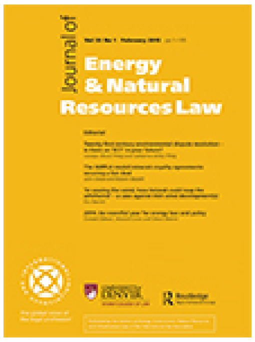

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The development of natural resources in outer space

Scot W Anderson, Korey Christensen & Julia LaManna

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The development of natural resources in outer space

Scot W Anderson, *is a partner in the Denver office of Hogan Lovells US LLP. Email: scot.anderson@hoganlovells.com;* **Korey Christensen,** *is a senior associate in the Denver office of Hogan Lovells US LLP. Email: korey.christensen@hoganlovells.com;* **Julia LaManna,** *is an associate in the Denver office of Hogan Lovells US LLP. Email: julia.lamanna@hoganlovells.com. This paper rests primarily on the work of Julia LaManna. Mr Anderson and Mr Christensen have attempted to expand on some of the themes and concepts in Ms LaManna's analysis.*

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The extraction of natural resources from outer space sources – once the stuff of science fiction – is closer than ever to becoming a reality, as several entities pursue the best way to unlock our solar system's most valuable resources. Space mining raises several intriguing legal questions to which there is currently no clear answer, as the scarce body of international law applicable to outer space activities lags behind the rapid advances in technology fuelling the advancement of this burgeoning industry. This paper provides an introduction to the outer space mining industry and the legal challenges it faces, including an overview of proposed space mining operations, the industry's first movers and the current state of the governing law (both domestic and international). It also analyses the potential for application of existing principles of both international law, including the law of the sea and terrestrial mining projects, to the not-so-distant future of space mining.

Keywords: mining; space mining; asteroid; asteroid mining; outer space; Outer Space Treaty; Moon Treaty; Law of the Sea; international law

1. Introduction

As the world's population grows, increasing demand for the planet's limited resources, governments and private enterprises are setting their sights on outer space. In asteroids and the moon, there is an abundance of water and various precious metals. Once the stuff of science fiction, people are now actively working to develop the technology to extract and utilise these resources.

Asteroids are the 4.6 billion-year-old remains of our solar system's formation.[1] They range in size from less than 33 feet to about 329 miles in diameter.[2] Most have odd, non-spherical shapes and they may have irregular rotations, 'sometimes tumbling quite erratically' as they orbit the sun.[3]

Most asteroids orbit in the main asteroid belt between Mars and Jupiter.[4] This belt contains more than a million asteroids,[5] but is so far away that it would be very difficult with existing technology to utilise their resources.

1 'Asteroids: In Depth' (NASA) https://solarsystem.nasa.gov/small-bodies/asteroids/in-depth accessed 28 July 2018.
2 *Ibid.*
3 Charles Q Choi, 'Asteroids: Fun Facts and Information About Asteroids' (*Space.com*, 16 March 2017) www.space.com/51-asteroids-formation-discovery-and-exploration.html accessed 28 July 2018.
4 *Ibid.*
5 *Ibid.*

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Fortunately, 'near-Earth asteroids' (NEAs) orbit closer to Earth.[6] NEAs are defined as having an orbital distance from Earth of 1.3 astronomical units (au) (equivalent to about 120 million miles) or less.[7] To date, scientists have documented about 18,000 NEAs and discover more every year.[8] NEAs that orbit at .05 au (approximately 4.6 million miles) or less and have a minimum magnitude that can generally be translated to a diameter of at least 500 feet are considered potentially hazardous asteroids (PHAs).[9] Though meteor[10] strikes caused by these PHAs are few and far between, their consequences can be severe. As such, an added benefit of pursuing technology for space mining is that it aids in the accumulation of knowledge about asteroids, which enables the protection of Earth from such an impact.

Despite modern advancements in scientific understanding of asteroids, there is still considerable uncertainty about how many and which asteroids contain valuable resources. Based on what scientists have been able to ascertain, there appear to be three general classes of asteroids: C-, S- and M-types.[11] C-type asteroids are likely made up of clay and silicate[12] rocks, S-types consist of silicate rocks and nickel-iron, and M-types are composed of nickel-iron.[13]

Although different asteroid types are made up of different component elements, 'some are rich in the platinum group materials and other highly valued metals'.[14] For context, it has been estimated that the value of a single platinum-bearing asteroid could be between \$25bn and \$50bn.[15] These metals are highly useful and valuable, both on Earth and in space.[16] As a result of Earth's gravity, much of our planet's supply of these metals is found near Earth's core, making the relatively smaller amounts that are more readily accessible in the crust layer even more valuable.[17] By contrast, on asteroids, the lower relative gravity makes these metals easier to

6 'NEO Basics' (Center for Near Earth Object Studies, California Institute of Technology) https://cneos.jpl.nasa.gov/about/neo_groups.html accessed 28 July 2018.

7 *Ibid.*

8 'Discovery Statistics' (Center for Near Earth Object Studies, California Institute of Technology) https://cneos.jpl.nasa.gov/stats/totals.html accessed 28 July 2018. Detailed information about asteroids can be found at www.asterank.com.

9 'NEO Basics' (Center for Near Earth Object Studies, California Institute of Technology) https://cneos.jpl.nasa.gov/about/neo_groups.html accessed 28 July 2018.

10 Once an asteroid passes through Earth's atmosphere, it is defined as a meteor. Marc Lallanilla, 'What Are an Asteroid, a Meteor, and a Meteorite?' (*Live Science*, 15 February 2013) www.livescience.com/27183-asteroid-meteorite-meteor-meteoroid.html.

11 'Asteroids: In Depth' (NASA) https://solarsystem.nasa.gov/small-bodies/asteroids/in-depth accessed 28 July 2018.

12 Silicates are salts in which the anion contains both silicon and oxygen. Definition of 'silicate' (*Merriam-Webster*) www.merriam-webster.com/dictionary/silicate accessed 28 July 2018.

13 'Asteroids: In Depth' (NASA) https://solarsystem.nasa.gov/small-bodies/asteroids/in-depth accessed 28 July 2018.

14 'Asteroid Mining: US Company Looks to Space for Precious Metal' *The Guardian* (London, 23 January 2013) www.theguardian.com/science/2013/jan/22/space-mining-gold-asteroids.

15 Jim Edwards, 'Goldman Sachs: Space-Mining for Platinum Is "More Realistic than Perceived"' (*Business Insider*, 6 April 2017) www.businessinsider.com/goldman-sachs-space-mining-asteroid-platinum-2017-4?r=UK&IR=T (quoting Goldman Sachs analyst note) (observing that harvesting even one such asteroid 'would instantly tank the entire platinum market' by flooding worldwide supply).

16 As of July 2018, platinum was priced at \$830 per ounce. 'Platinum' https://markets.businessinsider.com/commodities/platinum-price accessed 28 July 2018.

17 Robert Hackett, 'Asteroid Passing Close to Earth Could Contain \$5.4 Trillion of Precious Metals' (*Fortune*, 20 July 2015) http://fortune.com/2015/07/20/asteroid-precious-metals.

access.[18] These metals are used in automobiles, jewellery, medicines and electronics.[19] In space, they can be used to 3D print spacecraft components, enabling building and maintenance to occur in orbit.

The moon also holds significant amounts of water contained in beds of ice found in 'permanently shadowed craters'.[20] Scientists estimate that within about 40 of these craters there are 1.3 trillion pounds or 600 million metric tonnes of water-ice.[21] Translated to rocket fuel, this amount 'would be enough to launch one space shuttle per day for 2,200 years'.[22] This makes the moon a very attractive option to house a space refuelling station, and indeed, there are multiple proposals to this effect.

The nascent space mining industry is quickly becoming a viable reality. Many estimate that extracting and utilising water in space, the first step to creating a space mining economy, could be achieved within a decade.[23] However, there remains significant legal uncertainty about how mining the moon and asteroids can and should proceed under existing international and domestic law.

2. Mining mechanics

At present, it is not feasible to send a human to an NEA as part of a manned asteroid mining endeavour.[24] For that reason, current mining proposals are focused on purely robotic flights. Using unmanned spacecraft, water could be extracted from asteroids and the moon to support life and produce fuel. Likewise, robotic probes could mine asteroids for precious metals that, once refined, could be used in space to 3D print spacecraft components. Finally, these same precious metals could be returned to Earth for a multitude of uses, though there is some concern about the cost of such an endeavour as well as its effect on the global economy.[25]

With these goals in mind, companies and governments interested in space mining are considering a variety of approaches to identifying and harvesting space resources. These strategies are dictated by constraints imposed by a space environment that is distinct from the familiar terrestrial one. Specifically, the technology used will need to be

18 *Ibid.*

19 Martin Creamer, 'The Uses of Platinum-Group Metals' *Mining Weekly* (10 November 2006) www.miningweekly.com/article/the-uses-of-platinumgroup-metals-2006-11-10.

20 Andrea Thompson, '"Significant Amount" of Water Found on Moon' (*Space.com*, 13 November 2009) www.space.com/7530-significant-amount-water-moon.html.

21 'NASA Radar Finds Ice Deposits at Moon's North Pole' (NASA) www.nasa.gov/mission_pages/Mini-RF/multimedia/feature_ice_like_deposits.html accessed 28 July 2018.

22 Paul Rincon, 'Ice Deposits Found at Moon's Pole' (*BBC News*, 2 March 2010) http://news.bbc.co.uk/2/hi/science/nature/8544635.stm (paraphrasing comments made by Dr Paul Spudis of the Lunar and Planetary Institute in Houston, Texas, at the 41st Lunar and Planetary Science Conference).

23 Mike Wall, 'Asteroid Mining May Be a Reality by 2025' (*Space.com*, 11 August 2015) www.space.com/30213-asteroid-mining-planetary-resources-2025.html.

24 'Asteroid Retrieval Feasibility Study' (Keck Institute for Space Studies, 2 April 2012) at 15 ('Sending a human to a Near-Earth Asteroid now would require months of flight time and consequent life support and radiation protection systems not yet designed.') (hereinafter 'Keck Study').

25 'Going Platinum' *The Economist* (28 April 2012) www.economist.com/node/21553419. Though beyond the scope of this paper, it is worth noting that the prospect of building space-based solar power stations from which power could 'be beamed back to Earth via microwave or laser' has also been considered. See Lucas Mearian, 'China Considering Space-Based Solar Power Station' (*Computer World*, 30 March 2015) www.computerworld.com/article/2903588/china-considering-space-based-solar-power-station.html.

able to operate in deep space, which means low gravity, high vacuum, substantial harmful radiation and varying available sunlight.[26] In addition, it will need to grapple with asteroids that vary widely in size, shape and composition.

This section discusses the space mining process, and presents a sampling of ideas and technologies under consideration.

2.1. *Steps to space mining*

Much like leveraging resources on Earth, there are four basic steps to exploiting asteroid resources: (1) prospect, (2) extract or harvest, (3) process and (4) utilise.

2.1.1. Prospecting

While prospecting on Earth is often difficult and uncertain, prospecting in space poses unique challenges. Because there is more scientific certainty about the moon, this section deals primarily with the steps that are being taken to identify and learn about asteroids.

Prospecting for asteroids involves assessing their 'orbital economics' – meaning, determining how easy an asteroid is to access in relation to how much revenue could be derived from mining it. There are various strategies for collecting information about asteroids. As one example, Planetary Resources has considered using a single rocket launch to deploy multiple prospecting spacecraft that it refers to as Arkyd-301s.[27] These spacecraft will each gather data and physical samples from a pre-selected asteroid in the search for water and other valuable resources which might be used as a potential mine site in the future.[28] In 2015, Planetary Resources successfully deployed its first prospecting spacecraft, known as an Arkyd 3 Reflight on a 90-day mission to test its technologies.[29] The craft was small, just 12 by four by four inches, and flew to the International Space Station onboard SpaceX's Falcon 9, after which it was launched into orbit.[30] More recently, Planetary Resources conducted a test of its Arkyd-6 spacecraft, which was launched on an Indian rocket in January 2018.[31] During this recent test, the Arkyd-6 'satisfied all of its mission requirements', demonstrating 'its distributed computing system, communications, attitude control system, power generation and storage with deployable solar arrays and batteries, star tracker [and] reaction wheels, and the first commercial mid-wave infrared (MWIR) imager operated in space'.[32] The MWIR imager was tested through attempts to detect the

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26 Brad R Blair and Leslie S Gertsch, 'Asteroid Mining Methods' (Presentation to Space Studies Institute, 20 November 2010) http://ssi.org/2010/SM14_presentations/101030_SSI_Blair-Gertsch.pdf.

27 'About the Exploration Program' (Planetary Resources) www.planetaryresources.com/missions/arkyd-301 accessed 28 July 2018.

28 *Ibid.*

29 'Planetary Resources' First Spacecraft Successfully Deployed, Testing Asteroid Prospecting Technology on Orbit' (Planetary Resources, 16 July 2015) www.planetaryresources.com/2015/07/planetary-resources-first-spacecraft-deployed.

30 *Ibid*; Sarah Lewin, 'Asteroid Mining Company's 1st Satellite Launches from Space Station' (*Space.com*, 17 July 2015) www.space.com/29975-asteroid-mining-planetary-resources-satellite-launch.html.

31 'Mission Success: Arkyd-6 Tests Key Technologies for Commercial Space Resource Exploration' (Planetary Resources, 24 April 2018) www.planetaryresources.com/2018/04/mission-success-arkyd-6-tests-key-technologies-for-commercial-space-resource-exploration accessed 28 July 2018.

32 *Ibid.*

presence of water in various locations on Earth, and is planned to be used in the future to detect water on NEAs.[33]

2.1.2. Extracting

For extracting, as for prospecting, there are a variety of techniques being discussed and developed by private and governmental entities. Different techniques are dependent on varying circumstances such as the type and location of the resource being extracted, as well as on the characteristics of the asteroid itself.[34] Mining surface materials will require different technology than that for mining subsurface materials, and mining water will be distinct from mining metals.

Where an asteroid has significant rubble, one idea is to use magnets – perhaps in the form of a magnetic rake – to skim over the surface, lifting off metal grains.[35] By contrast, the techniques used to extract subsurface resources from other types of asteroids may involve drilling processes more analogous to those used in terrestrial mining.

Another extraction technique being developed by a team led by TransAstra Corporation, operating through a NASA grant is 'optical mining'.[36] Using this technique, 'excavating and processing asteroid materials is accomplished by highly concentrated sunlight which … can be used to drill holes, excavate, disrupt, and shape an asteroid while the asteroid is enclosed in a containment bag'.[37] Through a process called 'spalling', water and other volatiles could be expelled from rock using 'tiny, explosive pops of expanding gas [to] drive out particles and gas'.[38] Once extracted, the water would be 'pumped into a passively cooled bag and stored as solid ice'.[39] Using a single spacecraft, this method could harvest up to 100 metric tonnes of water and move the material into lunar orbit or other near-Earth locations.[40] NASA plans to utilise the extracted water in space for consumables, propellant and shielding.[41]

As a final example, in 2016, NASA launched a mission to collect materials from an asteroid called Bennu using a spacecraft with a robotic arm.[42] The spacecraft, known as

33 *Ibid.*
34 See Blair and Gertsch, 'Asteroid Mining Methods' (n 26).
35 Michael Belfiore, 'The Tech We'll Need to Mine Asteroids' *Popular Mechanics* (16 August 2012) www.popularmechanics.com/space/a8038/the-tech-well-need-to-mine-asteroids-11644892/.
36 Joel Sercel, 'Optical Mining of Asteroids, Moons, and Planets to Enable Sustainable Human Exploration and Space Industrialization' (NASA, 6 April 2017) www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Sustainable_Human_Exploration; Nell London, 'Solar-Powered Asteroid Mining? This Colorado Scientist Is on the Team Figuring It Out' (22 September 2017) www.cpr.org/news/story/space-innovation-mining-asteroids-using-sunlight.
37 Joel Sercel, 'Optical Mining of Asteroids, Moons, and Planets to Enable Sustainable Human Exploration and Space Industrialization' (NASA, 6 April 2017) www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Sustainable_Human_Exploration.
38 Leonard David, 'Asteroid-Mining Plan Would Bake Water out of Bagged-Up Space Rocks' (*Space.com*, 18 September 2015) www.space.com/30582-asteroid-mining-water-propulsion.html.
39 *Ibid.*
40 *Ibid.*
41 Joel Sercel, 'Optical Mining of Asteroids, Moons, and Planets to Enable Sustainable Human Exploration and Space Industrialization' (NASA, 6 April 2017) www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Sustainable_Human_Exploration.
42 See 'NASA's OSIRIS-REx Asteroid Sample Return Mission' (NASA) www.nasa.gov/sites/default/files/atoms/files/osiris_rex_factsheet5-25.pdf accessed 28 July 2018; see also 'OSIRIS-REx Asteroid Sample Return Mission' (Arizona Board of Regents) www.asteroidmission.org accessed 28 July 2018.

the OSIRIS-Rex, is scheduled to rendezvous with Bennu, survey the asteroid for one year, and then attempt to collect samples of the asteroid to return to Earth.[43] The sample, if the mission is successful, will be collected with a robotic arm that shoots nitrogen gas into the surface of the asteroid, stirring up rocks and allowing the arm to grab a few ounces of material.[44] While not specifically developed for commercial purposes, such technology could be applied to mining missions in the future.

2.1.3. Processing

As on Earth, processing extracted materials will likely occur relatively close to the mine site. Rather than returning the raw material to Earth, it is likely that processing centres will be placed in near-Earth orbit.[45] However, because the industry is currently focused on the first step to space mining – prospecting – information about how exactly processing will occur is sparse.

Because purifying water and other volatiles is significantly easier than refining metals, these materials are likely to be targeted as the first candidates for extraction and processing. Refining metal ores would require sophisticated refining centres to be placed into low Earth orbit (LEO), the technology for which is not yet well defined.

2.1.4. Utilisation and manufacturing

Scientists quip that Earth's orbit, though a small relative distance compared to the rest of the solar system, is 'halfway to anywhere'.[46] This has important consequences for how the space mining economy will likely develop. To illustrate, launching a spacecraft from Earth to LEO requires a velocity of about five miles per second.[47] By contrast, launching a spacecraft from LEO to an NEA would require a velocity of approximately three and a half miles per second.[48] This highlights that launching spacecraft from Earth is inefficient. Launching smaller craft from space stations already in orbit will allow companies and governments to send more spacecraft using less fuel.

Moreover, it would currently cost about $1bn to return two ounces of asteroid material to Earth.[49] Thus, while returning very tiny samples from asteroids has been done,[50] and will likely be repeated in the near future, returning space resources in large quantities is unlikely for many years. It will likely only become a viable possibility after an in-space economy develops, and some doubt whether it will ever be

43 www.nasa.gov/sites/default/files/atoms/files/osiris_rex_factsheet5-25.pdf last accessed 28 July 2018.
44 *Ibid.*
45 See 'How Would Asteroid Mining Work? A Visual Guide' *The Guardian* (London, 6 February 2016) www.theguardian.com/business/ng-interactive/2016/feb/06/how-would-asteroid-mining-work-a-visual-guide (hereinafter 'Visual Guide').
46 Doug Turnbull, 'Why Robots May Be the Future of Interplanetary Research' (*Space.com*, 3 January 2014) www.space.com/24150-robots-future-of-interplanetary-research.html. This is a famous Robert Heinlein quote that is often repeated.
47 Mark Sonter, 'The Technical and Economic Feasibility of Mining the Near-Earth Asteroids' (National Space Society 1998) www.nss.org/settlement/asteroids/sonter.html.
48 *Ibid.*
49 'Visual Guide' (n 45).
50 The Japanese spacecraft, Hayabusa, landed on an asteroid and was able to return dust particles from its surface. 'Asteroid Dust Successfully Brought Back to Earth' (*NBC*, 13 June 2010) www.nbcnews.com/id/40215035/ns/technology_and_science-space/t/asteroid-dust-successfully-brought-back-earth.

able to compete with terrestrial mining given the costs of launching from and returning to Earth.[51]

Given these challenges, most current proposals for space mining involve 'in situ resource utilisation' (ISRU). ISRU is the practice of recovering space resources on site for human consumables, spacecraft propellant and other needs.[52] Using space resources in space increases the longevity and decreases the cost of space exploration. Establishing this type of active in-orbit market using materials mined from space is the first step towards building a robust commercial space mining industry.

As previously noted, space mining will likely begin with the extraction of water from the moon and accessible NEAs. Hydrogen can be extracted from water to be used for jet fuel. Water can also be used for drinking and food production as well as providing protection from radiation.[53] However, ISRU is not limited to water. Mined metals from space can be used to 3D-print spacecraft components.[54]

In fact, 3D manufacturing in space is already happening. In 2014, the International Space Station's (ISS) 3D printer produced its first product. The ISS received the 3D printer as part of the 3D Print project, a collaboration between NASA and Made in Space, a California startup. The primary goal of the project was to verify that a 3D printer could function in a microgravity environment.[55] While the project confirmed that the printer does in fact operate in space, the additional challenge has been developing materials that are amenable to 3D printing and strong enough to withstand space's vacuum. To date, all printed objects have had to remain within the ISS because they are not durable enough to survive outside it. Recently, however, Made in Space developed a new material that it claims could be used on the exterior of the space station.[56] It remains to be seen whether metals extracted from space will be suitable for 3D printing.

Despite the difficulties, manufacturing in space has several benefits. Microgravity environments allow precise control of the convection of liquids and gases. Space's vacuum also allows for the creation of very pure materials, minimising defects. In addition, extreme temperatures in space, often necessary in the manufacturing process and energy intensive to create artificially, are readily available.[57]

2.2. *Bringing asteroids closer to Earth*

Beyond developing technology to identify, extract and process resources from asteroids, an additional hurdle to space mining is the distance between the asteroid itself

51 'Fool's Platinum?' *The Economist* (24 January 2013) www.economist.com/blogs/babbage/2013/01/asteroid-mining (explaining that doubling the Earth's supply of platinum might cause the price to plummet, undermining the business case for returning materials to Earth).

52 See 'Developing Technologies for Living off the Land … in Space' (NASA) www.nasa.gov/exploration/analogs/isru accessed 28 July 2018.

53 Mike Wall, 'Asteroid Mining May Be a Reality by 2025' (*Space.com*, 11 August 2015) www.space.com/30213-asteroid-mining-planetary-resources-2025.html.

54 See 'Visual Guide' (n 45).

55 Mike Wall, 'Space Station's 3D Printer Makes 1st Part' (*Space.com*, 25 November 2014) www.space.com/27861-3d-printer-space-station-first-part.html.

56 Dallon Adams, 'Tough New 3D Printing Plastic Lets Astronauts Print Spacewalk Tools on Demand' (*Digital Trends*, 24 July 2017) www.digitaltrends.com/cool-tech/3d-printing-in-space-new-material-withstand-vacuum

57 Kundan R Avchare and others, 'Space Manufacturing Techniques: A Review' (2014) 4(4) Int'l J of Scientific and Research Pub 1 www.ijsrp.org/research-paper-0414/ijsrp-p2802.pdf.

and a point of need. As an alternative to shuttling asteroid resources to processing plants in LEO, some space mining proposals involve retrieving entire small asteroids, or pieces of larger ones, and dragging them closer to Earth.

About ten per cent of NEAs are easier to reach than the moon.[58] Still, even the closest NEAs are much more difficult to reach than LEO. For context, LEO ranges from about 112 miles to 1,243 miles away from Earth's surface.[59] Most of the Earth's significant satellites orbit in this range including Sputnik-1 and the Hubble Space Telescope. The International Space Station orbits at an average altitude of 248 miles.[60] By contrast, a potentially hazardous asteroid (PHA) that has garnered recent attention for its proximity to Earth will, at its closest point, pass Earth at a distance of over 1 million miles away.[61] Apart from the astronauts who landed on the moon with the Apollo programme, all human spaceflights have taken place in low Earth orbit or below.[62]

Acknowledging that the large distances to asteroids make studying and mining them challenging to say the least, the Keck Institute for Space Studies conducted a study about the feasibility of asteroid retrieval in 2012 (the 'Keck Study').[63] The study examined the technological and economic issues related to returning a 500,000 kilogram (1.1 million pounds) NEA to high lunar orbit. Scientists chose lunar orbit rather than LEO for safety reasons – lunar orbit is about 0.25 million miles from Earth.[64] Thus, should something go wrong, the Earth would not be threatened by an asteroid plummeting to its surface.[65] The study determined that it would be possible to return a small NEA or a piece of a larger one to high lunar orbit by around 2025.[66] It estimated that such an endeavour would cost about $2.6bn, though some believed this number to be on the conservative side.[67]

NASA's Asteroid Redirect Mission (ARM), though defunded in 2017,[68] had planned to implement one of the methods studied in the Keck Study. Specifically, it

58 Mark Sonter, 'Asteroid Mining: Key to the Space Economy' (National Space Society, February 2006) www.nss.org/settlement/asteroids/key.html.

59 See 'Catalog of Earth Satellite Orbits' (NASA) https://earthobservatory.nasa.gov/Features/OrbitsCatalog accessed 28 July 2018.

60 Samantha Mathewson, 'How to Spot the International Space Station with New NASA Tool' (*Space.-com*, 8 November 2016) www.space.com/34650-track-astronauts-space-new-interactive-map.html.

61 Walter Wisniewski, 'Big Asteroid Is Heading Close to Earth' (*VOA News*, 8 April 2017) www.voanews.com/a/big-asteroid-heading-close-earth/3802630.html.

62 Note that there are two other classes of orbit. 'High Earth orbit' begins at 35,780km (22,233 miles) from Earth's surface. This is also the point where a spacecraft would enter an orbit that is 'geosynchronous' with Earth's orbit – meaning that it would be orbiting at the same speed that the Earth is turning, seeming to stay in place over a single longitude. If the spacecraft is directly above the equator, it will remain in the same place above the Earth's surface. 'Medium Earth orbit' ranges from 2,000km to 35,780km (1,243 miles to 22,233 miles) from Earth's surface. Global Positioning System (GPS) satellites are located within this range at 20,350km from Earth's surface. See 'Catalog of Earth Satellite Orbits' (NASA) https://earthobservatory.nasa.gov/Features/OrbitsCatalog accessed 28 July 2018.

63 Keck Study (n 24).

64 Tim Sharp, 'How Far Is the Moon?' (*Space.com*, 27 October 2017) www.space.com/18145-how-far-is-the-moon.html.

65 Keck Study (n 24) at 15.

66 *Ibid* at 5.

67 Louis Freedman, Statement of Dr Louis Freedman to the Space Subcommittee of the US House of Representatives Committee on Science, Technology and Space (21 May 2013) 4–5 https://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-113-SY16-WState-LFriedman-20130521.pdf

68 Jeff Foust, 'NASA Closing Out Asteroid Redirect Mission' (*SpaceNews*, 14 June 2017) http://spacenews.com/nasa-closing-out-asteroid-redirect-mission

had planned to rendezvous a robotic spacecraft with a large NEA, pick up a boulder approximately four metres in diameter from its surface, and return the boulder to lunar orbit.[69] Once in lunar orbit, NASA had planned to send astronauts to it to study its composition. The mission would have also tested capabilities that would be needed to send a crew to Mars because the space environment near the moon is similar to that of Mars.[70]

Despite NASA's ARM mission losing its funding, private enterprises may remain interested in retrieving parts of or entire asteroids for commercial mining purposes. For example, Planetary Resources had previously planned to capture small, water-rich NEAs and tow them closer to Earth to mine for their water.[71]

In sum, while certain mining technologies, such as prospecting telescopes and probes, are beginning to take shape, much about the mining process remains theoretical. Nevertheless, studies such as the one by the Keck Institute demonstrate that many of these theories can be realised given sufficient funding and time for development. Also, Goldman Sachs has argued that an asteroid with $25bn to $50bn worth of platinum could be mined at a cost of $2.6bn.[72] At the moment, it seems that the major barriers to space mining have less to do with the possibility of its realisation at a technical level, and more to do with making the enterprise cost-effective.

3. Commercial landscape

The economics of space exploration are changing. With private enterprises innovating new modular and cost-effective technologies, space travel is becoming increasing affordable. For example, whereas in the past it could cost as much as $35m to send a single person into space, today, companies hope to do the same for about $250,000.[73] While the current cost per pound of launching into Earth's orbit has been estimated at $10,000 per pound, SpaceX has targeted a ten-fold reduction in that cost in the near-term future.[74]

Notwithstanding this progress, space mining remains an industry that is not yet economical. Because revenue derived directly from extracted resources is still about a decade away, the companies discussed below, particularly Planetary Resources and Deep Space Industries (DSI), are strategising ways to leverage their technologies to make money in the interim.

3.1. *Planetary resources*

Planetary Resources was formed by Peter Diamandis and Eric Anderson in 2009 with the goal of mining asteroids for metals and water. Chris Lewicki is the company's

69 'What Is NASA's Asteroid Redirect Mission?' (NASA) www.nasa.gov/content/what-is-nasa-s-asteroid-redirect-mission accessed 28 July 2018.

70 'How Will NASA's Asteroid Redirect Mission Help Humans Reach Mars?' (NASA) www.nasa.gov/content/how-will-nasas-asteroid-redirect-mission-help-humans-reach-mars accessed 28 July 2018.

71 Karl Tate, 'How Asteroid Mining Could Work (Infographic)' (*Space.com*, 22 January 2013) www.space.com/15391-asteroid-mining-space-planetary-resources-infographic.html.

72 Adam Mann, 'Who's in Charge of Outer Space?' *Wall Street Journal* (19 May 2017) www.wsj.com/articles/whos-in-charge-of-outer-space-1495195097.

73 Jim Edwards, 'Goldman Sachs: Space-Mining for Platinum Is "More Realistic Than Perceived"' (*Business Insider*, 6 April 2017) www.businessinsider.com/goldman-sachs-space-mining-asteroid-platinum-2017-4?r=UK&IR=T.

74 Dallon Adams, 'Billionaire Space Prospectors Are Racing to Mine the Moon, and That's a Good Thing' (*Digital Trends*, 24 July 2017) www.digitaltrends.com/cool-tech/mining-the-moon-the-next-gold-rush

current Chief Executive Officer.[75] Its major investors have included the government of Luxembourg,[76] Google CEO Larry Page, Ross Perot Jr and filmmaker James Cameron.[77]

The company's goals include:

- providing fuel and raw materials that will be integral to any long-term, sustainable and scalable missions to the moon, Mars and beyond;
- harvesting water from asteroids to be used as fuel for spacecraft and satellites, life support for a space workforce, radiation shielding, and to grow food; and
- extracting metal from asteroids to be 3D printed for structures and components needed in space.[78]

3.2. *Deep Space Industries*

DSI was formed in 2013. Bill Miller is the company's current CEO and Guillermo Sohnlein serves as Chairman of the Board.[79] DSI has previously planned to launch a network of small, low-cost scouting spacecraft. Its 'Prospector series' were small spacecraft designed to locate, land on and assess the value of asteroids.[80] At present, DSI has a more general goal of using its technology to 'employ our technology to conduct asteroid science and exploration, support activities such as manufacturing in space, and enter other lucrative vertical markets'.[81]

3.3. *Moon Express*

Moon Express was founded in 2010 by Bob Richards, Naveen Jain and Barney Pell. The company plans to harvest the moon's water and other resources.[82] Moon Express recently won $1 million in an X-Prize competition for being the first company to present and test a lunar lander spacecraft.[83] It hopes to win an additional $20 million by actually landing its MX-1E, a spacecraft standing about five feet tall and weighing 65 pounds, on the moon.[84]

Moon Express was the first commercial enterprise to receive authorisation from the United States for a private robotic spacecraft trip to the moon.[85] Prior to its authorisation, the only spacecraft to travel beyond Earth's orbit were government-owned,

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75 Planetary Resources, www.planetaryresources.com/team/chris-lewicki accessed 28 July 2018.

76 'Planetary Resources and the Government of Luxembourg Announce €25 Million Investment and Cooperation Agreement' (Planetary Resources, 3 November 2016) www.planetaryresources.com/2016/11/planetary-resources-and-the-government-of-luxembourg-announce-e25-million-investment-and-cooperation-agreement

77 Tariq Malik, 'Billionaire-Backed Space Venture Planetary Resources to Be Unveiled April 24' (*Space.com*, 18 April 2012) www.space.com/15336-planetary-resources-space-exploration-announcement.html.

78 Peter Marquez, Testimony of Peter Marquez Before the Subcommittee on Space, Science, and Competitiveness of the Committee on Science, Space, and Technology United States Senate (23 May 2017) at 1 https://pri-wpengine.netdna-ssl.com/wp-content/uploads/2017/05/mr.-peter-marquez-testimony.pdf.

79 Deep Space Industries, http://deepspaceindustries.com/company accessed 28 July 2018.

80 Bruce Dorminey, Deep Space Industries To Probe Near-Earth Asteroid (November 8, 2016) www.forbes.com/sites/brucedorminey/2016/11/18/deep-space-industries-to-probe-near-earth-asteroid/#5c5c3fd95e3b accessed 28 July 2018.

81 Deep Space Industries, http://deepspaceindustries.com/company accessed 28 July 2018.

82 Moon Express, http://moonexpress.com accessed 28 July 2018.

83 Adams, 'Billionaire Space Prospectors' (n 74).

84 Jeff Foust, 'Moon Express Releases Details of Its Lunar Lander Mission' (*SpaceNews*, 12 July 2017) http://spacenews.com/moon-express-releases-details-of-its-lunar-lander-missions

85 See Ciara McCarthy, 'US Startup Moon Express Approved to Make 2017 Lunar Mission' *The Guardian* (3 August 2016) www.theguardian.com/science/2016/aug/03/us-startup-moon-express-2017-lunar-mission.

and were therefore compliant with the Outer Space Treaty by default. However, the Treaty's requirement that private missions be authorised and supervised by the appropriate state meant that, in order to fly to the moon, Moon Express would need governmental permission. The company overcame the regulatory gap, discussed below, through in-depth consultations with relevant agencies in an ad hoc mission authorisation process. It supplemented its payload review process for the Federal Aviation Administration (FAA) with voluntary disclosures about its mission, in a process not unlike the current proposed authorisation frameworks.[86]

4. Legal landscape

In addition to the technical and financial challenges, considerable regulatory uncertainty surrounds the space mining industry. It remains an unsettled question whether international law allows for private ownership of asteroid resources. Even if private entities can own asteroid resources, the current statutory frameworks developed in countries like the US and Luxembourg do not specify *how* an enterprise is able to obtain those rights. Still, it may be possible to move forward with the development of resources in outer space under existing laws and treaties. According to one of the leading authorities on space law:

> International agreements declare that no government can claim outer space or celestial bodies in outer space as its own. Private firms seeking to invest in potential space enterprises frequently point to these provisions as a major barrier to the future commercial development of space. Such businesses contend that the absence of property rights prevent them from obtaining external financing, hinder the protection of their investments in space, and deprive them of the assurance that they can appropriate income from their investment. In short, the lack of sovereignty in space jeopardizes the ability to make profits from private investment. … [But] most property rights exist in space and … the lack of sovereignty does not pose current or near-term problems for the types of business ventures likely to be developed in space. Furthermore, even in the case of future ventures, solutions based on terrestrial models would permit private companies to operate in space with reasonable reliance of the right to appropriate income from their investments.[87]

This section examines relevant international treaties, as well as current domestic law developed in the US, Luxembourg, Russia and the United Arab Emirates.

4.1. *International law*

4.1.1. Outer Space Treaty

4.1.1.1. Provisions

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies ('Outer Space Treaty') is the foundational text of international space law.[88] It entered into force in 1967 and has

86 *Ibid.*

87 Henry R Hertzfeld and Frans G von der Dunk, 'Bringing Space Law into the Commercial World: Property Rights Without Sovereignty' (2005) 6 Chi J Int'l L 81, 81–82.

88 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 27 January 1967, 18 UST 2410, 610 UNTS 205 (hereinafter 'Outer Space Treaty, Art [x]').

been signed and ratified by over 100 nations, including the US. While it deals in large part with preventing any one nation from gaining a military advantage in space, it also has significant consequences for commercial mining activity.

In relevant part, Article I provides, '[t]he 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* … Outer space, including the moon and other celestial bodies, *shall be free for exploration and use by all States without discrimination of any kind*, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.'[89]

Speaking directly to ownership of celestial bodies, the Treaty continues, '[o]uter 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.'[90]

Finally, '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 … shall require authorization and continuing supervision by the appropriate State Party to the Treaty.*'[91]

4.1.1.2. Ambiguities

While the Treaty makes it clear that there is a right of free access to celestial bodies for all nations, it prohibits ownership of the bodies themselves. It also qualifies that space activities by private entities must be authorised and supervised by the appropriate nation. However, the Treaty does not deal clearly with whether space resource extraction is a lawful enterprise under its terms. Discussed below are several ambiguities of import in assessing the legality of space mining.

First, what is meant by 'celestial bodies'? Because there is no single governing definition of celestial bodies, it is unclear whether the category includes asteroids.[92] If asteroids are not celestial bodies, then the Outer Space Treaty's prohibition on national appropriation of the moon and other celestial bodies would not apply to them. However, most legal scholars agree that asteroids should be encompassed within the treaty terms.[93] The International Astronomical Union likewise includes asteroids in its definition of celestial bodies.[94] Thus, it is safe to assume that the Treaty applies to asteroids and the remaining discussion in this overview proceeds accordingly.

Second, what is the effect of the Treaty's statement that the exploration and use of space 'shall be carried out for the benefit and in the interests of all countries'? While some have argued that this clause mandates an international profit-sharing mechanism,

89 Outer Space Treaty, Art I (emphasis added).
90 Outer Space Treaty, Art II (emphasis added).
91 Outer Space Treaty, Art VI (emphasis added).
92 Leslie I Tennen, 'Towards a New Regime for Exploitation of Outer Space Mineral Resources' (2010) 88 Neb L Rev 794, 796.
93 *Ibid* at 796–97.
94 *Ibid.*

the US and others have taken the position that it merely reiterates the right of free access articulated in Article I.[95]

Third, does the prohibition on national appropriation extend to a grant of private rights over extracted resources? Meaning, can private entities own resources extracted from the celestial body without any nation owning the body itself? The Treaty includes the phrase 'exploration and use' twice in its terms. The word 'use' seems to indicate that leveraging space resources was within the contemplation of the drafters, and thus, not prohibited.[96] Still, it is unclear how rights would be distributed where national appropriation is prohibited. The diplomatic history of the Treaty indicates that perhaps this point was left ambiguous deliberately in order to gain support across nations.[97]

The closest analogue to a legal framework of this type is the extraction and utilisation of resources, such as fish, from the high seas. While the high seas are outside the jurisdiction of any single nation, domestic laws protect property rights over resources extracted from them.[98] As discussed in greater depth below, US domestic law asserts that the same framework applies to the moon and asteroids. Proponents of this line of thinking argue that granting private property rights to asteroid *resources* does not conflict with the international prohibition on national appropriation of asteroid *bodies*.[99]

One scholar points out, however, that there may be substantive differences between fishing the high seas and mining asteroids, and thus equating the two oversimplifies the practical reality. Law professor Samuel Roth asks, 'If an asteroid-mining enterprise obtained control over a small asteroid in its entirety, with the intention of making use of all of its mineral content, would that be extraction of "asteroid resources" or assertion of exclusive rights over the territory?'[100] At this stage, there is not a definitive answer to Roth's question, as a situation of that kind has yet to be tested. However, as noted above, proposals involving the retrieval, relocation and use of entire asteroids are under consideration and would implicate precisely the issue that Roth highlights.

Notwithstanding these uncertainties, the US State Department has consistently maintained that the Outer Space Treaty allows for commercial extraction and ownership of resources.[101] In remarks in late 2016, State Department Legal Adviser Brian Egan

95 See Mike Gold, Testimony of Mike Gold Before the Subcommittee on Space, Science, and Competitiveness of the Committee on Science, Space, and Technology United States Senate (23 May 2017) at 7 www.hsdl.org/?view&did=807259.

96 See Joanne Gabrynowicz, Testimony of Joanne Irene Gabrynowicz Before the Subcommittee on Space of the Committee on Science, Space, and Technology United States House of Representatives (10 September 2014) at 7 https://science.house.gov/sites/republicans.science.house.gov/files/documents/Gabrynowicz%20Final%20Testimony%20H.R.%205063.pdf.

97 See Samuel Roth, 'Developing a Law of Asteroids: Constants, Variables, and Alternatives' (2016) 54 Colum J Transnat'l L 827, 841–42.

98 *Ibid* at 851.

99 At least one commentator has raised, but ultimately rejected, the possibility that the legal principle of accession – through which a person acquires ownership of property by improving it or combining it with other materials – might allow asteroid miners to avoid this non-appropriation issue entirely by using 3D printing to turn the harvested asteroid resources into an entirely new product to which the producers could claim title. See Michael Chatzipanagiotis, '3D Printing Using Material from Celestial Bodies' in P J Blount, Tanja Masson-Zwaan Rafael Moro-Aguilar, Kai-Uwe Schrogl (eds), *Proceedings of the International Institute of Space Law* (Eleven International Publishing, 2016) at 247 (hereinafter *Proceedings*).

100 Roth, 'Developing a Law of Asteroids' (n 97) at 851–52.

101 Matthew Schaefer, Written Testimony of Matthew Schaefer Before the Subcommittee on Space, Science, and Competitiveness of the Committee on Science, Space, and Technology United States Senate (23 May 2017) at 4 www.hsdl.org/?view&did=807259.

explained that the Treaty merely shapes the manner in which space resource utilisation may be carried out; it does not preclude such activities.[102] He went on to explain that it has been the State Department's position for several decades that the Treaty's non-appropriation principle applies to space resources only when such resources are 'in place'. This prohibition does not extend to governmental or private ownership of resources once they are removed from the celestial body.[103] Some have argued that there is a related loophole in the non-appropriation principle: while states may not appropriate celestial bodies, there is no prohibition on their appropriation by private parties.[104]

Likewise, the International Institute of Space Law takes the position that, while the Outer Space Treaty does not create an express right to take and consume space resources, it also does not prohibit such action.[105] Specifically, the Institute points out that Article I provides for the free exploration and use of outer space celestial bodies without discrimination. It notes further, however, that the Treaty does not make it clear whether consumption of non-renewable natural space resources is encompassed in 'free use'.[106]

At least one commentator has observed that 'it is widely (though not universally) accepted that commercial exploitation is lawful so long as it does not prevent any other entity from undertaking the same activity in space'.[107] Under this prevailing theory, 'natural resources "in place" are still part of the territory and cannot be owned[,] but once the resource is removed and no longer "in place", it may be extracted for non-scientific (i.e., commercial) purposes'.[108]

A final ambiguity relates to the authorisation and continuing supervision mandate in Article VI. Specifically, what action by the state in overseeing private space enterprises is sufficient to fulfil this requirement? Some scholars assert that Article VI requires only light touch regulation, arguing that the mandate exists only to ensure that activities are carried out in conformity with international legal obligations.[109] Even light touch regulation, however, would require some sort of mission authorisation framework. As discussed below, the US does not currently have a designated agency or process by which to authorise commercial space mining missions. A regulatory scheme to this effect must be put in place to provide companies and investors with certainty before a stable commercial landscape can develop.

Some argue that concern about the authorisation and supervision requirement in Article VI is misplaced because this requirement is not self-executing.[110] That is, the provision requires domestic legislation to be binding and enforceable in US

102 Brian J Egan, 'The Next Fifty Years of the Outer Space Treaty' (Galloway Symposium on Critical Issues in Space Law, 7 December 2016) https://2009-2017.state.gov/s/l/releases/remarks/264963.htm.
103 *Ibid.*
104 Fabio Tronchetti, 'Legal Aspects of Space Resource Utilization' in Frans von der Dunk (ed), *Handbook of Space Law* (Edward Elgar Publishers, 2015) at 779.
105 'Position Paper on Space Resource Mining' (International Institute of Space Law, 20 December 2015) www.iislweb.org/docs/SpaceResourceMining.pdf (hereinafter 'Position Paper').
106 *Ibid.*
107 Melissa K Force, 'The Paradox of United States' Position on Regulation of Space Resource Extraction' in *Proceedings* (2016) (n 99) at 267.
108 *Ibid* at 268.
109 Schaefer, Written Testimony (n 101) at 8.
110 James E Dunstan and Berin Szoka, Written Testimony of James E Dunstan and Berin Szoka Before the Subcommittee on Space, Science, and Competitiveness of the Committee on Science, Space, and Technology United States Senate (23 May 2017) www.hsdl.org/?view&did=807259.

courts.[111] The argument proceeds that, because Article VI is not specific about its requirements, adherence to it is merely aspirational, subject to each nation's implementation as it may see fit.[112] Governments may be held absolutely liable for the actions of their citizens in space, although only for terrestrial damage and damage to airplanes in flight.[113]

Others respond that, because President Obama's administration proposed a mission authorisation framework, though it remains as yet un-implemented, the Executive Branch operated under the assumption that Congress had authorised it to implement Article VI. Moreover, whether the provision is self-executing does not change that it imposes an international obligation on Member States, the avoidance of which risks foreign retaliation and threatens the business case for space mining in the US.[114]

In sum, while the Outer Space Treaty provides a potential basis for space resource extraction, its terms are far from clear. As discussed in Section 4.2 below, domestic laws may provide increased certainty where it is needed for companies and investors to proceed with space mining endeavours.

4.1.2. Other treaties

While the Outer Space Treaty is the 'constitution' of international space law, the following treaties also bear on commercial space mining ventures.

The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies ('Moon Treaty') addresses resource extraction from the moon, and likely also applies to asteroids.[115] It declares that the moon and other celestial bodies in the solar system, as well as their natural resources, are the 'province of all mankind'.[116] This language characterises the bodies and their resources as being the 'common heritage of all mankind',[117] a concept discussed in greater detail below. The Moon Treaty has been signed by fewer than 20 countries and was not signed by the US or other space-faring nations.[118] Some regard the Moon Treaty as obsolete.[119] In the event that there is a renewed international interest in the core provisions of the Moon Treaty, that treaty could present a significant barrier to private space mining.

Three other international documents that relate to space activities generally are the Convention on International Liability for Damage Caused by Space Objects ('Liability Convention'),[120] the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space ('Rescue Agreement')[121] and the

111 *Medellin v Texas*, 552 US 491, 504–06 (2008).
112 Dunstan and Szoka, Written Testimony (n 110) at 4.
113 Henry R Hertzfeld and Frans G von der Dunk, 'Bringing Space Law into the Commercial World: Property Rights Without Sovereignty' (2005) 6 Chi J Int'l L 81, 85.
114 Schaefer, Written Testimony (n 101).
115 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 18 December 1979, 1363 UNTS 3 (hereinafter Moon Treaty, Art [x]); see also Roth, 'Developing a Law of Asteroids' (n 97) at 842.
116 Moon Treaty, Art 4.
117 Roth, 'Developing a Law of Asteroids' (n 97) at 842.
118 *Ibid* at 844.
119 *Ibid* at 844.
120 Convention on International Liability for Damage Caused by Space Objects, 29 March 1972, 24 UST 2389, 961 UNTS 187.
121 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 22 April 1968, 19 UST 7570, 672 UNTS 119.

Convention on Registration of Objects Launched into Outer Space ('Registration Agreement').[122]

The Liability Convention creates a liability framework for damage cause by spacecraft. It establishes a strict liability standard for accidents on the Earth's surface and a negligence standard for accidents elsewhere. Where disputes arise, they are resolved through the Claims Commission. However, because Claims Commission decisions are only binding with the consent of the parties, the Liability Convention is largely ineffectual.[123] The Rescue Agreement provides a framework for the return of objects and people who land outside their national territory upon re-entry to Earth.[124] Finally, the Registration Agreement requires signatories to register vehicles launched into space with a United Nations-operated registry.[125] Any space mining mission would need to be in compliance with the requirements of these international agreements.

4.2. *Domestic laws*

4.2.1. United States

4.2.1.1. US Commercial Space Launch Competitiveness Act

In 2015, Congress passed the US Commercial Space Launch Competitiveness Act. The Act is the consolidated outcome of four bills that expand existing regulation of commercial space activity.[126] Most important, for space mining purposes, is Title IV, which establishes a basis for ownership of extracted space resources.[127]

Title IV, the 'Space Resource Exploration and Utilization Act' creates private property rights over resources extracted from space.[128] It directs the President to (1) facilitate the commercial exploration for and commercial recovery of space resources by US citizens; (2) discourage government barriers to the development of such industries in a manner consistent with US international obligations; and (3) promote the right of US citizens to engage in such industries free from harmful interference.[129] Further, it charges the President with submitting a report to Congress that identifies the authorities that will be responsible for overseeing space resource extraction missions.[130]

122 Convention on Registration of Objects Launched into Outer Space, 14 January 1975, 28 UST 695, 1023 UNTS 15.

123 See Roth, 'Developing a Law of Asteroids' (n 97) at 845–46.

124 See *ibid* at 844.

125 See *ibid* at 846.

126 US Commercial Space Launch Competitiveness Act, Pub L No 114-90, 129 Stat 704 (2015) (hereinafter Space Launch Act [s x]). For a complete analysis of the Act, see Michael Dodge, 'The U.S. Commercial Space Launch Competitiveness Act of 2015: Moving U.S. Space Activities Forward' (2016) 29 (3) Air & Space Law. 4.

127 The other parts of the Act include the following. Title I, the 'Spurring Private Aerospace Competitiveness and Entrepreneurship Act' ('SPACE Act'), updates requirements for the commercial launch industry. Space Launch Act ss 102–117, now codified at 51 USC ss 50901–50923 (2015). Title II, 'Commercial Remote Sensing', affirms congressional oversight of the commercial space industry and requires additional executive branch reports regarding the licensing process for private space-based remote sensing systems. Space Launch Act ss 201–202, now codified at 51 USC ss 60121–60126 (2015). Title III, 'Office of Space Commerce', renames the 'Office of Space Commercialization' the 'Office of Space Commerce', and clarifies its functions. Space Launch Act ss 301–302, now codified at 51 USC ss 50701–50703 (2015).

128 Space Launch Act ss 402–403, now codified at 51 USC ss 51301–51303 (2015).

129 51 USC s 51302(a).

130 51 USC s 51302(b).

The Act then establishes that '[a] United States *citizen engaged in commercial recovery of an asteroid resource or a space resource* under this chapter *shall be entitled to any asteroid resource or space resource obtained*, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States'.[131] The Act defines 'asteroid resource' as 'a space resource found on or within a single asteroid'.[132] It defines 'space resource' as 'an abiotic resource in situ in outer space', which includes water and minerals.[133] It does not make clear how exactly a citizen should go about claiming rights to space resources. The use of the word 'obtained' seems to indicate a framework akin to the rule of capture, but this is not specified in the law itself.

Finally, the statute clarifies that '[i]t is the sense of Congress that by the enactment of this Act, the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body'.[134]

The extent to which this statutory scheme complies with the Outer Space Treaty depends largely on the resolution of the question of whether the Treaty's prohibition on the appropriation of celestial bodies extends also to their extracted resources. As noted above, the International Institute of Space Law is of the position that the Treaty does not make such a prohibition, and instead implicitly allows ownership of space resources.[135] However, the Institute clarifies that it remains uncertain whether this dynamic between the international and domestic schema will work in the long term.[136]

Luxembourg's recent adoption of a similar, though more comprehensive, law may indicate that an international consensus around the legality of space resource extraction is beginning to take shape. That is, it seems to be the emerging understanding that space resource extraction is compliant with the Outer Space Treaty.[137] Moreover, industry responses to the legislation have been uniformly positive. Planetary Resources co-founder Eric Anderson stated, 'This is the single greatest recognition of property rights in history. This legislation establishes the same supportive framework that created the great economies of history, and will encourage sustained development in space.'[138] Responses such as these indicate that the legislation provides some amount of certainty on which investors and private enterprises can rely.

As discussed below, however, US companies will still need to contend with getting their missions authorised, an unclear task as there is no settled framework by which to do so.

131 51 USC s 51303 (emphasis added).
132 51 USC s 51301(1).
133 51 USC s 51301(2).
134 51 USC s 51301(1).
135 Position Paper (n 105) at 2.
136 *Ibid* at 3.
137 This emerging understanding comes from the actions and interpretations of *developed* nations who currently possess an opportunity to extract such resources. Developing states might place a greater degree of weight on the requirement that such activities be carried out for the benefit of all countries. See Force (n 107) at 267.
138 'President Obama Signs Bill Recognizing Asteroid Resource Property Rights into Law' (Planetary Resources, 25 November 2015) www.planetaryresources.com/2015/11/president-obama-signs-bill-recognizing-asteroid-resource-property-rights-into-law

4.2.1.2. Mission authorisation regulatory gap

In the US, there is a regulatory gap for unprecedented on-orbit space activities like mining. Because the Outer Space Treaty mandates that non-governmental space activities be authorised and subject to continuing supervision, it is essential that the US implement a regulatory framework that meets this obligation. Such action is the next step in the goal of the US to become a hub for commercial space mining ventures.

Comprehensive regulations exist for traditional space activities such as launch and re-entry, remote sensing and satellite communications. These regulatory frameworks are siloed into different categories and controlled by different federal agencies. In brief, to launch a spacecraft, a mission must be licensed with the Federal Aviation Administration (FAA).[139] If the spacecraft launched will transmit satellite communications via spectrum, it must be licensed with the Federal Communications Commission (FCC).[140] Missions that involve remote sensing of Earth require a licence from the National Oceanic and Atmospheric Administration (NOAA).[141] The launching entity must also be aware of rules that pertain to debris mitigation, which are imposed by the FCC and NOAA.[142]

To summarise:

Agency	Authority
FAA	Licenses the launch and re-entry of spacecraft.
FCC	Licenses satellite transmissions and spectrum use. Imposes debris mitigation requirements on licensees.
NOAA	Licenses commercial remote sensing aircraft. Imposes debris mitigation requirements on licensees.

The effect of this regulatory web is that many agencies have the authority to say 'no' to private space mining missions, but no single entity has the ability to say 'yes'.[143]

To fulfil the mandate of the US Commercial Space Launch Competitiveness Act, President Obama's administration proposed a mission authorisation framework in April 2016.[144] The proposal recommended that Congress adopt an authorisation and

139 51 USC s 50903 (granting authority to Secretary of Transportation to carry out the mandates of the chapter). This authority was subsequently delegated to the FAA's Office of Commercial Space Transportation. See 'Office of Commercial Space Transportation Regulations' (Federal Aviation Administration) www.faa.gov/about/office_org/headquarters_offices/ast/regulations/.

140 47 USC ss 701–757. See also 'Guidance on Obtaining Experimental Authorizations for Commercial Space Launch Activities' (Federal Communications Commission, 18 March 2013) www.spaceref.com/news/viewsr.html?pid=43606.

141 See 51 USC s 6011 (granting authority to the Secretary of Commerce to license private remote sensing space systems). This authority was subsequently delegated to NOAA. See 'About the Licensing of Private Remote Sensing Space Systems' (National Oceanic and Atmospheric Administration) www.nesdis.noaa.gov/CRSRA/licenseHome.html accessed 28 July 2018. See also 15 CFR ss 960.1–960.15.

142 See 47 CFR s 25.114; 'Commercial Remote Sensing Regulatory Affairs' (National Oceanic and Atmospheric Administration) www.nesdis.noaa.gov/CRSRA/licenseHome.html accessed 28 July 2018. See also Matthew Schaefer, 'The Contours of Permissionless Innovation in the Outer Space Domain' (2017) 39 U Pa J Int'l L 103, 134.

143 See Statement of Robert (Bob) Richards Before the United States Senate Committee on Commerce, Science, and Transportation Subcommittee on Science, Space, and Competitiveness, United States Senate (23 May 2017) at 3 www.commerce.senate.gov/public/_cache/files/fe68e195-f1ac-43a5-9ae8-10a3435749df/0F70D3F36637F5FA4283870BCD0CDE87.dr.-bob-richards-testimony.pdf.

144 Letter from John Holdren, Director and Assistant to President for Science and Technology to Sen Thune and Rep Smith (4 April 2016) https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/csla_report_4-4-16_final.pdf.

supervision framework modelled after the FAA's payload review process.[145] This review would require consideration of the US' 'international obligations, foreign policy and national security interests', and protection of 'United States Government uses of outer space'.[146] Under the proposal, the FAA would coordinate relevant agencies to review missions on a case-by-case basis.[147] The proposal did not authorise any agency to develop substantive regulations surrounding these activities. Rather, it directed the FAA to develop procedural regulations for mission authorisation, in coordination with other space-related agencies.[148]

There is some concern that this inter-agency approach to mission authorisation would result in too lengthy a review process.[149] To ensure a timely review, some scholars propose creating a default presumption in favour of mission approval.[150] Law professor Matthew Schaefer explains that this presumption could take the form of a 'foreseeable harm' requirement.[151] That is, the agency would be required to find a foreseeable harm to one of the specified conditions in order to disapprove a mission.

In 2016, then-Representative, and current NASA Administrator, Jim Bridenstine of Oklahoma, introduced an alternative authorisation framework called the 'American Space Renaissance Act'.[152] The bill would create an Assistant Secretary for Commercial Space Transportation within the Office of Commercial Space Transportation of the FAA, charged with issuing such regulations 'as are necessary to provide for an enhanced review and determination process for payloads and associated activities after deployment … '.[153] It would further require that a decision be issued within 60 days of submission, with automatic approval if the agency fails to reach a decision within that timeframe.[154]

While some form of enhanced payload review, with authority centred in the FAA, seems to be the prevailing strategy to meet the authorisation and supervision requirements of the Outer Space Treaty, neither of these proposals has yet been adopted by the legislature. Thus, the process by which a space mining mission can gain authorisation to launch remains uncertain.

In April 2018, the House of Representatives passed the 'American Space Commerce Free Enterprise Act', which would give the United States Commerce Department the authority to regulate asteroid miners' actions in outer space.[155] Under this proposed legislation, the Commerce Department would regulate in-space activities as well as take over NOAA's remote sensing regulatory responsibilities, while leaving the FAA and FCC regulatory responsibilities for launch/re-entry and satellite transmissions intact.[156] The bill is also noteworthy for its 90-day time limit on the permit approval

145 *Ibid* at 4.
146 *Ibid* at 6 (proposed statutory language).
147 *Ibid* at 4.
148 *Ibid.*
149 See Schaefer, 'The Contours of Permissionless Innovation' (n 142) at 167.
150 *Ibid.*
151 *Ibid* at 168.
152 HR Res 4945, 114th Congress.
153 *Ibid* s 309(a)(2).
154 *Ibid* s 309(a)(2)(C)(i).
155 Loren Grush, 'House Bill Would Regulate Bold Commercial Space Missions – But Not Very Closely' (*The Verge*, 24 April 2018) www.theverge.com/2018/4/24/17272338/hr-2809-american-space-commerce-free-enterprise-act-regulation.
156 See *ibid.*

process, which is subject to only a single possible 60-day extension.[157] Whether this bill, or anything similar to it, will ever be signed into law remains to be seen, as Senator Ted Cruz of Texas (Chairman of the Senate space subcommittee) has been leading a process to craft the Senate's own bill, which Jeff Foust of *SpaceNews* has said 'is not expected to be identical in scope or content to the House bill'.[158]

Notwithstanding the current lack of a formal authorisation process, in 2016, a company called Moon Express was able to obtain mission authorisation for a robotic flight to the moon.[159] The company coordinated with the FAA and other agencies, and submitted various voluntary disclosures to ensure compliance with the Outer Space Treaty.[160] However, the FAA made it clear that the authorisation was limited to a single flight, leaving future authorisations up in the air.[161]

4.2.2. Luxembourg

The only other nation besides the US to provide a private legal right to resources extracted from celestial bodies is Luxembourg. Similar to its strategy in satellite communications in the 1980s, Luxembourg is establishing an attractive regulatory and economic environment for space resource mining.[162]

Luxembourg announced its Space Resources initiative in 2016, stating that its goal was to create a 'legal and regulatory framework confirming certainty about the future ownership of minerals extracted in space from Near Earth Objects such as asteroids'.[163] Luxembourg also pledged to support space resource extraction companies by funding grants, purchasing equity and reimbursing costs for research and development.[164]

As part of this initiative, Luxembourg and DSI signed a Memorandum of Understanding 'to co-fund the development and launch' of the Prospector-X spacecraft.[165] The country also became a large shareholder in Planetary Resources, investing €25m in the company.[166] More recently, Luxembourg announced a partnership between its Institute of Science and Technology, a Luxembourg-based electronics company called EmTroniX, and the newly created Kleos Space, a UK-owned

157 Jeff Foust, 'House Passes Commercial Space Regulatory Bill' (*SpaceNews*, 25 April 2018) http://spacenews.com/house-passes-commercial-space-regulatory-bill
158 *Ibid.*
159 Ciara McCarthy, 'US Startup Moon Express Approved to Make 2017 Lunar Mission' *The Guardian* (London, 3 August 2016) www.theguardian.com/science/2016/aug/03/us-startup-moon-express-2017-lunar-mission.
160 Loren Grush, 'Moon Express Becomes First Private Company to Get US Approval for Lunar Mission' (*The Verge*, 3 August 2016) www.theverge.com/2016/8/3/12361256/moon-express-private-mission-spaceflight-us-government-approved
161 Statement of Bob Richards (n 143) at 3.
162 See Sarah Scoles, 'Luxembourg's Bid to Become the Silicon Valley of Space Mining' (*Wired*, 10 January 2017) www.wired.com/2017/01/luxembourg-setting-silicon-valley-space-mining
163 *Ibid* (quoting the Ministry of Economy's official statement about the programme).
164 *Ibid.*
165 Emily Calandrelli, 'Deep Space Industries Partners with Luxembourg to Test Asteroid Mining Technologies' (*TechCrunch*, 5 May 2016) https://techcrunch.com/2016/05/05/deep-space-industries-partners-with-luxembourg-to-test-asteroid-mining-technologies
166 'Luxembourg Becomes a Key Shareholder of Planetary Resources, Inc.' (Space Resources, 11 March 2016) www.spaceresources.public.lu/en/actualites/2016/luxgov-key-shareholder.html.

company that 'specializ[es] in geolocation services and developing space infrastructure'.[167]

In addition to these partnerships, the Luxembourgish legislature recently passed a new national space law bill.[168] Similar to the US Commercial Space Launch Competitiveness Act, the law provides that space resources are subject to private ownership.[169] It also sets out a comprehensive, though not overly arduous, regulatory structure for space mining.

To comply with the Outer Space Treaty's mandate of authorisation and continuing supervision, Luxembourg's law designates the ministers of the economy and space activities as the overseers of space mining missions.[170]

Mission authorisation requires the fulfilment of the following factors, among others:

- The applying operator ('operator') must be a public company, corporate partnership or private limited liability company under Luxembourg law or a European company having its registered office in Luxembourg.[171] Meeting this condition requires the production of evidence demonstrating that the operator's central administration and registered office are located in Luxembourg.[172]
- The operator must have a 'robust scheme of financial, technical, and statutory procedures and arrangements' for the planned mission as well as a clear and comprehensive internal governance scheme.[173]
- The operator must disclose the identities of its shareholders or members holding at least ten per cent of the capital or voting rights of the company. If no shareholders or members meet this threshold, the operator must disclose the identity of the 20 largest shareholders or members.[174]
- The operator's management members must at all times 'be of sufficiently good repute' and 'possess sufficient knowledge, skills and experience to perform their duties'.[175]
- With its authorisation application, the operator must provide a risk assessment of the mission. The assessment must specify coverage of such risk by personal finances, insurance or the guarantee of a credit institution.[176]
- The operator must have its finances audited annually.[177] Application for authorisation also requires the payment of a fee between €5,000 and €500,000, to be set by the ministers.[178]

167 Cecilia Jamasmie, 'Luxembourg Shoots for the Stars with Fresh Space Mining Deal' (*MINING.com*, 24 July 2017) www.mining.com/luxembourg-shoots-stars-fresh-space-mining-deal
168 Andrew Silver, 'Luxembourg Passes First EU Space Mining Law' (*The Register*, 14 July 2017) www.theregister.co.uk/2017/07/14/luxembourg_passes_space_mining_law
169 Law on the Exploration and Use of Space Resources, Art 1 (2017) https://spaceresources.public.lu/content/dam/spaceresources/news/Translation%20Of%20The%20Draft%20Law.pdf (hereinafter Luxembourg Space Law, Art [x])].
170 Luxembourg Space Law, Art 2, Art 15.
171 Luxembourg Space Law, Art 4.
172 Luxembourg Space Law, Art 7(1).
173 Luxembourg Space Law, Art 7(2).
174 Luxembourg Space Law, Art 8(1).
175 Luxembourg Space Law, Art 9(1).
176 Luxembourg Space Law, Art 10.
177 Luxembourg Space Law, Art 11.
178 Luxembourg Space Law, Art 13.

The law provides that the operator is fully responsible for any damage caused by the mission.[179] It also clarifies that mission authorisation granted under its terms does not replace other authorisations or approvals required by Luxembourg law.[180]

Finally, the new law sets out an enforcement structure for violations of its terms. Any person who fails to receive authorisation where it is required is subject to an imprisonment term between eight days and five years, and/or a fine between €5,000 and €1,250,000.[181] Any person who violates the conditions of a mission authorisation is subject to an imprisonment term between eight days and one year, and/or a fine between €1,250 and €500,000.[182] Additionally, a court may discontinue an authorisation and fine an operator where the law's requirements have been violated.[183]

Upon its passage, Deputy Prime Minister Etienne Schneider remarked that the law reinforces Luxembourg's role 'as a European hub for the exploration and use of space resources'.[184] While this remains to be seen, it is certainly the most comprehensive legal scheme dealing with space mining to date.

4.2.3. Russia

Though no other countries have laws that directly address space mining, certain Russian law could apply to such activity. Russian decree No 5663-1 creates an administrative system to address licensing space activities such as in-space manufacturing. The decree qualifies that, '[t]he rights of jurisdiction and control over space objects, as well as of ownership thereof shall not affect the legal status of the area of outer space or the surface or subsoil of a celestial body occupied by it'.[185]

This law seems to contemplate the use of space resources. However, its prohibition on ownership of the 'surface or subsoil' of celestial bodies is ambiguous and could be read to foreclose rights to space resources.[186] While the Russian government has ambitions to establish a base on the moon, an endeavour that would require space mining for its support, it is unlikely that private enterprises would want to organise a similar venture under such uncertain legal terms.[187]

4.2.4. United Arab Emirates

In recent years, the United Arab Emirates (UAE) has sought to develop its space-faring capabilities. In 2014, the country created a space agency, and has since invested more

179 Luxembourg Space Law, Art 16.
180 Luxembourg Space Law, Art 17.
181 Luxembourg Space Law, Art 18(1).
182 Luxembourg Space Law, Art 18(2).
183 Luxembourg Space Law, Art 18(3).
184 'Luxembourg Is the First European Nation to Offer a Legal Framework for Space Resources Utilization' (Press Release, Luxembourg Ministry of the Economy, 13 July 2017) www.spaceref.com/news/viewpr.html?pid=51198.
185 See Roth, 'Developing a Law of Asteroids' (n 97) at 857.
186 *Ibid.*
187 See Ellie Zolfagharifard, 'Russia's Plan to Conquer the Moon: Nation Will Send 12 Cosmonauts to Lunar Surface Ahead of Creating a Permanent Base by 2030' *Daily Mail* (London, 22 June 2016) www.dailymail.co.uk/sciencetech/article-3653942/Russia-s-plan-conquer-moon-Nation-send-12-cosmonauts-lunar-surface-ahead-creating-permanent-base-2030.html; Roth, 'Developing a Law of Asteroids' (n 97) at 857.

than $5bn in the programme, including a proposed mission to Mars.[188] In a recent meeting of the UN Office of Outer Space Affairs (UNOOSA), a representative of the UAE Space Agency presented the country's new space policy.[189] The policy includes a commitment to creating a competitive commercial environment for private enterprise. Without specifically discussing space mining, the policy indicates that the UAE is interested in creating an attractive regulatory and economic environment for private space companies.[190]

As an early step towards implementing its policy vision, in late 2017 the UAE entered into a memorandum of understanding with Luxembourg.[191] Through this five-year arrangement, the countries plan to share 'information and expertise between Luxembourg and UAE space sectors in the areas of space science and technology, human capital development and space policy, law and regulation' and 'consult on questions of international governance of space to reach common positions in relevant international fora'.[192]

Further, in 2016, the UAE indicated that it was drafting a comprehensive space law, the specifics of which are not yet available. In a recent article, however, Planetary Resources' Ben Baseley-Walker wrote that the UAE should attempt to establish itself, as Luxembourg is doing, as a regional hub for space resource extraction.[193] He argued that with the UAE's track record of strategic investments and experience with extractive exploration, it is well positioned to become such a hub.[194] While the specifics of the UAE's legal structure remain uncertain, it is a nation to keep an eye on in the future.

5. International law and resource development in space

Space law *is* international law. Article III of the Outer Space Treaty states that States Parties shall conduct activities in outer space 'in accordance with international law'.[195] At present, the relationship between traditional international law and space law remains unsettled. Professor Pierfrancesco Breccia argues, for example, that 'most international standards, related to the specific use of parts of the external world that are different from space, as the law of the sea, air or the rules related to

188 See Thomas Heath, 'Space-Mining May Be Only a Decade Away. Really' *Washington Post* (28 April 2017) www.washingtonpost.com/business/space-mining-may-be-only-a-decade-away-really/2017/04/28/df33b31a-29ee-11e7-a616-d7c8a68c1a66_story.html?utm_term=.1b65002680b6; Zahraa Alkhalisi, 'Dubai Space Center Is Joining the Race to Mars' (*CNN*, 15 February 2018) https://money.cnn.com/2018/02/15/technology/uae-space-program-mars-dubai/index.html.

189 'UAE National Space Policy' (Presentation to UNOOSA, 6 April 2017) www.unoosa.org/documents/pdf/copuos/lsc/2017/tech-08.pdf.

190 *Ibid.*

191 'Luxembourg and the United Arab Emirates to Cooperate on Space Activities with Particular Focus on the Exploration and Utilization of Space Resources' (*Business Wire*, 10 October 2017) www.businesswire.com/news/home/20171010006049/en/Luxembourg-United-Arab-Emirates-Cooperate-Space-Activities.

192 *Ibid.*

193 Ben Baseley-Walker, 'Space Mining: The Next Strategic Investment for Gulf Countries?' (*SpaceWatch Middle East*, 18 July 2017) https://spacewatchme.com/2017/07/swmethemes-space-mining-next-strategic-investment-gulf-countries

194 *Ibid.*

195 Outer Space Treaty, Art III.

Antarctica are, by their nature, inapplicable in this new field'.[196] There is some uncertainty, then, about just how activities in space are to be conducted 'in accordance with international law'.

5.1. *Amendments to treaties*

Along with establishing a mission authorisation framework, some government and industry representatives advocate seeking amendment to the Outer Space Treaty to provide private enterprises with legal clarity.[197] Specifically, they note that the Treaty was written at a time when commercial space mining was incomprehensible.[198] Even advocates acknowledge, however, that opening the Treaty for amendment and attempting to reach broad international consensus would be risky and difficult.[199]

Others are opposed to seeking amendment to the Treaty. For example, Mike Gold, Vice President of Washington Operations and Business Development for Space Systems Loral, suggests that, however imperfect, the Outer Space Treaty creates a necessary foundation for international space activities.[200] Its strength is that it is not prescriptive, but rather it sets out general principles that allow each nation the ability to meet the obligations in its own way.[201] Gold asserts that this flexibility is what has allowed the Treaty to stand the test of time, and proposes that uncertainty be resolved at the domestic level rather than opening up the Treaty for revision.[202]

In addition to congressional action defining the mission authorisation process, Gold proposes that legal clarity be achieved through bilateral and multilateral agreements between nations. He suggests that the US, in consultation with the private sector, reach out to like-minded launching states to establish consensus around ambiguous treaty terms.[203] In this way, the US would avoid acting unilaterally and risking backlash from the international community.

5.2. *International Space Resources Governance Working Group*

The Hague International Space Resources Governance Working Group ('Working Group')[204] seeks to address this uncertainty for resources development in outer

196 Pierfrancesco Breccia, 'Article III of Outer Space Treaty and Its Relevance in the International Space Legal Framework' in *Proceedings* (n 99) at 20.
197 Jeff Foust, 'Cruz Interested in Updating Outer Space Treaty to Support Commercial Space Activities' (*SpaceNews*, 26 April 2017) http://spacenews.com/cruz-interested-in-updating-outer-space-treaty-to-support-commercial-space-activities
198 *Ibid.*
199 *Ibid.*
200 Mike Gold, Testimony of Mike Gold Before the Subcommittee on Space, Science, and Competitiveness of the Committee on Science, Space, and Technology United States Senate (23 May 2017) at 7–8 www.hsdl.org/?view&did=807259
201 *Ibid.*
202 *Ibid.*
203 *Ibid.*
204 The Working Group platform is a Consortium serviced by a Secretariat. The founding Consortium partner is the International Institute of Air and Space Law, Leiden Law School, Leiden University (the Netherlands). Members are major stakeholders from government, industry, universities and research centres. The number of members of the Working Group is limited to 25, at which the number currently stands. *Ibid* at 165.

space. The goal of the Working Group is to 'assess, on a global scale, the need for a regulatory framework for space resource activities and to prepare the basis for such regulatory framework'.[205] The Working Group prepared a draft set of 'building blocks' for a regulatory framework for the development of resources in space, and circulated that draft for comment on 17 September 2017.[206] The objective of the building blocks is to 'create an enabling environment for space resource activities that takes into account all interests and benefits all countries and humankind'.[207] Toward this end, the Working Group rests the building blocks on international law, including the notion that the development of space resources should be exclusively for peaceful purposes, and for the benefit and in the interests of all countries and humankind irrespective of their degree of economic and scientific development.[208] The key concepts in the building blocks include:

- *International responsibility for space resource activities and jurisdiction over space products*

The Working Group recommends that states and intergovernmental organisations will undertake responsibility for resource development in outer space by creating laws to authorise and regulate these activities, as well as the products generated by these activities; the legal framework created by the state or intergovernmental organisation should be consistent with international legal principles. This building block is consistent with the requirement in the Outer Space Treaty that states supervise activities in outer space.

- *Access to space resources*

This building block anticipates unrestricted access to explore for space resources. An operator should be able to establish a priority right to explore for and recover space resources. This right would be registered on an international registry, and would be limited in time and to an area. This right is analogous to the right of prospectors in the American West to stake a claim for mineral prospecting. Staking the claim gave the prospector the exclusive right to explore for minerals if that exploration led to the discovery of a valuable mineral deposit. Then the prospector's right to develop this discovery could be extended.

- *Utilisation of space resources*

As discussed above, one of the key open issues is whether materials extracted from a celestial body are private property. This building block would require an international framework ensuring that raw minerals, volatile materials and the products from these items can be lawfully acquired with mutual recognition of these property rights.

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205 Tanja Masson-Zwaam and others, 'The Hague Space Resources Working Group: A Progress Report' in *Proceedings* (n 99) at 164.

206 Working Group, 'Draft Building Blocks for the Development of an International Framework on Space Resource Activities' (2017) ('Building Blocks') http://law.leiden.edu/organisation/publiclaw/iiasl/working-group/the-hague-space-resources-governance-working-group.html.

207 Building Blocks (n 206) para 1.1.

208 Building Blocks (n 206) paras 4.1–4.3.

• *Due regard for interests of all countries and humankind*

The Working Group proposes that governments should give due regard to the interests of all countries and humankind. The concept of 'due regard' is used in the United Nations Convention on the Law of the Sea (UNCLOS). Article 87 of the UNCLOS recognises the freedom of the high seas, but this freedom is to be exercised 'with due regard for the interests of other States'.[209] According to the leading commentary on UNCLOS, 'The standard of "due regard" requires all States, in exercising their high seas freedoms, to be aware of and consider the interests of other States in using the high seas, and to refrain from activities that interfere with the exercise by other States of the freedom of the high seas. … States are bound to refrain from any acts that might adversely affect the use of the high seas by nationals of other States.'[210]

Thus, this building block advocates the recognition of free use of outer space, but with some recognition of the interests of other parties using outer space.

• *Avoidance of harmful impacts resulting from space resource activities*

This building block suggests adopting a precautionary principle for outer space. Under this precautionary principle, parties would act in a manner to guard against unknown or unquantified risks, including potential damage to the safety of persons, the environment or property, and prevent adverse changes in the environment of the Earth, harmful contamination of celestial bodies or outer space, and interference with space activities or scientific resources.

• *Monitoring and redressing harmful impacts resulting from space resource activities*

States organisations should monitor whether any harmful impacts result from space resource activities authorised by them. The building block also suggests developing a process to require redressing such impacts.

• *Sharing of benefits arising out of the utilisation of space resources*

The Working Group is very careful about how it frames the concept of 'sharing'. The building block clearly requires benefit-sharing, but characterises the benefit to be shared as the 'promotion of the participation in space resource activities by all countries'. The building block states that this 'may' include sharing technology and information, and perhaps establishment of an international fund. The building block stops short of advocating global revenue sharing.

• *Liability in case of damage resulting from space resource activities*

The building block references existing treaties concerning damage in space[211] and suggests that an international framework should encourage operators to provide,

209 UNCLOS of 19 December 1982, entered into force on 16 November 1994, Art 87(2).

210 Satya N Nandan and others (eds), *United Nations Convention on the Law of the Sea 1982: A Commentary* (Brill | Nijhoff, 1995) at 87.9(1).

211 Articles VI and VII of the Outer Space Treaty and the 1972 Convention on International Liability for Damage Caused by Space Objects.

individually or collectively, compensation for damage resulting from their space resource activities.

• *Institutional arrangements*

The Working Group wants to establish an international registry for the priority right of an operator to search and recover space resources and give advance notification of space resource activities. In addition, the Working Group would also like to create an international repository to collect information and best practices, as well as to document outer space natural and cultural heritage sites and sites of scientific interest.

• *Settlement of disputes*

This building block endorses the amicable resolution of disputes, and specifically promotes arbitration under the 2011 Permanent Court of Arbitration Optional Rules for Arbitration of Disputes Relating to Outer Space Activities.

• *Monitoring and review*

The Working Group believes that implementation of the international framework should be monitored, perhaps on the basis of reports of states and intergovernmental organisations.

The building blocks provide a conceptual framework for comprehensive international regulation of resource development in outer space. The building blocks generally accord with the received wisdom on these issues, but there would be considerable debate about the details of such regulations.

5.3. *The common heritage of mankind*

The UN developed the Moon Agreement in 1979.[212] Only 16 countries have entered into the Moon Agreement – and the parties do not include key industrialised countries like China, Russia or the US.[213] The Moon Agreement describes the moon as 'the common heritage of mankind', and it may well be this concept that has chilled a wider acceptance of the Agreement.[214] The Moon Agreement failed to achieve any significant measure of ratification precisely because of the general unease of most major space-faring states regarding a system requiring investing enormous sums for exploitation somehow to share technologies used for and proceeds from such activities with every state so interested without further ado, which was presumed to apply by the reference to this concept.[215]

212 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, opened for signature on 18 December 1979, entered into force on 11 July 1984, 18 ILM 1434, 1383 UNTS 3.

213 Irmgard Marboe, 'The End of the Concept of "Common Heritage of Mankind": The Views of State Parties to the Moon Agreement' in *Proceedings* (n 99) at 226 fn 2.

214 Moon Agreement at Art 11, para 1; see also Marboe (n 213) at 226.

215 Frans von der Dunk, 'International Space Law' in Frans von der Dunk (ed), *Handbook of Space Law* (2015) at 101.

Describing the moon as the 'common heritage of mankind' brings the development of resources on the moon in parallel with the UNCLOS, which includes the same concept for the deep seabed.[216] Industrialised nations, in both instances, are concerned that their citizens will not recoup the benefits of the substantial investment necessary to develop resources on either the moon or the deep seabed.[217] The Outer Space Treaty refers to outer space as 'the province of all mankind', but not as its 'common heritage'.[218] Thus, the countries who are parties to the Outer Space Treaty, but not the Moon Agreement, have not adopted the view that outer space should be treated in a manner analogous to the deep seabed. Still, some commentators still use the phrase 'the common heritage of mankind' when talking about outer space, which is problematic.[219]

Article 87 of UNCLOS preserves the 'freedom of the high seas'. The high seas – which are those areas of the sea that are not part of any state's exclusive economic zone – are 'open to all States', with free access governed by UNCLOS and 'by other rules of international law'.[220] Consistent with the concepts in the Outer Space Treaty, the high seas 'shall be reserved for peaceful purposes' and the high seas are not subject to claims of sovereignty by any state.[221]

The treatment of resource development in UNCLOS is based on the notion that the deep seabed is the common heritage of mankind.[222] As with celestial bodies under the Outer Space Treaty, a state cannot claim sovereign right or 'appropriate' the deep seabed 'or its resources'.[223] That does not mean that the resources of the deep seabed cannot be exploited:

The Convention provides for the Area to be administered by a UN organ, whose role is presently fulfilled by the International Seabed Authority (ISA) based in Jamaica. The ISA is charged with the orderly, safe and rational management of resources of the area in such a manner 'as to foster healthy development of the world economy and balanced growth of international trade, and to promote international cooperation of the overall development of all countries, especially developing states … ' (Article 150). In a sense, the fundamental purpose of the ISA is economic, enabling the exploitation of the Area as a form of economic reserve, the last unclaimed mining territory on the planet. To perform this purpose, the ISA has a commercial arm, the Enterprise, which will act as a partner in joint ventures with licensed contractors exploiting the Area's resources. Its purpose will be to hold and represent the economic interests of mankind in the relevant production-sharing contracts. These contracts are expected to yield significant income. Annex III of the Convention provides essential details on how these contracts will be organised and particularly how the contractor will pay a royalty or a share of the proceeds to ISA. Further provisions are designed

216 UNCLOS UNTS 1833, 1834, 1835, Part XI.
217 Marboe (n 213) at 236–37.
218 See Virgilin Pop, 'Is Outer Space Proper the "Common Heritage of Mankind"?' in *Proceedings* (n 99) at 243–44.
219 *Ibid.*
220 UNCLOS, Art 87(1).
221 UNCLOS, Arts 88 and 89.
222 UNCLOS, Arts 136. Art 136 refers to the 'Area', which is the seabed 'beyond the limits of jurisdiction'. UNCLOS, Art 1(1).
223 UNCLOS, Art 137(1).

to prevent any one state developing a dominant position in the exploitation of any particular part of the Area.[224]

The requirement of a joint venture arrangement with the ISA and the payment of something like a royalty explain why some of the studies on resources development in outer space are keen to make it clear that the Outer Space Treaty does *not* describe space as the common heritage of mankind.[225]

John Noyes describes a sliding scale of legal regimes governing the development of natural resources:

- according states exclusive permanent sovereignty over natural resources, a system associated with territoriality;
- sharing resources, as in the cases of international rivers and migratory species;
- recognising common property rights, as in the case of the high seas, where no one user has exclusive rights to resources and no one can exclude others from exploiting them, but capturing resources results in exclusive property rights; and
- recognising property as the common heritage of mankind – or, to use a more contemporary phrase, the common heritage of humankind (CH) – whereby all manage resources and share in the rewards of exploiting them, even if they are not able to participate in that exploitation.[226]

Countries like the US and Luxembourg clearly see space resources as 'common property right' in this formulation, and not the common heritage of mankind. Under the common property approach, resources developed from an asteroid can be owned as private property, with no obligation to share those resources or revenue from those resources, with every other country on the planet. Given the low number of signatories to the Moon Agreement, it seems unlikely that outer space will become characterised as the common heritage of mankind in any clear or unequivocal manner.

6. International mining law and space resources development

The terrestrial mining industry is a global industry, and mining companies routinely develop mining projects in areas where the law is underdeveloped or uncertain. Looking at the key decision points for an international mining project illuminates the legal and commercial structures necessary to allow resource development to advance in space.

A mining project has an economic structure that is different from that of most industries. A mine requires enormous front end capital investment to secure mining rights, permits, financing and *then* the investment in building processing facilities, infrastructure and moving earth to bring ore to the market. Only then does a mining company begin to generate revenue and seek a return on that investment. Resources development

224 Reg Fowler, 'Cracks in the Ice: The Need for Review of the Legal Status of the Arctic Continental Shelf' (Special Institute: International Mining and Oil and Gas Law, Development and Investment, Rocky Mt Min L Fdn, April 2011); accord UNCLOS Art 140.

225 See, eg, Pop, 'Is Outer Space Proper the "Common Heritage of Mankind"?' (n 218).

226 John E Noyes, 'The Common Heritage of Mankind: Past, Present and Future' (2011–2012) 40 Den J Int'l L Pol'y 447.

in space will face a similar requirement to deploy capital before it will see a return on investment.

An international mining company will consider the following key issues when determining whether to proceed with a mining project:

(1) *Security of tenure*: Can the mining company secure the legal right to explore for and develop the mineral properties?
(2) *Fiscal regime*: What economic burdens, such as taxes, royalties and export duties will apply to the mining venture?
(3) *Bankability*: Does the legal and commercial regime applicable to the mining venture allow investors to finance the project?
(4) *Enforceability*: Are the agreements, licences, concessions and legal commitments enforceable, and is the project relatively safe from expropriation or naturalisation? A company looking to develop resources in outer space will look at similar issues.

6.1. *Security of tenure*

A company conducting resource recovery operations in space will want to know that it will hold legal title (of some sort) to those resources. The language of the Outer Space Treaty restricting appropriation of celestial bodies creates some uncertainty as to whether a space mining company can achieve the security of tenure necessary to move forward with an investment in space mining. The US Commercial Space Launch Competitiveness Act and the Luxembourg Law on the Exploration and Use of Space Resources are both designed to address that uncertainty, and provide a legal framework for securing and recognising the right to extract resources in space. As noted above, there remains some concern that those laws may be challenged as inconsistent with the Outer Space Treaty. The adoption of laws or treaties consistent with the Working Group building blocks would provide greater certainty. The building blocks recommend a legal framework for access to space resources, which would facilitate exploration, and an international framework to ensure the lawful acquisition and use of space resources.

6.2. *Fiscal regime*

There is at present no mechanism to charge rentals or royalties on resources recovered in outer space. If a company uses a 3-D printer or other technology to convert raw materials into goods on asteroids or in orbit around the Earth or the Moon, it can do so (so far) without incurring a governmental imposition. As the industry of resource development in outer space grows, however, governments may look for ways to tax the enterprise. If, for example, a company takes advantage of the legal frameworks established by the US or Luxembourg, those countries could impose some severance tax or royalty payment in addition to the fees associated with forming companies under their laws. Of greater concern to a space mining company is the risk that other countries will invoke the concept that space is the ‘common heritage of mankind’, or perhaps the language in the Outer Space Treaty that the exploration and use of outer space ‘shall be carried out for the benefit of all countries’. This language might be used to assert some economic interest in space resources, payable in a royalty or perhaps in kind. This concern could be addressed in part by adopting the ‘due regard’ standard in UNCLOS, as proposed in the Working Group building blocks.

Under that standard, a space mining company would have the freedom to conduct activities in space so long as those activities do not adversely affect the use of outer space by nationals of other states. In the absence of some clear resolution of this question, a space mining company will need to quantify the risk of economic burdens being imposed on its activities, and factor that risk into its project assessment.

6.3. *Bankability*

A terrestrial mining project typically requires a detailed feasibility study, describing how the mine will be designed, the applicable regulations and legal requirements, an assessment of resources and reserves, an analysis of social and environmental impacts, and an economic analysis based on the cost of mining and the likely sales price of the commodity. A feasibility study becomes 'bankable' when it presents a project that is of sufficient quality to attract financing. The bankability of a space mining project will be less certain, because it may be hard to take out a mortgage on an asteroid. Crucial to bankability, however, will be the certainty of the legal and commercial regime applicable to the mining venture. As noted above, the Outer Space Treaty and the viability of the legal regimes created by the US and Luxembourg create some uncertainty, and investors may want some further clarity around those risks before making an investment. It is likely that investments will be made in stages, as spacing mining ventures vet the technical, commercial and legal structures necessary to move forward with a project.

6.4. *Enforceability*

A mining company wants to know that its agreements are enforceable. Because mining can take place in jurisdictions with low transparency and a weak commitment to the rule of law, mining companies often rely on bilateral investment treaties or similar international norms and constructs to mitigate the risk of expropriation and nationalisation. In the context of resource development in outer space, there remains a risk that someone could claim a prior right to the resources being developed, or assert a claim to some portion of the proceeds derived from resource extraction and use. A space mining venture is more likely to move forward if the mining company has some assurance that its rights will be recognised and enforced, and if the company has access to a dispute resolution mechanism that will provide for the adjudication of those rights. The Working Group includes in its building blocks the recommendation that such disputes be subject to arbitration under the Rules for Arbitration of Disputes Relating to Outer Space Activities. Those Rules, however, apply only when parties have agreed to such arbitration.[227] The arbitration rules would not be available to adjudicate claims from competing companies or individuals, or claims made by non-space-faring nations under the 'common heritage of mankind' construct, for example.[228] Adjudication of those claims in a single country may not be honoured in other

227 Permanent Court of Arbitration, Optional Rules for Arbitration of Disputes Relating to Outer Space Activities (2011), art 1(1).

228 See generally Frans G von der Dunk, 'Space for Dispute Settlement Mechanisms – Dispute Resolution Mechanisms for Space? A Few Legal Considerations' (Space, Cyber, and Telecommunications Law Program Faculty Publications 2001) http://digitalcommons.unl.edu/spacelaw/38 accessed 28 July

countries. It may be advisable to establish an international adjudicatory body to address those claims, similar to the International Tribunal for the Law of the Sea under UNCLOS.[229]

Existing legal frameworks provide some guidance for space mining. Based on the decision-making process for earth-bound mine development, it is likely that space mining companies and their investment partners are likely to require a more sophisticated and complete legal and commercial structure before committing to a space mining venture.

7. Conclusion

In sum, companies and governments are working to develop technologies that will enable space resource extraction, beginning with technology that will improve the ability to identify valuable and accessible asteroids. While there is some legal uncertainty surrounding the field, consensus seems to be growing among space-faring nations that commercial resource extraction is compliant with international law. To increase domestic regulatory clarity and remain competitive with other nations, the US should establish a mission authorisation process. Otherwise, Luxembourg's new law provides a more certain legal environment for private companies than does US law.

Opportunities for legal work in the space mining field abound. The budding industry will present uncharted legal challenges that at times have an existing parallel and at others, require entirely novel solutions. Issues of interest include regulatory compliance for mining, remote sensing and spectrum use, as well as the protection and licensing of intellectual property related to emerging technologies, to name a few. International law provides a conceptual framework for resource development in outer space, and existing treaties and proposed regulations and laws borrow heavily from the principles of international law. Still, outer space is not the sea, and an asteroid is not an island or a distant land. Over time, the law of space will evolve in its own direction, and sail away from the current metaphorical relationship with the law of the sea.

2018; Maureen Williams, 'Dispute Resolution Regarding Space Activities' in Frans von der Dunk (ed), *Handbook of Space Law* (2015) ch 19.

229 UNCLOS, Art 186 and Annex VI.