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Property Rules for Martian Resources: How the SPACE Act of 2015 Increases the Likelihood of a Single Entity Controlling Access to Mars

Tyler Conte
Akin Gump Strauss Hauer & Feld LLP, tconte@akingump.com

PROPERTY RULES FOR MARTIAN RESOURCES: HOW THE SPACE ACT OF 2015 INCREASES THE LIKELIHOOD OF A SINGLE ENTITY CONTROLLING ACCESS TO MARS

TYLER CONTE*

I. INTRODUCTION

FOR DECADES, scientists, engineers, and entrepreneurs have dedicated their lives to expanding humankind's permanent presence beyond Earth for the purposes of technological progress, promoting human cooperation, and avoiding our inevitable extinction if we remain on our home planet indefinitely. The leaders of today's private aerospace companies that intend to establish permanent settlements on the Moon or Mars are carrying on the mission of avoiding the extinction of our species, as first described by planetary scientists as early as the 1970s.[1] In order to fund this dramatic undertaking, the most prominent aerospace companies are pursuing strategies built upon monetizing the literally infinite natural resources of our solar system and beyond.[2]

One of the greatest difficulties associated with establishing permanent human settlements on other celestial bodies is the

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* The author is an Associate at Akin Gump Strauss Hauer & Feld LLP in Houston, Texas. He primarily works on corporate transactions for companies in the oil and gas and renewable energy industries. He graduated from Duke University School of Law, where he served as an Articles Editor on *Law and Contemporary Problems*, and the University of Florida, where he graduated with degrees in Astronomy and Economics. He would like to thank Professor Joseph Blocher for his guidance in developing this Article and Professor Kate Bartlett for her dedication to teaching and her ability to show her students what strenuous legal analysis feels like.

1 *See generally* JOHN S. LEWIS, MINING THE SKY: UNTOLD RICHES FROM THE ASTEROIDS, COMETS, AND PLANETS (1996); GERARD K. O'NEILL, THE HIGH FRONTIER: HUMAN COLONIES IN SPACE (1977).

2 *See, e.g.*, Neel V. Patel, *SpaceX's Bold Plan to Generate Fuel on Mars*, INVERSE (Sept. 27, 2016), https://www.inverse.com/article/21492-spacex-methane-production-mars [https://perma.cc/XXT5-GLRC].

dramatic cost of launching and landing a payload capable of supporting such settlements under the harsh conditions of an uninhabited planet or moon. A promising proposal for limiting mission costs related to establishing a permanent human settlement on Mars—which has been discussed by companies such as SpaceX, Boeing, and Blue Origin, as well as nations such as the United States and the United Arab Emirates—would be collecting water and carbon dioxide on Mars.[3] Water exists on Mars in large, contiguous bodies at the planet's polar ice caps. Carbon dioxide exists in the planet's atmosphere and at its ice caps.[4] Water and carbon dioxide can be chemically converted into rocket propellant or used as water, carbon dioxide, and oxygen for life support and industrial purposes.[5] Any amount of these valuable resources that can be produced on Mars rather than launched from Earth would significantly decrease the cost of the mission and assist in developing a self-sustaining civilization on the planet and on other bodies throughout the solar system.[6]

In November 2015, the U.S. Commercial Space Launch Competitiveness Act (commonly known as the SPACE Act) became federal law.[7] For private aerospace companies, particularly those with the goal of eventually using or supplying resources obtained in outer space, the most promising element of the law is the creation of a property right in space resources for U.S. persons who obtain such resources.[8] This property right was heavily

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[3] *See id.*; Abigail Beall, *NASA Is Working Out How to Create Rocket Fuel on Mars*, WIRED (July 18, 2017), https://www.wired.co.uk/article/nasa-rocket-fuel-mars [https://perma.cc/HWP8-KGFD]; Alan Boyle, *Blue Origin Gets in on NASA Studies for Resource Utilization on Moon and Mars*, GEEKWIRE (May 31, 2018), https://www.geekwire.com/2018/blue-origin-gets-nasa-studies-resource-utilization-moon-mars/ [https://perma.cc/RME2-BDWB]; Dom Galeon, *UAE Announces Plans to Have a Human Colony on Mars by 2117*, FUTURISM (Feb. 15, 2017), https://futurism.com/4-mars-2117-project-the-uae-joins-the-race-for-the-red-planet [https://perma.cc/PUM5-HJST].

[4] David Darling, *Polar Caps of Mars*, ENCYCLOPEDIA OF SCI., http://www.daviddarling.info/encyclopedia/M/Marspoles.html [https://perma.cc/P7E4-EQZL] (last visited Sept. 3, 2019).

[5] *See* David B. F. Portree, *Making Rocket Fuel on Mars (1978)*, WIRED (Nov. 3, 2012), https://www.wired.com/2012/11/making-rocket-fuel-on-mars-1978/ [https://perma.cc/9AR5-XCGL].

[6] *See, e.g.*, Beall, *supra* note 3.

[7] U.S. Commercial Space Launch Competitiveness Act (CSLCA), Pub. L. No. 114-90, 129 Stat. 704 (2015).

[8] *See id.* § 402, 129 Stat. at 721 (codified at 51 U.S.C. § 51303 (Supp. | 2016)). This Article will refer to section 402 of the CSLCA as the SPACE Act. Title VI of the CSLCA, where section 402 is located, is technically denoted by the short title "Space Resource Exploration and Utilization Act of 2015." *Id.* § 401. However,

lobbied for by the budding asteroid mining industry, which plans to recover and sell resources found on the asteroids in the inner solar system.[9] For the first time, a national government has incentivized its citizens to pursue the rich resources of outer space by granting them full title to any resources they take possession of.[10]

While the SPACE Act's creation of a property right in space resources presents interesting international law issues involving the United States' adherence to the requirements of the Outer Space Treaty and other Soviet-era treaties,[11] this Article focuses on whether the incentives created by the SPACE Act could motivate the first resource-producing entity on Mars to obtain a significant portion—or potentially all—of the water and carbon dioxide on Mars before a viable competitor could establish itself. The establishment of a dominant producer of natural resources on Mars would allow such producer to charge monopoly prices to second comers whose missions would require the consumption of water and carbon dioxide acquired on the Martian surface or, alternatively and perhaps more importantly, to price any competitor out of this market.

If this scenario were to play out, the hypothetical firstcomer could effectively control access to the planet through the prices it charges to other entities that attempt to establish permanent settlements on the planet and that do not have feasible, alternative sources of water and carbon dioxide.[12] In a worst-case scena-

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this Article will refer to section 402 as the SPACE Act, as much of the literature about the law colloquially refers to the entire public law as the SPACE Act.

9 *See, e.g.*, K.G. Orphanides, *American Companies Could Soon Mine Asteroids for Profit*, WIRED (Nov. 12, 2015), https://www.wired.co.uk/article/how-to-mine-asteroids-for-fun-and-profit [https://perma.cc/AL9B-XG6M].

10 Luxembourg also passed a similar law within a few months that aligned with the United States' SPACE Act, and it invested €25 million for an equity stake in Planetary Resources, an American asteroid mining startup. David Schrieberg, *Asteroid Mining: The Next Grand Venture of Tiny Luxembourg*, FORBES (Jan. 24, 2017), https://www.forbes.com/sites/davidschrieberg1/2017/01/24/asteroid-mining-the-next-grand-venture-of-tiny-luxembourg/#4af86490375a [https://perma.cc/CB7U-CY9F].

11 *See* P.J. Blount & Christian J. Robison, *One Small Step: The Impact of the U.S. Commercial Space Launch Competitiveness Act of 2015 on the Exploration of Resources in Outer Space*, 18 N.C. J.L. & TECH. 160, 161–62 (2016); John Myers, *Extraterrestrial Property Rights: Utilizing the Resources of the Final Frontier*, 18 SAN DIEGO INT'L L.J. 77, 90–91 (2016).

12 This Article assumes that, for the foreseeable future, there will not be an adequate alternative supply of water or carbon dioxide to Mars from elsewhere in outer space (for example, via asteroid mining) that could compete with the firstcomer's production of these resources on Mars. At the time this Article was

rio, the firstcomer could refuse to sell to second comers for any competitive, political, or other conceivable reason, thereby shutting off second comers from these critical resources. A private company exercising singular control over access to resources on Mars, and therefore to the planet itself, would be an unintended result of the SPACE Act, unlikely to be supported in the future. This Article explores alternative methods of allocating resources on Mars that would allow the firstcomer to reap a substantial return on its investment from being the first to settle the planet without preventing subsequent entities from competing.

While this Article suggests qualifying the SPACE Act's property rule by adding a new Martian Riparian Rights Rule, its purpose is not to propose the optimal regulatory system for the allocation of resources on Mars. Rather, its goal is to draw attention to the potentially harmful incentives created by the current rule and to spark a discussion on a method of appropriation that better protects the benefits of Mars for all humankind. Such a result would better serve the pro-competitive purpose of the SPACE Act and ensure that Earth's governments do not enable a private entity to unilaterally control access to the benefits of the most substantial property expansion in human history.

In Part II, this Article discusses the motivations for expanding humankind's presence beyond Earth, selecting Mars as a destination, and the means for making the mission economically viable. Part III analyzes the provisions of the SPACE Act that establish the property right in space resources and the incentives created by its standard of appropriation. In Part IV, this Article explains how these incentives would encourage the development of a monopoly in this nascent industry and how the persistence of a monopoly could allow a company to effectively control access to Mars if left unregulated. Finally, Part V suggests potential alternative systems for allocating resources in space, as opposed to the property right created by the SPACE Act. It settles on the Martian Riparian Rights Rule, under which qualifications would be added to the property right established under the SPACE Act that impose objectively determinable limitations on the amount of resources a single entity can extract from a large celestial body, such as Mars.

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written, no company or nation has announced a Mars settlement plan that relies on the supply of resources to Mars via asteroid mining, and no asteroid mining companies have announced plans to transport recovered asteroid resources to Mars.

II. WHY HUMANS SHOULD GO TO MARS AND HOW TO MAKE IT ECONOMICALLY FEASIBLE

Since the 1970s, leading planetary scientists and space activists, such as Gerard K. O'Neill and John S. Lewis, have argued for pursuing the economic development and human colonization of space.[13] O'Neill and Lewis posit that the only way to ensure the indefinite survival of the human species is to leave our home planet, Earth, and form alternative, permanent habitats in outer space.[14] Whether by nuclear war, climate change, overpopulation, uncontrollable disease, or an existential threat, such as an apocalyptic asteroid impact, humans are almost certain to reach the point of extinction before increases in the Sun's temperature over the next 1.5 billion years render human life unsustainable on Earth.[15]

The desire to avoid humanity's inevitable extinction on Earth is the evolutionary stimulus that has motivated thousands of forward-thinking engineers, entrepreneurs, academics, and policy makers to seek to establish a permanent human presence in space outside of low earth orbit. While the potential for economic return is significant, this biologically worthy goal has been the primary motivation for the leaders of private aerospace companies such as SpaceX, Blue Origin, Planetary Resources, and others.[16] For example, Elon Musk, in a speech at the 2016 International Astronautical Congress, expressed how his desire to avoid humanity's extinction and open up the riches of space is the sole driver behind all of his entrepreneurial endeavors.[17]

This part first discusses the cost difficulties associated with traditional launch systems when applied to a Mars mission. Then, some methods to overcome these difficulties are sug-

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[13] *See* LEWIS, *supra* note 1; O'NEILL, *supra* note 1.

[14] LEWIS, *supra* note 1; O'NEILL, *supra* note 1.

[15] *See* Ethan Siegel, *The Four Ways the Earth Will Actually End*, FORBES (Sept. 27, 2017), https://www.forbes.com/sites/startswithabang/2017/09/27/the-four-ways-the-earth-will-actually-end/#235f746b4f0f [https://perma.cc/DY8X-DBV7]; *see also* LEWIS, *supra* note 1; O'NEILL, *supra* note 1; J.F. Kasting, *Runaway and Moist Greenhouse Atmospheres and the Evolution of Earth and Venus*, 74 ICARUS 472, 488 (1988).

[16] *See, e.g.*, Kate Wheeling, *Outer Space Treaties Didn't Anticipate the Privatization of Space Travel. Can They be Enforced?*, PAC. STANDARD (Aug. 14, 2019), https://psmag.com/social-justice/outer-space-treaties-didnt-anticipate-the-privatization-of-space-travel-can-they-be-enforced [https://perma.cc/7DH6-3VM8].

[17] Elon Musk, *Making Humans a Multi-Planetary Species*, 5 NEW SPACE 46, 57 (2017) (summarizing Musk's presentation at the 67th International Astronautical Congress, September 26-30, 2016).

gested, with a focus on taking advantage of the abundant natural resources already present on Mars.

A. The Problem with Establishing a Permanent Presence on Mars: Cost

Space travel is expensive. NASA's Saturn V rocket of the late 1960s, which carried the Apollo astronauts to the Moon, cost about $1.23 billion (in 2016 dollars) per launch.[18] One of the primary factors underlying the dramatically high cost of missions to the Moon and Mars is the need to reach 25,020 miles per hour, Earth's escape velocity,[19] while carrying a heavy payload that would include life support supplies and propellant for the return journey.

In order to make the cost of a Mars mission economically feasible, it is imperative that any launch system carry as little payload as possible. Since an object's acceleration is inversely proportional to its mass, the lower the mass of the launch system, the more efficiently (in terms of propellant usage) it will accelerate to Earth's escape velocity.[20] Limiting the total mass of the launch vehicle directly decreases a mission's cost by lowering development and construction costs, particularly those associated with handling higher propellant volumes.

The most important difference between establishing a permanent presence on Mars and the Apollo missions is that the Mars mission will require carrying a much larger payload than needed for travelling to the Moon for a few days.[21] The first Mars settlers will have to bring everything they need to survive on an unforgiving, isolated planet for an indeterminate amount of time—potentially the rest of their lives—with almost no hope

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18 Matt Williams, *Falcon Heavy vs. Saturn V*, Universe Today (July 25, 2016), https://www.universetoday.com/129989/saturn-v-vs-falcon-heavy/ [https://perma.cc/QH9Q-JR9G]; *see also* T.A. Heppenheimer, The Space Shuttle Decision 48 (1999).

19 *See, e.g.*, Matt Williams, *The Challenges of an Alien Spaceflight Program: Escaping Super Earths and Red Dwarf Stars*, Universe Today (Apr. 19, 2018), https://www.universetoday.com/139052/the-challenges-of-an-alien-spaceflight-program-escaping-super-earths-and-red-dwarf-stars/ [https://perma.cc/RT3A-3LTK]. Escape velocity is the velocity at which an object must travel in order to escape the gravitational force of a celestial body. *See id.*

20 *See Rocket Principles*, NASA, https://www.grc.nasa.gov/www/k-12/rocket/TRCRocket/rocket_principles.html [https://perma.cc/NK9F-HGPS] (last updated June 12, 2014). The text assumes a constant force produced by the rocket's engines.

21 Musk, *supra* note 17, at 46–47, 50.

of a rescue mission if disaster were to occur once they have settled there.[22] The Mars settlers will have to bring systems for waste disposal, energy generation, and protection from harmful solar particles.[23] They will need, at least initially, supplies of food, oxygen, and water.[24] And, if they plan on being able to return to Earth, they will need to bring a propellant supply for relaunch and the return journey.[25] If these or any other necessary items can be produced on Mars rather than launched from Earth, the cost of the endeavor would be decreased significantly.[26]

B. Gathering Water and Carbon Dioxide on Mars, Rather than Bringing These Resources from Earth, Would Dramatically Reduce Mission Costs

Water and carbon dioxide exist in vast quantities in easily accessible, contiguous bodies at the Martian surface.[27] These two resources are the keys for opening Mars up to human settlement. Water can be consumed by humans in its liquid form. Molecular oxygen can be chemically extracted from water or carbon dioxide for breathing by humans on Mars.[28] Carbon dioxide can be used to support newly introduced plants' efforts at photosynthesis on Mars.[29] Perhaps most importantly, combinations of rocket propellant can be extracted from these compounds in sufficient quantities to fuel return journeys to Earth

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22 *See* O. Glenn Smith & Paul D. Spudis, *Mars for Only $1.5 Trillion*, SpaceNews (Mar. 8, 2015), https://spacenews.com/op-ed-mars-for-only-1-5-trillion/ [https://perma.cc/N7QS-6HKB].

23 *See, e.g.*, Irene Klotz, *Boiling Blood and Radiation: 5 Ways Mars Can Kill*, SPACE.com (May 11, 2017), https://www.space.com/36800-five-ways-to-die-on-mars.html [https://perma.cc/66D9-ZDV9]; Ellis Talton & Remington Tonar, *Resource Utilization on Mars Could Be the Model of Efficiency and Sustainability*, Forbes (Sept. 17, 2018), https://www.forbes.com/sites/ellistalton/2018/09/17/resource-utilization-on-mars-could-be-the-model-of-efficiency-and-sustainability/#25647d0f5617 [https://perma.cc/L52J-BA42].

24 *See* Talton & Tonar, *supra* note 23.

25 *See* Musk, *supra* note 17, at 49.

26 *See id.*

27 *See* Jeffrey J. Plaut et al., *Subsurface Radar Sounding of the South Polar Layered Deposits of Mars*, 316 Sci. Mag. 92, 92, 94 (2007); *see also* Michael H. Carr & James W. Head III, *Oceans on Mars: An Assessment of the Observational Evidence and Possible Fate*, 108 J. Geophysical Res. 1, 24 (2003).

28 *See* Talton & Tonar, *supra* note 23.

29 Kirsi M. Lehto et al., *Suitability of Different Photosynthetic Organisms for an Extraterrestrial Biological Life Support System*, 157 Res. Microbiology 69, 70 (2006).

or expeditions deeper into the solar system.[30] If water and carbon dioxide can be gathered on Mars and utilized for these vital purposes rather than launched from Earth, the decreased payload would help decrease the cost of the mission to the point of rendering its financing attainable.[31]

Water on Mars can primarily be found at the planet's polar ice caps in solid form.[32] There are a combined 3.2 million cubic kilometers of ice in thick, contiguous sheets at the northern and southern polar ice caps.[33] There is also evidence of ice at more temperate latitudes just beneath the top layer of Martian soil.[34] The total amount of ice on Mars is close to 5 million cubic kilometers.[35] Water on Mars that is extracted will not replenish through any natural processes, so the quantity of water, while significant, is inherently limited.[36] The following image from the Mars Reconnaissance Orbiter shows Mars's northern polar ice cap, which is primarily comprised of ice.[37]

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[30] *See, e.g.*, Musk, *supra* note 17, at 49.

[31] *Id.* Systems also exist for recycling human urine into water and carbon dioxide into oxygen. *See* Beall, *supra* note 3; Erika Engelhaupt, *How Urine Will Get Us to Mars*, Sci. News (Apr. 11, 2014), https://www.sciencenews.org/blog/gory-details/how-urine-will-get-us-mars [https://perma.cc/E5R5-JPQC]. While the first settlers would surely bring these systems with them, the cost of future missions could be reduced if those missions do not have to carry additional urine and carbon dioxide recycling systems with them as the population on Mars grows. *See* Beall, *supra* note 3.

[32] Carr & Head, *supra* note 27, at 1; Plaut et al., *supra* note 27, at 92.

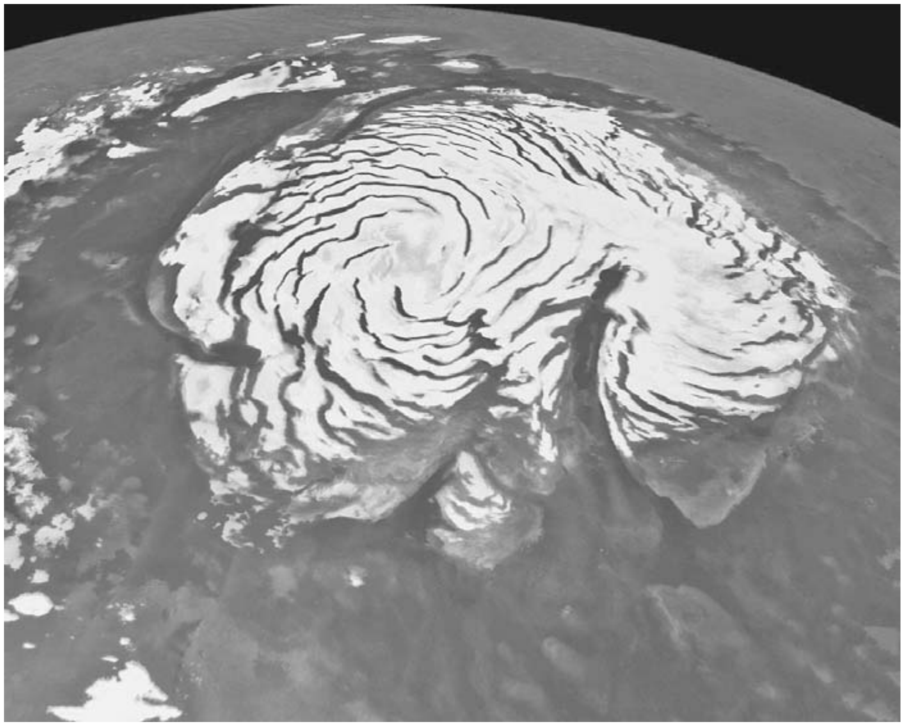
[33] *See The Red Planet in 3D*, NASA (May 27, 1999), https://www.nasa.gov/audience/foreducators/informal/features/F_Red_Planet.html [https://perma.cc/7KSK-MC26] (last visited Sept. 9, 2019).

[34] *See* Lujendra Ojha et al., *Spectral Evidence for Hydrated Salts in Recurring Slope Lineae on Mars*, 8 Nature Geoscience 829, 832 (2015).

[35] *See* Magdalena Osumi, *Architect Pair Tap 3-D Printing, Ice to Share Top NASA Prize for Mars Habitat Design*, Japan Times (Oct. 16, 2015), https://www.japantimes.co.jp/news/2015/10/16/national/science-health/architect-pair-tap-3-d-printing-ice-share-top-nasa-prize-mars-habitat-design/#.XXb0tZNKi2x [https://perma.cc/Y994-Z4UT].

[36] Lawrence H. Kuznetz, *Last Place to Boil Away, First Place to Look: The Hunt for Water and Life on Mars*, 19 Gravitational & Space Biology 85, 85–86 (2006).

[37] *Mars Reconnaissance Orbiter*, NASA (May 26, 2010), https://www.nasa.gov/mission_pages/MRO/multimedia/pia13163.html [https://perma.cc/GL3H-TABX].



Carbon dioxide, on the other hand, makes up over 95% of Mars's thin atmosphere.[38] There are about 25 trillion metric tons of carbon dioxide on Mars.[39] During the northern hemisphere's winter, the polar ice cap is in complete darkness, and gaseous carbon dioxide in the atmosphere condenses into solid carbon dioxide (commonly known as dry ice), which settles into a one-meter-thick layer over the water ice that makes up the majority of the ice cap.[40] The southern polar ice cap has an eight-meter-thick layer of dry ice over its sheet of ice that does not completely disappear during summer.[41] Therefore, carbon dioxide on Mars is as nearly as accessible as nitrogen and oxygen are on Earth. As mentioned above, up to 25% of the carbon dioxide on Mars can be found in solid form as dry ice at the polar ice

[38] *See* David R. Williams, *Mars Fact Sheet*, NASA (Sept. 27, 2018), https://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html [https://perma.cc/7JSR-KYUP].

[39] *See id.*

[40] *See* Darling, *supra* note 4; Nola Taylor Redd, *Mars' Thick Dry Ice Sheet Points to Planet's Wetter Past*, SPACE.COM (Apr. 21, 2011), https://www.space.com/11456-mars-dry-ice-liquid-water.html [https://perma.cc/E4QH-82JG].

[41] *See* Darling, *supra* note 4.

caps,[42] immediately adjacent to the primary sources of water on the planet. Carbon dioxide on Mars, like water, will not be replenished by any natural processes, so its supply is also limited.[43]

It is worth emphasizing just how accessible these resources are from the Martian surface. Water, which exists in solid form at the polar ice caps, can be "mined" from Mars's surface.[44] For comparison, "mining" water on Mars would be similar to gathering water from Antarctica, a giant sheet of ice. Carbon dioxide can be removed from the atmosphere similarly to how animals on Earth take oxygen out of the air with every breath. Additionally, solid carbon dioxide exists at the northern ice cap during winter,[45] which can be gathered from the same locations as ice.

Following collection, water (H_2O) and carbon dioxide (CO_2) can be converted into two common combinations of rocket propellant: (1) liquid oxygen (O_2) and liquid hydrogen (H_2); and (2) liquid oxygen (O_2) and liquid methane (CH_4).[46] These molecules can be produced from water and carbon dioxide via electrolysis and the Sabatier process, simple chemical reactions that rely on energy produced by solar arrays constructed on the Martian surface, which also provide energy for other life support systems.[47] If the spaceship used to fly to Mars runs on one of these combinations, the spaceship's propellant could be produced on Mars, which would alleviate the need to carry additional fuel for the return journey all the way from Earth.[48]

If the first Martian settlers successfully land and establish resource-gathering capabilities, a valuable industry will be born. While the usefulness of water and oxygen for human life support is apparent, the true value of water and carbon dioxide on Mars lies in their ability to be chemically rearranged into various types of rocket propellant.[49] If propellant for the return journey

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[42] Jerry Coffey, *What Is Mars Atmosphere Made Of*, UNIVERSE TODAY (Mar. 6, 2011), https://www.universetoday.com/84657/what-is-mars-atmosphere-made-of/amp/ [https://perma.cc/A8ZJ-QERT].

[43] *See* Deborah Williams-Hedges et al., *Loss of Carbon in Martian Atmosphere Explained*, NASA (Nov. 24, 2015), https://www.nasa.gov/feature/jpl/msl/loss-of-carbon-in-martian-atmosphere-explained [https://perma.cc/EUN3-ER7F].

[44] *See, e.g.*, Tanya Lewis, *Incredible Technology: How to Mine Water on Mars*, SPACE.COM (Dec. 23, 2013), https://www.space.com/24052-incredible-tech-mining-mars-water.html [https://perma.cc/5UMZ-2H99].

[45] *See* Darling, *supra* note 4.

[46] Musk, *supra* note 17, at 49, 49 tbl.4.

[47] *Id.* at 56, 56 fig.16; Talton & Tonar, *supra* note 23.

[48] *See* Musk, *supra* note 17, at 48 tbl.3.

[49] *See* Talton & Tonar, *supra* note 23.

or further expeditions into the solar system has to be brought from Earth, the initial Mars settlement mission would likely never proceed because the additional weight would render the launch too costly and the remote potential for economic return would make financing the mission improbable.[50]

In summary, for purposes of this Article, the following four points are the most salient:

1. While there is enough water and carbon dioxide to supply any inhabitants of Mars with the valuable resources derived from these compounds far into the future, the amounts of each of these resources are limited in the sense that they will not replenish on their own.
2. Water and carbon dioxide primarily exist on Mars in contiguous bodies. Ice is mainly found in two large ice sheets, similar to Earth's polar ice caps, and carbon dioxide is freely associated in the planet's atmosphere.
3. Water and carbon dioxide are the most valuable resources on Mars for anyone who wishes to settle there. They can be converted into two types of rocket propellant or used for drinking, breathing, cooling, growing plants, or the countless industrial processes that require these compounds and their derivatives.
4. Any future settlers of Mars that are not associated with the firstcomer will also need to use water and carbon dioxide for the same purposes. These second comers could dramatically decrease the cost of their Mars mission if they can procure these resources on Mars at a lower cost than they would incur by bringing them from Earth.

III. THE SPACE ACT OF 2015: PROMOTING COMPETITION IN THE PRIVATE AEROSPACE INDUSTRY BY INCENTIVIZING THE COLLECTION OF NATURAL RESOURCES IN SPACE

The SPACE Act was signed into law by President Obama on November 25, 2015.[51] The SPACE Act's long title announced its purpose as "facilitat[ing] a pro-growth environment for the developing commercial space industry by encouraging private sector investment and creating more stable and predictable

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[50] *See* Musk, *supra* note 17, at 47–48.

[51] U.S. Commercial Space Launch Competitiveness Act (CSLCA), Pub. L. No. 114-90, 129 Stat. 704 (2015).

regulatory conditions . . . ."[52] The titles of the SPACE Act (the Spurring Private Aerospace Competitiveness and Entrepreneurship Act, the U.S. Commercial Space Launch Competitiveness Act, and the Space Resource Exploration and Utilization Act)[53] signal that Congress intended to promote competition among private aerospace companies.

Of prime importance, the law created a new property right in asteroid and space resources.[54] Now, under U.S. law, any citizen who obtains non-biological resources from an asteroid or, more broadly, anywhere in outer space gains title to those resources.[55] This right is similar to the rule of capture in oil and gas exploration and production[56] or the rule regarding possession of wild animals from the classic property case *Pierson v. Post*.[57]

The SPACE Act was heavily lobbied for by the three leaders in the asteroid mining industry at the time: Planetary Resources, Deep Space Industries, and Bigelow Resources.[58] Industry commentators hailed the law as a boon to the asteroid mining industry, with little focus on the SPACE Act's application to and effects on the market for resources on Mars.[59]

This part analyzes the property right created by the SPACE Act and goes on to explain how the incentives created by this right promote the development of a monopoly producer of natural resources on Mars.

A. The SPACE Act Establishes a Property Right in Space Resources

The SPACE Act reads: "A United States citizen engaged in commercial recovery of an asteroid resource or a space resource . . . shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with

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[52] *Id.*

[53] *Id.* § 1.

[54] *Id.* § 402 (codified at 51 U.S.C. § 51303 (Supp. | 2016)).

[55] *Id.*

[56] *See, e.g.*, Ohio Oil Co. v. Indiana, 177 U.S. 190, 209 (1900).

[57] *See* Pierson v. Post, 3 Cai. 175, 175–76 (N.Y. Sup. Ct. 1805).

[58] *See* Matthew Shaer, *The Miner's Guide to the Galaxy*, Foreign Pol'y, May–June 2016, at 44, 49–50.

[59] *See* Sarah Fecht, *Senate Votes to Legalize Space Mining*, Popular Sci. (Nov. 11, 2015), https://www.popsci.com/congress-votes-to-legalize-asteroid-mining [https://perma.cc/J962-P83U]; Richard Yonck, *The Dawn of the Space Mining Age*, Sci. Am.: Guest Blog (Nov. 24, 2015), https://blogs.scientificamerican.com/guest-blog/the-dawn-of-the-space-mining-age/ [https://perma.cc/4ZGL-T3A4].

applicable law . . . ."[60] The SPACE Act defines an asteroid resource as "a space resource found on or within a single asteroid," and it defines a space resource as "an abiotic resource in situ in outer space."[61] Abiotic means "of or characterized by the absence of life or living organisms,"[62] and in situ means "situated in the original, natural, or existing place or position."[63] Asteroids are any "rocky object," other than planets or moons, "in space that can be a few feet wide to several hundred miles wide."[64]

A "space resource" therefore includes any non-biological resource found in its original or natural place anywhere in outer space.[65] This definition is not limited regarding location in outer space, so it applies to resources found on or in asteroids, moons, planets, stars, or any celestial body around stars or in other galaxies.

B. The SPACE Act Incentivizes the Overproduction of Space Resources, which Could Lead to the Entrenchment of a Martian Monopolist

By granting title to anyone who obtains space resources, the SPACE Act creates a property right based on prior appropriation that is analogous to the basic rule of capture from oil and gas law[66] or the rule from *Pierson v. Post* regarding taking title to wild animals.[67] These rules incentivize those with access to a class of rival goods to acquire ownership of the goods at a greater rate than necessary for current and reasonable future consumption. However, in the cases of oil and gas production and hunting, external limitations temper the potential for these rules to allow a single producer to gain control over the markets for these goods.[68]

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[60] CSLCA § 402 (codified at 51 U.S.C. § 51303 (Supp. | 2016)).

[61] *Id.* (codified at 51 U.S.C. § 51301(1)–(2) (Supp. | 2016)).

[62] *Abiotic*, DICTIONARY.COM, https://www.dictionary.com/browse/abiotic [https://perma.cc/CLD4-U7BV] (last visited Sept. 12, 2019).

[63] *In situ*, DICTIONARY.COM, https://www.dictionary.com/browse/in-situ [https://perma.cc/9NM6-DJGT] (last visited Sept. 12, 2019).

[64] *Asteroid*, NASA, https://www.nasa.gov/audience/forstudents/k-4/dictionary/Asteroid.html [https://perma.cc/J2EV-YEBQ] (last updated Aug. 7, 2017).

[65] *See* CSLCA § 402 (codified at 51 U.S.C. § 51301(2) (Supp. | 2016)).

[66] *See* Ohio Oil Co. v. Indiana, 177 U.S. 190, 209 (1900).

[67] *See* Pierson v. Post, 3 Cai. 175, 178 (N.Y. Sup. Ct. 1805).

[68] *See, e.g.*, Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243, 1244 (1968).

The rule of capture states that the first person to capture or obtain a natural resource, such as oil or gas, takes ownership of that resource.[69] The rule of capture evolved from situations where adjacent producers were extracting oil or gas from a shared underground reservoir that extended beneath each of their adjacent properties.[70]

For example, if only 10% of a shared reservoir of oil exists directly beneath the boundaries of Landowner A's land, Landowner A may extract, and thereby take title to, 100% of the oil in the reservoir, even though 90% of the reservoir sits beneath Landowner B's land.[71] The rule of capture is thus an exception to the Latin principle *cujus est solum ejus est usque ad coelum*, meaning "[h]e who owns the soil owns everything above (and below), from heaven (to hell)."[72]

Similarly, the classic property case *Pierson v. Post* dealt with a situation in which a hunter had spent considerable effort tracking a fox on a public beach when a rival hunter interceded by killing and carrying off the fox as his own.[73] In deciding in favor of the interceding hunter, the court held that a hunter does not own a wild animal until he takes control of the animal by capturing or mortally wounding it.[74] The rule of capture and the rule from *Pierson* are thus standards of determining ownership of a resource based on prior appropriation.

Rules based upon prior appropriation create a property right only when an individual takes control of the resource in question.[75] Under the rule of capture and *Pierson*, the eventual owner is one from a group of actors who desires a currently unclaimed resource. Prior appropriation incentivizes each individual to take control and ownership of the resource as quickly as possible because the amount available to each individual de-

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69 *See Ohio Oil Co.*, 177 U.S. at 202.

70 *See* Bruce M. Kramer & Owen L. Anderson, *The Rule of Capture – An Oil and Gas Perspective*, 35 ENVTL. L. 899, 907–08 (2005).

71 *See id.* at 907.

72 *See* Herbert David Klein, *Cujus Est Solum Ejus Est . . . Quousque Tandem*, 26 J. AIR L. & COM. 237, 238 (1959).

73 *See, e.g.*, Kathryn Loncarich, *Nature's Law: The Evolutionary Origin of Property Rights*, 35 PACE L. REV. 580, 614 (2014).

74 Pierson v. Post, 3 Cai. 175, 178 (N.Y. Sup. Ct. 1805).

75 *See* Nisha D. Noroian, *Prior Appropriation, Agriculture and the West: Caught in a Bad Romance*, 51 JURIMETRICS J. 181, 192 (2011); *see also* Bryan Leonard & Gary D. Libecap, *Collective Action by Contract: Prior Appropriation and the Development of Irrigation in the Western United States* 2 (Nat'l Bureau of Econ. Research, Working Paper No. 22185, 2017).

creases as others acquire ownership of a greater amount of the resource.[76] Such incentives often arise in regard to resources for which public policy encourages the growth and development of the affected industries.[77]

Most importantly, rules based on prior appropriation, such as the rule of capture, do not contain inherent limitations on the monopolization of the resource in question.[78] If policy considerations mediate against allowing a monopolist to develop in an industry based upon determining legal ownership of property through prior appropriation, other legal or practical limitations must exist that prevent a monopoly from developing.

Legal rules impose limits on the potentially harmful effects of the rule of capture and the rule from *Pierson*. An individual's ability to access oil and gas is limited because only those with appropriate mineral rights have the right to extract oil and gas.[79] If a single entity attempted to secure the rights to extract oil and gas from every reserve on Earth, they would have to negotiate among hundreds of governments and virtually infinite private actors with insurmountable attendant transaction and holdout costs. Similarly, since wild animals typically cross private lands freely, entering another's land to hunt would constitute a trespass, which likewise prevents a single entity from hunting every wild animal on Earth.

The incentive created by the SPACE Act's property rule is most similar to those involved with the rule of capture. For those engaged in the commercial recovery of space resources, the only barrier to owning resources is obtaining them.[80] Therefore, once an entity has access to space resources, it has a similar incentive to collect and store as much of these resources as possible in order to sell them to future buyers.[81] The rule of capture and the rule for hunting wild animals were developed when external limitations to the reach of these rules that encourage

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76 *See, e.g.*, Stephen F. Williams, *The Law of Prior Appropriation: Possible Lessons for Hawaii*, 25 NAT. RES. J. 911, 931 (1985).

77 *See* Noroian, *supra* note 75, at 182–83.

78 *See* Williams, *supra* note 76, at 925.

79 *See generally* Ernest E. Smith & John S. Dzienkowski, *A Fifty-Year Perspective on World Petroleum Arrangements*, 24 TEX. INT'L L.J. 13 (1989).

80 *See* U.S. Commercial Space Launch Competitiveness Act (CSLCA), Pub. L. No. 114-90, § 402, 129 Stat. 704, 721 (2015) (codified at 51 U.S.C. § 51303 (Supp. 2016)).

81 *See* Rhett Larson, *If There Is Water on Mars, Who Gets to Use It?*, SLATE (Nov. 2, 2015), https://slate.com/technology/2015/11/the-tricky-question-of-water-rights-on-mars.html [https://perma.cc/LBN9-BEAV].

overproduction already existed, as discussed above. However, the SPACE Act does not prohibit a single entity from taking ownership of all of the resources on Mars or in any way limit the amount of Martian resources that a single entity could obtain and own.[82] Therefore, there is a strong possibility that the first-mover advantage in this market would be adequate to secure a monopoly position moving forward in the absence of external limitations that could otherwise prevent such a result from occurring.[83]

IV. THE SPACE ACT'S PROPERTY RULE INCREASES THE LIKELIHOOD OF A SINGLE ENTITY CONTROLLING ACCESS TO MARS

The SPACE Act's property rule incentivizes anyone with the ability to obtain asteroid or space resources to do so at a rate beyond their needs for consumption. This would limit the ability for future competition after the first producer has overcome the extreme fixed costs of beginning resource production on a large, resource-rich celestial body such as Mars. The SPACE Act, which was passed with the purpose of promoting a pro-growth environment for the aerospace industry, thus instituted a property rule for asteroid and space resources that is potentially at odds with its stated purpose.[84]

While it is desirable for any rule's purpose and effect to align, if there are not limitations on the reach of the SPACE Act's property right, the first-moving producer that overcomes the high fixed cost of establishing resource production on Mars could take a monopolistic position as the sole provider of resources on the newly-settled planet. Success for the firstcomer could prevent second comers from competing because they would be unable to match the price offered by the firstcomer who enjoys a significant supply advantage.[85] This supply and pricing advantage would increase the likelihood of the second comer accepting the price offered by the monopolist rather than undertaking its own production activities in the first place.

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[82] *See* CSLCA § 402.

[83] *See* Larson, *supra* note 81.

[84] *See* CSLCA § 402 (codified at 51 U.S.C. § 51303 (Supp. | 2016)).

[85] *See* TIMOTHY TAYLOR ET AL., PRINCIPLES OF ECONOMICS ch. 9.1 (OpenStax CNX ed., 2016), https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Economics2e-OP_h3weDXv.pdf [https://perma.cc/7G23-BJG6].

Allowing a monopoly over the provision of resources is not necessarily a bad thing.[86] However, when it comes to the initial human settlement of Mars, there are policy reasons that mediate against allowing a single private entity to control access to an entire planet.

This part posits that there is a proper limiting factor that will prevent the monopolization of asteroid resources, thereby aligning the SPACE Act's purpose and effect in that instance; however, there is no such limiting factor when it comes to gathering resources from a large, resource-rich celestial body, such as water and carbon dioxide on Mars. Once a monopoly develops on Mars, that entity could discriminate against potential customers that would rely on purchasing resources from the monopoly, with the result of effectively controlling access to the Red Planet.

A. The SPACE Act's Property Rule Will Not Facilitate the Monopolization of the Production of Asteroid Resources

The SPACE Act's property rule does not increase the likelihood of a monopoly emerging in the *asteroid* mining industry in the same fashion as in the *Martian* natural resource industry due to the vast distances among the hundreds of millions of asteroids in our solar system. Recall from Part III that the SPACE Act's property rule was lobbied for most heavily by the asteroid mining industry[87] and that the SPACE Act differentiates between asteroid resources and space resources.[88] A space resource is any non-biological resource found "in situ in outer space," while an asteroid resource is any "space resource is found on . . . a single asteroid."[89]

There are an estimated 150 million asteroids with a diameter greater than 100 meters within the orbit of Jupiter.[90] Jupiter's average orbital radius from the Sun is 779,000,000 kilometers.[91] Assuming hypothetically that asteroids are evenly distributed,

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[86] *See generally* GIFFORD PINCHOT, THE POWER OF MONOPOLY: ITS MAKE-UP AND ITS MENACE 6 (1928).

[87] *See* Shaer, *supra* note 58.

[88] *See* CSLCA § 402 (codified at 51 U.S.C. § 51301 (Supp. | 2016)).

[89] *Id.*

[90] *See, e.g.*, Jason Major, *How Many Asteroids Are Out There?*, UNIVERSE TODAY (Sept. 25, 2012), https://www.universetoday.com/97571/how-many-asteroids-are-out-there/ [https://perma.cc/AL9M-WCBQ].

[91] *See, e.g.*, Fraser Cain, *How Far Is Jupiter from the Sun?*, UNIVERSE TODAY (Nov. 9, 2009), https://www.universetoday.com/44615/distance-from-the-sun-to-jupiter/ [https://perma.cc/43CX-9WG6].

each asteroid of this size would be, on average, about 3,000,000 kilometers away from the nearest asteroid of this class. This distance is about 9 times farther than the distance from Earth to the Moon.[92] These distances are difficult for any human to comprehend. However, they suggest that any single entity that plans to capture a substantial portion of all asteroids in the inner solar system would be significantly limited by the time it takes to travel from a given human settlement to each asteroid, gather resources, and return to the settlement, especially since asteroids are not actually evenly distributed throughout the solar system.[93] Going through the process of returning resources from a single asteroid could take years.[94] The amount of time it would take to travel to every asteroid in the solar system and return resources collected thereon to a human civilization is therefore difficult to estimate.

The time cost imposed by the vast distances among the hundreds of millions or billions of asteroids in the solar system provides an external limitation that prevents the incentives created by the SPACE Act's property rule from allowing a single entity to control all of the asteroid resources in the solar system.[95] This practical limitation to the reach of the SPACE Act's rule as applied to asteroid resources operates similarly to the legal limitations attendant to the rule of capture and the rule from *Pierson v. Post.* Since it is impracticable for a single entity to gather substantially all of the asteroid resources in the solar system within any foreseeable period of time, there is little to no potential that the first successful asteroid mining company will preclude others from competing in the industry.

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[92] *See* Tim Sharp, *How Far Is the Moon?*, SPACE.COM (Oct. 27, 2017), https://www.space.com/18145-how-far-is-the-moon.html [https://perma.cc/JZE2-8495]. The average distance from the Earth to the Moon is about 380,000 kilometers. *Id.*

[93] *See* Matt Williams, *How Long Does It Take to Get to the Asteroid Belt?*, UNIVERSE TODAY (Aug. 10, 2016), https://www.universetoday.com/130231/long-take-get-asteroid-belt/ [https://perma.cc/X4YH-TQDB].

[94] *See id.*

[95] *Cf.* Ross Meyers, *The Doctrine of Appropriation and Asteroid Mining: Incentivizing the Private Exploration and Development of Outer Space*, 17 OR. REV. INT'L L. 183, 199 (2015).

B. The SPACE Act's Property Rule Could Allow the First Entity to Establish Resource Production on Mars to Effectively Control Access to the Planet as Its Sole Producer of Critical Resources

In contrast to the SPACE Act's effects on the asteroid mining industry, application of the law's property rule to space resources opens the door for the first entity to arrive at localized, easily accessible resources to gain title to those resources without the time limitations that would prevent the monopolization of asteroid resources discussed above.[96]

The first entity to gather resources on Mars will have an incentive to obtain as much carbon dioxide and water as quickly as possible in order to gain title to these resources before a second comer does. The firstcomer's ownership of a meaningful percentage of the carbon dioxide and water on Mars could lead to a single entity, likely an American company, effectively controlling access to the entire planet by being the sole supplier of vital resources to any second comer. The second comer would then be forced to accept any price, up to the cost of producing the water and carbon dioxide itself, and would have no alternative supply if the firstcomer decided to cut it off from access to these resources. The firstcomer could discriminate against or in favor of captive buyers—who have no alternative source for these resources—for any reason. This section reasons that the first successful resource producer on Mars will likely establish itself as a monopoly. It then argues that a monopoly resource producer on Mars could effectively control access to the planet by discriminating against potential customers and that such a result would be deleterious to the purposes underlying the mission for continued human expansion into space.

1. The First Producer of Water and Carbon Dioxide on Mars Will Likely Develop into a Monopoly

Monopolies generally develop in industries in which there are large barriers to entry.[97] While other factors can contribute to the development of a monopolistic market, the resource production market on Mars will be characterized by such dramatically high fixed costs that it is difficult to imagine a competitor establishing itself before a successful first producer has gathered

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[96] *See supra* part IV(A).
[97] Taylor et al., *supra* note 85, at ch. 9.1.

enough resources to be able to price any future competitor out of the market.[98]

Fixed costs include the amount of expenses a company must incur before producing a single unit of whatever they are trying to sell.[99] The fixed costs of initiating water and carbon dioxide gathering, chemical conversion, and storage capability on Mars include the research and development necessary to design effective gathering, conversion, and storage systems, the cost of producing these systems on Earth, the cost of transporting the equipment, and the cost of installing it on the planet.[100] Fixed costs would also include providing adequate energy generation capacity to power these systems. Success in funding this undertaking, much less safely establishing a permanent presence on Mars, will be very difficult for any private or government entity to achieve.[101]

By being the first to establish this infrastructure in the face of extreme cost and difficulty, the firstcomer would gain a natural monopoly-like advantage in the industry, much like early electricity providers did in the United States around the turn of the 20th century.[102] At that time, and to a lesser extent today due to the deregulation of electricity markets, any firm that attempted to compete had to succeed in bringing online competing electrical power infrastructure—a relatively enormous fixed cost—in the face of stiff competition from the small number of established firms in the industry.[103] When second comers to the industry attempted to compete, the firstcomer would simply lower its prices below those that were economically feasible for the second comer, who would then be unable to earn revenue to recoup the fixed costs that it had incurred much more recently than the firstcomer.[104] As a result, electrical utilities are considered classic examples of "natural monopolies"—firms operating in industries in which it is more economically efficient for the

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98 *See id.* at ch. 9.2.

99 *Id.* at ch. 7.2.

100 *See, e.g.*, Beall, *supra* note 3.

101 *See* Musk, *supra* note 17, at 56.

102 *See, e.g.*, Matthew Lasar, *How AT&T Conquered the 20th Century*, WIRED (Mar. 11, 2009), https://www.wired.com/2011/09/att-conquered-20th-century/ [https://perma.cc/YRL9-QT7B]; David Roberts, *Power Utilities Are Built for the 20th Century. That's Why They're Failing in the 21st*, Vox (Sept. 9, 2015), https://www.vox.com/2015/9/9/9287719/utilities-monopoly [https://perma.cc/WY6V-3RDN].

103 *See* Roberts, *supra* note 102.

104 *See id.*

established firm to invest in increasing its production capacity and not competing on price with other firms than it is for competitors to overcome the dramatic fixed costs and compete on price with the established firm.[105] A result of the persistence of a natural monopoly is that it is able to set prices higher than would generally prevail in a more competitive market.[106]

Under the SPACE Act's property rule, there is a high likelihood that the first firm to establish resource production activities on Mars would enjoy similar advantages as natural monopolies have in the United States. Similar to utilities, the Martian monopolist could set the price for water, carbon dioxide, oxygen, and rocket propellant at higher prices than would prevail in a competitive market. Additionally, since the monopolist would have no competitors, it could manipulate its prices without affecting its market share. If the monopolist raises the price of its production above the profit-maximizing point, the firm does not suddenly start losing market share to a competitor. Rather, the monopolist simply sells a lower quantity and thereby makes a smaller profit in exchange for whatever non-economic purposes it values more than it values maximizing profits.[107]

Compare the early Martian natural resource industry with the retail gasoline industry, which is characterized by a high degree of competition.[108] As there is no meaningful difference in the quality of gasoline available for purchase and there are a high number of accessible suppliers, customers are likely to respond to even the smallest price increase by finding a competing supplier that is otherwise less convenient for the customer.[109] This renders gasoline retailers "price-takers," which means that the price they set is determined by macroeconomic forces outside of an individual producer's control.[110] The result is a highly com-

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105 TAYLOR ET AL., *supra* note 85, at ch. 11.3.

106 *See* Prateek Agarwal, *Natural Monopolies*, INTELLIGENT ECONOMIST (Apr. 27, 2019), https://www.intelligenteconomist.com/natural-monopolies/ [https://perma.cc/2BHE-RMN5].

107 *See* TAYLOR ET AL., *supra* note 85, at ch. 9.3.

108 *See* FLORENCIA JAUREGUIBERRY, AN ANALYSIS OF STRATEGIC PRICE SETTING IN RETAIL GASOLINE MARKETS 24, 33 (2010), https://www.rand.org/content/dam/rand/pubs/rgs_dissertations/2010/RAND_RGSD269.pdf [https://perma.cc/EV3J-M36F]; *see also* James Alm et al., *Perfect Competition, Urbanization, and Tax Incidence in the Retail Gasoline Market*, 47 ECON. INQUIRY 118, 121 (2009).

109 *See* JAUREGUIBERRY, *supra* note 108, at 32.

110 *See, e.g.*, *Price-Taker*, INVESTOPEDIA, https://investopedia.com/terms/p/pricetaker.asp [https://perma.cc/P6PC-RXZQ] (last updated July 10, 2019).

petitive market in which gas stations on opposite corners of the same street almost invariably advertise identical prices on a given day.[111]

The first-coming monopolist producer of water, carbon dioxide, oxygen, and rocket propellant on Mars, however, would not have competitors that potential customers could turn to if the monopolist decides to increase its prices for any reason whatsoever. It is hard to comprehend why the first company to establish resource production on Mars would act in a nefarious manner. The next subsection explores that possibility and concludes that allowing a monopoly to develop in the resource production industry on Mars could be disastrous from a policy perspective.

2. A Monopoly Resource Producer on Mars Could Effectively Control Access to the Planet

Policy justifications mediate against allowing a monopoly supplier of natural resources to develop and persist on Mars. This subsection explores how the property right in space resources established under the SPACE Act could lead to the first resource producer on Mars controlling access to the planet.

If the firstcomer develops resource gathering on Mars and no second comers establish a competitive position, a single entity could effectively exclude others, including sovereign nations or coalitions thereof, from accessing Mars by cutting off their supply of these vital resources on which their mission architectures will likely rely.[112] If a mission to Mars relies on the purchase of water, carbon dioxide, oxygen, or rocket propellant from the monopolist and the monopolist refuses to meet the mission's needs, the group would have no alternative supply sources. In that case, the group might not be able to make it back to Earth safely.

Additionally, in a worst-case scenario, the firstcomer's Martian settlement could begin to exist as a self-sustaining society outside the reach of Earth-based regulation and influence. Under the current international model of national nonintervention in space, there would be no basis for a sovereign government to enforce any type of legal judgment against a private

[111] *See* JAUREGUIBERRY, *supra* note 108, at 32.

[112] *See* Larson, *supra* note 81.

entity in outer space.[113] And even if there were legal grounds to enforce such a judgment, the risks associated with fostering any form of conflict between entities established on separate planets could lead to Mars falling outside of Earth-bound influence altogether. This is the harm that an amendment to the SPACE Act's property right needs to address.

Finally, the ideals underlying human space exploration—fostering technological progress, promoting human cooperation, and protecting ourselves from the many threats to our prosperity as a species—would be seriously harmed if the result warned against in this Article were to occur. The hope for the future and sense of pride that would flourish due to the successful establishment of a Mars settlement could be irreparably harmed if the entity that settles Mars handles its newfound position of power irresponsibly. Such a result could set the continuing development of space exploration so far back that the industry might never recover.

While the hypothetical motives that would cause the firstcomer to act in a nefarious manner seem out of line with the ideals of the people at the helm of the private companies currently planning missions of this type, it is impossible to predict who will be leading the company that is the first to establish resource production on Mars and what their or their successor's unspoken interests may be. A more fully developed regulatory model is needed to balance the competing interests at play—the need to create incentives for entities to settle distant planets while still protecting the right of all humans to enjoy in the benefits of the endeavor. The SPACE Act's property rule perhaps overzealously supports the former interest while not adequately protecting the latter.

V. AN ALTERNATIVE PROPERTY RULE WOULD PREVENT A SINGLE ENTITY FROM CONTROLLING ACCESS TO THE PLANET WHILE STILL INCENTIVIZING INVESTMENT IN THE MARTIAN NATURAL RESOURCE INDUSTRY

To this point, this Article has illustrated the possible negative consequences of allowing the production of natural resources on Mars to be determined by granting a property right similar to that under the SPACE Act. In its place, a method of regulating

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[113] *See* Vidya Sagar Reddy, *Commercial Space Mining: Economic and Legal Implications* 16 (Observer Research Found., Occasional Paper No. 122, 2017).

resource production and distribution on Mars should limit the likelihood of these potential negative effects while adequately rewarding the pioneering firstcomer to Mars with a significant return on their investment for being the first entity to establish resource production on another planet.

This part proposes three methods for determining ownership of resources on large celestial bodies: (1) a licensing regime for resource production on Mars that would be granted by a coalition of sovereign governments under an international treaty; (2) price regulation for the sale of resources by the first producer that has established a natural monopoly-like advantage on Mars, which would, to a certain degree, resemble the rate-making process for vertically integrated electricity providers in the United States; and (3) the Martian Riparian Rights Rule, under which existing producers of Martian resources would not have the right to extract more than necessary for their own use or for sale to current or foreseeable future consumers. The goal for an amendment to the SPACE Act's property rule is to preserve second comers' opportunities to compete with the firstcomer, thereby preventing the first-moving monopolist from effectively controlling access to the planet through its provision of water, oxygen, and rocket propellant to all second comers.

While this part ultimately concludes that the Martian Riparian Rights Rule is the best option among the three discussed to achieve this purpose, it should be noted that this is not necessarily the optimal system for balancing the policy need to avoid a single entity controlling access to Mars with the need to create the economic incentives to achieve the goal of settling Mars in the first place. Rather, this part is intended to show how various alternative methods of regulation could be weighed and what their potential drawbacks are while also suggesting a potential starting point for amending the property rule found in the SPACE Act.

A. Centralized Licensing Regime

While the rule of capture is the legal standard governing oil and gas production in the United States, the vast majority of sovereign nations grant licenses for conducting oil and gas exploration and production activities to public, private, and public-private oil and gas companies or joint ventures (similar sets of rights are called "concessions").[114] A standard license grants

[114] *See, e.g.*, Smith & Dzienkowski, *supra* note 79, at 14, 19–20.

"the exclusive rights to explore, search, and drill for, produce, store, transport, and sell" the resource in question within the designated licensed area for a specific period of time.[115] In similar arrangements, in return for granting a temporary right to use government-owned land for oil and gas production, the government typically demands a flat fee or a share of revenues, profits, or recovered resources.[116] While there is wide variation in the forms these arrangements can take, in general, competing producers submit their project proposals and fee or profit-sharing offers in "bidding rounds," and an agency of the national government approves a proposed plan to search for and produce oil or gas beneath a certain area of land that is owned by the government.[117] The land is then leased to the energy company that submits the best bid.[118] Most governments operating under these models retain ownership of the oil and gas that remains in the ground—title only passes to the producing company once the resources have been removed from the ground, if title passes at all.[119]

A system for licensing the right to gather water and carbon dioxide on Mars would have to be administered by an international coalition made up of either all nations or all space-faring nations, likely under the authority of an original treaty principally fashioned by the space-faring nations.[120] Similar to the bidding rounds used by most countries for oil and gas licenses on Earth, nations or private companies wishing to collect resources such as water and carbon dioxide on Mars would submit proposals, which would include justifications for the amount of resources they intend to gather, and the international coalition would approve the proposals. There would be no need for anything resembling consideration—such as profit or production sharing arrangements—to flow to the international coalition in return for granting a license.

Rather than serving a revenue-generating function for participating national governments, centralized licensing is meant to allow all affected countries, which could include all nations, to participate in determining the current use of resources on Mars,

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115 *Id.* at 36.

116 *See id.* at 40.

117 *See* Ernest E. Smith, *From Concessions to Service Contracts*, 27 TULSA L.J. 493, 503–04 (1992).

118 *See id.* at 503–05.

119 *See id.* at 515.

120 *See* Larson, *supra* note 81.

since the current use of resources affects the future use for all other humans.[121] This approach would better align with the international obligations underlying the Outer Space Treaty.[122] Furthermore, eliminating the production-incentivizing property rule of the SPACE Act and replacing it with a model under which the right to collect resources on Mars would be determined by representatives of all or most nations would prevent the monopolistic outcome discussed above.

While centralized licensing would alleviate some concerns about a Martian monopolist, it is not without its drawbacks. If licensees are free to sell resources gathered on Mars to second comers, a licensing regime would do little to resolve the issues presented by a natural monopoly, where the firstcomer establishes gathering and conversion infrastructure before anyone else does, since economies of scale allow it to sell resources to second comers at the replacement cost of competing for production.[123] Alternatively, if licensees are restricted from selling their resources to other groups of Martian settlers, any entity that wishes to gather resources on Mars would have to produce water and carbon dioxide for itself. This would be an inefficient result because it would be better for potential settlers with interests other than resource production to focus on whatever they are trying to specialize in.[124]

Most importantly, a licensing regime would not adequately incentivize private investment in the mission to settle and establish resource production on Mars in the first place as strongly as would the creation of a general property right.[125] This is because private industry is reticent to rush into areas where governmental entities have direct control over the profitability of the endeavor and ultimate ownership of critical resources.[126]

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[121] *See* Craig Foster, *Excuse Me, You're Mining My Asteroid: Space Property Rights and the U.S. Space Resource Exploration and Utilization Act of 2015*, 2016 U. ILL. J.L. TECH. & POL'Y 407, 429 (2016).

[122] *See* Blount & Robison, *supra* note 11, at 181–83; Myers, *supra* note 11, at 127. *See generally* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies arts. I, III, *opened for signature* Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205.

[123] *See* TAYLOR ET AL., *supra* note 85, at ch. 9.1.

[124] *See id.* at ch. 33.1.

[125] *See* Lauren E. Shaw, *Asteroids, the New Western Frontier: Applying Principles of the General Mining Law of 1872 to Incentivize Asteroid Mining*, 78 J. AIR L. & COM. 121, 138–39 (2013).

[126] *See, e.g.*, William Aldred, *Outdated Policy Is Stifling Space Tech Advancement*, COMET LABS (Aug. 8, 2018), https://blog.cometlabs.io/outdated-policy-is-stifling-space-tech-advancement-2cd29a9abe79 [https://perma.cc/Q7RL-SG2Q].

A strong anecdotal argument against a centralized licensing regime is found in the success of the American oil and gas industry, operating under the rule of capture, as opposed to international countries that almost universally employ centralized licensing.[127] The tepid development of private oil and gas companies in countries other than the United States demonstrates how the absence of a strong investment-incentivizing property right seriously hinders the success of the industry.

B. Price Regulation for Sales of Resources on Mars

A second option to counter the negative effects of allowing a monopolist to produce resources on Mars would be to concede the development and continuance of a natural monopoly in the industry while attempting to limit its harmful effects by instituting price regulation. This method is applied in many industries, but its presence is most familiar in the sale of electricity to consumers by vertically-integrated energy companies.[128]

Regulating the price the firstcomer is allowed to charge for its production would involve a central authority determining a price that allows the firstcomer to recoup the costs of its investment in infrastructure and ensure an adequate return on investment while allowing the purchaser of resources to pay less than they would pay under unregulated monopoly pricing. This system could even feature an obligation to provide service like that common to the electric utility industry in the United States.[129] The central authority would have to enforce producers' compliance with the price directive.[130]

While price regulation would lower the cost to second comers of establishing a permanent settlement on Mars, it would do little to address the policy concerns behind allowing a single entity to control access to all critical resources on Mars. Regulating the price charged by natural monopolies can be thought of as a redistribution of wealth from the natural monopolist to its customers, which results in a better economic outcome for the customer than would exist in an unregulated monopoly market.[131] Additionally, if the monopoly decides to ignore its obligation to sell its production to customers, the central authority's

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[127] *See* Smith & Dzienkowski, *supra* note 79, at 33–34.

[128] *See, e.g.*, Jim Lazar, Electricity Regulation in the US: A Guide 5 (2d ed. 2016).

[129] *See id.* at 195.

[130] *See id.* at 130.

[131] *See generally* Taylor et al., *supra* note 85, at ch. 11.3.

ability to enforce any penalties would be tenuous at best, as discussed in subpart IV(B)(2).

Furthermore, as discussed in the preceding section, in a centralized licensing regime, investors are weary of government involvement because the level of government involvement often changes with the people in government and usually leaves less flexibility for commercial realities to prevail. Since a massive upfront investment will be required for the monopolist to succeed in the first place, investors prefer a regulatory regime that leaves as much control in the hands of businesses as possible. Instead of attempting to regulate prices in advance and punishing noncompliance, a method of regulation under which entities are freer to structure their interactions, with the potential for judicial interpretation on the back end, tends to promote flexibility and allow for reasoned judgments after actual situations have played out.

C. THE MARTIAN RIPARIAN RIGHTS RULE

Riparian rights in America are traced to Justice Story's opinion in *Tyler v. Wilkinson.*[132] *Tyler* involved an industrial era conflict between rival mill owners over the flow of a stream.[133] Due to a trench and dam being dug further upriver, mill owners downriver sued the owners of the trench and dam because they suffered a lower flow of water as a result of the construction.[134] Justice Story decided that all landowners along a shared body of water have equal rights to use the water of the river and that "no one has a right to diminish the quantity which will . . . flow to a proprietor below, or to throw it back upon a proprietor above."[135] Justice Story limited the impact of this riparian right by stating that reasonable use is allowed, judged by the extent of injury to landowners affected by that use.[136]

California, a state plagued by constant water-use issues, takes Justice Story's position a step further by placing value on the ultimate beneficial use of water. The California Constitution states that "the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable . . . the conservation of such waters is to be

132 *See* 24 F. Cas. 472 (C.C.D.R.I. 1827) (No. 14,312).
133 *Id.* at 473.
134 *Id.*
135 *Id.* at 474.
136 *Id.*

exercised with a view to the reasonable and beneficial use thereof . . . ."[137] California thus promotes the optimal use of water over more traditional considerations, such as who was the first to establish a particular use, thereby molding community expectations regarding allocation of the resource.

A similar riparian rights model on Mars (a Martian Riparian Rights Rule) would borrow from and build upon the versions implemented in the United States. This qualification to the SPACE Act's rule of prior appropriation would allow any resource producer on Mars to take possession and ownership of the resources it reasonably needs for its own use and could foreseeably sell to other settlers, as long as its activities do not harm the ability of future settlers to provide these resources for themselves.[138] Other settlers would be subject to the same rule vis-á-vis the firstcomer and all subsequent comers. Producers would never have the opportunity to gain ownership of resources that would not be reasonably used or sold in the foreseeable future.

The reasonableness of the amount of resources gathered would depend on the producer's own needs and the needs of other current settlers for water, carbon dioxide, rocket propellant, and other derivatives of these compounds. The amount needed for reasonable operations is thus fairly determinable, since the settlers' life support, industrial, and launch system needs can be objectively assessed.

Whether an entity is storing resources for foreseeable future sale would depend on whether there are known plans for other entities to attempt to settle Mars and whether their likely resource needs would be known. If no one has reasonably certain plans to follow the firstcomer to Mars or if the second comer plans on competing with the firstcomer by producing resources of its own, the firstcomer has no reason to store any more of these resources than is reasonably required for its own use. However, if there are other missions that plan on purchasing resources already produced on Mars, the firstcomer could store an additional amount that would be sold to these entities.[139]

This standard for resource allocation on Mars and other large celestial bodies would prevent the first resource producer from building up an inventory that would allow it to indefinitely price

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137 CAL. CONST. art. X, § 2.

138 *See* Larson, *supra* note 81.

139 *See id.*

a second producer out of the market.[140] Instead, the second comer that wished to compete would have a chance of constructing the necessary infrastructure for the production and sale of resources to potential third and fourth comers, since the firstcomer could not develop an inventory that would make it impossible for the second comer to compete economically. Since previously established producers would still have the right to store resources for sale to existing and foreseeable future settlers, producers of Martian resources would still be able to earn a significant return on their investment by establishing this capability. Although it would no longer be a full monopoly return, these first producers could likely form an oligopoly that would earn profits somewhere between that of a monopoly and perfectly competitive market.

D. The Martian Riparian Rights Rule Would Best Promote Competition for Resource Production on Mars Without Depriving the Firstcomer to the Industry of the Profit from Its Investment

The Martian Riparian Rights Rule discussed above represents the best approach that balances the interests of the firstcomer to Mars, future entities that settle Mars, and humanity in general.

First, the Martian Riparian Rights Rule would lessen the monopoly concerns presented by the SPACE Act's property rule as applied to water and carbon dioxide on Mars. Most importantly, the firstcomer would be limited to taking ownership of only the amount of resources needed for its own reasonable current and future consumption, sale to current settlers, and sale to foreseeable future settlers.[141] Since the firstcomer could not stockpile an unnecessary supply of water and carbon dioxide before others arrive on Mars, the latecomers would have an incentive to compete with the firstcomer to produce these resources in order to establish themselves as one of the few producers in the maturing industry. This would result in an oligopoly, under which lower prices would be charged to future settlers who do not wish to compete with the resource producers than would be charged under a monopoly market.[142] The market would be more competitive, and the incentives created by the rules for

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140 *See* Meyers, *supra* note 95, at 198–99.

141 *See id.* at 201.

142 *See* Taylor et al., *supra* note 85, at ch. 10.2.

property distribution on Mars would better align with the purpose of the SPACE Act.

Second, the firstcomer and other future settlers could never effectively gain title to all of the resources on Mars by obtaining far more resources than they need for reasonable current and future consumption. The Martian Riparian Rights Rule, while still allowing the firstcomer to collect ample resources for its own use and for sale to foreseeable purchasers, ensures that the firstcomer's use of these freely available resources does not unnecessarily detract from the productive use of these resources by other settlers. This preference for avoiding uses of common resources in ways that harm others traces back to the Lockean maxim, "[f]or he that leaves as much as another can make use of, does as good as take nothing at all."[143] The Martian Riparian Rights Rule promotes this utilitarian view of property,[144] and when the rule's utilitarian focus is combined with allowing more room for multiple competing producers on Mars than the SPACE Act's property rule, the policy concerns about allowing a single entity to control production and distribution of critical resources on (and thereby effective access to) Mars would be meaningfully reduced.

Third, the Martian Riparian Rights Rule would provide a flexible standard for courts presided over by mere Earthlings to address future conflicts over Martian resources. The alternatives suggested in this Article (centralized licensing or price regulation) would involve *ex ante* assessments of the most valuable or least harmful approach from a set of competing options. The flexibility of the Martian Riparian Rights Rule would allow courts to consider *ex post* the wider development of Martian property law as they adjudicate specific controversies and apply standards for a resource producer's storage of reasonably necessary reserves of water and carbon dioxide because the amounts needed for the producer's own uses and for foreseeable future inhabitants of Mars would be objectively determinable.

Finally, if the SPACE Act's property rule were qualified by the Martian Riparian Rights Rule, the firstcomer and subsequent producers on Mars would still be able to earn a significant return on their investment[145] that would lie between a monopolistic and perfectly competitive market, likely closer to the

[143] JOHN LOCKE, TWO TREATISES OF GOVERNMENT 189 (1689).
[144] *See* Meyers, *supra* note 95, at 200.
[145] *See* Larson, *supra* note 81.

monopoly side of the spectrum between these two extremes. While the firstcomer would no longer be able to earn a monopoly return indefinitely, being the first to succeed on this daring new frontier would add a significant amount of prestige to the firstcomer's reputation that could help drive customers in the future. This Article has in no way tried to argue that a private aerospace company that establishes resource production on Mars does not deserve a significant return on its investment, reflecting the inherently drastic risks taken to establish a permanent, self-sustaining settlement on Mars. Rather, the Martian Riparian Rights Rule is meant to allow the firstcomer to Mars to receive almost as substantial of a return while ensuring that no one entity is capable of controlling the rest of humanity's access to potentially the most valuable property expansion in human history.

VI. CONCLUSION

Establishing a permanent human settlement on Mars that has the capacity to produce its own water, oxygen, energy, and rocket propellant for journeys back to Earth and elsewhere in the solar system is an ambitious goal given the monetary, technological, and psychological barriers that must be overcome to make such an endeavor a reality. Any viable mission design needs to leverage the abundant, accessible bodies of water and carbon dioxide on the surface of Mars to accomplish this goal.

The property rule created by the SPACE Act incentivizes the first entity to arrive at Mars with the goal of producing natural resources to stockpile more water and carbon dioxide than necessary for their consumption in order to sell such resources to subsequent settlers. Such activity will discourage or preclude a second comer from competing in the production of these resources. If the firstcomer is able to persist as the monopoly producer of water and carbon dioxide on Mars, a single entity could effectively control access to the planet through its unilateral control over the production and sale of water, oxygen, carbon dioxide, and multiple combinations of rocket propellant.

In order to limit the negative effects of a potential monopoly, Congress and the United Nations should not support a simple prior appropriation-based ownership rule for resources produced on Mars and other planets or large moons. Rather, these and other legislative bodies should consider alternative methods of regulation that increase the likelihood of potential competitors gaining a foothold in this market, which would limit the prices charged to future non-producing Martian settlers and would prevent a single entity from effectively controlling access to the planet.

The Martian Riparian Rights Rule developed in Part V of this Article—under which any resource producer on Mars could not take title to more resources than necessary for current and future personal consumption and sale to other settlers—is an ideal qualification to the SPACE Act's property rule. This addition to the SPACE Act would prevent the firstcomer to Mars from amassing such a substantial supply of water and carbon dioxide that a second comer would be discouraged from attempting to compete due to the firstcomer's established success and supply advantage. Since a monopoly would not develop under this rule, the concerns surrounding a single private entity effectively controlling access to the planet would be meaningfully tempered.

This qualification, however, would not prevent the mission from getting off the ground in the first place. The firstcomer would still benefit from being the first producer of such resources on Mars and would hold a significant experience-based and reputational advantage in the sale of resources to foreseeable future settlers. Additionally, this flexible standard could be shaped by courts to best balance the interests of all parties involved as this promising market develops.

While alternative property rules for appropriating resources on Mars have benefits and drawbacks, the method of allocating resources on Mars should not allow a single private entity to control access to the most valuable celestial body (besides Earth) in the solar system. Preventing this result would help ensure the valuable use of Mars for all humankind as a source of vast, newly accessible resources and a safe haven from disaster on Earth.