one million tons of Helium-3, which is virtually non-existent on Earth and has massive potential for radiation-free nuclear fusion. Until recently, all of the aforementioned resources have been unattainable. However, as private companies come closer and closer to developing the technological capabilities necessary for asteroid and lunar mining, exploiting the vast wealth of space may become economically feasible. The greatest uncertainty is neither technology nor money—it is the existing legal regime. In the words of Reinstein, “Space development is a highly risky endeavor, as well as mind-bogglingly expensive. Who would expend the effort in developing a space colony, if they were not certain of the project’s legality?”[[131]](#footnote-131) A second generation of public international space law that resolves the aforementioned problems, elucidates the existing ambiguities in the *corpus juris spatialis*, and promotes peace and outer space security is urgently needed, both to precede and to incentivize the beginning of a new era of human space exploitation.

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65. *The term “launching” includes attempted launching.* [↑](#footnote-ref-65)
66. *The term “launching State” means: (i) A State which launches or procures the launching of a space object; (ii) A State from whose territory or facility a space object is launched.*  [↑](#footnote-ref-66)
67. *The term “space object” includes component parts of a space object as well as its launch vehicle and parts thereof.* [↑](#footnote-ref-67)
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