

CELESTIAL AGRICULTURE: LAW & POLICY GOVERNING  
THE USE OF *IN SITU* RESOURCES FOR SPACE  
SETTLEMENTS

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“It is time to explore other solar systems... I am convinced that humans  
need to leave Earth.”<sup>1</sup>—Stephen Hawking

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1. Abby Norman, *Stephen Hawking: “I Am Convinced That Humans Need to Leave Earth,”* FUTURISM (June 20, 2017), <https://futurism.com/stephen-hawking-i-am-convinced-that-humans-need-to-leave-earth>.

## I. INTRODUCTION

Life in the present era is marked with an ever-increasing dependency on the realm of outer space. The technologies used there bring numerous benefits to the people of Earth. Satellite-based navigational systems, remote sensing satellites monitoring the health of the Earth's environment, telecommunications, and numerous other technological marvels make it possible to live as we do, and have markedly improved many aspects of human activity. Yet, a time is coming when humanity needs to plan to reach beyond the Earth and find ways to explore and live outside of the safety our planet provides. Indeed, since the late 1950s, space technologies have painted a picture of the solar system inhabited by our Pale Blue Dot and have demonstrated that there are other worlds out there calling for exploration and perhaps, eventually settlement by human colonists. The technological, political, and legal challenges associated with creating human settlements are myriad. Some present intractable difficulties, at least under our current capabilities. Others, like producing enough food for colonists to survive, are receiving attention from the scientific community. No matter what the challenges are long-term, the exploration of our solar system continues, and with it, the understanding that humans will eventually be living, working, and settling on other celestial bodies. It is therefore important to ask whether law and policy permit the types of activities explorers will need to undertake in order to sustain their permanent presence in space.

## II. THE *LEX SPECIALIS* OF OUTER SPACE

Efforts at creating colonies in space have yet to produce much more than sensationalized media attention;<sup>2</sup> yet, the notions of humans exploring and concomitantly settling the cosmos have been capturing the attention of our imagination for some time.<sup>3</sup> The technical capacity to design, build, and operate potential settlements on celestial bodies will vary, requiring planners to adapt to the particular needs of each environment. Early space theorists saw great opportunity to use the space environment for just such possibilities. McDougal speculated that “among the possible uses of the moon in the more distant future one may mention the establishment of permanent settlements . . . conversion of various minerals, should they be found, would undoubtedly

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2. Mike Wall, *Elon Musk Floats ‘Nuke Mars’ Idea Again (He Has T-Shirts)*, SPACE.COM (Aug. 17, 2019), <https://www.space.com/elon-musk-nuke-mars-terraforming.html>. Mr. Musk, of SpaceX fame, has proposed nuking parts of the Red Planet in order to begin a process of terraforming that would, in his view, make it more livable for human beings.

3. Innumerable examples exist in the pop-culture world of science-fiction. Scientists, entrepreneurs, and others have also made statements encouraging humanity to begin living off-world. See Norman, *supra* note 1; Wall, *supra* note 2.

accelerate the creation of larger settlements.”<sup>4</sup> Whatever challenges brought by settling on celestial bodies, each object will carry with it shared needs wherever humans go—among these is the need to feed the people settling on the object, which may be accomplished through various means dependent upon location, number of people and any special needs, and specific mission parameters.

Still, while real-world colonization efforts have yet to materialize—and are likely decades away, even under the most optimistic of projections—scientists have labored over the problems of agriculture in space for decades.<sup>5</sup> Ideally, resources found on celestial objects would be mined to serve as a stratum or a component of a mixture for crop growing operations. Studies could be roughly divided into two camps, with one group examining whether and how *in situ* resources may be utilized to grow food crops, and others examining the more fantastical notion of terraforming entire celestial bodies. The former is a more likely scenario for future lunar or Martian base operations, and the latter a more distant possibility.

Whatever may be required to technically achieve future space settlement, the topic requires legal analysis to determine whether or not the current state of the law permits, encourages, or obstructs the possibility of repurposing celestial *in situ* resources for agricultural needs. Accordingly, this essay seeks to assess the topic from the perspective of international and domestic (U.S.) law and policy. As such, this is both a survey of current law (*lex lata*) as well as an exercise in *lex ferenda*,<sup>6</sup> speculating at the future of laws governing human activities in outer space, and how current laws will impact future operations.

4. MYERS S. MCDUGAL, HAROLD D. LASSWELL & IVAN A. VLASIC, *LAW AND PUBLIC ORDER IN SPACE* 760 (1963).

5. See, e.g., Donald L. Henninger, Daniel J. Barta, Randal S. Stahl, & Terry O. Tri, *Johnson Space Center's Regenerative Life Support Systems Test Bed*, NASA (Jan. 1, 1991), <https://ntrs.nasa.gov/citations/19920018914>; see also, Douglas Ming, D.C. Golden, & Donald Henninger, *Utilization of On-Site Resources for Regenerative Life Support Systems at Lunar and Martian Outposts*, SAE INT'L (July 1, 1993), <https://doi.org/10.4271/932091>; S. J. Russell & S. K. Fieber-Beyer, *An Evaluation of CI Carbonaceous Asteroid Regolith as a Plant Growth Medium for Space Crop Production*, DEP'T OF SPACE STUD., UNIV. OF N.D., (2021) (52nd Lunar and Planetary Science Conference 2021 (LPI Contrib. No. 2548)), <https://www.hou.usra.edu/meetings/lpsc2021/pdf/1406.pdf>. More recent studies have proposed using Earth species to jump start creating soil for space settlements. See, e.g., Jane Shevtsov, *Making Soil for Space Habitats by Seeding Asteroids with Fungi*, NASA (Feb. 25, 2021), [https://www.nasa.gov/directorates/spacetech/niac/2021\\_Phase\\_I/Making\\_Soil\\_for\\_Space\\_Habitats/](https://www.nasa.gov/directorates/spacetech/niac/2021_Phase_I/Making_Soil_for_Space_Habitats/).

6. Professor Bin Cheng warns that when discussing issues of ‘future law’, or *lex ferenda*, one must take care to be clear that these are rules that we wish to see, and not rules that already exist. He stated that “it is one thing to consciously invoke *lex ferenda*, with one’s eyes wide open, as a defiant and unilateral announcement of a new rule, as a serious proposal of law reform, as a propaganda weapon, or merely as a negotiating ploy, but it is fatal not to be clear as to what exactly one is doing.” Bin Cheng, *How Should We Study International Law*, 13 CHINESE (TAIWAN) Y.B. INT’L L. & AFF. 214, 217 (1994).

Studies of ‘future law’ have historically populated the *lex specialis* of outer space. This is a common enough exercise in space law, given the origin of the field as a predictive tool for geopolitical relations in space during the contentious years of the Cold War. Andrew Haley, one of the early organizers of the field, purported that laws and ambitions ought to be worked out *before* one traipses out into the universe, rather than coming about after something has gone wrong that requires redress. His book, *Space Law and Government*,<sup>7</sup> set the stage for structuring the laws applicable to States in space long before the actual treaty system which the world currently enjoys came into being. Haley’s view was that it is better for humanity to create laws to govern activities in space, so that our better angels would govern our activities there. He noted that “whatever the ultimate products of space exploration and occupation may prove to be, man in his present state of civilization will . . . determine whether they will be beneficial or nefarious.”<sup>8</sup> Putting it poetically, humanity was presented with an opportunity to take the better aspects of itself into the heavens and leave the worst aspects of itself on Earth.

While Haley’s views on our better angels guiding space activities may seem Pollyannish, they carried with them measures both hopeful and practical. Insofar as they were and are useful to spacefaring States today, scaffolding rules to promote sound activities for the future remains a priority for academics and policymakers alike. Speculation about the future is healthy for the law. Still, the current legal regime in space has much to say about how Nation-States—and their citizens—may use and explore the environs of space. It may be seen that the current rules, however useful they may be, nevertheless skirt around giving a direct answer to the question at hand—whether we may legally use space to grow food crops using its resources.

Answering this question requires an analysis of the two fronts of law directly impacting space activities. The first of these is international law, and the second the domestic laws of individual States.

### III. SPACE SETTLEMENTS & INTERNATIONAL LAW

Recognizing the need for States to have set rules to follow in space, the United Nations drafted a series of five space-specific treaties to guide their peaceful activities. These treaties account for a host of activities in space, including matters as diverse as military uses of space, legal responsibility for non-State actors in space, and the creation of lunar bases.<sup>9</sup> The first among

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7. ANDREW G. HALEY, *SPACE LAW AND GOVERNMENT* (1963).

8. *Id.* at 10.

9. See *Space Law Treaties and Principles*, UNITED NATIONS OFF. FOR OUTER SPACE AFF., <https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html> (last visited Feb. 23, 2022).

these was the Outer Space Treaty,<sup>10</sup> which was followed by four additional instruments covering anything from registering space objects,<sup>11</sup> to space mining operations on celestial bodies.<sup>12</sup> There are a host of soft-law implements that also apply to space,<sup>13</sup> though these are less binding on State activity. Together, these instruments shape current and future activities in space, and therefore they are the basis on which an analysis of space agriculture must begin.

These laws will have three primary questions to address with respect to the legality of agricultural operations in space. Firstly, whether or not the ‘use’ of outer space and its celestial bodies permits the extraction, processing, and repurposing of *in situ* resources found in space. This topic is controversial, but is one that has been addressed through several legal and scholarly angles,<sup>14</sup> and is thus a familiar concern for contemporary and future space exploration planners. Secondly, there is a question as to whether States would be bound to follow increasing policy pressures to maintain the status quo for celestial objects of use to astrobiological research; i.e., the search for past or current life on other worlds. This area is scaffolded by a series of international and domestic planetary protection policies (PPP). Finally, there is a need to resolve whether terraforming of celestial objects, should it ever become technologically feasible, is permitted under international law.

#### IV. THE OUTER SPACE TREATY REGIME

The Outer Space Treaty (“OST”) is the first of the major international laws governing space, and is often thought of as the Magna Carta, or Constitution, of space.<sup>15</sup> The Treaty was written during the Cold War and sought to set basic rules of behavior for Nation-States’ activities in space. Accordingly, the drafters had to create articles of behavior acceptable (or at least tolerable) to both space powers of the era, as well as States with an interest in how space would be used in the future. In this way, the provisions of the OST can be maddeningly vague—designed to permit much and bar little,

10. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter *OST*].

11. Convention on the Registration of Objects Launched into Outer Space, Nov. 12, 1974, 28 U.S.T. 695, 1023 U.N.T.S. 15.

12. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 1979, 1363 U.N.T.S. 3 [hereinafter *Moon Agreement*].

13. See, e.g., G.A. Res. 51/122 (Dec. 13, 1996), <https://digitallibrary.un.org/record/231739?ln=en>.

14. See, e.g., Fengna Xu, Jinyuan Su & Miqdad Mehdi, *A Re-Examination of Fundamental Principles of International Space Law at the Dawn of Space Mining*, 44 J. Space L. 1 (2020).

15. See, e.g., WILLIAM A. HYMAN, *MAGNA CARTA OF SPACE* (1966) (while this book came out shortly before the Outer Space Treaty, the nickname has stuck, and occasionally scholars still refer to the OST this way).

though with minimal specificity for either. It is therefore unsurprising there are no references to agriculture or resource extraction in the language of the OST. Despite this, Article I of the Treaty expresses that space is the “province of all mankind” and that it “shall be free for exploration and use by all States.”<sup>16</sup> While the OST does not grant free reign to any conceivable activity, it does strike a permissive tone from the start, encouraging States to explore and use space for their needs.

Mining the resources needed to facilitate agriculture at lunar or other celestial bases probably qualifies as a ‘use’ of space;<sup>17</sup> yet, whether the Treaty condones resource extraction and utilization is a contentious issue involving technical, ethical, and legal challenges. There is, as of yet, no definitive conclusion for the matter, nor an international consensus. However, the legal opinion is trending in the direction of permitting extraction. Regardless, the Treaty does posit one explicit barrier that space colonists ought to consider: namely, Article II of the OST, which prohibits the national appropriation of space or any celestial bodies therein, including “by means of use or occupation.”<sup>18</sup> Consequently, no State may simply lay claim to a celestial object, forbid its exploration and use by other powers, and begin claiming any and all of its potential bounties for itself alone. The tone and letter of this article kept either the USSR or the USA from rushing out into space during the Cold War to claim valuable orbits, the Moon, or other planets for their own, and continues to ensure the space environment is free and open to the use of all States.

Despite the prohibition on claiming national territory in space, the Treaty system does permit States to build and inhabit permanent facilities on celestial objects. Article XII envisions States will have “stations, installations, equipment and space vehicles on the Moon and other celestial bodies[.]”<sup>19</sup> and any attempt by States to set up such affairs will necessarily bring with them the need for constant resupply of resources sustaining human life. While shipments of food to the Moon might be possible in the short term, larger populations of colonists, or outposts further in the solar system, will require methods of replenishing supplies without direct dependency on the Earth. Agricultural operations onboard such stations or installations would alleviate this concern if they could be made functional. Assuming technical hurdles to growing plant life on the Moon, Mars, or other bodies (e.g. asteroids) could be resolved, the question as to where the resources necessary to

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16. *OST*, *supra* note 10, at art. I.

17. *See infra*, Section VI, at 107.

18. *Id.* at art. II: (“Outer Space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.”).

19. *Id.* at art. XII.

grow them may be found, and whether States would be permitted to use them, needs further exploration.

## V. *IN SITU* RESOURCE EXTRACTION & EXPLOITATION

Article I of the OST sets a positive and expansive tone that enables States to pursue their exploration and use of space vigorously. Its aim is to express the potential of space, and how any State may pursue its aspirations under the welcoming arm of the Treaty. Yet, permissive though it may be, the OST is silent respecting the legality of extracting and exploiting resources found *in situ* on celestial bodies. Agricultural operations on an asteroid installation, for instance, may need to acquire materials directly from the surface or sub-surface of the object to serve as the ‘soil’ from which plants would be grown. Operations to gather resources must respect Article II’s prohibition on national appropriation. It is important to read this barrier in line with Article I permitting the ‘use’ of space by States. Further, Article VI of the Treaty allows non-State actors to enjoy the use and exploration of space, so long as they are properly supervised and authorized by their host State.<sup>20</sup> This creates opportunities for both official State settlements, and for private enterprises seeking to set up their own outposts. Either way, food resources will be a limiting factor for time spent and distance reached, and either type of settler will need to rely on resources produced on their own.

Two questions must therefore be further explored. Firstly, does resource extraction by States or their representatives of *in situ* resources constitute impermissible national appropriation of celestial bodies? Secondly, does the term ‘use,’ as referenced in the Article I of the OST, encompass the notion of extracting, processing, and repurposing *in situ* resources? Only where the former may be answered in the negative, and the latter in the positive, may research stations, installations, and other outposts legally engage in agricultural activities in space.

## VI. ‘USE’ AND THE APPROPRIATION OF SPACE RESOURCES

If the Treaty system obliges activity like agriculture when it authorizes States to ‘use’ space, then proposals to undertake farming experiments on space facilities are internationally permissible, unless such use also amounts to national appropriation. To suss out the germane details, it behooves us to ask what is meant by ‘use’ in the first place. Likewise, ‘national appropriation’ must be examined for its relationship, if any, to the use of space referred to in Article I of the OST.

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20. *Id.* at art. VI.

The language of the OST does not explain what is meant by the prescription that space may be explored and used by State Parties. The question is not a new one, and “[d]uring the debates on the Principles Treaty in July 1966 an effort was made to clarify the meaning of the word ‘use’ . . . .”<sup>21</sup> France considered ‘use’ “to be the equivalent of ‘exploitation,’”<sup>22</sup> and subsequent State practice in space demonstrated exploitation was considered part and parcel of the Agreement.<sup>23</sup>

During early space exploration, it quickly became evident that States intended to exploit the resources of space to achieve their ends. Remote sensing technology exploited the unique and useful orbits around the Earth to help States gather intelligence on foreign powers, monitor the weather on Earth, and conduct long term studies to the surface of the Earth.<sup>24</sup> States have and continue to exploit the natural resource of radio frequencies for communication in space or on the Earth. Even the Apollo Program is an example of how space was exploited by States early in the Space Age (in this case, for technological and geopolitical gains).<sup>25</sup> None of these activities are considered internationally illicit, and each has continued to attract State participation by new and old players alike. Indeed, Professor Christol noted “[t]his gloss presently has converted the terms ‘use’ and ‘exploration’ . . . into the non-exclusive right to engage in exploitative activities. A contrary conclusion could not survive the realities of the practices of States in the space environment since 1958.”<sup>26</sup>

The above examples demonstrate that exploitation of space resources has been seen by States as equivalent to using space. If that stands, then other, developing exploitative activities—such as mining for minerals or water, or agricultural experimentation—are also protected under the umbrella of ‘use,’ so long as there are no contrary provisions in the Treaty. Many States feel there are no such barriers and have announced their approval of or plans to extract space resources for their own use, perhaps demonstrating they are happy to use the flexibility of the OST to explore new opportunities under the banner of *nulla poena sine lege*, or perhaps more accurately in this instance, that which is not forbidden is permitted.

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21. CARL Q. CHRISTOL, *THE MODERN INTERNATIONAL LAW OF OUTER SPACE* 39 (1982).

22. *Id.*

23. *Id.* at 40.

24. *See, e.g.*, L. G. POWELL, *The Legal Implications of Remote Sensing in Outer Space on National Security*, 5 AUCKLAND U. L. REV. 329 (1984-1987) (describing the uses and controversies of remote sensing technologies).

25. *See, generally*, JOHN M. LOGSDON, JOHN F. KENNEDY AND THE RACE TO THE MOON (2010) (explaining in detail the geopolitical factors pushing the development of projects Mercury, Gemini, and Apollo).

26. CHRISTOL, *supra* note 21, at 41.



## VII. MECHANISMS OF TREATY INTERPRETATION

Most of the ways States have exploited space to date have dealt with intangibles, which makes extracting and processing physical materials from celestial objects a new objective.<sup>27</sup> Whether ‘use’ should include acquiring and processing *in situ* resources found on celestial bodies to use in agricultural experiments or programs deserves further attention. When treaties fail to be clear or specific regarding the meaning of questionable terms, like ‘use’ in this instance, States may have recourse to the interpretive mechanisms of international law. The Vienna Convention on the Law of Treaties (“VCLT”)<sup>28</sup> was created to address just these kinds of issues and gave States a manual of sorts for treaty drafting and interpretation. Not all States have ratified the VCLT; yet, its interpretive provisions are so helpful at resolving international disputes that they have arguably passed into customary international law,<sup>29</sup> which if true would mean they are applicable to cases such as the one before us, even for non-State Parties. In any case, it is useful to use the VCLT because failing to go through this exercise “can result in the discussion being directed not to the question of interpretation methodology and law, but instead on presumptions formulated from premises neither party articulates.”<sup>30</sup>

Theoretically, using the VCLT to interpret questionable terms of treaties is a simple exercise. The VCLT contains widely-recognized and respected rules for approaching problems of interpretation, as it sets up a neutral and rational method to examine troublesome terms. Further, the VCLT provides a platform for States to work out their differences, thereby stabilizing the discourse surrounding legal disagreements. The primary tool for interpreting treaties is covered via Article 31, which notes:

### Article 31

#### General rule of interpretation

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27. A relatively new objective, at least. States have a history of acquiring samples from celestial objects for study, including retrieval and transportation back to Earth. These efforts have been for scientific purposes thus far, making efforts at using *in situ* resources for agriculture or commerce a ‘new’ activity for States and private entities who may soon be seeking their fortunes in space.

28. Vienna Convention on the Law of Treaties, opened for signature May 23, 1969, 1155 U.N.T.S. 331, [https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg\\_no=XXIII-1&chapter=23&Temp=mtdsg3&clang=\\_en](https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXIII-1&chapter=23&Temp=mtdsg3&clang=_en) [hereinafter *VCLT*].

29. The International Court of Justice has stated that “in accordance with customary international law, reflected in Article 31 of the 1969 Vienna Convention on the Law of Treaties, a treaty must be interpreted in good faith in accordance to the ordinary meaning to be given to its terms . . .” Territorial Dispute (Libya v. Chad), Judgment, 1994 I.C.J. 7, at 19. (Feb. 3), <https://www.icj-cij.org/public/files/case-related/83/083-19940203-JUD-01-00-EN.pdf>.

30. Michael C. Mineiro, *FY-1C and USA-193 ASAT Intercepts: An Assessment of Legal Obligations under Article IX of the Outer Space Treaty*, 34 J. SPACE L. 321, 322-23 (2008).

1. A treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose.

2. The context for the purpose of the interpretation of a treaty shall comprise, in addition to the text, including its preamble and annexes:

(a) any agreement relating to the treaty which was made between all the parties in connection with the conclusion of the treaty;

(b) any instrument which was made by one or more parties in connection with the conclusion of the treaty and accepted by the other parties as an instrument related to the treaty.

3. There shall be taken into account, together with the context:

(a) any subsequent agreement between the parties regarding the interpretation of the treaty or the application of its provisions;

(b) any subsequent practice in the application of the treaty which establishes the agreement of the parties regarding its interpretation;

(c) any relevant rules of international law applicable in the relations between the parties.

4. A special meaning shall be given to a term if it is established that the parties so intended.<sup>31</sup>

Ordinary meaning of treaty terminology may be approached in different ways, so long as good faith efforts are used. For some queries, meaning may be ascertained with reference to common dictionaries that capture the general idea of a term, or, reference may be made to the *travaux préparatoires*—the drafting history of the treaty—which could include diplomatic notes, early drafts, and committee minutes.

Taking a look at the dictionary approach, one sees that Black’s Law Dictionary defines ‘use’ as “the application or employment of something; esp., a long-continued possession and employment of a thing for the purpose for which it is adapted.”<sup>32</sup> Other definitions include to “take, hold, or deploy as a means to achieving something.”<sup>33</sup> National appropriation is trickier, with two juxtaposed terms to define. National may be defined as “[o]f or relating to a nation or country, esp. as a whole; affecting or shared by a whole nation.”<sup>34</sup> Appropriation is “[t]he making of a thing private property, whether

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31. *VCLT*, *supra* note 28, at art. 31.

32. *Use*, BLACK’S LAW DICTIONARY (8th ed., 2004).

33. *Use*, CONCISE OXFORD ENGLISH DICTIONARY (11th ed. 2009).

34. *National*, OXFORD ENGLISH DICTIONARY, <https://www.oed.com/view/Entry/125287?re-directedFrom=national#eid> (last visited Mar. 11, 2022).

another's or (as now commonly) one's own."<sup>35</sup> Taken together, these terms imply that the OST forbids States from engaging in a kind of land-grab in space, preventing them from exerting territoriality. As a consequence of this view, some scholars have gone so far as to speculate whether private enterprises may engage in appropriative activities on celestial objects, since by some definitions these would not be 'national' in character<sup>36</sup>—an approach dismissed by the great weight of academic work on the topic, especially since it may be argued any activity in space is national in character, given that Article VI of the OST requires that even non-State actors (e.g. corporations, individuals, etc.) must be authorized and supervised by a State to work in space.

Different dictionaries will employ their own definitions, but the gist is clear: the ordinary, good faith meaning of the word implies that States can find and utilize resources as needed, to achieve their ends—including whatever needs to be done to ensure the success of settlements in space. Further, phrases like 'use' and 'national appropriation' ought to be read in conjunction with one another. Together, they generate a controlling meaning, including the notion that States "have a legal right to the fruits of space exploration and use, by whomsoever carried out[.]"<sup>37</sup> When States begin mining resources in space, they will no doubt argue that *in situ* materials found on celestial objects constitute such 'fruits' of space exploration.

Further, the *travaux préparatoires* of the OST provide some backing for the idea that, during draft negotiations, the meaning of Article II's non-appropriation principle was questioned by some States. France in particular stated that it thought the words implied the differences between public and private law as applied to space,<sup>38</sup> which would give the term a substantially different meaning than most interpret it to have today. Professor Cheng clarified that other States did not read the term this way, but rather believed "that the alleged ambiguity does not, in fact, exist . . . it simply means that as among the contracting States, none will be entitled to exercise *territorial* jurisdiction . . . over any part of outer space or celestial bodies."<sup>39</sup> Looking at the debate over the term, "statements made by Brazil, Chile, Japan, the Netherlands, and the Philippines . . . would imply that they were of the view that

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35. *Appropriation*, OXFORD ENGLISH DICTIONARY, <https://www.oed.com/view/Entry/9877?redirectedFrom=appropriation#eid> (last visited Mar. 11, 2022).

36. Ricky Lee, *Article II of the Outer Space Treaty: Prohibition of State Sovereignty, Private Property Rights, or Both?*, 11 AUST. I.L.J. 128 (2004).

37. BIN CHENG, *STUDIES IN INTERNATIONAL SPACE LAW* 234 (1997).

38. *See, e.g.*, U.N. GAOR, 44th mtg., at 41, U.N. Doc. A/AC.105/PV.44 (Sept. 19, 1966) (questions posed by the French representative during negotiations).

39. CHENG, *supra* note 37, at 230.

the provision related to the prohibition of state sovereignty only,”<sup>40</sup> and not specifically to the idea of ownership over celestial resources for private property uses.

Finally, subsequent agreements between States provide some light on the topic. National appropriation in particular has been referenced by some of the State Parties to the OST in the more recent agreement known as the Artemis Accords.<sup>41</sup> While technically not a treaty under international law,<sup>42</sup> this agreement nevertheless represents the mood and intent of several space powers respecting a host of future space activities, best practices for space exploration, and the commitment towards cooperation in their pursuit. Among these pursuits is the idea that States will engage in resource extraction and utilization, and that “the Signatories affirm that the extraction of space resources does not inherently constitute national appropriation under Article II of the Outer Space Treaty, and that contracts and other legal instruments relating to space resources should be consistent with that Treaty.”<sup>43</sup> This agreement aligns with the sense that extracting *in situ* resources for numerous State purposes—including agriculture—does not offend the prohibition on non-appropriation set by Article II of the OST, at least in the view of the signatories.

It should be noted that the issue of resource extraction is contentious enough to attract the attention of the International Institute of Space Law, which tasked a group of scholars to determine if the OST forbade such activities. Their report analyzed the OST, as well as subsequent international agreements, and examined the topic using these agreements and national laws.<sup>44</sup> Ultimately, they neither supported nor rejected the idea that space mining or other forms of resource extraction are permissible, but took a more nuanced approach that assumed a multitude of legal considerations must be

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40. Lee, *supra* note 36, at 134 (referring to U.N. GAOR, 21<sup>st</sup> Sess., 1492 mtg., U.N.Doc. A/C.1/PV.1492 (Dec. 17, 1966)).

41. *The Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes*, NASA (Oct. 13, 2020) <https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf> [hereinafter *Artemis Accords*]. As of this writing, States having signed the Accords include: Australia, Brazil, Canada, Israel, Italy, Japan, Luxembourg, New Zealand, Poland, the Republic of Korea, Ukraine, the United Arab Emirates, the United Kingdom, and the United States.

42. The Accords are a meaningful geopolitical commitment between States, but they lack the features of a full-blown treaty, such as ratification and consent to be bound. See ANTHONY AUST, *HANDBOOK OF INTERNATIONAL LAW* 49-62 (2d ed. 2010).

43. *Artemis Accords*, *supra* note 41, § 10(2).

44. IISL Directorate of Studies, *Does International Space Law Either Permit or Prohibit the Taking of Resources in Outer Space and on Celestial Bodies, and How is this Relevant for National Actors? What is the Context, and What are the Contours and Limits of this Permission or Prohibition?*, INT’L INST. OF SPACE L. (2016), [https://iislweb.space/wp-content/uploads/2020/01/IISL\\_Space\\_Mining\\_Study.pdf](https://iislweb.space/wp-content/uploads/2020/01/IISL_Space_Mining_Study.pdf).

in place before any such activities happen. They conclude their study by stating:

“Considering the balancing of rights and prohibitions of the Outer Space Treaty, the use of space resources is not explicitly prohibited as long as the other obligations in the treaty are met. More concretely, the treaty guarantees the freedom of exploration and use, but under certain conditions, e.g. ‘for the benefit and in the interests of all countries’, ‘without discrimination of any kind’, ‘in accordance with international law’, with ‘free access to all areas of celestial bodies’, ‘guided by the principle of cooperation and mutual assistance’, ‘with due regard to the corresponding interests of all other state Parties to the Treaty,’ and so as to ‘avoid harmful contamination.’ States should endeavor to ensure that these conditions are met before the ‘right to use space resources’ can be exercised. This is necessary to ensure that space activities, including exploitation endeavors, will serve all humankind.”<sup>45</sup>

The weight of scholarship indicates that using space resources, including for agricultural needs, does not offend the OST or other international agreements, at least so long as the particulars of those agreements are effectively implemented along the way. There is, however, one notable exception in international law: namely, the Moon Agreement.<sup>46</sup> The final treaty in the OST regime, the Moon Agreement sets up a series of rules and expectations for States using the space environment, and this includes the only direct reference to resource extraction in any of the space treaties. With two exceptions, the Moon Agreement forbids resource extraction and ownership by any States, international organizations, or private entities, claiming that the resources of the Moon and other celestial bodies are the common property of humanity, or more notably the “common heritage of mankind.”<sup>47</sup> This barrier can be overcome if States agree to subject their mining opportunities to supervision and redistribution by an international body that determines how much of the extracted resources the extracting State gets to keep.<sup>48</sup>

The challenges this rule provides to developing space resources are profound, and currently would preclude State Parties to the Moon Agreement from engaging in resource extraction for most purposes. However, the same treaty authorizes a specific type of resource extraction by States that does not

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45. *Id.* at 34.

46. *Moon Agreement*, *supra* note 12.

47. *Id.* at art. XI(1).

48. *Id.* at art. XI(5). This redistribution of wealth, by an international body which does not yet exist, and for which rules of operation have yet to be determined, has become a sticking point for State ratification. Few States have ratified this treaty, making its potency in the realm of space law comparatively diminished within the context of the other four treaties.

require the implementation of an international body to redistribute resources. Article VI(2) authorizes “the right to collect on and remove from the moon samples of its mineral and other substances. Such samples shall remain at the disposal of those States Parties which caused them to be collected and may be used by them for scientific purposes.”<sup>49</sup> It is unclear whether this type of scientific investigation by States would include extracting *in situ* resources for the purposes of agriculture to sustain a facility or installation on a celestial object. It remains to be determined if it would matter if the facility was one dedicated exclusively to scientific pursuits, or if commercial enterprises would be barred by this rule from studying the application of space resources towards agriculture. It may be presumed that exploratory studies involving agriculture would not outright offend the Moon Agreement, so long as these are couched as ‘scientific.’ Yet, surely the kind of large-scale application of extracted resources needed to sustain the nutritional needs of a space settlement would not be permitted, since these would be, seemingly, outside of the scope of the exception. Thus, States which have ratified the Moon Agreement will have a more challenging time finding a way to feed their colonists.

Based on the above processes, as guided by Article 31 of the VCLT, treaty terms like ‘use’ and ‘national appropriation’ give the sense that the international law regime, at least as dictated by the OST and with the exception of the Moon Agreement, does not preclude the right to acquire, process, and repurpose materials found on celestial bodies. Certainly, there is no prohibition on using materials for the purposes of agriculture or experiments with food crops, especially in light of the fact that these activities fully conform with the purpose and intent of the Treaty for States to freely use and explore the space environment.

## VIII. ASTEROIDS & COMETS

Finally, a peculiar question remains regarding a potential target of space agriculture—asteroids. Some of these objects may provide the means by which agricultural experiments or processes may be engaged. As stated above, it seems as if international law currently contains no clear objection to the use of space resources for these purposes.<sup>50</sup> However, there is some question as to whether asteroids are even considered celestial bodies, for the purposes of the OST. Certainly the original drafters meant to claim bodies like the Moon, or Mars, were celestial in their legal nature. Yet, it is less clear that substantially smaller objects—like asteroids and comets—are given the same attention by the Treaty and its progeny. If they are not, then any vacillations or concerns over ‘appropriation’ of such objects need not

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49. *Id.* at art. VI(2).

50. *Supra* Section VII, at 109.

worry intrepid space farming operators, as the Treaty would arguably not apply to them in the first place.

Judge Manfred Lachs—of the Court of International Justice fame—broached this topic in his 1972 work, *The Law of Outer Space*.<sup>51</sup> Reflecting on the vast size differences between the types of objects naturally found in space, he noted that “in the present state of man’s knowledge there is little that can serve as a basis for any distinction between a natural or physical definition of a celestial body, on the one hand, and a legal definition, on the other.”<sup>52</sup> In other words, lacking a definitive, universal, and immutable scientific definition of ‘celestial body,’ it is legally sound to simply consider any and all non-manmade objects in space to be celestial objects for the purposes of the OST regime. Asteroids are celestial objects under current legal understanding. This stated, they are still subject to potential exploitation by States or their representatives in space, so long as these activities do not amount to national appropriation by their nature.

## IX. NATIONAL LAW & POLICY

If international law permits, or at the very least does not actively restrict, gathering *in situ* resources on celestial bodies, then the law of individual States will determine if and when these activities take place. Of national law, precious little has been produced. A notable exception to this is the United States’ Commercial Space Launch Competitiveness Act (CSLCA) of 2015,<sup>53</sup> which extended the right to engage in space mining to U.S. citizens or entities working with the United States.<sup>54</sup> Title IV of the CSLCA is known as the Space Resource Exploration and Utilization Act, and it specifically authorizes United States citizens to extract and keep space resources found *in situ* on celestial objects.<sup>55</sup> Cognizant of possible pushback from the other powers, Congress specifically noted that this kind of activity does not, in its view, constitute impermissible national appropriation in violation of Article II of the OST.<sup>56</sup> The view of the United States is that space resources are fair game for exploitation, including for commercial applications. As written, the

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51. MANFRED LACHS, *THE LAW OF OUTER SPACE: AN EXPERIENCE IN CONTEMPORARY LAWMAKING* (Tanja Masson-Zwaan & Stephan Hobe, eds., Martinus Nijhoff Publishers 2010) (1972).

52. *Id.* at 44.

53. U.S. Commercial Space Launch Competitiveness Act, 51 U.S.C. §§ 51301-03 (2015).

54. *Id.*

55. *Id.* § 51302(a)(3).

56. *Id.* § 51303. In crafting this section, Congress sought to preemptively dismiss arguments that might be forthcoming, and which would suggest space mining is a ‘national appropriation’ under the OST. The view of Congress here is that this law is not authorizing a violation of Article II, but merely permitting the lawful extraction of resources from a ‘commons’, in much the same way that catching fish in international waters is not an appropriation of those waters.

law would permit resource extraction and processing for agricultural needs to sustain space settlements, providing an opportunity to citizens wishing to seek their fortunes pursuing such a service.

The view of Congress was that permitting citizens to use and exploit celestial resources was consistent with historical activities. They argued that “State practice is consistent with finding that exploration and use of outer space includes the right to remove, take possession, and use *in situ* natural resources from celestial bodies.”<sup>57</sup> This was a specific reference to how several States have taken resources from the Moon or other celestial objects, and have asserted a form of State ownership over them. Such actions “have never been protested by a State party to the treaty or judged in a court of law to be in violation of the Outer Space Treaty.”<sup>58</sup> Congress took note of a case involving the attempted sale of a Moon rock, and how the court involved intoned that a State was permitted to own such an object.<sup>59</sup>

These examples were provided by a subcommittee in the House of Representatives that was attempting to assuage the concerns other lawmakers might have had regarding the attempt to permit the commercialization of *in situ* resources. In fairness, these examples cite to scientific recovery missions, where celestial resources were acquired by States with the intention of studying their properties. These activities were not commercial in nature, nor were they representative of the kind of largescale mining of space resources that may be needed for sustainable agricultural programs on installations or facilities. In this way, they establish that resources may be owned by States—at least for scientific analysis—but they are neutral with respect to the types of activities future space settlements would need to undertake.

Whatever its political origins, the CSLCA’s permissiveness reflects the drive towards exploration and commercialization often promulgated in U.S. space policies. As noted earlier, the intentions of the CSLCA are echoed in the Artemis Accords, where the United States and several other States have agreed on rules of the road for future space exploration. In this way, state practice for both the United States and several other States is emerging in the direction of engaging in space resource extraction and utilization for a host of purposes. As currently developed, State practice provides no barriers to agricultural studies or provisioning in space.

All roads lead to the conclusion that agricultural uses of *in situ* resources would be permissible, at least where those resources are used or processed inside a State’s facility or installation. States retain jurisdiction and control

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57. H. REP. NO. 114-153, at 8 (2015).

58. *Id.*

59. *United States v. One Lucite Ball Containing Lunar Material*, 252 F. Supp. 2d 1367 (2003).



over their activities inside such facilities,<sup>60</sup> and if the OST is not a bar to their plans, then colonists can use resources from their surroundings to grow crops onboard.

## X. PLANETARY PROTECTION POLICY

If the law allows space mining for agricultural needs, the remaining non-technical barriers to these activities, if any, are based in policy. It is left to the States, as participants in the international world, and as sovereigns over their own citizens, to determine if policies protecting celestial objects from a human presence will override the desire to encourage manned exploration and colonization of the solar system.

Legal permissibility notwithstanding, States are subject to other guiding forces that will impact their ability to successfully settle celestial objects. Foremost among these are space exploration policies concerning planetary protection, both at the international and national levels. Planetary protection policies (“PPP”) can be split into two general categories: 1) those intended to protect the Earth from potentially devastating interactions with asteroids or other “planet killing”<sup>61</sup> objects; and 2) those intended to protect both the Earth and other celestial objects from biological or chemical contamination resulting from the process of exploration. The first of these PPP categories is outside of the scope of this article. The second category directly concerns States considering building, staffing, and sustaining facilities or installations on celestial objects as a result of their goals to settle or colonize outside of Earth.

For international planetary protection policies, the Committee on Space Research (“COSPAR”) Planetary Protection Policy is the gold standard.<sup>62</sup> COSPAR is an international body whose members promote scientific studies in space.<sup>63</sup> The work of the organization is diverse, but their PPP serves to assist States planning missions to space. The PPP helps States consider what precautions ought to be taken to prevent biological contamination of celestial objects being explored; i.e., it serves to help set standards to prevent the transfer of organisms and organic contaminants from Earth to the celestial object being studied. The Policy notes:

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60. *OST*, *supra* note 10, at art. VIII.

61. *See, e.g.*, Ed Browne, *NASA Would Consider Nuking an Asteroid Hurling Towards Earth, Says Agency Scientist*, NEWSWEEK, (April 30, 2021), <https://www.newsweek.com/nasa-would-consider-nuking-asteroid-hurling-towards-earth-says-agency-scientist-1587875>.

62. G. Kminek, et. al., *COSPAR Planetary Protection Policy*, COMM. ON SPACE RSCH. 12-25 (2017), <https://cosparhq.cnes.fr/assets/uploads/2019/12/PPPolicyDecember-2017.pdf> [hereinafter *COSPAR PPP*].

63. *About*, COMM. ON SPACE RSCH. (May 20, 2019), <https://cosparhq.cnes.fr/about/>.

[F]or certain space mission/target body combinations, controls on contamination shall be imposed in accordance with a specified range of requirements, based on the following policy statement:

The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with issuances implementing this policy. ([4, 5]; ESA PPWG 2008)<sup>64</sup>

This policy demonstrates that COSPAR's primary concern is that Earth-based contaminants do not impede the search for extraterrestrial life, or any chemical clues that life has once or one day could exist on a celestial object outside of the Earth. This kind of forward contamination may be eliminated through rigorous protocols sanitizing objects that will be in close contact with celestial objects of interest. Further, there are five distinct categories—each with its own standards of care—that guide missions to different types of objects in the solar system.<sup>65</sup> Of these objects, Earth is clearly the most important, and so there is also a concern that contaminants may be discovered on celestial objects that could pollute the Earth when brought back for study; such pollution is known as backwards contamination.<sup>66</sup> For other objects, the likelihood that life exists or has existed on them will determine the types and depth of protection offered.

COSPAR's Planetary Protection Policy is influential on States acting and operating in space, despite the fact that at the end of the day, these are not hard laws which restrict States to certain behaviors. Still, the Policy exists as an extension of a hard law rule to which State Parties to the OST are bound. Article IX of the OST sets up an environmental standard for the use and exploration of space, requiring that States:

[S]hall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial

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64. *COSPAR PPP*, *supra* note 62, at 13.

65. For example, Categories I and II concern missions where there is a limited concern that contaminants from Earth could cause harm to the body under study, whereas Category IV “comprise certain types of missions (mostly probe and lander) to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant chance of contamination which could compromise future investigations.” *COSPAR PPP*, *supra* note 62, at 14.

66. *Id.* at 19.

matter, and where necessary, shall adopt appropriate measures for this purpose.<sup>67</sup>

In this way, the COSPAR PPP is designed to assist State Parties to the OST in fulfilling their obligations towards responsible exploration of the space environment. As such, any State interested in exploring celestial objects for potential locations for a research installation, facility, or settlement, would be wise to consider the PPP before undertaking their mission, especially where they are already bound by the provisions of the OST. Even States who are not bound by international law to follow this Policy have a blueprint readily available to conduct their own space exploration in ways that do not interfere with the search for life or its origins.

While the COSPAR PPP is primarily concerned with exploration, and not colonization, the concern over impeding the search for life becomes all the more pressing for permanently inhabited stations or installations on celestial objects. Using Mars an example, if States choose to engage in micro-terraforming, or changing small parts of that world in order to make it more hospitable to growing plants, the PPP rules regarding Category IV bodies would stand opposed. Any State which opts to follow the PPP will need to respect the intended protections for Mars and may be restricted from performing agricultural experiments where those activities could jeopardize the search for life. For instance, even if sections of Mars might be cut off from the outside weather through the use of biodome architecture, the soil contained within the agricultural facility could be exposed to microbiological life from Earth—anything from fungi to bacteria—that would impermissibly alter the composition of soil on that section of the planet. It could be argued that such a facility would not expose the outside to the same microbial fauna; yet, the risk would always be present that what is cultivated inside the facility could eventually escape their confines through leakage, accidents, etc.

## XI. NATIONAL SPACE POLICY

Just as few States have space-specific laws in place, many lack national space policies. An exception to the norm is the United States of America, which has a robust tradition of crafting and abiding by space policies set by the president. At the time of this writing, the National Space Policy of 2020<sup>68</sup> (“NSP 2020”) governs U.S. governmental priorities for the outer space environment, and its breadth captures anything from defense policy in space,<sup>69</sup>

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67. *OST*, *supra* note 10, at art. IX.

68. *National Space Policy of the United States of America*, TRUMP WHITE HOUSE ARCHIVES (Dec. 9, 2020), <https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/12/National-Space-Policy.pdf>.

69. *Id.* at 4.

to caring for the environment upon which space operators depend.<sup>70</sup> The current National Space Policy of the United States<sup>71</sup> does emphasize the need to preserve the space environment during its exploration and use. However, it also prioritizes experimentation and commercialization in space.<sup>72</sup> These provisions will help shape opportunities for growth in space, including efforts at colonizing, that are bound by responsible uses. As a State Party to the OST, the United States must abide by all of its provisions, including Article IX's prohibition on harmful contamination of the space environment. With the 2020 policy, the president has directed the US Government to help both public and private space actors to explore and exploit outer space, so long as this is done in compliance with international law.

In the United States, there are additional environmental policies that control specific federal agencies, like NASA, working in space. Private or corporate actors operating in space would have more leeway, unless they are working in cooperation with NASA and subject to its policy directives. However, even private actors are bound to the OST by virtue of the fact that the State which authorized their activities is internationally responsible for whatever they do in space.<sup>73</sup> Consequently, any private corporate attempts to experiment with agriculture in space not only are bound by the obligations imposed by the OST on the host State, but State-specific policies, like the NSP 2020, will impact how private actors behave.

For NASA, many of their own exploration requirements are founded in one way or another on international planetary protection policy, with particularized guidance offered relevant to distinct space missions. Indeed, while the COSPAR PPP guidelines are not legally binding hard law, States that elect to follow them anyway will limit their own operations through various means. Because Article IX of the OST encourages States that are party to the treaty to create their own policies and laws to protect the environment of space “where necessary[,]”<sup>74</sup> States sometimes produce their own regulations to effectuate this requirement. In the United States, NASA designs its own PPPs<sup>75</sup>—reflective of what is seen in the COSPAR guidelines—and consequently will need to refrain from any agricultural experiments or programs on celestial bodies that would be potentially damaged by such activities.

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70. *Id.* at 5.

71. *Id.* at 1.

72. *Id.* at 3.

73. *OST*, *supra* note 10, at art. VI.

74. *OST*, *supra* note 10, at art. IX.

75. See *Planetary Protection*, NASA OFF. OF SAFETY & MISSION ASSURANCE (Dec. 5, 2021), <https://sma.nasa.gov/sma-disciplines/planetary-protection> (listing and describing various directives the space agency follows when authorizing and conducting both robotic and human missions in space).

NASA's internal directives make it clear that the agency will conduct its missions—both robotic and human—with reference to the COSPAR PPP, and in deference to Article IX of the OST.<sup>76</sup> NASA's specific Interim Directive (“NID”) on human exploration of Mars notes its breadth, stating, “[T]he provisions of this NID cover human spaceflight missions with NASA involvement, which may intentionally or unintentionally carry terrestrial organisms and organic constituents to the planets or other solar system bodies.”<sup>77</sup> This is applicable even to private contractors working with NASA or recipients of NASA grants.<sup>78</sup> NASA can and does periodically change its internal directives and procedural requirements, but given its dedication to COSPAR and the OST as guiding forces in its exploration policies, future changes will, if anything, likely be increasingly cautious regarding the impact exploration can have on the search for life on celestial bodies. Consequently, NASA will need to take care that its own plans to explore and colonize Mars<sup>79</sup> do not offend COSPAR guidance. Long duration missions to the Red Planet will necessitate the need for a food sustainability program, and early missions to Mars will need to pioneer effective and reliable agricultural methods.

## XII. TERRAFORMING: THE DISTANT FUTURE

No discussion of agriculture in space would be complete without referencing the fantastic notion of terraforming—the process of changing the nature of a celestial object to become more hospitable to human life, or to become Earthlike enough to support crop growth on a massive scale. The myriad issues associated with terraforming deserve their own analysis; however, for the purposes of this essay, the focus should be on obligations States have to either the OST regime, or to planetary protection policies. The idea of terraforming has been studied as a challenging, but not necessarily impossible task if given enough resources and time.<sup>80</sup> Given the current technical infeasibility of such a project, it seems the time is still far off before attorneys will need to wrestle with the legality of planet-altering processes.

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76. See, e.g., *NASA Procedural Requirement 8715.24: Planetary Protection Provisions for Robotic Extraterrestrial Missions*, NASA OFF. OF SAFETY AND MISSION ASSURANCE, (September 24, 2021), <https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8715&s=24> (this policy mandates a high level of care taken for robotic space missions, directly listing the need to hew closely to both the COSPAR standards as well as the OST).

77. *NASA Interim Directive 8715.129, Biological Planetary Protection for Human Missions to Mars*, at 2, NASA OFF. OF SAFETY & MISSION ASSURANCE (July 9, 2020), [https://nodis3.gsfc.nasa.gov/OPD\\_docs/NID\\_8715\\_129.pdf](https://nodis3.gsfc.nasa.gov/OPD_docs/NID_8715_129.pdf).

78. *Id.*

79. See, e.g., *NASA is Recruiting for Yearlong Simulated Mars Mission*, NASA (Aug. 6, 2021), <https://www.nasa.gov/feature/nasa-is-recruiting-for-yearlong-simulated-mars-mission>.

80. See, e.g., M. J. Fogg, *Terraforming Mars: A Review of Current Research*, 22 *ADV. SPACE RES.* 415, 416 (1998).

Still, assuming *ad arguendo* that terraforming could be done, the current structure of international law and policy would bar the attempt—at least for some celestial objects, if not for all. Recalling Article IX of the OST, States are required to conduct their exploration of space and any celestial objects therein “so as to avoid their harmful contamination[.]”<sup>81</sup> As with the terms ‘use’ and ‘national appropriation’ above, whether terraforming a celestial object would constitute harmful contamination would need to be subjected at the very least to the VCLT’s Article 31 to ascertain what those words mean in good faith.

Yet, terraforming a celestial object could involve not only changing its atmospheric composition, but also introducing innumerable species and organic compounds to change the soil into something arable for Earth species. Such an activity would immediately offend the COSPAR PPP for objects like Mars, where scientific investigation into the possibility of life would be thwarted by the introduction of Earth species. States that have ratified the Moon Agreement would be especially restricted, as that treaty tells them that “[i]n exploring and using the moon, States Parties shall take measures to prevent the disruption of the existing balance of its environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise.”<sup>82</sup>

As for the OST, it would be hard to imagine a clearer example of contamination than intentionally introducing Earth species in an effort to change the nature of a planet. The real test of Article IX here, and the question for space law, is whether that contamination is harmful. Proponents of creating new farmlands for deep space explorers and colonists might say it is far from harmful, since in their view space is meant to be explored and used by humanity. Scientists studying the nature of life in the universe would vociferously disagree and would argue there is much knowledge that could be lost to terraforming.

### XIII. CONCLUSION & ADDITIONAL CONSIDERATIONS

The above survey of law and policy demonstrated that there are few rules governing the possibility of *in situ* resource extraction with the goal of supplying raw material for agricultural experiments or food production in space. Those that exist trend towards permitting, or at least not barring, the use of material found in space to help sustain settlements on celestial objects. Increasingly, States are agreeing that mining space resources is consistent with obligations under the OST, although those few which have also ratified the Moon Agreement may find their future efforts at extraction and utilization

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81. *OST*, *supra* note 10, at art. IX.

82. *Moon Agreement*, *supra* note 12, at art. VII(1).

challenging. Domestic laws are few and far between, but the CSLCA in the United States explicitly authorizes extraction and use of *in situ* space resources, clearing the way for citizens to live and work in space, and to use what they find there to do so.

International policy poses the larger challenge. States which purport to follow the COSPAR PPP will need to design their use and exploration of space so as to avoid introducing biological materials from Earth into any celestial objects which are of interest to the search for extraterrestrial life. Specific policies, like the NIDs and NASA's Procedural Requirements followed by NASA in the United States, also create challenges for future space settlements. However, COSPAR's PPPs are not legally binding on States, and internal domestic policies may be altered by States at any time. Should a State seriously wish to build a permanently inhabited facility on the Moon, Mars, or another celestial object, they could do so. International law as currently written does not prohibit agricultural production in such facilities, including using *in situ* resources as needed.

Whether and how States will use such resources to sustain their future space settlements is currently unknown. What is known is that even if international law does not bar their activities, they nevertheless need to conduct them with other elements and obligations of the OST regime in mind. In particular, Article I of the OST notes that the use and exploration of space must be for the benefit of all States.<sup>83</sup> What exactly this means has yet to be fully explored, but it is clear that it is a binding aspect of the law. Some have argued this phrase is merely aspirational,<sup>84</sup> but future settlements may need to explain how their agricultural practices benefit all of humanity, and not just the State or corporation engaged in them.

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83. *OST*, *supra* note 10, at art. I.

84. CHENG, *supra* note 37, at 234-35 ("there seems to be no valid reason why [benefiting all States in with space activities] should not be treated as stating a binding legal obligation... [But] the discussions which took place on several articles of the treaty clearly showed that its draftsmen hardly intended this part of Article I to be anything more than a declaration of principles from which no specific rights of a legal nature were to be derived, even though it might give rise to a moral obligation.").