# SPACE GOVERNANCE 3.0[*]

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I want to first give my thanks and congratulations to the editors of the *Georgia Journal of International and Comparative Law* and to the Dean Rusk Center, for a timely and beautifully executed symposium.

I will contribute to our confrence theme, the "Future of Space Governance," by offering a perspective on evolutionary changes in how the rules governing human activity in the space domain are made, and who makes them.[1] I'll begin by unbundling what I see as the constitutive strands of our topic. Assumptions about the future of space activities necessarily underpin predictions about the future of space governance, and I will shortly outline my assumptions in this regard. I will do the same for the national and international lawmaking processes that shape the international regime for outer space. In short, I do not foresee the conditions for major multilateral treatymaking returning in the near term,[2] although I hope to be proven wrong. I do foresee the intervention of a new technological medium for governance enriching the future of space governance. Accordingly, I will introduce blockchain technologies and illustrate how the capacity of spacecraft operators to make and enforce commitments, without recourse to a national legal system, may unlock new solutions to governance challenges inherent in the legal and physical attributes of the space domain.

My assumptions about the future of space endeavors are closely linked with my own experience with emerging space technologies and activities; I'll summarize this experience to make my biases and blind spots apparent. I served in the State Department's Office of the Legal Adviser from 2009 to 2017. For most of this time, I was the primary official responsible for international negotiations to interpret and apply the international legal framework for space to newly-contemplated space activities. I also worked to adapt U.S. regulatory frameworks for non-governmental space activities to implement international obligations. My time at the State Department coincided with a new

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[1] The scope of space governance rules I address are those of common concern to users and beneficiaries of activities in the space domain. Domestic rules about space activities serving only national public policy ends, such as public safety in the vicinity of a launch range or national security restrictions on Earth imaging, are outside my concept of space governance.

[2] *See* Brian R. Israel, *Treaty Stasis*, 108 AJIL UNBOUND 63 (2014).

dynamism in commercial space activities. While private enterprise has been involved in space exploration since the beginning, the planned activities that began to surface in the early 2010s combined two attributes that enlivened space governance debates in both the United Nations and in national capitals. First, whereas a government had generally been a customer—if not an operator—of commercial space activities, the government's relationship to this new generation of pure commercial space activities would be solely as a regulator. Second, some of the planned private space missions went beyond what governments had achieved in space and implicated the international legal framework in novel ways.

In 2017 I left government and became General Counsel of one such company: Planetary Resources, a venture-backed asteroid mining company. From that vantage point as a private operator trying to push forward the boundaries of space exploration, I gained some fresh perspective on the limits of the traditional mechanisms of space governance and began to envision a future with a richer set of tools for collective action in the space domain. About this time last year, Planetary Resources was acquired by ConsenSys, a blockchain technology company, and I co-founded ConsenSys Space and began to put my ideas for space governance tooling into action.

On the opening day of the International Astronautical Congress, ConsenSys Space released an experimental open source, open-sensor system called TruSat for creating an independent record of satellite orbits.[3] We designed TruSat to fill what we believe is a crucial gap in transparency and accountability for sustainable orbital operations by supplying a freely accessible, globally-trusted source of space situational awareness data that can be used to measure satellite operators' performance against sustainability standards. Progressing TruSat from a limited prototype to a valuable resource for preserving the future of spaceflight will depend on the ideas and efforts of a global open source community.

TruSat is but a modest first step along a path I see for how blockchain technologies could unlock new solutions to some of the most stubborn space governance challenges. I will introduce the opportunities I see, mindful of the perils of predicting the future not only of space activities, but also a promising-but embryonic technology in its early days.

Before we explore solutions, let's begin with the problem. The most general challenge of space governance I am concerned with is maintaining a cohesive international regime for all space actors. I use "international regime" as defined by Stephen Krasner: "principles, norms, rules and decision-making procedures around which actor expectations converge in a given issue-area."[4]

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[3] Press Release, ConsenSys, ConsenSys Space Launches TruSat System (Oct. 21, 2019), https://consensys.net/blog/press-release/consensys-space-trusat-_-10-22-2019/.

[4] Stephen D. Krasner, *Structural Causes and Regime Consequences: Regimes as Intervening Variables*, 36 INT'L ORG. 185 (1982).

While I refer to international regime in the singular for simplicity, the future of human space endeavors will likely require a number of specialized regimes to account for practical and political realities that vary by activity and location. For example, the physics and prevailing uses of Low Earth Orbit (LEO) counsel for different end-of-life spacecraft disposal practices than the Geosynchronous Orbit (GEO). The maturation of space resource utilization activities will almost certainly require an international regime addressing the most fundamental dimensions of this family of activities, as well as specific regimes for, say, the Moon, or even lunar poles.

The growing number and diversity of space actors, a symptom of progress in many respects, also challenges the cohesion of the international regime. This growth, diversity, and the attendant governance challenges are most apparent in LEO, where university cubesat missions share the increasingly congested orbital regime with all manner of commercial satellites and government national security missions. So-called "mega-constellations" of LEO satellites blanketing the Earth in broadband internet coverage are projected to increase the population of active LEO satellites ten-to-twenty-five-fold over the coming decade.[5] This magnitude of LEO congestion, dramatically increasing the frequency of potential satellite collisions, heightens the imperative for clear, rules-of-the-road-like norms internalized by all actors. In this domain beyond territorial jurisdiction, with this diversity of public and private actors, how do we achieve such a cohesive international regime?

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[5] The lower range of the estimate is based upon regulatory filings and public statements by SpaceX, OneWeb, and Amazon's Project Kuiper. The Federal Communications Commission (FCC) authorized 7,518 of the V-band satellites, and 4,409 of Ku- and Ka-band satellites comprising SpaceX's Starlink constellation. *See* In the Matter of Space Holdings, LLC, F.C.C. 18-161 (Nov. 19, 2018), docs.fcc.gov/public/attachments/FCC-18-161A1.pdf; In the Matter of Space Holdings, LLC, D.A. 19-342 (Apr. 26, 2019), docs.fcc.gov/public/attachments/DA-19-342A1.pdf. Amazon subsidiary Kuiper, LLC has sought approval of a constellation that "will consist of 3,326 satellites in 98 orbital planes at altitudes of 590 km, 610 km, and 630 km." FED. COMMC'NS COMM'N, APPLICATION FOR AUTHORITY TO LAUNCH AND OPERATE A NON-GEOSTATIONARY SATELLITE ORBIT SYSTEM IN KA-BAND FREQUENCIES. Whereas OneWeb received FCC authorization for a constellation of 720 satellites in 2017 and indicated it was considering adding an additional 1,972 satellites, more recent public statements suggest the constellation will be fully operational at 648 satellites. *Compare* Press Release, Federal Communications Commission, FCC Grants OneWeb Access to U.S. Market for Its Proposed New Broadband Satellite Constellation (June 22, 2017), https://www.fcc.gov/document/fcc-grants-oneweb-us-access-broad band-satellite-constellation, *and* Tereza Pultarova and Caleb Henry, *OneWeb Weighing 2,000 More Satellites*, SPACENEWS (Feb. 24, 2017), spacenews.com/oneweb-weighing-200 0-more-satellites/, *with* Caleb Henry, *How OneWeb Plans to Make Sure Its First Satellites Aren't Its Last*, SPACENEWS (Mar. 18, 2019), spacenews.com/how-oneweb-plans-to-make-sure-its-first-satellites-arent-its-last/. The upper range of the estimate accounts for the October 2019 regulatory filings by SpaceX for an additional 30,000 Starlink satellites. *See* Caleb Henry, *SpaceX Submits Paperwork for 30,000 More Starlink Satellites*, SPACENEWS (Oct. 15, 2019), spacenews.com/spacex-submits-paperwork-for-30000-more-starlink-satel lites/.

For much of the first half century of spaceflight, the solution was to negotiate the rules of the road on a global basis and then extend these global rules to non-governmental space missions through national legislation and regulation.[6] The dynamics of these international negotiations are shaped by the constitutional nature of the Outer Space Treaty, and the Treaty's constitutional role within the international regime for space.[7] I have called this paradigm "Space Law 1.0."[8] The role of national legislatures in this paradigm is to extend agreements reached on the international plane to non-governmental space activities conducted by their nationals. In a world of frictionless international and national lawmaking processes, Space Law 1.0 might be the end of the story. But in labeling this "Space Law 1.0," you have probably deduced that the plot thickens.

What I term "Space Law 2.0" is a diffusion of the interpretation of the Outer Space Treaty to national legislatures; from an *inter-state* negotiation to a series of uncoordinated *intra-state* negotiations. My first encounter with Space Law 2.0 was the Space Resources Exploration and Utilization Act of 2015,[9] which, as its name suggests, concerns the exploration and utilization of the natural resources of celestial bodies. At the State Department I was involved in shaping the Act for consistency with the United States' obligations under the Outer Space Treaty. I was also the U.S. Representative to the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space at the time, and so I was responsible for explaining this controversial law to the world. Contrary to the breathless headlines and genuine concern this law generated around the world, I submit it changed precisely

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[6] Whereas non-governmental actors are not directly bound by the Outer Space Treaty and its progeny, Article VI of the Treaty provides that States Parties are internationally responsible for the non-governmental space activities of their nationals and obligates States Parties to continuously supervise such non-governmental activities to ensure their conformity with the Treaty. *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies art. VI, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205.

[7] In *Space Resources in the Evolutionary Course of Space Lawmaking*, 113 AJIL UNBOUND 114 (2019), I explained:

> Much like the U.S. Constitution, the treaty abstains from regulating specific activities, supplying instead the basic legal building blocks for addressing new activities and capabilities. The treaty's open-textured principles do not prescribe a single solution in most cases, but shape and constrain the universe of solutions. Solutions require negotiation, and the treaty's open texture leaves room for negotiated outcomes that accommodate a range of interests. Changing the OST's principles themselves is not on the table for negotiation.

[hereinafter Israel, *Space Resources*]; *see also* Israel, *supra* note 2, at 64, 67 (explaining the forces that make amending or replacing the treaty unlikely and undesirable, placing the treaty in a de facto constitutional role within the regime).

[8] *See* Israel, *Space Resources*, *supra* note 7, at 115.

[9] Pub. L. No. 114-90, § 402(a), 129 Stat. 721 (codified at 51 U.S.C. § 51303).

nothing about the substantive law or procedure regarding space resource utilization in the United States. But the concern is understandable, because, upon first reading, it can easily be mistaken for casually answering one of the most sensitive questions in international space law at the time: Whether, and under what conditions, the natural resources of celestial bodies may be utilized.

I'm not going to unpack the law and politics of space resources; what's important here is that the Act simply points back to the United States international obligations without opining on the content of those obligations. Congress abstained from interpreting the Treaty to expressly delineate the contours of permissible space resource utilization activities.[10] It left this to the Executive Branch, which evaluates non-governmental space activities for conformity with the United States' international obligations through federal licensing processes.

While the Space Resources Exploration and Utilization Act did not effectuate substantive changes in space law, it is nevertheless noteworthy for the evolutionary trends in space activities that led the U.S. Congress to be seized with a controversial matter concerning the interpretation of the Outer Space Treaty. With the prospect of private space missions that go beyond what even governments have done in space, national legislatures are wading into controversies over the interpretation and application of the Outer Space Treaty in parallel with—or even ahead of—international lawmaking processes. This diffusion of treaty interpretation to national legislatures is what I classify as Space Law 2.0.[11]

A distinctive feature of Space Law 2.0 is that national legislators are not simply extending a settled treaty interpretation to their nationals. Absent international consensus on what the rule is, national legislatures are in the position of weighing in on one side or another of an unresolved interpretive debate. In Space Law 2.0, knotty questions of treaty interpretation that have traditionally been the province of inter-state negotiations become the subject of multiple intra-state negotiations.

Why does any of this matter? Devolving the interpretation and application of the Outer Space Treaty to multiple intra-state negotiations makes it much more difficult to maintain a single, coherent international regime for all actors in the space domain. The worst-case scenario is legislative outcomes completely divorced from available interpretations of the Treaty, fracturing the regime. This, thankfully, was not what happened with the Space Resource Utilization Act.

The best-case scenario is what I term "constitutional multipolarity": the constitutional role of the Treaty is preserved across multiple uncoordinated

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[10] The Act embodies an *implicit* interpretation of the Treaty, insofar as it implies that the universe of space-resource utilization that is consistent with the United States' international obligations is not a null set.

[11] *See* Israel, *Space Resources*, *supra* note 7, at 116.

national lawmaking processes, in that policy options are constrained to available interpretations of the Treaty. The absence of a centralized, authoritative mechanism for adjudicating divergent interpretations suggests that there will be more variability in national approaches than in the Space Law 1.0 paradigm. The difference between constitutional multipolarity and regime-destroying fragmentation is in the degree of variability permitted. Good faith interpretations may diverge but remain tethered to the Treaty. The regime bends but does not break.

What variables contribute to constitutional multipolarity in Space Law 2.0? In my limited experience, the engagement of foreign ministry lawyers in the legislative process is a key determinant of whether policy options will be constrained to available interpretations of the Outer Space Treaty, preserving the Treaty's constitutional role within the regime. While engagement by foreign ministry lawyers makes constitutional multipolarity more likely, it does not guarantee the outcome. Relative to international negotiations, the burden of persuasion for the relevance of international legal considerations in legislative negotiations shifts from the myriad interest groups seeking to influence the legislative outcome to the foreign ministry lawyer. The foreign ministry lawyer is often just one interest group among many, and concern for treaty compliance just one more interest to be balanced. This is not to pretend that industry and other stakeholder interests are absent as foreign ministries formulate positions for international negotiations. But, on the international plane, the foreign ministry lawyer holds the pen and interest groups bear the burden of persuasion. In Space Law 2.0, the dynamic is reversed.

Contrary to the software versioning convention I've adopted, Space Law 2.0 is not an improvement; it is a byproduct of disfunction in Space Law 1.0 processes. Yet it appears that Space Law 2.0 will form a part of our present and future of space governance. The dynamics leading national legislatures to be seized with interpreting and applying the Outer Space Treaty to new activities are just beginning. Non-governmental space missions are continuing to break new ground. And there does not appear to be political will for resolving some of the most intractable interpretive controversies on the international plane. I foresee private planetary missions and the questions they will raise about obligations under Article IX of the Outer Space Treaty to avoid "harmful contamination" of celestial bodies as the next Space Law 2.0 moment.

Space Law 2.0 has not, and will not, displace Space Law 1.0. They exist in parallel, in layers. Space Law 1.0 is inter-state: rules negotiated by governments on the international plane and extended to private actors via national legislation and regulations. Space Law 2.0 is intra-state: rules are negotiated in national legislatures ahead of, or in parallel with, negotiations on the international plane. Both are regulatory in nature; rules are made by governments and imposed on private actors utilizing the public law powers of the state. As I consider the likely trajectories of space activities and blockchain technologies and contemplate a "full stack" of space governance layers,[12] I envision a new layer. Space Governance 3.0 will be inter-operator: private law regimes constructed from contracts between spacecraft operators (and spacecraft, in some cases) in which all space actors, public and private, play on a level field.[13]

With ubiquitous private ordering among spacecraft operators, law in the space domain begins to more closely resemble the layering of public and private law found in terrestrial legal systems. Public law provides an overall framework and some guardrails for private ordering; that is, there are some public law rules that private parties may not contract around. But in many dimensions of commerce, sophisticated parties *do* routinely contract around public law default rules to adopt rules better tailored to their collaborative objectives. Take patent pools for example: patent holders contract away certain public law patent rights where doing so serves their interests.[14]

What does inter-operator private ordering add to space governance? To illustrate, let's imagine that a critical mass of the world's private satellite operators can agree on a set of rules for the disposal of spacecraft at the end of their operational life. While such rules entail a cost for operators, the operators have sufficient facility with math and physics to appreciate that the rules serve their long-term business interests, provided that substantially all operators comply with the rules. How would this community of satellite operators spanning dozens of countries overcome this classic collective action problem and secure universal adherence to the rules, ensuring that compliance will not place an operator at a competitive disadvantage? The traditional path would be for operators to lobby their respective governments to negotiate and conclude an international agreement embodying the end-of-mission disposal rules, which would then be extended to private operators by national legislation and regulation. A Space Law 1.0 solution. The operators' consensus on mutually-beneficial rules faces perils at every stage along this path. In my experience, national governments don't necessarily share the operators' pragmatism, and the consensus rules may be distorted or held hostage by unrelated issue-linkages or broader political agendas. Provided the operator-consensus rules survive intact through negotiations on the international plane, they will face political dynamics in national legislatures that have prevented many

[12] With "full stack" I continue to borrow software lingo. In software architecture, the "stack" refers to the layers of functionality that make up an application.

[13] My substitution for "governance" in place of "law" for the 3.0 layer in part reflects that the layer does not rely the coercive powers of a state to enforce. It also reflects my equivocation about the boundaries of these layers, and how they map to various philosophical conceptions of law. This lecture comes at a midpoint of my thinking about how the rules for the space domain will be made in the future, and I expect my concept of layers to evolve with further research and reflection.

[14] *See, e.g.*, Robert P. Merges, *Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations*, 84 CAL. L. REV. 1293, 1340–42 (1996).

countries, including the United States, from acceding even to international agreements overwhelmingly in the national interest.

Could our hypothetical satellite operators enter into a contract committing to one another to follow the end-of-life disposal rules? In theory they could construct a contractual regime prescribing rules for end-of-life disposal and consequences for their transgression. Yet both the negotiation and enforcement of such a contract would generate transactional friction at a magnitude the operators would likely find disproportionate to the benefits of cooperation. Contracts, after all, rely on the coercive power of a national legal system to enforce. In contract negotiations between nationals of different states, agreement on which state's laws will govern the interpretation of the contract, which state's courts will have jurisdiction over disputes, and which language will be authoritative in interpreting the contract's terms, can consume as much time as negotiations over the content of those terms. This transactional friction increases with the number of nationalities involved. Fixing these jurisdictional terms at the time the original parties enter into the contract makes it less likely that new satellite operators will opt-in to the contractual regime at a later date. And the high cost of enforcing a transnational contract makes the threat of sanctions for non-compliance less credible, diminishing the deterrence value of the contractual regime as operators weigh the costs and benefits of compliance.[15]

Constructing this contractual regime utilizing smart contracts built atop blockchain networks, such as Ethereum, would remove most of this transactional friction, making the formation of such private regimes more likely and the resultant regimes more effective. Smart contracts are similar to traditional legal contracts insofar as their parties agree on a set of rules and consequences for breach of those rules. Unlike a traditional legal contract, which depends on a national legal system to adjudicate and enforce, smart contracts are self-executing. Their rules and consequences are hard-coded, and they can automatically transfer valuable digital assets such as cryptocurrency between the parties. They are best suited for commitments for which compliance can be objectively determined.[16] It's not yet possible to code "good faith," for

[15] Opting for international commercial arbitration can reduce the uncertainty and costs of enforcement somewhat, but the costs remain high enough that enforcement may present its own collective action problem among the parties. Recognition and enforcement of an arbitral award still requires recourse to national courts with jurisdiction over the breaching party's assets.

[16] I submit that the automated *enforcement* functionality of smart contracts may offer advantages even where it's not possible to automate *adjudication*. In cases in which compliance cannot be automatically determined to the parties' satisfaction utilizing sensors and algorithms, the parties may designate individuals or institutions as "oracles," and prescribe the standards to be applied, the sources of data, etc., similar to an arbitration clause. Such hybrid smart contracts would not have the benefit of full automation but would extend the benefits of automated *enforcement* to a wider range of agreements (those whose terms are not sufficiently objective to be measured solely by machine). Whereas the *adjudication* of

example. Where the bargain can be reduced to sufficiently objective rules, smart contracts do provide the basic functionality of a self-contained, light-weight legal system. They enable their parties to efficiently make enforceable commitments to one another without recourse to a national legal system. For participants, regimes implemented in smart contract may feel more "legal"—in terms of precision and enforceability—than much of the international legal framework for outer space.

Let's examine how our hypothetical satellite operators could employ smart contracts to construct a more efficient, more effective regime for end-of-life disposal of satellites. Like a traditional contract, the parties must precisely describe their commitments, and the consequences for breach of those commitments. Unlike a traditional contract, these commitments and consequences are ultimately embodied in computer code; it is unnecessary to reach agreement on whether English, French, Russian, or Chinese is the authoritative language for interpreting a contract interpreted and applied by machines. Nor is it necessary for parties to agree on which nation's laws and courts have jurisdiction over the contract, as the contractual regime does not rely on any national legal system for enforcement.[17] Smart contracts are creatures of public blockchain networks, such as Ethereum, which are distributed across thousands of nodes, beyond the control of any entity.

The satellite operators would likely devote considerable attention to specifying the "oracles" that determine compliance with the smart contract's rules and trigger enforcement. For an unusually simple rule—say, all satellites must be lower than 285 kilometers within "x" days of an objectively observable event—a fully-automated oracle, informed by agreed sources of space situational awareness (SSA) data, is theoretically possible. More likely, the parties would designate a panel of individuals or entities to interpret the SSA data and determine compliance with the regimes satellite disposal rules. Once an oracle designated by the smart contract has determined a breach of a rule, the contract automatically executes the consequences prescribed by the parties, possibly transferring valuable digital assets from the breaching party to the other parties. The automaticity of enforcement should enhance the deterrent value of the regime for operators weighing the costs and benefits of compliance.

I'll invite you to join me in two further thought experiments to probe the possibilities of blockchain technologies both for Space Governance 3.0 inter-

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such contracts may come to resemble international arbitration, the automatic enforcement of the oracles' determination holds significant efficiency advantages over seeking recognition and enforcement of an arbitral award in national courts.

[17] The parties may wish to construct their smart contract in a manner enabling the courts of a selected nation to interpret and enforce the contract through traditional legal channels, as a backup measure. *See, e.g.*, U.K. JURISDICTION TASKFORCE, LEGAL STATEMENT ON CRYPTOASSETS AND SMART CONTRACTS (2019).

operator regimes, and for unlocking new Space Law 1.0 solutions.[18] To begin with a provocative one, let's imagine a private, international regime for allocating mining rights in celestial bodies. The regime comprises a set of rules, encoded in a web of smart contracts, that spacecraft operators may voluntarily contract into. Whether governmental or non-governmental, all operators participate on a level playing field. For the sake of imagination, let's import the basic bargain of the patent system for purposes of allocating mining rights: an operator that explores a resource deposit receives a twenty-year mining right in exchange for making this information available to the world. To obtain a mining right, let's assume the operator must also lock up $1 million in a smart contract as a deposit. If that operator infringes upon another party's mining interest or otherwise violates the conditions of the contract, that value is automatically transferred to the injured party.

The traditional mechanism for constituting and administering such a regime would be to stand up a treaty-based international organization, such as the International Seabed Authority, to administer and enforce the rules agreed by the contracting parties. To date, there has not been sufficient political will to create such a Space Law 1.0 regime for space resources, whether pursuant to Article 11 of the Moon Agreement or otherwise. In broad brushstrokes, this thought experiment illustrates, how blockchain technologies could enable operators from multiple countries to construct a regime providing a level of predictability that would aid both financing and mission planning. The contractual rights to non-interference with a mining interest are not enforceable against all comers; rather, the right is only enforceable against actors that participate in the regime. Accordingly, the efficacy of this voluntary regime depends upon a critical mass of operators perceiving their interests as better served inside the regime than outside it.

How would such a private contractual regime mesh with the international law and politics of space resources? The legal question is the easier of the two. To get to space, the participants in this hypothetical regime must be authorized by their respective governments, which in turn are obliged by Article VI of the Outer Space Treaty to ensure the space activities of their nationals are carried out in conformity with the Treaty. It is through these national licensing processes that the provisions of the Outer Space Treaty—for example, Article IX obligations to prevent harmful contamination to celestial bodies—would be applied to space resource utilization activities on a region of the Moon, at a particular asteroid, or elsewhere.[19] Again, this parallels the layering of public

[18] To be clear, these thought experiments are not intended as proposals but illustrations of how blockchain technologies could unlock new possibilities for space governance.

[19] As indicated above, I fear that the interpretation and application of Article IX's harmful contamination obligations to private planetary missions will present a Space Law 2.0 moment if a private mission forces national licensing authorities to confront these interpretive questions ahead of an understanding on the international plane. Whereas Article IX

and private law in terrestrial legal systems: the Outer Space Treaty establishes some guardrails for private ordering, and operators supplement its basic framework with rules embodied in commitments to one another. These operator commitments to respect each other's mining rights—applicable only to operators that voluntarily opted into the regime and enforced by smart contract rather than the coercive machinery of a state—would not, as a legal matter, offend the national appropriation prohibition of Article II of the Outer Space Treaty.

As a political matter, the formation of such a private space resources regime is almost certain to offend a great many people who could be expected to challenge its legitimacy on the basis that the disposition of celestial body resources is a matter of broader interest than the relatively few actors capable of exploring and exploiting them. In particular, larger cross-domain political controversies over equitable sharing of benefits derived from resources beyond national jurisdiction have thwarted progress toward global agreement on space resources. A politically savvy group of operators may be able to construct a private space resources regime in a manner that proactively diffuses these concerns by, for example, allocating a percentage of operator profits to a global fund. On this too, private companies have proven themselves to be far more pragmatic than their governments. Or perhaps the formation of a private regime would catalyze Space Law 1.0 lawmaking on space resources by supplying the political will for a global bargain. In either case, transparently tracing and allocating resource exploitation revenues falls within the fundamental technical strengths of blockchain technologies. Whether a benefit-sharing regime is voluntarily fashioned by enlightened private operators or imposed by governments, blockchain networks, which enable all parties to have confidence that the rules will execute as agreed and allow parties to trace and independently audit transactions across the network, efficiently perform many of the functions that would have traditionally required parties to establish and place their trust in an organization of international civil servants to carry out the agreed rules.

For a closer look at how smart contracts might unlock new solutions in concert with Space Law 1.0 lawmaking, let's return to the problem of incentivizing spacecraft operators to dispose of their spacecraft at the end of its operational life. I have heard many proposals for a tax on mass launched into orbit that would go into a fund to pay for active debris removal. While I appreciate the relative administrative simplicity of these proposals for solving one of the more difficult political challenges in space governance, I think we should be able to do better. For one, a mass tax creates no incentive to refrain from polluting Earth orbit, as operators are taxed whether or not they properly dispose of the mass they place in orbit. Moreover, such a mass tax would not

affords state parties a great deal of flexibility to adapt it to prevailing needs and circumstances, maintenance of a cohesive regime will depend on coordination across states.

compensate operators who are harmed by the failure of other operators to remove their satellites at the end of their operational life, in that they must expend fuel and operational resources to maneuver around debris. Could smart contracts enable smarter regimes?

For the sake of illustration, let's turn the tax on mass launched into orbit into a security deposit. Among the requirements for obtaining a spectrum license, let's imagine that operators must lock $500,000 in a smart contract.[20] This security deposit is returned to operators upon the successful disposal of their spacecraft. This would supply an economic incentive to ensure proper end-of-mission disposal that is presently absent.[21] It would increase the value to operators of investments in satellite design and test that make on-orbit failure less likely. Some percentage of satellites can be expected to fail before the end of their operational life in spite of operators' efforts, and an appropriately priced security deposit would create a market for active debris removal services.

What if a satellite is non-functional, or the operator otherwise decides to leave it in place? Or the operator goes out of business before the satellite can be brought down? With a globally-trusted source of SSA data feeding an orbital maneuvers "oracle," a smart contract could transfer value from the defunct satellite operator's security deposit to the operators forced to maneuver around it to compensate for the expenditure of fuel.[22] With an open, permissionless network allowing any spacecraft operator to exchange value with any other, I can imagine a system in which operators of maneuverable satellites that conjunct trade credits for maneuvers: I maneuver today, you give me a credit; I use that credit tomorrow with a different operator. The value to

[20] This thought experiment is intended as an illustration of new technological capabilities for governance rather than a proposal. Nevertheless, this illustration has elicited some strong reactions. Specifically, a security deposit that locks up a substantial amount of operator capital would be vigorously resisted by operators, raise the capital intensity of space operations, and potentially price some operators out of the market. While I believe all three to be true, they point to an uncomfortable reality about externalities in the international regime for outer space: the price of space activities does not reflect their true cost, which could lead to an unsustainable oversupply of space activities.

[21] In a Twitter exchange, Matt Desch, CEO of the satellite constellation operator Iridium, responded to a question about how much Iridium would pay to remove the thirty dead satellites it was unable to deorbit, by illuminating the faint economic incentives to procure active removal services. Matt Desch (@IridiumBoss), TWITTER (Nov. 29, 2019), twitter.com/IridiumBoss/status/1200554977460133889 ("Incremental ops cost saved is zero. Decreased risk to my network equals zero (all are well below). Decreased regulatory risk is zero (I spend the $$, and someone else runs into something). Removing 1 or 2 things from a catalog of 100,000 is perhaps worth only PR value. $10K?").

[22] Through the lens of the Calabresi-Melamed framework for legal entitlements, such a regime would shift entitlements from polluters to other users of space: instead of paying (in fuel and operational life) for clear space, operators would pay to pollute. *See* Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the* Cathedral, 85 HARV. L. REV. 1089 (1972).

operators of such a maneuver credit trading system is proportional to its network effects: an operator is able to trade with any other operator it encounters. Were it constrained like terrestrial carbon credit trading systems—I could only trade credits with operators from the U.S., or the U.S. and two countries with which the U.S. has bilateral agreements for interoperation of credit trading systems—the system's value would be greatly diminished. Blockchain networks serve as a medium for spacecraft operators to transact and make enforceable commitments to any other operator, irrespective of their countries of origin. It is this attribute that I believe will be among this technology's most transformative contribution to governance and commerce in the space domain.

To conclude, I have stratified space governance into three layers, distinguished by who makes the rules, and the paths those rules take on their way to shaping the behavior of spacecraft operators. In Space Law 1.0, the rules are forged through inter-state negotiation by national governments represented by their foreign ministries. To bind the growing majority of space actors that are non-governmental, these rules must be extended by national legislatures and regulators. In principle, national legislatures and regulators are not making the rules, but extending rules adopted on the international plane to nongovernmental actors. In Space Law 2.0, the rules are made through intra-state legislative negotiations involving many of the same actors as the 1.0 paradigm, but with a different balance of authority between them, shifted burdens of persuasion, and a fainter signal from international legal and governance considerations. The rules bind nationals of the state in question and other operators under its jurisdiction. The risk to a cohesive regime is that the operators of different states will be bound by different, incompatible rules. In Space Governance 3.0, the rules are made through inter-operator negotiation, public and private, or accepted by operators that opt in after the rules are fixed.

Space governance layers are not distinguished solely by tooling: whether the rules are fixed in treaties, statutes, or smart contracts. For example, the thought experiment around security deposits for mass placed in orbit illustrates how blockchain technologies could be employed to enhance the range and efficacy of Space Law 1.0 lawmaking. The rules in that thought experiment—thou shall not place mass in orbit without posting a security deposit in accordance with these procedural rules and formulas—are fixed by national governments on the international plane and extended to private operators by national radiocommunications regulators, the common gate through which virtually every private mission passes on its way to space.[23] Once fixed and

[23] Given its coordinating role in the national radiocommunications licensing processes through which virtually every private space mission passes, the International Telecommunications Union (ITU) would provide a logical forum for the interstate agreement mandating our hypothetical security deposit regime, provided this subject matter could be squared with the ITU Constitution. Within its relatively narrow bands of competence for space

extended, those rules could be *administered* more efficiently and effectively by operation of smart contracts, than by standing up an international organization to administer those rules or an international agreement prescribing detailed technical rules for coordination among national regulators. Smart contracts allow all concerned to have very high confidence that the rules will be executed. It is whether those rules are set by intergovernmental negotiation or directly by operators that determines whether it is 1.0 or 3.0.

Whereas I have illustrated each layer using cases of mandatory rules binding upon operators—whether by regulatory or contractual mechanisms—I believe that the important corpus of expressly non-binding norms relating to space activities fit within the three layers I have described, rather than comprising distinctive layers of space governance. For example, I see the UN Remote Sensing Principles[24] as a classic case of Space Law 1.0, notwithstanding the fact that the intergovernmental rules are non-binding: the Principles were negotiated over the course of a decade in COPUOS, adopted unanimously by the General Assembly. Portions of the Principles became binding on private operators through national legislation and regulation.

I see the Space Safety Coalition's *Best Practices for the Sustainability of Space Operations*,[25] formulated and endorsed by spacecraft operators and civil society participants, and the Space Sustainability Rating,[26] a voluntary rating initiative designed to strengthen operator incentives for sustainable orbital operations, as fitting most comfortably within Space Governance 3.0. I conceptualize these recent initiatives as direct-to-operator norm construction: the rules are made by (or with the active involvement of) spacecraft operators, and the initiatives aim to propagate norms of behavior internalized by operators without regulatory intermediation.[27] The "undersigned space industry stakeholders" of the Space Safety Coalition "[u]rge . . . [a]ll space actors to promote and adhere to the best practices herein . . . ,"[28] perhaps calculating that the articulation of best practices endorsed by an influential cross-section of operators, and their own demonstrated adherence to them, will gradually increase the normative pull of the best practices. The Space Sustainability

governance, the ITU radiocommunications coordination processes, implemented by national licensing authorities, is perhaps the most consistent Space Law 1.0 process to date.

[24] G.A. Res. 41/65, Principles Relating to the Remote Sensing of Earth from Outer Space (Dec. 3, 1986).

[25] *Best Practices for the Sustainability of Space Operations*, SPACE SAFETY COALITION (Sept. 16, 2019), https://spacesafety.org/best-practices/ [hereinafter *Best Practices*].

[26] *See, e.g.*, WORLD ECON. FORUM, *Space Sustainability Rating* (2020), https://www.weforum.org/projects/space-sustainability-rating.

[27] Whereas Space Governance 3.0 mixes governmental and non-governmental actors, without hierarchy, in the process of formulating norms of behavior, my approach is shaped by the International Relations literature on the origination and internalization of norms by states. *See* Martha Finnemore & Kathryn Sikkink, *International Norm Dynamics and Political Change*, 52 INT'L L. ORG. 897 (1998).

[28] *Best Practices*, *supra* note 25, at 9.

Rating will follow a corporate social responsibility path for promoting norms of sustainable operations by rating satellite operators. Because the rules are made by (or in close cooperation with) satellite operators and are designed to shape operator behavior without governmental intermediation, I believe both initiatives fit the Space Governance 3.0 paradigm.

It is too early to classify the recently concluded initiatives of the *Guidelines for the Long-Term Sustainability of Outer Space Activities* (LTS Guidelines) adopted by UN COPUOS,[29] and the *Building Blocks for the Development of an International Framework on Space Resource Activities* adopted by the Hague International Space Resources Working Group (Hague Working Group).[30] The LTS Guidelines were forged through nearly a decade of international negotiations in the UN and were adopted by consensus; governments have said the LTS Guidelines will be reflected in national legislation and regulations. This appears to follow the classically Space Law 1.0 pattern of the Remote Sensing Principles. Should the Principles' ultimate influence upon space operations follow the direct-to-operator path, however, the Principles will straddle my 1.0 and 3.0 layers. The Hague Working Group, a track 1.5 initiative in which operators, civil society, and governments played on a level playing field, was initially conceived as pre-work for a treaty on space resources. It thus initially appeared to straddle the layers in the opposite direction: 3.0 on rule formation, and a 1.0 path to shaping operator behavior. At the conclusion of its work, however, the Hague Working Group charted a direct-to-operator course, encouraging operators of all kinds to "consider and use the Building Blocks,"[31] further aligning the initiative with the 3.0 paradigm.[32]

Ultimately, my task is not a comprehensive taxonomy of space governance initiatives, but to envision the future of space governance. My aim in stratifying initiatives into layers is to isolate salient trends in who makes the rules governing space activities and how those rules come to shape the behavior of spacecraft operators. Space Governance 3.0 is not *the* future of space governance but will be an increasingly important layer in an overall governance

[29] Comm. on the Peaceful Uses of Outer Space, Guidelines for the Long-Term Sustainability of Outer Space Activities, UN Doc. A/AC.105/2018/CRP.20 (2018).

[30] The Hague Int'l Space Res. Working Grp., *Building Blocks for the Development of an International Framework on Space Resource Activities* (Nov. 12, 2019), https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht—en-ruimterecht/space-resources/bb-thissrwg—cover.pdf.

[31] *Id.* at 1.

[32] The Hague Working Group initially appeared to follow the traditional pattern of the International Law Commission (ILC), in which expert deliberations form the basis for multilateral treaty making. The Hague Working Group's ultimate product, however, follows the ILC's more recent (and controversial) practice of commending the product to the attention of states. *See* David D. Caron, *The ILC Articles on State Responsibility: The Paradoxical Relationship Between Form and Authority*, 96 AM. J. INT'L. L. 857 (2002).

"stack" including Space Law 1.0, and Space Law 2.0 when 1.0 lawmaking mechanisms fail to keep pace with path-breaking private space activities. Today, I see potential for a vibrant future of space activities enabled by more efficient, effective governance mechanisms, as well as signs of a future stunted by regime fragmentation. The single most important determinant between the optimistic and dismal versions of the future, in my view, is actors in every governance layer respecting and maintaining the constitutional role of the Outer Space Treaty. As rule making becomes increasingly decentralized, a state of constitutional multipolarity will preserve a regime that may flex and bend at times but does not break.