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Understanding the Promises and Pitfalls of Outer Space Mining and the Need for an International Regulatory Body to Govern the Extraction of Space-Based Resources

Mitchell Powell

Abstract

Space exploration is about to undergo a monumental change and the global legal and regulatory infrastructure is massively unprepared. When the bulk of international space law was written, the Cold War was raging, and man had not even landed on the Moon yet. Now, thanks to advances in technology, a seismic shift has occurred which will see private industry leading the future of space exploration with national space agencies as partners, rather than the other way around as has been the status quo for decades. One of the most lucrative possibilities luring private firms to space is the opportunity to extract resources from a celestial body such as an asteroid, another planet, or the Moon. It is estimated that trillions of dollars' worth of precious metals, liquids, and gasses exist on these bodies. A galactic resource race will soon be underway, and space-faring nations must take the lead to ensure that legal, economic, and environmental issues posed by such space exploration is hammered out before it is too late. I assert that if left to their own devices, firms will fail to follow the same standard of their fore-father government space agencies. As a result, we need an international agreement or body for the twenty-first century to govern and regulate the extraction of resources from outer space led by the great space hegemons.

Understanding the Promises and Pitfalls of Outer Space Mining and the Need for an International Regulatory Body to Govern the Extraction of Space-Based Resources

Mitchell Powell[*]

> "The first trillionaire there will ever be is the person who exploits the natural resources on asteroids."
>
> **—Dr. Neil deGrasse Tyson**[**]

INTRODUCTION

This Article will examine the issues surrounding the commercialization of outer space and will specifically focus on the extraction and monetization of space-based resources including minerals from other planets or celestial bodies, such as asteroids or the Moon. Section I of this Article provides an overview of the laws that govern outer space, space exploration, and the existing international treaties, accords, and agreements in support thereof. Section II examines the relevant firms vying to commercialize space to understand the mission that each firm is seeking to undertake through outer space mining and the extraction of space-based resources. Section III explores the legal, financial, and environmental issues posed by space mining. In Section IV, I propose my solution to the problems suggested in Section II and emphasize the need for a new international body or charter between the great space-faring nations. Finally, Section V offers some concluding thoughts.

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I. AN INTRODUCTION TO THE AMERICAN SPACE PROGRAM

A. The U.S.-Soviet Space Race and the Establishment of NACA & NASA

On October 4, 1957, the Soviet Union shocked the world when it launched the tiny, yet infamous beeping probe named Sputnik I.[1] That seemingly harmless, beach-ball sized artificial satellite set off what would become a great race to conquer outer space between the East and West. The United States was, suffice it to say, caught off guard by the ambitious little probe that passed over American soil for roughly 22 days.[2] That we, as Americans, could do nothing about it shook us to the core.

As early as November 25, 1957, then-Senator Lyndon B. Johnson chaired meetings on the Preparedness Investigating Subcommittee of the Senate Armed Services Committee to assess the readiness and status of the United States as it related to missiles, rocketry, and space flight.[3] These meetings are widely seen as the impetus which propelled the establishment of the February 6, 1958, Senate Special Committee on Space and Aeronautics; this Special Committee, chaired by Senator Johnson was convened with the express intent of founding a national space agency.[4] Contemporaneously, in the United States House of Representatives, Congress swiftly acted to create the Select Committee on Astronautics and Space Exploration.[5] It had been over a decade since such a standing committee had been formed in the House. Moreover, it had been the first committee established since 1892 that was tasked with overseeing a brand-new dominion of authority within the government.[6]

On March 5, 1958, President Eisenhower and his advisors, including Nelson Rockefeller—who served on the President's Advisory Committee on Government Organization, were reviewing and ultimately signed a memorandum which called for the establishment of a civilian-led space agency to be built around the already-

[1] Kiona N. Smith, *Sputnik 1 Launched The Space Race 60 Years Ago Today*, FORBES (Oct. 4, 2017, 2:32 PM), https://www.forbes.com/sites/kionasmith/2017/10/04/sputnik-1-launched-the-space-race-60-years-ago-today/#5a03fc1b590f.

[2] NASA Content Administrator, *First Contact: Sputnik*, NASA (Oct. 2, 2007), https://www.nasa.gov/mission_pages/explorer/sputnik-20071002.html.

[3] Alex Roland, *NASA SP-4103Model Research: The National Advisory Committee for Aeronautics, 1915–1958, Volume 1*, *in* THE NASA HISTORY SERIES 445, 291 (1984).

[4] *Id.*

[5] John E. Naugle, *First Among Equals: The Selection of NASA Space Science Experiments*, *in* THE NASA HISTORY SERIES (1991).

[6] Comm. on Science, Space, and Technology, H.R, *About*, *History and Jurisdiction*, https://science.house.gov/about/history-and-jurisdiction.

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existing NACA.[7] The National Advisory Committee for Aeronautics was initially established on March 3, 1915.[8] NACA had, for quite some time, struggled with its identity.[9] It was originally tasked with studying the various issues surrounding flight.[10] This broad charter, however, meant that by 1958, NACA was spending almost half of its time and resources devoted to issues including space-flight.[11] President Eisenhower recognized the need to form a separate entity, one which was to be the primary and driving force behind our nation's future in outer space. Following draft legislation which was sent to Congress and deliberated over thereafter, the President signed the National Aeronautics and Space Act into law which formally established the National Aeronautics and Space Administration, or NASA, on July 29, 1958.[12]

B. A Brief Overview of the American Space Program's Achievements

In the years that would follow this visionary move, President Kennedy famously tasked our nation to go to the Moon and back within a decade, and we did.[13] For the first time in history, a human stepped foot on another celestial body, and an American at that.[14] The Apollo program captured the hearts and minds of the global populace in a way that no other singular event in the history of mankind had before. For a brief period in time following the epic achievements of the Apollo 11 crew, men, women, and children from across the globe celebrated in a collective sense of human, and not nationalistic, achievement.[15]

In the period following the iconic Apollo Program, the United States successfully built and flew the first ever large-scale reusable space vehicle, the space

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[7] Naugle, *supra* note 5.

[8] Yvette Smith, *The NACA Centenary: A Symposium of 100 Years of Aerospace Research and Development*, NASA (July 10, 2014), https://www.nasa.gov/naca_symposium.

[9] Naugle, *supra* note 5.

[10] Smith, *supra* note 8.

[11] Elizabeth Suckow, *NASA History Program Office Overview*, NASA (Apr. 23, 2009), https://history.nasa.gov/naca/overview.html.

[12] *Id.*

[13] President John F. Kennedy, Address at Rice University on the Nation's Space Effort (Sept. 12, 1962) (*transcript available at the John F. Kennedy Presidential Library and Museum*).

[14] *July 20, 1969: One Giant Leap For Mankind*, NASA (July 20, 2017), https://www.nasa.gov/mission_pages/apollo/apollo11.html.

[15] *Apollo 11 Moon landing: ten facts about Armstrong, Aldrin and Collins' mission*, THE TELEGRAPH (July 18, 2009), https://www.telegraph.co.uk/news/science/space/5852237/Apollo-11-Moon-landing-ten-facts-about-Armstrong-Aldrin-and-Collins-mission.html (explaining that 600 million people watched the Apollo 11 landing live on television).

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shuttle. Capable of launching vertically from earth like a rocket and landing horizontally like an airplane, the shuttle—formally designated as the Space Transportation System ("STS")—was able to ferry herculean amounts of cargo into low-earth orbit ("LEO") to develop and build the International Space Station ("ISS") while in orbit.[16] At present, the ISS is formally designated as a U.S. National Laboratory tasked with studying science in a microgravity environment.[17] Astronauts from around the world have manned the ISS together in space, orbiting the Earth dozens of times a day, nonstop for nearly twenty years.[18]

The shuttle, famous for both its tremendous utility and two tragic disasters, Columbia and Challenger, was the work-horse of the NASA fleet for decades. The Shuttle built, resupplied, and ferried astronauts to the International Space Station. However, due to massive budget cuts and a new vision for the future of NASA, the United States ultimately decided to retire the ageing shuttle program in preference for a new vision for NASA and the future of American spaceflight and exploration.[19]

With the cancellation of the space shuttle, the United States was left without the ability to send American astronauts to outer space via an American owned and launched spacecraft for the first time in decades.[20] As a result, the United States now relies on one of their most important partners in space exploration, the Russian governmental space agency Roscosmos, to send astronauts to the International Space Station, paying a hefty price tag to do so per-seat.[21] NASA currently pays approximately $81 million per astronaut to the Russian government for each seat on a Soyuz rocket launched from Kazakhstan and bound for the ISS.[22] The retirement of the shuttle program and subsequent decision to utilize Roscosmos to send astronauts and cargo to the ISS spurred a change in the American space sector.

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[16] Alan Taylor, *The History of the Space Shuttle*, THE ATLANTIC (July 1, 2011), https://www.theatlantic.com/photo/2011/07/the-history-of-the-space-shuttle/100097/.

[17] *About the ISS National Lab: Science in Space to Benefit Life on Earth*, CASIS, https://www.iss-casis.org/about/about-the-iss-national-lab/ (last visited Mar. 27, 2019).

[18] *Id.*

[19] Ian Sample, *Space shuttle retirement leaves 'yawning gap' in human spaceflight*, THE GUARDIAN (July 7, 2011), https://www.theguardian.com/science/2011/jul/07/space-shuttle-retirement-human-spaceflight.

[20] Marina Koren, *When Will Astronauts Launch From U.S. Soil Again?*, THE ATLANTIC (Jan. 17, 2018), https://www.theatlantic.com/science/archive/2018/01/when-will-astronauts-launch-from-us-soil-again/550730/.

[21] David Mosher & Skye Gould, *NASA is paying Russia more than $70 million to bring an astronaut home in this spaceship tonight*, BUS. INSIDER (Sept. 6, 2016, 3:36 PM), https://www.businessinsider.com/space-travel-per-seat-cost-soyuz-2016-9.

[22] *Id.*

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While this brief and perhaps romanticized history of NASA and American spaceflight may read as a ringing personal endorsement of the agency, and in many respects, it is, its inclusion serves a purpose. The simple fact of the matter is that one cannot understand the future of human spaceflight and exploration without understanding its origins. This incredibly storied and complex field of science has always been at the bleeding edge of what humans are capable of doing given the technology of the day.

C. The Evolving Structure of the American Space Program

Since its inception, NASA has partnered with private industry (designated as corporate contractors) to design, test, and build probes, rockets, vehicles, and a litany of components used in the exploration of outer space.[23] These private American contractors such as North American/Rockwell, Northrop Grumman, Raytheon, IBM, Boeing, Lockheed Martin, Honeywell, Aerojet-Rocketdyne, and many others were always part of an important structure which is now changing.[24] These corporate entities each had shareholders, boards, employees, and a history unique to their own purpose and mission; many specialized in singular design areas such as engines or highly-specific control systems, such as guidance computers. In the past, NASA retained final say over designs, specifications, costs, missions, and the like. Contractors were just that, paid for their expertise and awarded bids, but did not possess ultimate decision making abilities or larger technological prowess beyond their respective industries of focus. While working with corporate contractors, NASA always was, technically, the boss.

NASA is an independent federal agency that is free of direct presidential control and is overseen by congress.[25] After the Director of NASA sends the needs of the space program to the Office of Management and Budget, the request makes its way to the White House which, in turn, subjects it to scrutiny and then later sends it as a part of the annual budget to Congress for consideration.[26] NASA has always retained, therefore, the ability to design its own missions, select the contractors that work on their vehicles and equipment, and train astronauts. All missions, spanning from the fledgling Project Mercury through today were launched from U.S. military

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[23] Arnold S. Levine, *Managing NASA in the Apollo Era* 65 Washington, D.C., GOV'T PRINTING OFFICE, 1982.

[24] *Id.*

[25] Ron Mochinski, *About Us—Background and Charter*, NASA, https://www.nasa.gov/offices/nac/about.html (last updated Sept. 12, 2018).

[26] Jason Callahan, *How NASA's Yearly Budget Request Comes Together*, THE PLANETARY SOC'Y BLOG (Jan. 29, 2015), http://www.planetary.org/blogs/guest-blogs/jason-callahan/0129-how-the-presidents-budget-comes-together.html.

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installations, paid for with public taxpayer funds, and bore the NASA logo alongside the American flag for all the world to see on the fuselage of the rockets involved. It seems, however, that the era of big government leading the way with corporate contractors contributing small, yet essential components to a grander mission is changing. This change is being brought about by several visionary private corporations. In recent years, NASA has begun to pay *private firms* to launch their own rockets to the ISS for resupply missions rather than NASA continuing to build, develop, and launch the spacecraft on their own as they have done since the inception of the agency.[27] This dramatic shift began, largely, as the result of the private commercial firm SpaceX.

Elon Musk made his first round of millions by cofounding an e-payments website which would later become PayPal in 2000.[28] PayPal was acquired by eBay for $1.5 billion in 2002.[29] Musk did not stop there, however. With a larger and more ambitious vision, Musk created Space Explorations Technology Corp, better known colloquially as SpaceX in the same year as the eBay acquisition of PayPal.[30] The firm, based in California, initially germinated as a result of Musk's dream to make space travel cheaper and to colonize the Martian planet as an alternative home-base for humans.[31] Musk initially wanted to place a greenhouse containing plant life and seeds from earth on the Martian surface to begin the process of creating life on another planet.[32] The problem that Musk ran into was funding; the costs to do so were exorbitant.[33] Musk knew he could not afford an American rocket to send his prospective plants to Mars, so he instead turned to the Russians seeking a lower-cost alternative.[34] Ultimately, this did not pan out given Musk's apprehension with spending such a large-sum of capital in the less-financially regulated Russian

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[27] Loren Grush, *NASA is saving big bucks by partnering with commercial companies like SpaceX*, THE VERGE (Nov. 10, 2017), https://www.theverge.com/2017/11/10/16623752/nasa-commercial-cargo-crew-spacex-orbital-atk-boeing-orion.

[28] Sergeui Klebnikov, *8 Innovative Ways Elon Musk Made Money Before He Was a Billionaire*, TIME (Aug. 8, 2017), http://time.com/money/4883868/8-innovative-ways-elon-musk-made-money-before-he-was-a-billionaire/.

[29] Caleb Melby, *How Elon Musk Became a Billionaire Twice Over*, FORBES (Mar. 12, 2012), https://www.forbes.com/sites/calebmelby/2012/03/12/how-elon-musk-became-a-billionaire-twice-over/#3afb7e3e1c88.

[30] Alison Eldridge, *SpaceX*, BRITANNICA (Aug. 6, 2012), https://www.britannica.com/topic/SpaceX.

[31] Ajaj Raj, *Here's The Wacky Reason Elon Musk Founded SpaceX*, BUSINESS INSIDER (Oct. 14, 2014), https://www.businessinsider.com/elon-musk-wanted-to-send-plants-to-mars-2014-10.

[32] *Id.*

[33] *Id.*

[34] *Id.*

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business environment.[35] Musk founded SpaceX, with two express aims: (1) to make spaceflight routine and affordable and (2) to make humans a multi-planet species.[36] Musk has been largely successful in his mission, and SpaceX is widely seen as the standard-bearer for a new wave of companies operating in what is now known as the "commercial space sector." In May of 2012, SpaceX became the first private firm in history to build and launch a space craft capable of reaching, docking with, and resupplying the International Space Station.[37] This accomplishment laid the groundwork for a $1.6 billion minimum contract which provides that SpaceX will fly 12 resupply flights to the ISS.[38] This accomplishment is an exemplar of the foundational shift which has happened and is continuing to occur in spaceflight today. Nationally-backed space agencies such as NASA, which used to be the de-facto and foremost authorities on spaceflight, are now entering into real partnerships with private businesses, resembling more of a joint-venture rather than the contractor for-hire relationships of the past in order to push human exploration of space ahead.

As it will become clear in this Article, SpaceX is not alone in the race to commercialize space. Several other firms have been established with the sole aim to transform space exploration into a for-profit business in contrast to more than six decades of largely scientifically driven exploration. Given that NASA and other international space agencies have always been non-profit agencies with the sole aim to conduct research for the benefit of mankind, the idea that private firms are looking to reap the benefits through exploration of the cosmos may be off-putting to many. It is at this critical crossroads that we find ourselves today. Great space-faring nations' space-industrial complexes are beginning to realize that they want a larger piece of the proverbial pie. And is that such a bad thing? I posit that it is not. I do, however, strongly believe that if we are to successfully extract resources from outer space that it must be done right the first time.

II. A BEGINNER'S GUIDE TO THE LAWS OF THE GALAXY

A. The Backbone of International Space Law

While it may seem obvious, outer space is neither owned nor governed by any singular nation or entity.[39] Space has famously been referred to as the "final frontier,"

[35] *Id.*

[36] *Id.*

[37] Kenneth Chang, *First Private Craft Docks With Space Station*, N.Y. TIMES (May 25, 2012), https://www.nytimes.com/2012/05/26/science/space/space-x-capsule-docks-at-space-station.html.

[38] Press Release, *NASA Awards Space Station Commercial Resupply Services Contracts*, NASA (Dec. 23, 2008) (on file with NASA Press Release Archives).

[39] Adam Mann, *Who's in Charge of Outer Space?*, WALL ST. J. (May 19, 2017), https://www.wsj.com/articles/whos-in-charge-of-outer-space-1495195097.

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though human exploration has changed that over time. From the advent of the first probes such as Sputnik through the International Space Station, nations and agencies have launched things and even people into space. Despite the wealth of achievements, research, and innovation that has taken place in outer space and in orbit, the question still remains as to how space should be governed.

The governance of space is intrinsically an international and complex legal affair. In 1959, as tensions between the Soviet Union and the United States were beginning to boil, the United Nations General Assembly acted to create the Committee on Peaceful Uses of Outer Space ("COPUOS").[40] The stated mission of COPUOS is to "govern the exploration and use of space for the benefit of all humanity: for peace, security, and development."[41] These certainly lofty goals enabled COPUOS to establish five international treaties and principles; moreover, COPUOS has grown to become one of the largest Committees within the entire United Nations body, currently boasting 84 member-states.[42] The seminal work of COPUOS, adopted in 1963, was the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space.[43] This declaration would lay the groundwork for what would become the preeminent international treaty governing outer space, what has now colloquially become known as the "Outer Space Treaty."[44] This treaty adopted by the General Assembly went into force in 1967.[45] Adding several additional provisions from its baby-brother, the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, the Outer Space Treaty clearly laid out the following key tenets on space law:

- the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;
- outer space shall be free for exploration and use by all States;

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[40] Benjamin Perlman, *Grounding U.S. Commercial Space Regulation in the Constitution*, 100 GEO. L.J. 929, 931 (2012).

[41] *COPUOS History*, UN OFFICE FOR OUTER SPACE AFFAIRS, http://www.unoosa.org/oosa/en/ourwork/copuos/history.html.

[42] *Id.*

[43] G.A. Res. 18/62, *Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space*, A/RES/18/1962 (Dec. 13, 1963), http://www.un-documents.net/a18r1962.htm.

[44] Elizabeth Howell, *Who Owns the Moon? Space Law & Outer Space Treaties*, SPACE.COM (Oct. 27, 2017), https://www.space.com/33440-space-law.html.

[45] *Space Law Treaties and Principles*, UN OFFICE FOR OUTER SPACE AFFAIRS, http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html (last visited Mar. 25, 2019).

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- outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
- States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;
- the Moon and other celestial bodies shall be used exclusively for peaceful purposes;
- astronauts shall be regarded as the envoys of mankind;
- States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;
- States shall be liable for damage caused by their space objects; and
- States shall avoid harmful contamination of space and celestial bodies.[46]

The Outer Space Treaty has, over time, become almost universally accepted and has been ratified and signed by key international players in outer space including Canada, Germany, India, Italy, Japan, the former USSR (The Russian Federation), the United Kingdom, and the United States.[47] Despite the overwhelming support for the Outer Space Treaty, few subsequent international agreements have been as substantial.

In 1968, the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space ("Rescue Agreement") was signed into effect as the second treaty under COPUOS.[48] As its name suggests, this Agreement expands certain provisions found in Articles 5 and 8 of its predecessor, the Outer Space Treaty, and stipulates that any signatory shall rescue and return both astronauts and space objects that return to Earth in their respective territory to the "Launching State."[49]

Three subsequent treaties were also passed by COPUOS. The third, titled the Convention on International Liability for Damage Caused by Space Objects, entered

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[46] *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, New York, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205, http://www.unoosa.org/oosa/oosadoc/data/resolutions/1966/general_assembly_21st_session/res_2222_xxi.html (last visited Mar. 25, 2019).

[47] *Id.*

[48] G.A. Res. 2345 (XXII), *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space* (Dec. 19, 1967), http://www.unoosa.org/pdf/gares/ARES_22_2345E.pdf.

[49] *Id.*

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into force in 1972.[50] This provides that "a launching State shall be absolutely liable to pay compensation for damage caused by its space objects on the surface of the Earth or to aircraft, and liable for damage due to its faults in space."[51] The major space powers have all ratified this treaty, as well.[52] The fourth, titled the Convention on Registration of Objects Launched into Outer Space, was enacted in 1976 in order to aid states in their identification of space objects should they be found by a non-Launching State and assist in their return to their rightful owners.[53] The fifth and final treaty, which was enacted in 1984 and is often seen as a failure, is titled The Agreement Governing the Activities of States on the Moon and other Celestial Bodies ("Moon Treaty").[54] While the Moon Treaty reiterates many of the key provisions of the Outer Space Treaty, it distinctly stipulates that the Moon and its resources shall be "the common heritage of mankind and that an international regime should be established to govern the exploitation of such resources when such exploitation is about to become feasible."[55] It is important to note that, unlike its sibling COPUOS treaties, the Moon Treaty has not been ratified or signed by a single nation that is actually capable of launching a rocket into space on its own, let alone landing a spacecraft on the moon. Signatories to the Treaty *exclude* The United States and China *but include* nations like Peru, Pakistan, Chile, and the Philippines to mention a few.[56]

B. The Dawning of a New Era in Space Law: The U.S. Commercial Space Launch Competitiveness Act of 2015

Save for the aforementioned five outer space treaties enacted by COPUOS from 1968 to 1984, no other significant or landmark treaties were enacted immediately thereafter. Decades of space exploration occurred under these treaties, and they still serve as the essential framework upon which space-faring nations agree to and

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[50] G.A. Res. 2777 (XXVI), *Convention on International Liability for Damage Caused by Space Objects*, RES/27777/XXVI (Nov. 29, 1971), http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html.

[51] *Id.*

[52] *Id.*

[53] G.A. Res. 3235 (XXIX), *Convention on Registration of Objects Launched into Outer Space* (Sept. 15, 1976), http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html.

[54] G.A. Res. 34/68, *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, RES/34/68 (Dec. 18, 1979), http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/moon-agreement.html.

[55] *Id.*

[56] G.A. Res. 34/68, *supra* note 54.

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operate under.[57] In 2015, however, President Barack Obama signed into law H.R. 2262, formally designated as the U.S. Commercial Space Launch Competitiveness Act.[58] The signing of this Act was hotly contested and drew sharp criticism; the Act has been dubbed the "Asteroid Mining Bill" thanks, in part, to Title IV of the Act.[59] Title IV, Space Resource Exploration and Utilization, appears at the bottom of the Act. Despite this, the drafters truly did save the proverbial "best for last." While earlier titles achieve items such as extending the American commitment to fund the International Space Station, Title IV, §402 provides the following:

> The bill directs the President, acting through appropriate federal agencies, to:
>
> - facilitate the commercial exploration for and commercial recovery of space resources by U.S. citizens;
> - discourage government barriers to the development of economically viable, safe, and stable industries for the commercial exploration for and commercial recovery of space resources in manners consistent with U.S. international obligations; and
> - promote the right of U.S. citizens to engage in commercial exploration for and commercial recovery of space resources free from harmful interference, in accordance with such obligations and subject to authorization and continuing supervision by the federal government.
>
> A U.S. citizen engaged in commercial recovery of an asteroid resource or a space resource *shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell it according to applicable law, including U.S. international obligations*.[60]

Of note is, of course, the final provision which grants the ownership right of any space-obtained resource to individual American citizens. This provision was, and still is, truly radical and represents the first time that a space-faring nation has, in writing, provided a private citizen a legal property right to celestial resources and seems to be at odds with the generally agreed upon notion, as referenced by the

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[57] Loren Grush, *How an international treaty signed 50 years ago became the backbone for space law*, THE VERGE (Jan. 27, 2017), https://www.theverge.com/2017/1/27/14398492/outer-space-treaty-50-anniversary-exploration-guidelines.

[58] U.S. Commercial Space Launch Competitiveness Act, H.R. 2262, 114th Cong. (enacted), https://www.congress.gov/bill/114th-congress/house-bill/2262.

[59] Kate E. Lee, *Colonizing the Final Frontier: Why Space Exploration Beyond Low-Earth Orbit Is Central to U.S. Foreign Policy, and The Legal Challenges It May Pose*, 27 S. CAL. INTERDISC. L.J. 231, 243 (2016).

[60] *See supra* note 58.

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language in the various COPUOS treaties, that space shall belong to and benefit all of mankind.[61]

The signing of the U.S. Commercial Space Launch Competitiveness Act did not just have an impact domestically, it also sent shockwaves through the international community. It is believed that the Act was the driving force behind Luxembourg's launch of its own initiative, known as "Spaceresources.lu," which is geared toward the "development of a legal and regulatory framework that grants corporations property rights to resources extracted from asteroids."[62] Luxembourg's announcement signaled a legal parallel to the American Commercial Space Launch Competitiveness Act in Europe as Luxembourg became the first European nation to begin the process of recognizing private rights in outer space.[63] I suspect it will not be the last.

While this Article may highlight at times the dangers posed by such activities as space mining and the extraction of space resources, it is not an argument against the commercialization of space; rather it is a cautionary note to the soon to be commercial space industry—but more particularly nations—with the proviso that space must be cared for. Many, including myself, see the future of space being conquered by great titans of private industry working alongside their national space programs. I would assert, however, that without fundamental, realistic, and forward-thinking parameters which must be established by a consortium of the space-faring nations, the extraction of space resources may have drastic consequences.

III. AN OVERVIEW OF COMMERCIAL SPACE MINING AND RESOURCE EXTRACTION

A. Some of the Relevant Companies

While NASA and other international space agencies such as Roscosmos or the European Space Agency have led the way for space exploration in the past, the future wave of exploration will be primarily led by private enterprise.[64] As such, it is

[61] Andrew Griffin, *Asteroid mining made legal after Barack Obama gives US citizens the right to own part of celestial bodies*, THE INDEPENDENT (Nov. 26, 2015), https://www.independent.co.uk/news/science/asteroid-mining-made-legal-after-barack-obama-gives-us-citizens-the-right-to-own-parts-of-celestial-a6750046.html.

[62] John Myers, *Extraterrestrial Property Rights: Utilizing the Resources of the Final Frontier*, 18 SAN DIEGO INT'L L.J. 77, 90 (2016).

[63] *Id.*

[64] Allie Owens & Navjot Singh, *Perspectives on the future of space exploration*, MCKINSEY (July 2017), https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/perspectives-on-the-future-of-space-exploration.

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important to understand just who the players and what their ultimate missions are. While each firm has their own unique technologies, business models, or long-term goals, one thing that can be said about all of them is that they will each seek to extract resources from outer space (whether gaseous, liquid, or solid in nature) and/or transport the equipment necessary to do so.

1. Planetary Resources

Perhaps the best-known firm in the space-mining field is Planetary Resources. Founded in Seattle in 2012, the firm was backed by billionaire investors including Larry Page (co-founder, Google) and Charles Sumonyi (former chief software architect, Microsoft) and received an investment of $28 million from the Grand Duchy of Luxembourg, for which a reported 10% of the firm was exchanged.[65] However, on October 31, 2018, the firm was acquired by a blockchain technology company known as ConsenSys.[66] It is unclear how the two firms meld together, or what the leadership structure will be going further.[67] Nevertheless, the original, and assumedly future, goal of Planetary Resources/ConsenSys is to mine water ice which, in addition to being used as a form of hydration for astronauts in outer space, can be broken down to the core elements of hydrogen and oxygen—both of which can be used as key ingredients in the production of rocket propellant or oxygen for breathing.[68] The firm believes if they are successful, that they will be able to sell this water ice to NASA or other firms in the future who are living or working in outer space and require any of the aforementioned byproducts of the water ice, including fuel for spacecraft, to travel deeper into space.[69] Planetary Resources plans to achieve its mining goals by using a robotic asteroid mining system.[70] The Arkyd 3, a small test satellite, was launched on an Antares rocket but exploded during takeoff in 2014; the satellite was redesigned and launched instead from the ISS in July of 2015 to great success.[71] The purpose of the Arkyd satellites was to establish and test essential

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[65] Kenneth Chang, *If No One Owns the Moon, Can Anyone Make Money Up There?*, N.Y. TIMES (Nov. 26, 2017), https://www.nytimes.com/2017/11/26/science/moon-express-outer-space-treaty.html.

[66] Jeff Foust, *Asteroid Mining Company Planetary Resources Acquired by Blockchain Firm*, SPACE.COM (Nov. 2, 2018), https://www.space.com/42324-asteroid-mining-company-planetary-resources-acquired.html.

[67] *Id.*

[68] Chang, *supra* note 65.

[69] *Id.*

[70] Craig Foster, Note, *Excuse Me, You're Mining My Asteroid: Space Exploration Rights and the U.S. Space Resource Exploration and Utilization Act of 2015*, 2016 U. ILL. J.L. TECH & POL'Y 407, 411 (2016).

[71] *Id.*

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communications and avionics data.[72] In January of 2018, the Arkyd-6 was launched; this satellite is designed to test 17 critical new technologies, including remote sensing of water resources via mid-wave infrared imaging sensors.[73] Planetary Resources hopes to be able to take all of the data garnered from the Arkyd-6 launch in order to send exploratory probes and crafts to near-Earth asteroids which, according to their CEO Chris Lewicki, the firm plans to accomplish sometime in 2020.[74]

2. Deep Space Industries

Deep Space Industries is a San Jose, California-based space technology company that primarily focuses on designing and building innovative low-cost propulsion systems to be used in high-performance missions in Earth's orbit and deep space.[75] Due to the unique capabilities of their water-powered propulsion systems, Deep Space Industries has developed and plans to launch the Prospector-X and subsequent Prospector-1 spacecraft; the former will be launched into low earth orbit to test the technology while the latter will land on, and study, a near-Earth asteroid.[76] The government of Luxembourg has also decided to partner and financially back Deep Space Industries, though specific details of their partnership remain undisclosed.[77] Deep Space Industries' vision for asteroid mining is two-fold. In phase one, tiny CubeSat (miniature satellites) will be launched using a mothership and, using their proprietary technology, will scan and map resources for prospecting potential on an asteroid or celestial body.[78] Phase two involves Deep Space Industries' advanced harvesters and propulsion systems landing on said asteroid or celestial body and extracting resources to ship back to Earth. Due to the design of their self-proclaimed "flying steam kettle" propulsion system which, when heated, expels water vapor at 1,000°C, Deep Space Industries may be able to design a spacecraft which is refuellable *in orbit* given its inherent ability to mine water from

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[72] *Id.*

[73] Michael Sheetz, *Planetary Resources' new satellite launch is big step in the mission to mine water from asteroids*, CNBC (Jan. 12, 2018), https://www.cnbc.com/2018/01/12/planetary-resources-new-satellite-launch-succeeds.html.

[74] *Id.*

[75] Jeff Foust, *Deep Space was acquired by Bradford Space*, https://spacenews.com/deep-space-industries-acquired-by-bradford-space/ (Jan. 2, 2019).

[76] James Wynbrandt, *How to Become an Asteroid Prospector*, FLYING (Nov. 10, 2017), https://www.flyingmag.com/how-to-become-an-asteroid-prospector.

[77] Andrew Zaleski, *Luxembourg leads the trillion-dollar race to become the Silicon Valley of asteroid mining*, CNBC (Apr. 16, 2018), https://www.cnbc.com/2018/04/16/luxembourg-vies-to-become-the-silicon-valley-of-asteroid-mining.html.

[78] Marcus Woo, *Designing a Mothership to Deliver Swarms of Spacecraft to Asteroids*, WIRED (Dec. 17, 2014), https://www.wired.com/2014/12/cubesat-mothership-space-asteroid-exploration/.

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an asteroid and turn that water into fuel.[79] Deep Space Industries is a for-profit business and if successful could also serve as a galactic gas station, providing rocket fuel mined from asteroid/celestial body surface water or volatile chemicals to spacecraft on their way to the Moon, Mars, or beyond just as Planetary Resources plans to do.[80]

3. Moon Express

Moon Express was founded in 2010 in Silicon Valley with the goal of "applying commercial practice to lunar exploration."[81] The firm's founders wanted to extract lunar water from day one.[82] Having forty employees at its peak, the firm has struggled over the years to attract sustainable funding, recently maintaining an office without running water and behind on employee salary payments.[83] Nevertheless, CEO Bob Richards remained focused on his and his company's mission. The firm, which early on was located at NASA's Ames Research Center facility in California, eventually relocated to Kennedy Space Center in Cape Canaveral, Florida.[84] The firm achieved notoriety internationally when it was one of five finalists in the Google designed and sponsored Lunar X Prize contest which promised to give $20 million to the first firm to create a viable, private lunar lander.[85] When nobody won the competition, Moon Express was forced to redesign their lander in an effort to achieve much needed additional funding; moreover, private investors pulled out large chunks of capital, and the company floundered for a while.[86] Nevertheless, in the summer of 2018, the firm was able to obtain new funding and recently got news that NASA had named it as one of nine finalists in a competition to vie for $2.6 billion Commercial Lunar Payload Services contract over the course of about a decade.[87] The company's strength lies in its "fleet of landers, MX-2, MX-5, and MX-9 in addition to the

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[79] Zoe Corbyn, *The asteroid rushing sending 21st century prospectors into space*, THE GUARDIAN (June 9, 2018), https://www.theguardian.com/science/2018/jun/09/asteroid-mining-space-prospectors-precious-resources-fuelling-future-among-stars.

[80] Woo, *supra* note 78.

[81] Chabeli Herrera, *Layoffs and stalled projects plagued space start-up moon express. Then NASA stepped in*, ORLANDO SENTINEL (Dec. 9, 2018), https://www.orlandosentinel.com/business/space/go-for-launch/os-bz-moon-express-update-20181114-story.html.

[82] *Id.*

[83] *Id.*

[84] *Id.*

[85] *Id.*

[86] *Id.*

[87] *Id.*

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already announced MX-1, which is about as tall as a person and resembles R2-D2."[88] The MX-9 lander is designed to carry over one-thousand pounds of cargo to the surface of the Moon.[89] The future looks much brighter for Moon Express and it is possible that it will become an important player in lunar supply missions and mining expeditions.

B. Why Bother?

1. The Benefits of Asteroid Mining

Asteroids are rich with resources. NASA currently has a mission dubbed Psyche to visit a near-Earth asteroid whose worth has been estimated at a staggering, and seemingly incomprehensible, $10,000 quadrillion.[90] 16 Psyche, the officially designated name of the object, is believed to be the remnants of a planetary core rife with iron, nickel, and other precious metals.[91] Comparing the value of just this one asteroid with the world's total domestic gross product of about $80 trillion dollars, truly helps provide a frame of reference as to why private firms are dying to attempt asteroid mining.[92] That in one successful mission a firm could tap into a rock 192,238 times more valuable than the annual output of the global economy is an astonishing thought and is largely the impetus behind eager investors who are dying to get their hands on this untapped wealth.[93]

Asteroids can be found in three varieties and are grouped according to their "spectral type," a classification which is based upon how light reflects off of their surfaces.[94] C-type asteroids are dark and carbon rich and feature prominent amounts of water which is bound as hydrated clay minerals.[95] These types of asteroids would be less valuable to Earth but, given their location in the atmosphere, they are just the type of asteroids looking to be used by Planetary Resources or Deep Space Industries

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[88] *Id.*

[89] *Id.*

[90] Brid-Aine Parnell, *NASA Will Reach Unique Metal Asteroid Worth $10,000 Quadrillion Four Years Early*, FORBES (May 26, 2017), https://www.forbes.com/sites/bridaineparnell/2017/05/26/nasa-psyche-mission-fast-tracked/#32c6c20d4ae8.

[91] *Id.*

[92] Susanne Barton & Hannah Recht, *The Massive Prize Luring Miners to the Stars*, BLOOMBERG (Mar. 8, 2018), https://www.bloomberg.com/graphics/2018-asteroid-mining/.

[93] *Id.*

[94] William Steigerwald, *New NASA Mission to Help Us Learn How to Mine Asteroids*, NASA (Aug. 7, 2017), https://www.nasa.gov/content/goddard/new-nasa-mission-to-help-us-learn-how-to-mine-asteroids.

[95] *Id.*

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in their pursuit to break down water into its essential elements of hydrogen and oxygen. S-type asteroids feature a stony composition and are comprised of mostly metal (e.g. nickel, iron, and cobalt) but also have the potential to hold gold, platinum, or rhodium; a small s-type asteroid only ten yards in size could contain one-hundred pounds of the aforementioned precious metals.[96] M-class asteroids, otherwise known as metallic-class, have ten times the amount of metal in them than s-type asteroids do.[97]

Asteroids, unlike the Moon or other planets, do not possess an atmosphere of their own. As a result, achieving the requisite "escape velocity" to depart or launch off of the surface of an asteroid is much easier than doing so on other types of celestial bodies.[98] In fact, some asteroid mining experts believe that rather than landing on an asteroid, future probes would merely dock with an asteroid by hovering just off the surface and use an anchor or extendable arm in order to support the spacecraft while another arm or probe removed the valuable resources from the asteroid itself.[99] However, it is likely that more burdensome tasks, such as extracting metals or liquids, will have to occur by gently landing the probe on the surface of the asteroid itself.

In December of 2018, NASA's OSIRIS-REx spacecraft will reach the asteroid Bennu after two years of travel from Kennedy Space Center.[100] The OSIRIS-REx mission is hugely significant for both NASA and private industry as it will mark, if successful, the first time that any spacecraft will rendezvous with an asteroid, retrieve a sample, and bring it back to Earth for study.[101] OSIRIS-REx will not land on an asteroid, however. Instead, out of an abundance of caution, it will use an extendable arm to stir up, retrieve, and store samples taken from the asteroid's surface.[102] It took OSIRIS-REx two years to reach Bennu and will take another year to survey the asteroid in preparation for sample collection and then, if all goes well, OSIRIS-REx

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[96] *Id.*

[97] *Id.*

[98] Austin C. Murnane, Note, *The Prospector's Guide to the Galaxy*, 37 FORDHAM INT'L L.J. 235, 239 (2013).

[99] Michael Belfiore, *How to Mine an Asteroid*, POPULAR MECHANICS (Oct. 27, 2014), https://www.popularmechanics.com/space/a7942/how-to-mine-an-asteroid-11644811/.

[100] Christine Hoekenga, *TAGSAM Testing Complete: OSIRIS-REx Prepared to TAG an Asteroid*, ASTERIODMISSION.ORG (last updated Nov. 21, 2018), https://www.nasa.gov/feature/goddard/2018/tagsam-testing-complete-osiris-rex-prepared-to-tag-an-asteroid.

[101] *Id.*

[102] *Id.*

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will face a return journey to Earth with an expected landing date of 2023.[103] Regardless, if the mission is successful, it will be a signal to scientists and investors in private industry that asteroid mining has a viable and replicable future.

2. The Benefits of Mining Other Celestial Bodies

Mining on a celestial body, for example Earth's Moon, has the potential to deliver rich natural resources. The Moon is largely seen as an opportunity to provide energy for Earth-based nuclear fission reactors. It is not just the United States, however, that could stand to benefit from such a type of energy production. China, France, England, Italy, Finland, Russia, Thailand, Egypt, and Vietnam are all heavily investing in nuclear fission energy facilities at home.[104] The issue is, though, that nuclear fission uses Uranium-235 and Plutionium-239.[105] After the fission process causes these heavy-element atoms to split, the byproduct is nuclear waste which remains very radioactive; this waste is not only dangerous to humans but also very difficult and expensive to store properly.[106] Nuclear fission waste must be placed in steel-lined tanks underground and never truly goes away.[107]

The Moon, however, is home to tremendous amounts of a different kind of energy, most notably Earth helium-3 ("He-3").[108] He-3 is not very abundant on Earth, though vast deposits are believed to exist on the Moon. He-3 can be used in nuclear fusion reactors which are believed to be safer than their fission brethren.[109] Fusion reactions produce no radioactive waste whatsoever; any other waste products resulting from a fusion reaction decay naturally and harmlessly.[110] It is estimated that if 40 tons of He-3 were brought back to Earth, the amount of energy produced could fuel fusion reactors sufficient to meet 100% of the electrical needs of the United States for an entire year.[111] It is clear, then, that just harvesting this sole element from

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[103] Nola Taylor Redd, *OSIRIS-REx: Bringing Home Pieces of an Asteroid*, SPACE.COM (Jan. 25, 2019), https://www.space.com/33776-osiris-rex.html.

[104] Benjamin D. Hatch, Comment, *Dividing the Pie in the Sky: The Need for a New Lunar Resources Regime*, 24 EMORY INT'L L. REV. 229, 232 (2010).

[105] *Id.*

[106] *Id.*

[107] *Id.*

[108] Richard B. Bilder, *A Legal Regime for the Mining of Helium-3 on the Moon: U.S. Policy Options*, 33 FORDHAM INT'L L.J. 243, 246 (2009).

[109] Hatch, *supra* note 104, at 232–34.

[110] *Id.*

[111] Michael Schirber, *How moon rocks could power the future*, NBC NEWS, http://www.nbcnews.com/id/26179944/ns/technology_and_science-science/t/how-moon-rocks-could-power-future/ (last updated Aug. 13, 2008, 2:28 PM ET).

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the Moon could bring about fantastic changes to the Earth-based energy industry. In addition to providing resources for energy, the Moon is believed to possess vast deposits of water ice which, as previously mentioned, can be broken down into its core elements to create various byproducts including rocket propellant, oxygen, and potable water.[112] As such, mining at the lunar ice caps could serve as another viable option for would-be entrepreneurs to benefit from the Moon's resources.

Finally, Mars is seen as being the most habitable planet for humans after Earth; in order for humans to live successfully on Mars for extended periods of time, they will have to learn to perfect In-Situ Resource Utilization ("ISRU") in order to capture precious mineral rich soil and "notable quantities of water."[113] Practicing ISRU on the Moon first will provide astronauts, space agencies, or private firms the ability to refine their ISRU skills before making the epic journey to Mars.

IV. The Legal, Economic, and Environmental Issues Posed By Space Mining

A. Conflict of Laws: The Outer Space Treaty and the Space Act of 2015

When the United States passed the Space Act of 2015, it drew sharp critics and ardent supporters alike regarding its legality. The Outer Space Treaty specifically provides that "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."[114] Article III further establishes that State Parties to the treaty will explore outer space (including the Moon and other celestial bodies) pursuant to the U.N. Charter, in respect of international law, all the while respecting international peace and security.[115] Critics of the Space Act's legality would argue that the term "national" appropriation in Article II shall be defined by Article VI of the Outer Space Treaty which explicitly references both government and non-governmental activity.[116] Critics have suggested that by recognizing private industry,

[112] Leonard David, *Mining Moon Ice: Prospecting Plans Starting to Take Shape*, SPACE.COM (July 13, 2018), https://www.space.com/41164-mining-moon-water-plans-take-shape.html.

[113] Amir H. Khoury, *Intellectual Property and the Red Planet: Formulating IP Policies Towards the Successful Colonization of Mars*, 19 N.C. J.L. & TECH. 337, 346 (2017).

[114] G.A. Res. 2222 (XXI), Annex, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, at Article II (Dec. 19, 1966), http://www.unoosa.org/oosa/oosadoc/data/resolutions/1966/general_assembly_21st_session/res_2222_xxi.html.

[115] *Id.* art. III.

[116] Symposium, *The Promise and Perils of an International Law of Property Enterprise Rights and the Legal Regime for Exploitation of Outer Space Resources*, 47 U. PA. L. REV. 281, 283 (2016).

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though under a separate Article and in a somewhat veiled manner, that the drafters intended to and the Treaty itself expressly prohibits any claims of appropriation over a celestial body, period. Supporters of this line of thinking argue that while Article IV of the Outer Space Treaty provides "the use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall not be prohibited," that it does not provide a right to extract resources for a non-scientific purpose.[117]

Article I of the Outer Space Treaty explicitly authorizes "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 . . . ."[118] Supporters of the Space Act believe that there are "many different things that could be seen as benefits to all countries."[119] Moreover, it is suggested that "the ambiguous language covering the use of space for the benefit and interest of all countries, while not expressly prohibiting uses that may be both beneficial and detrimental, arguably allows certain uses as long as they provide some benefit."[120]

This Article does not suggest that either side is correct. In fact, to do so would merit a lengthy examination focusing on legislative history, purpose, and could even dive into the semantics regarding the definition of each and every word as passed in the Outer Space Treaty. Instead, it is important to highlight that, nevertheless, the United States passed into law the Space Act and for all intents and purposes, it is binding on American citizens and businesses. Moreover, the American legislation has inspired Luxembourg's government to do much the same. As a result, more than sixty startups have approached the government of Luxembourg which, according to Deputy Prime Minister Etienne Schneider, has a virtually unlimited budget to attract space firms to the small European nation.[121] We are now engaged in, I believe, the beginnings of a great race to legalize or legitimize the race to extract outer space resources. The simple fact of the matter is that, while armchair critics can argue over semantics of the decades old and Cold War-era Outer Space Treaty, private industry and governments alike are pushing onward and upward into the cosmos in the hopes of striking cosmic riches. The race to commercially mine and extract resources from space will only heat up, not cool down. It is essential, then, to understand the practical

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[117] *Id.* at 289.

[118] G.A. Res. 2222 (XXI), *supra* note 114, art. I.

[119] Andrew Lintner, *Extraterrestrial Extraction: The International Implications of the Space Resource Exploration and Utilization Act of 2015*, 40 FLETCHER F. WORLD AFF. 139, 145 (2016).

[120] *Id.* at 145–46.

[121] Aliya Ram, *US and Luxembourg frame laws for new space race*, FINANCIAL TIMES (Oct. 19, 2017), https://www.ft.com/content/af15f0e4-707a-11e7-93ff-99f383b09ff9.

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and likely to occur issues that will crop-up as technology advances to meet the dreams of space mining entrepreneurs.

B. Economic Issues Posed by Space Mining

Imagine a world where precious metals are no longer precious. Estimates suggest that, for example, three separate asteroids may contain $8 trillion worth of iron and nickel, $6 trillion of cobalt, or $6 trillion of platinum, respectively.[122] When outer space mining becomes a reality, it is possible that the vast newly found celestial riches will have destabilizing effects; many have speculated that it is possible that the influx of these commodities will have effects on Earth, good and bad, that we cannot begin to appreciate until it actually happens.[123] Will the price of these metals plummet rapidly due to said influx? Or, alternatively, will it simply make a select few entities or people richer without having destabilizing effects for the global precious metals market? It is hard to say for sure. If space mining proves to be as lucrative as experts believe, Earth will experience a never before seen incursion of precious and uber-valuable commodities in record time.

It is also important to consider what effects a sudden boom of natural resources could have on developing nations. As has happened in the past, a rush to extract resources could be won, largely, by the great developed nations and economies of the world, thus leaving developing nations behind or exploited. Given that the firms with the most promise of extracting space-based resources are based in developed nations, there is a chance that resource-sharing is unlikely to occur. This result would, if true, increase inequality between rich and poor nations. The government of, say, an African nation would be hard-pressed to ensure that its citizenry was benefitting from the extraction of space resources in the same way as those of a North American or a Western European nation. Similarly, to the anticipated effects on the global financial markets, those touching and concerning developing nations are hard to foresee.

C. Orbit Space Debris ("Space Junk")

As early as the very first launch of a rocket into orbit, mankind has been polluting outer space. An oft overlooked problem, space debris or space junk as it is

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[122] Ian Hedges, Note, *How the Rest Was Won: Creating a Universally Beneficial Legal Regime for Space-Based Natural Resource Utilization*, 40 VT. L. REV. 365, 374 (2015).

[123] Matthew Davis, *Will Asteroid Mining be an Outer-Space Gold Rush?*, BIG THINK (Sept. 28, 2018), https://bigthink.com/technology-innovation/economic-impact-of-asteroid-mining?rebelltitem=3#rebelltitem3.

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colloquially known, poses an immense threat to all man-made items in orbit.[124] NASA estimates that, since the launch of Sputnik in 1957, "more than 28,000 objects have been launched into space. Of these, 9,000 are still in orbit. Only 6% are still functional spacecraft; the rest are now part of the growing population of space debris."[125] While seemingly harmless due to their often microscopic size, orbital debris—which can refer to any manmade objects which remains in Earth's orbit after its useful life—can include everything from the bodies of rockets to batteries or millimeter sized chips of paint to nuts and bolts.[126] To illustrate the catastrophic havoc that space debris could wreak on satellites, the International Space Station, or a space vehicle, a single piece of debris 1-cm in diameter would act as though it were "a bowling ball hitting an object on Earth at 300 miles per hour."[127] That kind of force has the potential to sever critical communications systems or put the lives of astronauts in jeopardy.

The job of tracking all of this space debris is an immense one. In the United States, the Space Surveillance Network (SSN) is tasked with the work.[128] The SSN is composed of radar and optical sensors located at 25 sites across the world that are manned and operated by the U.S. Navy, Army, and Air Force.[129] Tracking the space debris is essential as, if any single object were to get away, it would set in motion a chain of events which would be catastrophic in nature. For example, the "cascade effect" describes the series of events which occurs given the continued addition of space debris. The cascade effect can be summarized as follows:

> (1) As the number of space objects in earth-orbit increases, the probability of collisions between them also increases; (2) collisions would produce new orbiting fragments (secondary debris), each of which would heighten the risk of further collisions; (3) collisions and any ensuing cascading collisions would lead to an exponential increase of debris flux and could lead to the formation of a debris belt around the Earth by the end of this century; and (4) the near-earth environment could

[124] Elise Epperson Crow, Note and Comment, *Waste Management in Space: Addressing the Challenge of Orbital Debris*, 18 S.W. J. INT'L L. 707, 709 (2012).

[125] *Id.*

[126] *Id.*

[127] *Id.*

[128] Dave Mosher, *The U.S. government logged 308,984 potential space-junk collisions in 2017—and the problem could get much worse*, BUSINESS INSIDER (Apr. 15, 2018, 9:51 AM), https://www.businessinsider.com/space-junk-collision-statistics-government-tracking-2017-2018-4.

[129] *Space Surveillance*, U.S. SPACE COMMAND, http://www.au.af.mil/au/awc/awcgate/usspc-fs/space.htm.

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> become so populated with space debris that portions of LEO [low-earth orbit] would be unusable.[130]

The creation of space debris is impossible to eliminate entirely, though efforts are made to reduce the amount put into orbit with each launch. Moreover, it is possible to cut-down on space debris in the future by carefully "reviewing development plans to ensure measures to prevent pollution, exit strategies of endeavors, or plans of relative permanence are in place before the projects take-off."[131] Nevertheless, the prospect of mining a celestial body certainly raises a host of questions, many too lengthy to be considered here in totality. How will private firms act in their rush to profit off of outer space vis-à-vis space debris? For decades, the only entities sending objects into orbit were nationally-backed and, even then, debris has been a major issue. Will, then, the issue of space junk be exacerbated or lessened with the introduction of private firms? There are arguments to be made that private firms work in a less-constricted manner than, say, a government agency burdened by immense amounts of red tape. Firms like SpaceX have famously cut costs and increased efficiencies on Earth through unique design and production methodologies, seeking to cut the regulations intrinsically linked to agencies like NASA.[132]

A joint-report published by the California Institute of Technology in Pasadena, California and the Technical University of Madrid in Spain suggest that, as a result of asteroid mining, roughly 5% of the escaped debris dust will reach areas where satellites live.[133] Moreover, this study estimates that satellites in geostationary orbit (GEO) may be particularly vulnerable, finding that over a ten-year period, particles have been found to intersect GEO "up to 900 times, 63 on average."[134] If particulate or dust from asteroid mining were, in theory, to enter geostationary orbit while a satellite was traversing, the effects could be sufficient to impair or ruin the satellites functionality entirety.

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[130] David Tan, *Towards a New Regime for the Protection of Outer Space as the "Province of All Mankind,"* 25 YALE J. INT'L L. 145, 152–53 (2000).

[131] Claudia Pastorius, *Law and Policy in the Global Space Industry's Lift-Off*, 19 BARRY L. REV. 201, 231 (2013).

[132] Sandra Erwin, *On National Security: Lessons from SpaceX about the power of incentives*, SPACE NEWS (Feb. 28, 2018), https://spacenews.com/on-national-security-lessons-from-spacex-about-the-power-of-incentives/.

[133] Javier Roa & Casey Handmer, *Quantifying hazards: asteroid disruption in lunar distant retrograde orbits* 1, 8, CORNELL U.: ARXIV.ORG (May 14, 2015), https://arxiv.org/pdf/1505.03800.pdf.

[134] *Id.*

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It is impossible to anticipate all of the effects that space mining will have on the environment of outer space, but what can be said with near certainty is that space debris will always be a factor which, to some degree, must be accounted for.

D. Licensing Issues

The Federal Aviation Administration (FAA) has admitted that with the passing of the Commercial Space Launch Competitiveness Act and the sure to follow commercial space firms vying to launch and harvest the vast riches of space "new ways about thinking about regulations and about what constitutes government authorization and supervision" must take place.[135] According to the Commercial Space Launch Act of 1984 (the groundwork for the 2015 Obama-era Space Act), the role of the FAA's Office of Commercial Space Transportation is to "oversee, authorize, and regulate both launches and reentries of launch and reentry vehicles, and the operation of launch and reentry sites when carried out by U.S. citizens or within the United States."[136] Article VI of the Outer Space Treaty clearly provides that parties to the treaty (in this case the U.S.) shall bear total responsibility to its international partners for its own nation's activities in space, "including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty."[137] This will present a whole host of legal challenges in the near future as, in my opinion, the terms of the Outer Space Treaty are rather clear regarding liability for damage stemming from space exploration. Moreover, "while the FAA licenses the launch and reentry of commercial space launch vehicles, the agency does not license their activity in Earth orbit or beyond."[138]

Concerning the licensing process in other nations and the obligations they face under the Outer Space Treaty, it is said that:

> The process of state authorization and continuing state supervision provides an opportunity for the development and supplementation of regulation of commercial activities in space. The Outer Space Treaty does not designate any specific form of legal regime to be adopted by states for the purpose of providing authorization and continuing supervision of their private entities. States can

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[135] Kate E. Lee, Note, *Colonizing the Final Frontier: Why Space Exploration Beyond Low-Earth Orbit Is Central to U.S. Foreign Policy, and The Legal Challenges It May Pose*, 27 S. CAL. INTERDISC. L.J. 231, 248 (2018).

[136] *Office of Commercial Space Transportation Regulations*, FAA.GOV, https://www.faa.gov/about/office_org/headquarters_offices/ast/regulations/ (last updated Feb. 27, 2019).

[137] G.A. Res. 2222 (XXI), *supra* note 114, art. VI.

[138] Lee, *supra* note 135, at 248.

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> adopt any form of domestic regulatory oversight they deem appropriate and consistent with their national interests and policies, subject to international treaty obligations. At least fifteen nations have enacted legislation for the authorization of private activities in space. Common provisions of national authorization regimes include the examination of a license application for potential liability concerns, any inconsistencies with national security interests, and compliance with the international obligations and policies of the state. States usually require a licensee to obtain insurance, although the state is internationally liable for damages which exceed the amount of insurance coverage.[139]

In a power vacuum where responsibility is unclear, nations and their industries may decide to enact similar laws to that of the U.S. Space Act of 2015, putting commercialization and private ownership rights in front of regulation. If this new wave to commercialize outer space becomes the next great space race, there is a chance (though hard to measure at this point in time) that standards and safety may be skirted in favor of cost or time saving. Private enterprises are not like their government foils of NASA, Roscosmos, the Japanese Space Aerospace Exploration Agency (JAXA), or the European Space Agency (ESA). Private firms do not have immense oversight from Congress, nor do they have extensive public manuals detailing safety procedures. While private firms have boards and investors, which require mandatory disclosure of certain regulatory information, said information is less proprietary and policy-oriented and more financial and managerial based. In many instances, the innovative firms vying to commercialize space are not publicly traded and thus less information is readily available in the public domain. Given the immense amount of money that stands to be made from space mining and the billionaire investors often drawn to backing these potentially lucrative, though speculative firms, it is possible that lobbying for lax registration laws will take place, thus enabling a firm to setup shop quickly and inexpensively in a host nation willing to "turn a blind eye" to The Outer Space Treaty, other treatises, environmental laws, or other regulatory standards. This type of quid-pro-quo has not seemed to happen yet, though as in many industries ranging from pharmaceuticals to technology firms, utilizing the legal loopholes of a nation in order to more effectively carry out its mission with reduced oversight seems to be all but inevitable arrangement.

E. Planetary Protection

Detailed and thorough safety precautions have allowed NASA and other space programs to succeed for decades. Despite these rigorous precautions, nations have still tragically lost spacecraft and crew lives. Space exploration is a dangerous

[139] Symposium, *supra* note 116, at 287–88.

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business, even when humans are not present on spacecraft. In addition to safely building and designing spacecraft to the highest standards, handling spacecraft components before their launch into space and after they return to Earth is a crucial, yet seldom appreciated topic. Planetary Protection in the United States delineates how NASA is supposed to handle spacecraft and their components so as to avoid damaging or contaminating the Earth or another celestial body.[140] The goals of NASA's Planetary Protection Office include:

- Preserving our ability to study other worlds as they exist in their natural states;
- Avoiding the biological contamination of explored environments that may obscure our ability to find life elsewhere—if it exists; and
- To ensure that we take prudent precautions to protect Earth's biosphere in case life does exist elsewhere.[141]

NASA takes Planetary Protection so seriously that there is an entire Office and an Officer responsible for ensuring that spacecraft are decontaminated before they even leave the Earth.[142] The mission of the Office is two-fold.[143] The first consideration is to protect Earth from the arrival of bacteria or other microorganisms from outer space which could lead to many of the same issues posed when an invasive species of biological life travels around the Earth, triggering a disruption of the ecological balance of life; this is known as backward contamination.[144] The second consideration, called forward contamination, is to ensure that NASA does not send a spacecraft which contains Earth-based contaminants to disturb the environment on another celestial body as contaminating a foreign body with unfamiliar bacteria would destroy the scientific value of researching a planet, the Moon, or an asteroid which has never known human life or bacteria.[145] For example, on NASA's InSight Mars lander, the entire spacecraft contained only 300,000 spores of bacteria which

[140] *About the Office of Planetary Protection*, NASA, https://planetaryprotection.nasa.gov/about (last updated Dec. 20, 2018).

[141] *Id.*

[142] *Overview of Planetary Protection*, NASA, https://planetaryprotection.nasa.gov/overview (last updated Dec. 20, 2018).

[143] *Id.*

[144] Jeb Butler, Note, *Unearthly Microbes and the Laws Designed to Resist Them*, 41 GA. L. REV. 1355, 1356 (2007).

[145] *Id.* at 1356–57.

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would fit on a human hangnail whereas the typical home contains 10,000 bacterial spores per square-inch.[146]

NASA maintains several "clean rooms" at its various facilities located across the United States. These clean rooms have standards higher than any hospital in terms of allowable bacteria in the air or surfaces inside the room. At NASA's Goddard Space Flight Center in Greenbelt, Maryland, their clean room ventilation system can filter one million cubic feet of air every minute through their specially designed HEPA filters.[147] NASA also maintains clean rooms at its California-based Jet Propulsion Laboratory,[148] Johnson Space Flight Center in Texas,[149] Kennedy Space Center in Florida,[150] and Marshall Space Flight Center in Alabama.[151]

While, as mentioned, Planetary Protection is an office specific to NASA, the threat of contaminating celestial bodies or being contaminated by them is a global issue. Unfortunately, no single international agreement exists to address planetary contamination.[152] The Outer Space Treaty did not, in its original form, address planetary protection directly; the Moon Treaty attempted to delineate several processes but failed to achieve international signatories.[153] The best attempt so far at achieving a baseline for international sterilization and planetary protection standards stems from COSPAR or the Committee on Space Research.[154] COSPAR was founded in 1958 "to promote international cooperation in the pursuit of scientific

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[146] Matt Simon, *Inside the Cleanroom Where NASA's New Mars Lander Waits to Launch*, WIRED (Apr. 9, 2018), https://www.wired.com/story/inside-the-cleanroom-where-nasas-new-mars-lander-waits-to-launch/.

[147] Robert Garner, *NASA's Clean Room: Last Stop for New Hubble Hardware*, NASA (Apr. 16, 2008), https://www.nasa.gov/mission_pages/hubble/servicing/series/cleanroom.html.

[148] *JPL High Bays Give a Whole New Meaning to 'Clean Your Room,'* NASA (June 24, 2002), https://www.jpl.nasa.gov/news/news.php?feature=551.

[149] Adam Mann, *NASA 'clean' room is contaminated with fungus*, SCIENCE MAG. (Mar. 23, 2018, 8:00 AM), https://www.sciencemag.org/news/2018/03/nasa-clean-room-contaminated-fungus.

[150] *New Horizons Spacecraft in the Clean Room at NASA's Kennedy Space Center*, NASA (Nov. 4, 2010), https://www.nasa.gov/image-feature/new-horizons-spacecraft-in-the-clean-room-at-nasas-kennedy-space-center.

[151] Rob Gutro, *NASA's New Gamma Ray Satellite Currently Lodging in a Comfortable 'Clean Room,'* NASA (June 26, 2007), https://www.nasa.gov/vision/universe/starsgalaxies/gamma_cleanroom.html.

[152] Butler, *supra* note 144.

[153] *Id.* at 1359.

[154] *About COSPAR*, COMM. ON SPACE RESEARCH OF THE INT'L COUNCIL OF SCI. UNIONS, http://cospar2018.org/cospar-committees/cospar/ (last visited Mar. 29, 2019).

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research in space."[155] COSPAR was able to, eventually, provide a number of recommendations which were adopted by the Scientific and Technical Sub-Committee of COPUOS concerning planetary protection; only as a result of their diligence did provisions "concerning the harmful contamination of celestial bodies" find its way into Article IX of the "Outer Space Treaty."[156] The language as passed in Article IX of the Outer Space Treaty, however, only contains language concerning the act of "backward contamination and not forward contamination, as it may have been perceived to be the greater risk at the time."[157] Article VI of the Outer Space Treaty provides:

> States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. When activities are carried on in outer space, including the Moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.[158]

Article VI, in essence, provides that States must take responsibility for the actions of their governmental or non-governmental entities in outer space and that they must ensure they are cooperating with international treaty obligations. States are *not*, however, obligated to "enact national space laws, as they are free to comply with their obligations under the international space law system."[159]

In 2002, COSPAR provided standards which international space agencies can elect to follow to decontaminate their crafts; the standards are quite rigorous and get

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[155] *Id.*

[156] Gustavo Boccardo, *UPDATE: Planetary Protection Obligations of States Pursuant to the Space Treaties and with Special Emphasis on National Legislations Provisions*, NYU GLOBALEX (Jan. 2018), http://www.nyulawglobal.org/globalex/Planetary_Protection_Obligations_States1.html.

[157] *Id.*

[158] G.A. Res. 2222 (XXI), *supra* note 114, art. VI.

[159] *Id.*

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stricter depending on the complexity of the mission.[160] Unfortunately, however, COSPAR does not legally bind any nation as its regulatory framework is voluntary in nature.[161] Many suggest, however, that the COSPAR framework is so closely aligned with, and respected, by NASA's Planetary Protection Office, that NASA will not conduct a mission whose parameters do not meet COSPAR standards.[162]

While NASA is the standard-bearer for space exploration globally, many key nations, who are NASA partners, also have robust and truly essential space programs and technology. As in any case of differing laws, international borders tend to complicate compliance and uniformity. Space law is no different. The European Space Agency (ESA) complies with COSPAR's guidelines, though it is unclear to what degree, as NASA believes that ESA still differs from their own standards.[163] It has been suggested by scholars that the Russian space program Roscosmos has, in the past, followed less rigorous standards during two of its missions to the planets Venus and Mars, thus contaminating each planet; it has also been suggested that the Japanese Aerospace Exploration Agency ("JAXA") has enacted COSPAR-esque guidelines in its missions, but is hard to verify with certainty.[164] Moreover, China and India have recently sent probes to the Moon and Mars, though it is unclear if they too followed COSPAR guidelines.[165]

The following table provides a brief overview as to whether or not major international space-faring nations have enacted specific laws regarding planetary protection or the protection of the general space environment:

Nation	**Is There a Law That Contains Specific References to Planetary Protection or the Protection of Celestial Bodies?**	**Is There a Law That Contains Specific References to the Protection of the Space Environment?**
Argentina	No	No
Australia	No	No

[160] Butler, *supra* note 144, at 1359–60.

[161] Boccardo, *supra* note 156.

[162] *Id.*

[163] *Id.*

[164] *Id.*

[165] *Id.*

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Nation	Is There a Law That Contains Specific References to Planetary Protection or the Protection of Celestial Bodies?	Is There a Law That Contains Specific References to the Protection of the Space Environment?
Austria	Yes	Yes
Belgium	No	No
Brazil	No	No
Canada	No	No
Chile	No	No
China	No definitive laws. White Paper suggests governmental interest in the protection of the space environment and/or resources, though no specific measures are stipulated.	
France	No	Yes
Germany	No	No
Japan	No	No
Kazakhstan	Backward-contaminant focused, though does mention interest in following international norms/standards regarding outer space pollution.	
The Netherlands	Possession of license contingent upon protecting outer space, but no specific laws in place to protect outer space exclusively.	
Norway	No	No
Russia	Illegal to harm outer space or unfavorably change its environment. License applicants must prove the safety of their operations.	

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Nation	Is There a Law That Contains Specific References to Planetary Protection or the Protection of Celestial Bodies?	Is There a Law That Contains Specific References to the Protection of the Space Environment?
South Africa	No	No
South Korea	No	No
Spain	No	No
Sweden	No	No
Ukraine	No	No, though the law does stipulate that the damage to the environment is illegal.
United Kingdom	Yes, vague however.	No

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It is clear, then, that no two nations share the same goals, visions, or legally binding protocols as it relates to planetary protection. This fact may be the single most important reason why the advent of space mining could have destructive consequences unless properly regulated *before* it begins.

V. A CALL TO ACTION

The United States and Russia have always been the foremost authorities on space exploration. While the European, Canadian, and Japanese space agencies are partners of the American and Russian space programs, the U.S.-Russian relationship in space exploration has been the unique catalyst behind some of the greatest achievements in spaceflight history. Many are quick to cite recent tensions between the two nations related to election hacking or the omnipresent differing views on global affairs or politics as roadblocks to cooperation between the two governments. However, if there is one great lesson that can be learned through space exploration, it is that the unlikeliest of partners can achieve great things in the name of a greater good. The International Space Station is the finest example of how the U.S-Russian

[166] *Id.*

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relationship continues to support forward-thinking and progressive ideas. For 20 years, we have been partners and allies in space, sharing costs, supplies, technological know-how, and facilities.[167] This relationship can be, I believe, the spark behind a new force for good. As recently as November of 2018, the Director of Roscosmos, Dmitry Rogozin, and the head of NASA's Human Explorations and Operation, Bill Gerstenmaier, said in a joint press conference that the two nations "absolutely trust each other, and political winds haven't touched us."[168] Moreover, Gerstenmaier reiterated that due to the unique nature of human space flight and exploration, "we have to be totally honest with each other, we have to be totally transparent with each other."[169]

The special relationship that has been and is continuously fostered between the U.S. and Russia is allowing for future plans wherein both nations will cooperate on a mission to return to the Moon to perhaps establish a lunar colony.[170] I believe that the best chance of protecting outer space for decades to come can only be achieved if the U.S. and Russia spearhead an effort to form an international body establishing economic, scientific, and environmental protection standards for future space exploration and mining.

Several commentators have suggested detailed and well-thought-out treaties, international bodies, or legal regime changes, each of which present advantages and disadvantages. Ezra Reinstein suggests a system which, I believe, is the best that I have come across while conducting research for this Article.[171] While not infallible, Reinstein's idea of a U.N. Space Exploration Registry may be the best option to effectively and efficiently regulate commercial space mining.[172] Reinstein suggests that the Registry will exist as a sort of oversight committee, which would oversee the applications of a "person, corporation, of governmental body that designs and plans to execute a space development project."[173] The Registry will only approve a plan if it meets certain legal, environmental, scientific, and security criteria; the applications will be publicly available and will include the rationale behind the plan

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[167] Vladimir Isachenkov, *Russian, US Officials say space cooperation remains strong*, AP NEWS (Nov. 19, 2018), https://www.apnews.com/9687d0640d9d4c8d8e2f9eaa1352e49f.

[168] *Id.*

[169] *Id.*

[170] Dan Falk, *NASA's Deep Space Gateway seen as key to bold plan for mars and beyond*, NBC NEWS (Jan. 16, 2018, 1:56 PM EST), https://www.nbcnews.com/mach/science/nasa-s-deep-space-gateway-seen-key-bold-plan-mars-ncna838056.

[171] Ezra J. Reinstein, *Owning Outer Space*, 20 NW. J. INT'L L. & BUS. 59 (1999).

[172] *Id.* at 85.

[173] *Id.*

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and expected profits/revenues.[174] Moreover, the project must be commenced within a fixed time window of achieving approval; if the approved entity is unable to carry out the project within the time frame, then they lose the right to commence the project and must re-apply.[175] Finally, the Registry will be funded by the signatory states based on the aggregate revenue derived by state actors or private individuals/ companies.[176]

An oversight committee, such as Reinstein's Registry, is much more likely to stand the test of time rather than a singular treaty. A committee of this type will be able to keep abreast of current scientific and technological trends such that its provisions will not become outdated several years after its formation as often happens after the signing of a treaty. A committee will be able to adjust to modern norms, standards, and best-practices in order to best determine how to protect Earth, the Moon, and other celestial bodies when hearing and ruling on applications. In contrast to treaties-past, this new body must be vested with the legal ability to levy fines or prohibit/enforce certain types of behavior on the applicants. Most importantly, if this committee is to get off the ground, it must have support from the major players in space exploration.

An American firm is the most likely to first achieve the ability to mine outer space. The Russian government is, arguably, the next most advanced nation in terms of space hardware and prowess, with a decades-long proven track record.[177] Cooperation and support from key U.S. and Russian space allies, including the Japanese Aerospace Exploration Agency, the European Space Agency, and the Canadian Space Agency, is also essential. If the world's leading space agencies and governments agree to join this committee, it is possible to protect space for the benefit of all mankind for generations to come. A committee of this sort will enable governments and enterprise to rest assured that no one sovereign nation or individual entity will operate alone or in a power vacuum, pilfering space without respect for environmental, economic, or political factors.

Competing scholars suggest a litany of alternative options to tackle the space mining dilemma. Andrew Tingkang suggests selling off asteroids as though they

[174] *Id.* at 85–86.

[175] *Id.* at 86.

[176] *Id.*

[177] *Which Space Agencies are Considered The Best in the World?*, FORBES (May 22, 2017, 1:56 PM), https://www.forbes.com/sites/quora/2017/05/22/which-space-agencies-are-considered-the-best-in-the-world/#607236635245.

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were chattel via auction to the highest bidder.[178] Lauren Shaw advocates for an application of the General Mining Law which would "split the acquisition of property rights in valuable mineral deposits into two phases" whereby a prospector would first stake a claim thus affording him/her a plenary right to exclude others (contingent on the maintenance of certain labor investments) from the deposit and second obtain a deed in fee simple for the land surrounding the deposit.[179] Scott Shackelford advocates for a leasehold contingency whereby the first "investors to arrive at a new resource area, occupy the territory, improve it, and equitably share some of the profits would be entitled to. . . auction off the property rights."[180] Finally, Matthew Feinman proposed a treaty, robust in detail, applying only to asteroids which would contain provisions for planetary protection but fell short of calling for mandatory enforcement mechanisms for violators.[181]

That individuals are debating mechanisms by which space can be protected is nothing but positive as it signals a shift in the thinking of legal and academic scholars as it relates to space law. A commission, similar to Reinstein's Registry is, I believe, best suited to tackle to job of regulating outer space mining. It would be in the best interest of would-be member states such as Russia, the United States, major European nations, and Japan to join this deliberative certification body as it will be national space agencies and private companies within their own respective borders that will be at the forefront of this new scientific achievement. If these states are to comply with their outstanding international treaty obligations, they are subject to liability for any and all damage caused by private or governmental actors in outer space.[182] While space exploration to this point has not been easy whatsoever, there is little evidence to suggest that lunar mining, celestial resource extraction, harvesting metals from an asteroid, or converting precious liquids or gasses into rocket fuel in situ will be any easier.[183] A committee made up of the finest space faring nations which rigorously vets, reviews, and questions prospective outer space mining plans will be the best equipped to provide meaningful and intelligible feedback on missions in order to protect outer space. Cross-pollination and sharing

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[178] Samuel Roth, Note, *Developing a Law of Asteroids: Constants, Variables, and Alternatives*, 54 COLUM. J. TRANSNAT'L L. 829, 862 (2016).

[179] *Id.* at 859–60.

[180] *Id.* at 860.

[181] *Id.* at 860–61.

[182] G.A. Res. 2777 (XXVI), annex, Convention on International Liability for Damage Caused by Space Objects (Mar. 29, 1972).

[183] Laura Yan, *Should We Really Be Mining in Space?*, POPULAR MECHANICS (May 5, 2018), https://www.popularmechanics.com/space/a20195040/should-we-be-really-be-mining-in-space/.

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of knowledge and experience can be achieved by member states on this committee in order to come up with the most cutting-edge, feasible, and lucrative missions while helping to ensure that no single nation is caught off guard by a half-baked or improperly vetted mission carried out by a private entity which could wreak havoc on outer space resources, thus leaving a member state liable for the cleanup costs and remedies pursuant to current international treaty obligations. Moreover, it is typically national space agencies of sovereign nations that conduct space exploration and missions. For example, it is nations, not private firms, which oversee military and communications satellites or have responsibility for launching new satellites or send exploratory probes to other planets or fulfill missions to the ISS.[184] If space mining is improperly regulated, there exists the potential that the *very nations* whose private entities are responsible for doing damage will be jeopardizing key national space assets or making the job of national space agencies harder in the future. It is possible that satellites can become damaged by orbital debris or that astronaut lives will be put in danger due to the reckless actions of a less-experienced and less-regulated private firm. It is, then, in the best interest of these nations to join this committee, the sole purpose of which is to promote the extraction of space-based resources by government and private entities alike, ensuring that the rich and abundant natural resources of outer space are harvested for the benefit of all mankind.

VI. CONCLUSION

The process of harvesting space-based resources is likely to be immensely challenging and lucrative. Several firms, major industrialists, and governments are investing tens of millions of dollars to make this complex dream a reality. Just as international laws have, in the past, adapted to meet the evolving needs of the day, international space law too must change and quickly. Major space-faring nations must take up the baton to push for the adoption of an international regulatory committee which will oversee applications and issue permits based on a set of robust, modern, and forward-thinking ideals that are best equipped to govern and protect outer space as individuals, businesses, and nations compete to commercialize space through mining and the extraction of space-based resources. This committee must have a thorough understanding of the outstanding international legal obligations that each member state is a party to. Moreover, the committee must anticipate the economic and environmental issues posed by space mining and the harvesting of resources in space. It is entirely possible to ensure that private citizens and firms are capable of profiting off of space while also respecting well-founded norms, regulations, and laws. An international committee possessing the requisite

[184] Alicia Ault, *Ask Smithsonian: How Does a Satellite Stay Up?*, SMITHSONIAN MAG. (Feb. 6, 2015), https://www.smithsonianmag.com/smithsonian-institution/ask-smithsonian-how-does-satellite-stay-180954165/.

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knowledge, decision making, and punishment abilities is the best equipped to oversee what very well may be a renaissance for space exploration.

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