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Economic and Legal Implications

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ABSTRACT

The United States and Luxembourg have adopted domestic space laws granting certain legal rights to space mining companies. These moves have initiated a debate on the future of this industry, as well as the passing of relevant laws governing outer space and its resources. This paper makes an assessment of commercial space mining activities in the broader context of the emerging space economy. It finds that entrepreneurs are increasingly looking at outer space for providing terrestrial solutions, and Western entrepreneurs in particular are working towards setting up basic infrastructure enabling a new industrial age based in outer space. Commercial space mining is part of this vision, which also has the added advantage of reducing dependency on terrestrial resources and thus limiting environmental degradation. The paper also identifies specific NewSpace companies working on affordable, frequent access to outer space, as well as space manufacturing technologies. Together, these activities form the backbone of the space economy. However, the future of this vision is uncertain, as existing international space law has not evolved beyond Cold War concerns.

INTRODUCTION

Celestial bodies like the Moon and asteroids possess metals that are currently mined from Earth. They also possess water, in the form of water ice, which can be extracted and transported to astronauts in space. Government and commercial entities from advanced spacefaring countries are making plans to extract these resources either for profit or to sustain future human habitations on the Moon and Mars. The United States (US) has the lead in commercial space mining activities both from operational and legal perspectives. Moreover, the US' National Aeronautics and Space Administration (NASA) as well as SpaceX—the space transport services company set up by Elon Musk—have declared their intention to "colonise" Mars, which requires maximum utilisation of local resources.

Across the Pacific, China is also steadily advancing its lunar and asteroid exploration programmes with the intent of bringing samples back to Earth. The European Space Agency is promoting its idea of a "Moon Village" that also requires utilisation of local resources, while Luxembourg wants to emerge as the global hub for commercial space mining operations.

In this context, this paper attempts to highlight two distinct but interconnected issues arising from this quest. One is the disruption in traditional manufacturing processes that are at present completely reliant on earth resources. Space manufacturing is on the anvil, sourcing raw materials from celestial bodies such as the Moon and asteroids. In addition, efforts are underway to establish routine, low-cost access to space. In essence, the world is witnessing the beginning of a space economy. The other is governance of space mining. The US and Luxembourg have adopted domestic laws granting legal protection to rights of commercial entities to own, transport, use and sell mined space resources. However, uncertainty still exists due to states' obligations to international space treaties, and under-evolved international norms on space mining. The risk of different entities competing for a particular location on the Moon or an asteroid is also not inconceivable.

The absence of relevant norms or a competent international authority governing space mining activities could provoke unilateral decision-making, leading to resource conflicts in outer space. Some of the advanced spacefaring nations have already demonstrated their space weapons. As evident from history, conflicts can only undermine development. This paper argues that the international community needs to be more aware of these potential conflicts and work to prevent them. This is possible only with space mining companies creating their own 'Sputnik moment'.

I. ESTABLISHING A SPACE ECONOMY

A. Unsustainable Economic Practices

In capitalist countries, entrepreneurial spirit has been the foundation for advancing economic progress. A prime example is the growth of the US national economy following the devastating Civil War.[1]

Technological advances have helped refine these processes. For example, it is now possible to dig deeper into the seabed and unlock new energy resources such as gas hydrates. Tunnelling machines have connected previously inaccessible parts of countries, while the aviation industry has supported expansion of businesses overseas. International shipping is vital to sustaining the global economy. Space services have had their impact on these processes by helping spot resources, easing financial transactions, providing location and navigation solutions, as well as communications, remote sensing, maritime domain awareness and weather forecasting.

Ironically, technology has also come to identify and assess the environmental costs the current level of economic activity has imposed. The devastating effect of oil spills on the marine environment; greenhouse gas emissions, man-made disasters, and other tragedies, are being recorded. Global temperatures are rising steadily due to unrestricted emissions, leading to the melting of polar ice caps and warming of oceanic temperatures. This, in turn, is decreasing fisheries resources, raising sea levels and leading to haphazard rains. Scientific studies warn that the planet is about to witness its sixth mass extinction.[2]

Although Earth has its own cycle of warming and cooling, as well as of evolution and extinction of species over its life spanning billions of years, the impact of human activity in accelerating global warming and exploitation of biotic resources to the point of extinction has become evident. Overexploitation of resources, use of non-biodegradable products, clearing of forests for mining, and other human activities, continue to threaten the planet's biodiversity and therefore the sustenance of human life.

These adverse effects are only likely to get compounded given the rising population of the earth, which is set to reach almost 10 billion by 2050.[3] Therefore, there is urgent need to think creatively to sustain both high economic activity and the environment.

With the aid of technology, scientists have peered deep into outer space and explored the planets close to Earth. Mars is identical to Earth in many respects and once had flowing water on its surface, meaning life could have existed there some billions of years ago. Elon Musk, the entrepreneur who founded SpaceX, intends to terraform Mars in order to make it habitable for human life. The Moon is also a potential target for space colonisation.

However, space colonisation that is still dependent on Earth's resources and manufacturing is not only unsustainable but will also cost massive amounts of money to maintain. Fortunately, there are resources spread throughout our solar system that can be mined for use in space. Together with cheaper space transportation options and advances in autonomous, in-space manufacturing techniques, it is possible to shift terrestrial manufacturing to space. The concurrent decrease in the intensity of these activities on Earth, coupled with sustainable practices such as using solar energy and electric vehicles, can help avoid the danger of crossing the 'point of no return' in environmental degradation.

With resources mined from lifeless outer space bodies, and manufacturing eventually occurring in outer space, it is possible to realise a space economy that would strengthen space colonisation efforts, which is seen as a solution to overcrowding of Earth and overexploitation of terrestrial resources. This is essentially the driving point of space entrepreneurs who are attempting to establish the basic infrastructure for a space economy.

B. Celestial Resources: Asteroids

Asteroids are rocky remnants from the formation of the solar system about 4.6 billion years ago. The majority of asteroids are found in the main asteroid belt between Mars and Jupiter. They have played a critical role in the formation of life on earth by bringing to it metals, organic compounds and water. Advanced spacefaring nations have launched several missions to assess their composition. Asteroids are primarily classified into three types – Chondrite (C), Stony (S) and Metallic (M).[4]

Asteroids contain metals such as iron, nickel, tungsten, cobalt, platinum, and others, along with gases such as ammonia, nitrogen and hydrogen.[5] Platinum is one of the rarest metals, used in industries such as automotive (where it reduces emissions, a key priority), medical implants, fertiliser, chemical, electrical and jewellery. A 10-metre 'S type' asteroid could potentially contain about 650,000 kg of metal including 50 kg of gold and platinum.[6] One of the targets of the asteroid mining company Planetary Resources is an asteroid containing more platinum than has ever been mined on Earth.[7]

Most importantly, asteroids are a valuable source of water (frozen ice) in outer space. It currently costs about US$2,500 to send a water bottle into space for astronauts. Water extraction from asteroids could lower this cost and help sustain future settlements on the Moon or Mars. Water can also be broken down into hydrogen and oxygen to fuel rockets and spacecraft.

The 'C type' asteroids are known to have an abundance of water along with organic compounds containing carbon, phosphorous, and others, which could act as fertiliser for growing food in space.[8] A 100-metre asteroid of this type could possess enough water to fuel all the 135 space shuttle missions flown to space till date. US space technology company Deep Space Industries is developing a water based thruster to demonstrate the potential of asteroid water and possibly kickstart a market.[9]

Estimates of the potential value of asteroids range from a few billion to more than a trillion dollars, depending on the size, composition and current value of the metals they contain. Goldman Sachs estimates that an asteroid grabbing probe can be built for US$2.6 billion, while an asteroid the size of a football field could be worth US$50 billion. A NASA mission is set to investigate the 16 Psyche asteroid – one of the largest in existence – which is estimated to be worth US$10,000 quadrillion.[10]

Establishing a robust supply chain that supports space mining will help drive down its cost as well as the inherent risks associated with this activity. The supply chain would include services for mineral prospecting, extraction, tools and engineering, as well as life support systems. The US-based company Moon Express intends to provide such services to enable low-cost lunar exploration, even as it is also interested in mining the Moon. NASA could become its first customer, as the agency is seeking commercial payload delivery services to the Moon.[11]

C. Celestial Resources: the Moon

The Moon is also a valuable source of minerals and water. The Apollo missions returned with 382 kg of lunar samples, whereas Russia's unmanned Luna programme collected about 0.326 kg.[12] The Moon samples showed concentrations of silicon, iron, aluminium, titanium, calcium, magnesium, among others.[13] Helium-3 is another element that was discovered in these samples. It could produce vast amounts of energy, but requires nuclear fusion engines that are yet to be successfully built, even experimentally.

Again, the Lunar Prospector spacecraft that mapped the Moon, revealed the presence of Thorium, which is a major source of nuclear energy, like Uranium. India, for example, is designing Thorium-based reactors to supply electricity to its burgeoning economy.[14] It could be interested in mining lunar Thorium or buying it from commercial space mining entities given the environmental sensitivities in extracting it from the ground.

Moreover, the permanently shadowed craters of the Moon, particularly the poles, are great sources of water. A series of lunar exploration spacecraft have confirmed the presence of water ice as proposed, although new evidence suggests presence of water across the lunar surface as well.[15] Apollo 17 was the last manned mission and Luna 24 the last sample return spacecraft to touch the lunar surface.

More than four decades after Luna 24 brought soil samples from the Moon back to Earth, China is attempting to do the same using its Chang'e 5 spacecraft, which will land there in 2018. This programme will specifically target lunar poles and test in-situ resource utilisation mechanisms.[16] Supported by its space station operations in the low earth orbit, China could become the second country in space history to land a man on the Moon around 2040. The European Space Agency is providing close technical and communications support to China for its lunar robotic spacecraft.[17]

In turn, the European Space Agency wants China's partnership in realising its Moon Village concept.[18] The idea is to engage different space actors who share a general interest in lunar exploration and bring together their unique capabilities to realise common goals. These goals include scientific exploration, testing various technologies, lunar mining and exploitation of resources, tourism, and manned exploration of Mars. China and Europe are planning such joint efforts, including establishing a human lunar outpost.[19] Given the cost of space transportation, it is conceivable that this outpost will be mining lunar resources for fuel and survival.

Space mining companies also fear the high cost of space transportation impeding their business models. Daniel Faber, Chief Executive Officer of Deep Space Industries, concedes that launch services is the biggest factor slowing his company's prospects.[20] He questions the rationality of spending tens of millions of dollars to launch a spacecraft that costs merely a few millions.

D. Affordable Space Transportation

The US launch service industry is dominated by the United Launch Alliance (ULA), owned by Boeing and Lockheed Martin, which holds a monopoly. One of its rockets, Atlas V, costs about US$160 million. Estimates show the cost of the Atlas V, along with its launch readiness component, escalating to US$422 million in 2020 if the monopoly persists.[21] This is certainly an exorbitant price for commercial space mining entities, particularly when the business is yet to be streamlined.

Fortunately, a few US entrepreneurs are leading the much required disruption in this sector. Elon Musk established SpaceX in 2002 with the intention of offering frequent, affordable transportation services to space. His idea is to reuse the rocket which is discarded after just a single use in the traditional model. Undeterred by an initial set of failures, SpaceX has demonstrated its rocket landing and reuse technologies successfully.

SpaceX is already offering cheaper space transportation than ULA at US$61.2 million. It hopes to offer at least a 30-percent cut on this initial cost by streamlining its business model. This would reduce the price to US$42.8 million or possibly even US$37 million, if the company transfers all the savings from reusing the rocket to its customers.[22] Musk also wants to reduce the turnaround time to a mere 24 hours which could further lower costs.

Jeff Bezos, founder of Amazon, has established Blue Origin, which is also experimenting with reusable launch vehicles. Blue Origin has less experience in the business than SpaceX and is yet to operationalise its launch vehicles. However, Bezos has vowed to continue funding the company by selling US$1 billion worth of Amazon stock every year.[23] He also proposed creating Amazon-like delivery services to the Moon, which could help to create and strengthen the much needed supply chain space mining companies are calling for. Bezos shares space mining enthusiasts' concern about the future of our planet, which led him to start Blue Origin.

Elon Musk feels the same way. His vision is to make humanity a multi-planetary species by colonising Mars, which will require efficient and affordable means of space transportation. Musk takes inspiration from earlier entrepreneurs who enabled innovative manufacturing and management of airplanes. The airline industry manufactures planes that can be reused multiple times with minimal checkouts and fast re-fuelling between flights. This started a revolution in the transportation sector, enabling businesses to expand across the world. SpaceX has been modelled to use the same principles.

In turn, SpaceX can benefit from the mining on Mars to fuel its rockets. It is building methane fuelled Raptor engines that can use the abundant quantities of this gas found on Mars.[24] Local sourcing of rocket fuel, which is about 90 percent of the total weight of the rocket, will help keep the cost down and make management of space transportation simpler. Such a co-dependent relationship between resource miners and space transportation companies will help sustain the supply chain in space.

E. Space Manufacturing

Even as the cost of space transportation is coming down, the weight of equipment that needs to be launched for a basic outpost on the Moon or Mars is extraordinary. It would require a number of heavy lift launches and assembling of parts in space for the longer voyage to other celestial bodies. If the necessary equipment could be produced in space, it would cut down the weight of launches and thereby cost. Astronauts could launch with minimum equipment such as life support systems and produce more oxygen and water from celestial resources.

The International Space Station (ISS) has become the testing ground for space manufacturing. A 3D printing machine was installed on the station in

2014 which produced a few simple items using plastic. The latest such item is a ratchet wrench which took four hours to make using the design file received from Earth.[25] The experiment successfully demonstrated that articles could be manufactured in space, that may not have been envisioned for use during the mission design, but for some reason became immediately required.

NASA collaborated with a small business entity, Made In Space, to design this printer. The company also tested a satellite manufacturing machine prototype, a 3D printer coupled to a robotic assembly system, which printed small circuit boards and assembled them to produce a functioning pico-satellite.[26] An improved version, dubbed Archinaut, will be deployed on the ISS, which can produce large scale structures and assemble them.[27] An independent Archinaut orbiting the earth could help replace defunct components on a satellite, prolonging its life.

These capabilities will allow future space explorers and settlers to produce most of the required equipment in space instead of launching them on rockets. It will also help enhance crew survivability during emergencies. For example, the Apollo 13 astronauts, in jeopardy following the explosion of an oxygen tank, used socks, plastic bags and duct tape to devise a crude filter to protect themselves from toxic gases. Access to a 3D printer on future spaceships could avert such problems allowing the crew to concentrate on critical operations.

The additive required for space manufacturing could be gathered by mining celestial bodies. It is possible to make radiation resistant habitats from lunar material, thus reducing launch costs and at the same time creating a market for the space mining industry.[28] Moreover, goods for consumption on Earth could also be manufactured in space and transported. It will eliminate the need to establish more factories on earth, which are a source of pollution.

F. Pioneering a Space Economy

Jeff Bezos puts forward the idea of relocating ground based heavy industries in space.[29] He wants to build basic infrastructure to enable future space entrepreneurs, much the way his Amazon took advantage of existing infrastructure to succeed. Thus, Blue Origins is in essence a cheaper delivery mechanism to outer space that is taking advantage of reusable launch vehicle technology. Bezos believes that lifting the industrial ecosystem into space is essential to preserve the environment and continuity of human life.

Elon Musk shares the concern of Bezos about existing manufacturing mechanisms and lifestyles, agreeing they are unsustainable for humanity's future. His solution is to pursue space colonisation starting with Mars, essentially helping expand humanity's presence in the solar system. SpaceX came into existence to build transportation infrastructure for eventual colonisation of Mars. Space mining companies are not indifferent to this vision and are in fact trying to consolidate it by shifting mining operations off ground.

The task of shifting these processes into outer space is daunting. Nevertheless, the current pace of population growth and dwindling resources make it imperative to support these initiatives. Resource conflicts are expected to multiply in the future and unlike the oil wars, they could well be over plain drinking water. The United Arab Emirates' plans to diversify its economy, followed by similar attempts by Saudi Arabia, attests to this fact.

Chris Lewicki, founder of Planetary Resources, is, however, optimistic about humanity's survival. Much like the earlier explorers crossing the oceans and settling in new frontiers, he envisions millions of people working and living in the final frontier.[30] This could be the Moon, Mars, or even giant space stations orbiting celestial bodies. This new civilisation will be not merely about humanity's survival but also about continuing its development. Lewicki asserts that space mining is not just about space, but a resources project to establish a new industrial economy in space.[31]

The mining, transportation and manufacturing sectors, once refined and consolidated, will help build a space economy, much like the processes sustaining the current global economy. Most of these space projects are in design and testing phase, but with Moore's Law doubling computing power approximately every 18 months, it is possible to develop new technologies and platforms faster than anticipated.

Consider, for example, the decreasing time interval in which humanity migrated from horse carriages to cars, and then from cars to airplanes. Within the space age, the ongoing adoption of reusable launch vehicles is occurring within a much shorter timescale. Most importantly, the entrepreneurial spirit imbued in Western business practices cannot be undermined. Elon Musk himself stands as an example of this attitude, having successfully compelled traditional rocket companies to adapt to reusability. The current pace of development signals that the decade of the 2020s will unleash a new wave of technologies required for space mining.

This new generation of environment-minded space entrepreneurs can build a sustainable future provided governments gives them the legal space to attract investments, develop technologies and profit from their innovations. Therefore, the NewSpace entrepreneurs have been proactively seeking regulations to avoid venturing into a "new Wild West" in outer space.

II. GOVERNANCE ISSUES IN SPACE MINING

A. Institutional Support

The US is at the forefront of developing this space economy. The US government has aided the commercial development of space using policy instruments, supporting small and innovative businesses as well as providing university grants. US Departments of State and Commerce have undertaken reforms to ease the satellite export control regime while the Office of Space Commerce coordinates relevant policies to promote the growth of the domestic commercial space industry. The concerned areas include remote sensing, space transportation, global positioning and navigation, and space entrepreneurship.

NASA organises various competitions and provides technical assistance for the development of novel technologies such as 3D printing, space solar power, electric propulsion, and others. Space entrepreneurs and their commercial enterprises have also benefitted from these policies and missions. NASA's development grants and commercial cargo and crew transport contracts to the ISS helped SpaceX sustain its operations despite critical failures.

NASA has also tried collaborating with Planetary Resources and Deep Space Industries to validate key space mining technologies. It envisioned an Asteroid Redirect Mission that would grab a boulder from a large asteroid and place it in a lunar orbit. Astronauts would then visit this boulder to test relevant technologies and mechanisms being developed for space mining. NASA was supposed to partner with Planetary Resources and Deep Space Industries to enable its space mining vision, but the Trump administration has cancelled this mission.[32]

The mission was initially supported by the previous Obama administration that also adopted the Commercial Space Launch Competitiveness Act (CSLCA).[33] This law granted an extension of the 'learning period' for commercial entities using ISS as the test bed. The plan was to enable the US commercial space industry to operate independently in the low earth orbit and eventually in deep space, while NASA concentrates on human exploration of Mars. Moon Express is the first commercial spacecraft to be granted permission to venture beyond Earth's orbit and land on the Moon.[34]

The CSLCA is also significant for granting legal rights and protection to US citizens engaged in space mining. It allows them to own, use, transfer and sell mined space resources without granting exclusive ownership over the celestial bodies. The US declared that it is exercising the authority to make domestic laws in compliance with its obligations to international treaties such as the Outer Space Treaty (OST).[35]

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, generally known as the OST, prohibits states from owning celestial bodies by claims of sovereignty, use, occupation or any other means. Moreover, the OST makes states responsible for governing the activities of non-governmental organisations by authorising and continually supervising such activities.

However, Luxembourg criticises the CSLCA for being limited to US citizens and entities with majority US capital. It has adopted a space law governing space resources utilisation that grants permission for space mining entities under its jurisdiction to acquire foreign capital.[36] It has created a Space Resources initiative with an initial € 200 million euro fund for promoting research and development in space mining.[37]

This has already had the effect of both Deep Space Industries and Planetary Resources deciding to set up offices in Luxembourg. The initiative will fund Deep Space Industries' satellite Prospector-X, designed to test key asteroid mining technologies such as propulsion, avionics and optical navigation.[38] Planetary Resources and Luxembourg will collaborate on earth observation and space resources utilisation.

B. A Caveat

Both the US and Luxembourg space laws signal that it is the prerogative of states to make relevant domestic laws affecting space mining while still complying with the international law. However, they are limited to granting rights to mined space resources, and cannot allocate resource sites. However, Robert Bigelow, founder of Bigelow Aerospace, that manufactures space habitats, concedes that defining an area of operations on celestial bodies is necessary for interference free operations.[39]

Neither states nor an international regime currently has the authority to define the spatial and temporal parameters requisite for a specific mission. Although Luxembourg proclaims that its law is a measure against outer space becoming another Wild West, where use of force dictates life and businesses, the absence of an authority to appropriate 'resources in place' creates uncertainty and struggle for resources.

Consider this thought experiment relating to the peaks of eternal light on the Moon.[40] These peaks are small areas on the Moon that receive sunlight for more than 80 percent of the time. The sunlight can be converted into electric power for human settlements, exploration, mining and transportation. However, such peaks are scarce and are found only near the lunar poles, spanning only a few hundred metres. Considering that lunar poles are also a great source of water, these peaks could become a source of intense competition and possibly assertion of quasi-property rights.

To demonstrate this, the experiment had drawn out a situation where an entity places a solar telescope on one of the peaks. It requests other parties not to enter the area for fear of foreign electromagnetic emissions distorting the telescope's readings. Although this entity is not claiming sovereign or property rights, the very fact that it has restricted the use of that peak to other entities could indirectly entail quasi-ownership of the area. It could also report to the UN under the provisions of the OST were a new entity to disregard the safety or interfere with its installation.

Such a scenario is close to future reality as Moon Express has already been contracted by International Lunar Observatory Association to land its telescope on the South Pole of the Moon in 2019.[41] The telescope will be placed on a peak of eternal light while Moon Express provides commercial communication, navigation and power services. Moreover, the lander will also explore the lunar South Pole for minerals and water.

Therefore, the probability of clashes over water, metals and solar energy on the Moon is high. This situation signals that arriving first at a prospective location will offer greater material and legal rights to any entity. US Senator Ted Cruz, Chairman of the Senate Commerce Subcommittee on Space, Science, and Competitiveness, attests to these conclusions, saying that conflicts should be anticipated because of the race for celestial resources and it is imperative to reach first at a site for economic and operational advantages.[42]

The US tried legalising this assertion by inserting a 'first in time, first in right' rule in the proposed American Space Technology for Exploring Resource Opportunities in Deep Space Act (ASTEROIDS Act).[43] The CSLCA that absorbed this act pared it down limiting itself to legal protection for extracted resources only. However, the CSLCA or even the ASTEROIDS Act is a domestic initiative and therefore cannot be helpful in a potential situation where, for example, Moon Express and China's state agency compete for the same location on the moon.

Even if the entity to first occupy a specific area on the Moon could prove to the international community the damage or intentional interference from an approaching second entity, it is not possible to obtain relief, since there is no international regime authorised to investigate and implement any legal verdict. At best, the affected entity could seek consultations facilitated by the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS) that studies legal problems arising from space exploration.

The legal subcommittee could gather expert opinions and solutions to the evolving situation, but these suggestions are not binding on states or their commercial entities.[44] The OST is equally silent on legal proceedings and verdict implementation mechanisms.

C. Amending the Outer Space Treaty

Senator Cruz opined that OST should be amended to make it relevant to the changing times. It was drafted 50 years ago when the US and the Soviet

Union were locked in intense geopolitical competition, with outer space also becoming a zone of contest.

These Cold War rivals attempted a series of 'space firsts' to garner international prestige and supremacy. The Soviet Union initiated the space race with the launch of Sputnik in 1957 and followed it up by sending the first man, woman and animal into orbit in addition to landing the first robotic spacecraft on the Moon. The US decided in 1962 to beat the Soviet Union by first landing a man on the Moon, which paved the way for the Apollo programme.

Simultaneously, outer space became a test bed for high altitude nuclear explosions conducted by both the US and the Soviet Union between 1958 and 1962. The American Starfish Prime nuclear explosion in 1962 was the largest of these and reached the highest altitude (400 km) in space. The damage to space exploration from nuclear explosions became immediately evident as the radiation fried Telstar 1, the satellite to first relay television pictures and live transatlantic television feed.[45] The radiation also damaged components or degraded the power output of other satellites.

These tests challenged the spirit and effectiveness of the UN General Assembly which constituted the COPUOS to govern exploration and use of space for the benefit of humanity. Although successive declarations and resolutions established the fact that international law, including the Charter of the UN, was applicable to outer space, it is accepted that a legally binding treaty is necessary to prevent competition and conflict.[46]

Therefore, the OST is more concerned with preventing placement of weapons of mass destruction in space as well as national appropriation of celestial bodies. Article II declares that celestial bodies are not subject to national appropriation by claims of sovereignty, use, occupation or any other means. Article IV prohibits placement of nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies.

Regarding commercial exploitation, Article VI stipulates that appropriate states shall bear responsibility for activities of non-governmental entities in outer space by providing authorisation and continual supervision of such activities. The US and Luxembourg contend that their space laws granting ownership rights to mined space resources comply with the stipulations of the OST.

Rather, it can be stated that these laws do not violate OST, at least explicitly. They have not laid sovereign claims to even specific resource sites or appropriated them for commercial entities. However, considering that commercial entities from these countries could very well be the first to step on celestial resources and establish installations, it could lead to de facto appropriation of specific resource sites, as demonstrated in the thought experiment.

In case of a conflict, the commercial entities will have to rely on state governments to resolve it. The OST is limited in this case, as it only offers international consultations (Article IX) to resolve conflicts arising from interference but not a legally binding resolution.

Moreover, opening the OST regime to introduce safeguards for commercial space mining could in fact lead to worse outcomes. It would provide space for a number of countries to acquire and demonstrate new capabilities given the proliferation of nuclear weapons and missile technologies since the adoption of OST. More countries could try testing anti-satellite weapons which are not explicitly prohibited by the OST but only restricted by its spirit.

The OST tries safeguarding outer space from weapons of mass destruction and enable international cooperation for peaceful 'exploration' of the final frontier. However, it does not possess the required scope to discuss and govern commercial 'exploitation' of space resources in a comprehensive manner.

The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies or the Moon Treaty tried resolving this issue.[47] It banned private ownership of extraterrestrial property but recommended establishing an international regime to govern exploitation of lunar natural resources whenever it becomes feasible to do so.

States are responsible for drafting appropriate procedures for the purpose of orderly and safe development of natural resources and their rational management, expansion of opportunities in using these resources, and an equitable sharing of the benefits derived from these resources by all states parties, particularly the developing countries.

The US initially favoured ratification of the treaty but industry and advocacy groups persisted in opposing it, claiming that the treaty, particularly the proposal for an international regime, had "socialist" connotations. The treaty came into effect in 1984, but it is considered a failure since the three major spacefaring countries – the US, the Soviet Union/Russia and China – did not become parties to it.

D. Undesirable Post-Conflict International Regime

It is desirable to put in place minimum guarantees for the safety and security of commercial space mining entities in addition to supporting the development of a market for space resources. However, the existing international space law is vague at best on these issues. Both OST and the Moon Treaty were drafted during the Cold War when the fear of nuclear weapons exploding in outer space was high and the prospect of mining celestial bodies, let alone establishing a space economy, was nil.

With the Moon Treaty in limbo, and the expanding of the OST regime seeming inadvisable for fear of escalating space weaponisation, space mining companies are indeed heading into a new Wild West. The likelihood of a conflict arising out of the competition for precious resources will only increase as more governmental and commercial entities get spurred by initial successes. Even as a conflict in outer space is undesirable, perhaps an escalating situation is necessary to jolt the international community into action.

The nuclear and space treaties that came into effect during the Cold War exemplify this behaviour. The nuclear non-proliferation treaty (NPT) as well as the OST are results of the international community, including the two superpowers, being concerned at the prospect of a conflict escalating beyond control and leading towards mutual annihilation. In addition to the UN treaties, the US and the Soviet Union also concluded bilateral treaties such as the Strategic Arms Limitations Treaty, the Anti-Ballistic Missile Treaty, etc.

The caveat to adopting this line of reasoning is that of a competing party which is equally capable, and poses a challenge to the activities of space mining companies. Much like the Soviet Union which challenged the West during the Cold War; the current international order could be challenged by China. Thanks to its financial clout, China is fast modernising its military, including acquiring the capability to deny the use of outer space to others by fielding anti-satellite weapons.

China has been demonstrating these weapons since 2007 in the form of direct ascent kinetic kill projectiles or directed energy weapons.[48] These tests are assessed to be part of China's strategy to acquire asymmetric capabilities against the conventional superiority of the US. However, it could also be that China is trying to acquire parity with both the US and Russia, which have demonstrated their own anti-satellite weapons. China possessing this capability would allow it to negotiate from a position of strength for any possible treaty banning these weapons. This would legitimise China's anti-satellite weapons and its *de-jure* status, akin to the NPT legitimising the nuclear weapons of the five big powers.

A parallel logic can be extended to exploitation of space resources where acquiring necessary capabilities is the first step. China's leadership has pledged its political and financial support for manned missions in the low earth orbit, and robotic exploration of the Moon and asteroids. China's space planners are confident that this support will be extended to manned landings on the Moon with the intention of settling and mining resources.

China's energy needs continue to expand even as it struggles to regulate emissions by switching to cleaner fuels. It is also the leading producer of rare earth elements with the US, Europe, Japan, among others, depending on China's exports for the manufacture of high-end devices. China had cut down exports to these countries as an act of political coercion.[49] Such leverage will be lost if American or Luxembourg based space mining companies are able to extract these elements from the Moon. The situation can worsen from China's viewpoint considering the quasi-ownership rights acquired by 'arriving first' at resource sites.

In addition, the international community does not possess the wherewithal to investigate claims and counterclaims, let alone the ability to resolve the conflict. The availability of anti-satellite weapons, which are currently not restricted by any international treaty except the spirit of the OST, makes the conflict potentially uncontrollable. This adds a certain legitimacy to the assumption of a future conflict in outer space between two equally capable entities rooted in differing political and economic ideologies, and backed by their respective anti-satellite weapons.

Such a scenario will spell doom. Nevertheless, there is room for faint optimism if the international community or even concerned major spacefaring powers take early cognizance of it and act. Even as nuclear explosions and geopolitical competition during the early 1960s signalled a bleak outlook for the future of outer space, the International Telecommunications Union (ITU) was proactive in securing the geostationary orbit. It had recognised radio frequencies and orbital slots as limited 'natural resources' and therefore established Radio Regulations, guaranteeing equitable access to these slots and frequencies for all states.

The ITU is a specialised agency of the UN with a Constitution and maintains the Master International Frequency Register, the formal database of space and terrestrial frequency assignments. This confers international recognition to allocated frequencies and protection from interference or infringements. The ITU Council considers recommendations from the World Radio Communication Conferences held every three to four years to review and revise Radio Regulations, the international treaty that governs the use of frequencies and satellite orbits.[50]

Member states can propose and vote on changes to these regulations during the conferences. On the domestic side, a concerned ministry, department or specialised agency is nominated to ensure compliance with these regulations and coordinate with the ITU for acquiring orbital slots. The US had assigned these duties to Federal Communication Commission. The ITU encourages member states to settle disputes by reaching a compromise through negotiations and reconciliation. It does not possess a formal dispute resolution body but plays an active role only if its member states vote for such an action.[51]

The ITU swiftly moved to recognise the electromagnetic spectrum and geostationary orbit as limited natural resources and set up regulations for ensuring equitable access to all states. This is a prime example of a proactive approach towards safeguarding outer space and could be an inspiration for setting up an international agency, as proposed by the Moon Treaty, to regulate space mining in advance of entities contesting for resources.

E. A Commercial Sputnik Moment

It is imperative to understand that the ITU is already an existing agency, standardising and governing the use of telegraph communications[52] and later, telephone communications. Sputnik not only unleashed a new technological age but also set new international norms. The experience from regulating terrestrial radio communications helped ITU recognise the future growth in space communications, including commercial development, with Sputnik relaying communication signals from outer space.

Sputnik also resolved a dilemma confronting the US administration of President Eisenhower. The upper boundary of national airspace was extended to infinity and therefore the administration was concerned about violating other countries' airspace as American satellites flew around the earth. The US was particularly concerned about the reaction from the Soviet Union. Sputnik caused panic and challenged American technological supremacy, but the US was encouraged by the fact that other states offered compliments to the Soviet Union instead of protesting violation of their airspace.[53]

Sputnik had established airspace limitations and outer space as new, freely accessible global commons. This was achieved by a technological feat rather than consensus of states and is a guiding principle for the Radio Regulations or space treaties such as the OST. In fact, a group of equatorial countries comprising Venezuela, Colombia, Indonesia, etc., tried asserting sovereign claims over parts of the geostationary orbit but were unable to convince other states to oppose the norm.[54]

Commercial space mining is about to unleash a new era in space history and a new industrial age in human history. Another "Sputnik moment" is what is required to convince states of the need to establish international norms governing space mining. A preliminary mission that brings back space resources (at least a few grams) which are then commercially traded on earth, even for symbolic reasons, would establish a new set of norms as a fait accompli.

This is a future possibility with commercial entities such as Moon Express or Planetary Resources on the verge of demonstrating their technological competence supported by legal guarantees provided by the US or Luxembourg. The optimistic result would be the establishment of a basic set of regulations before a potential conflict arises on celestial bodies.

CONCLUSION

The US has built and sustained its national economy by encouraging entrepreneurs to take risks and innovate. The current generation of entrepreneurs has concentrated its efforts on building a new industrial economy based in outer space. Manufacturing processes will be shifted to outer space and soon the required raw material will be mined from celestial bodies such as the Moon and asteroids. Affordable and frequent space transportation options are also on the anvil. This basic set of disruptive technologies is promising to turn the global economy into a space economy. The entrepreneurs working on this project are united in the thought of sustaining earth's environment for future generations by establishing the space economy.

However, existing international norms and space law has not evolved to support this vision. The OST that established basic international space law was a response to Cold War concerns and did not take into consideration the prospect of commercial space mining. The US and Luxembourg have adopted domestic space laws guaranteeing legal protection to space mining companies to own, transfer, use and sell mined space resources. However, these entities are still uncertain of their future since neither the OST nor the US and Luxembourg space laws offer solid safeguards to mining operations on celestial bodies.

No doubt Western space mining companies will be the first to erect installations at various resource sites in space granting them quasi-ownership rights. But emerging competition from state entities such as China could not only limit the resources available to space mining companies but also lead to conflict. This is highly probable given the scarcity but high demand for resources such as water and solar energy on the Moon and asteroids. The OST offers only international consultations and does not have any specific dispute resolution mechanism or legally binding resolution in this regard. Neither the international community nor the UN possesses the wherewithal to validate claims and counterclaims.

The Moon Treaty proposed setting up an international regime to govern exploitation of space resources, but its failure has meant space mining companies are heading into a new Wild West. What is required to get the international community to act is another Sputnik moment. The original Sputnik moment led to establishment of basic international norms for outer space, while the possibility of conflict encouraged states to adopt the OST.

The space mining companies could conduct a preliminary mining expedition on an asteroid and sell those resources on earth, thus leading to the establishment of a new set of international norms. This could propel states to draft a comprehensive law to govern space mining, thus enabling the space economy to take shape. ORF

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