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Relevance of Composable Governance to the space domain and sustainable lunar activities: Re-imagining a Computational Jurisdiction to deal with safety zones on the Moon

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MIT Computational Law Report

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Context and preliminary definitions

Collected Works on Composable Governance is an open-access publication published by the **MIT Computational Law Report**. Submissions include original research, practical guides, tutorials, and overviews of topics related to Composable Governance, and a first batch has already been published in December 2022[1].

As of Spring 2023, there is no normative definition of what Composable Governance is. The concept, which isn't yet fully apparent in law and governance literature, may be qualified as "emerging". Nonetheless, empirical and theoretical attempts led by the MIT Computational Law Report, as fleshed out by Dazza Greenwood et al. during the *Idea Forum on Composable Governance*, have led us to '*explore the idea of Composable Governance in the contexts of legal tech, business automation, and web3*'[2]. It is in that context that I frame the topic of Composable Governance for this article.

In a nutshell, I may describe Composable Governance as a modular technology and data-driven interoperable model for the provision of governance oversight and services, with various degrees of automation and autonomy in regulating activities and organizations.

But first, let's review the definition of composability and its relationship with modularity. In software planning practice, *'The principles of composability and modularity are often interlinked. Modular systems consist of subcomponents with well-defined interfaces and functions that can be consumed independently of each other. Composability is the degree to which these subcomponents can be combined to form more complex systems'*[3]. That relationship between composability and modularity implies necessary conditions for standards and interoperability*: 'Many cyber-physical systems are actually systems of systems, compositions of diverse subsystems, typically developed by diverse teams, often from different organizations. Modularity is the problem of designing subsystems (modules) with well-defined interfaces that can be used in a variety of contexts. Composability is the ability to combine modules'*[4].

Second, let's acknowledge upfront the need and relevance of considering composability as a factor characterizing an emerging breed of organizations, as reviewed by MIT Computational Law Report leadership team member Bryan Wilson in '*Exploration of Composable Organizations*'[5]:'*The rise of Decentralized Autonomous Organizations (DAOs), Cybernetic Organizations (cybOrgs), and other digitally enabled business models represents the next evolution in the ways that people can organize themselves, work on tasks, raise funds, or build communities. However, defining the attributes of these newfangled forms of governance has proven particularly tricky. The reason this matters is because the different architectures – or code – that are used for representing an organization require different safeguards to protect it.'*

I acknowledge that composability is a hardware and software architecture-based, data-driven construct. As such, the concept features prominently specific technologies linked to successive generations of internet

networks, data creation, harvesting, machine learning and deep learning algorithms, blockchain and other decentralized ledger-based processes for transaction immutability via cryptographically-secured mechanisms, etc. In addition, the concept of composability establishes that these technologies enable the management at scale of a large number of human and machine stakeholders whose relationship is based on verification rather than blind trust.

However, in this article, I approach the topic from a more techno-politically agnostic angle.

I posit that any *activity* run by government, private sector organizations, and civil society stakeholders at large, may include a component of composability for said activity. But that doesn't necessarily imply that the *organization* running the *activity* is itself determined by a composable infrastructure. And neither does it imply that a given organization is based on a decentralized model at all, although that organization model may be geographically, culturally, and socio-professionally distributed.

When it comes to governance of global activities on Earth and beyond, I may stick to a simple pyramidal model, with a three layered framework: a first layer represents international law, supra-national institutions that embody it and to a certain extent enforce it, and *inter-states* relationships. A second layer represents national laws and the *intra-states* mechanisms by which they comply with international law. A third layer represents private sector organizations such as industry operators, and civil society stakeholders at large. For each of these layers, beyond the core of legally binding instruments, there is both a mature and emerging body of norms, standards, and codes of conduct that regulate parties' behavior.

This is what constitutes governance, and this article's arguments fit in all three layers. The first layer, *international*, includes future governance regimes in outer space at its core, beyond more or less legally binding instruments of hard and soft law. The second layer, *intra-national*, is no less crucially important, as the theater where laws and regulations are made binding for the purpose of national implementation in a context of national and global responsible and adaptive governance. The third layer may once have been considered not as important as the first two layers, but is likely to grow in relevance and influence as operators co-design and co-implement norms, standards, and codes of conducts, through collaborative processes that increasingly involve civil society, as will be reviewed in this article.

For each of these layers, technology, automation, and autonomous mechanisms will create a foundation for composability of activities whose mechanisms will need to be regulated. It is worth noting that, while human and machine behaviors and interactions will need regulating, it is not necessarily the case that the organizations and stakeholder groups they belong to will have a strong degree of composability. I would argue that this evolution toward composability would be the most prominent in its beginnings at the third layer, and slowly make its way up toward *intra-national* and *international* layers of legal and regulatory constructs.

Thus, at least within the scope of this article, I opt for a prudent, conservative definition and techno-politically agnostic approach toward the concept of Composable Governance within a multilayered international context and construct[6] [7]: I posit that the various degrees under which Composable Governance may manifest can be characterized first by the composability of the activity being regulated, then, by the degree of automatization and autonomy with which an organization would run such activity. And overall, how *international* and *intra-national* legally binding instruments and regulations, as well as norms, standards, and codes of conduct, will be reflected within the composability of the activity and organization being regulated, thus regulating private sector and civil society stakeholders and human and machines behavior. This implies a notion of '*compliance by design*' i.e. to which extent compliance and behavior may be engineered within machines and their relationship with occasionally whimsical humans.

Introduction

Composable Governance, when described as *a modular technology and data-driven interoperable model for the provision of governance oversight and services*, may be part of the solution for governing sustainable activities in outer space, *though with various degrees of automation and autonomy in regulating activities and organizations in their contexts*.

Could a Composable Governance model support the safe, peaceful, and sustainable development of space activities, for the benefit of all humankind? And what could be the role and features of a re-imagined Computational Jurisdiction? What might be an approach to engineering that would ensure a data-driven, yet human-centered Composable Governance model? There is no shortage of sustainability issues in outer space, starting with the reduction of Earth orbital debris, and their economically viable management.

In this opinion piece, I venture beyond orbit toward sustainable lunar activities and resource utilization, and will focus explicitly on the issue of *safety zones* on the Moon[8]. I will cover relevant business-legal-tech cases and will review problems, needs, and objectives. I will estimate the current state of space affairs governance and how Composable Governance - within a Computational Jurisdiction framework - could contribute to improvements and solutions. This article is written for readers without previous knowledge of space law and governance issues and of on-going debates. Nonetheless, I suggest reading beforehand the articles of the Outer Space Treaty (OST), in order to get familiar with several concepts including and not limited to the OST Article IX notions of "due regard" and "harmful interference" [9] [10].

Governance of the space domain is already a multi-stakeholder affair

The current narrative surrounding the space domain is that it has the potential of evolving into a multi trillion-dollar economy in decades to come. These speculations are derived from the already strong foundation built by satellite markets, designed for Positioning, Navigation, and Timing (PNT) and Earth Observation. These markets are already adding up to several hundred billions of dollars[11]. Space economic development, through a number of enabling technologies, is also expected to benefit development on Earth. For example, Earth

observation satellites currently contribute to the creation of a data economy underwriting the development of solutions supporting major sectors in need of material and digital transformation, such as climate change, water management, agriculture, fisheries, critical infrastructures, and security. PNT satellites are essential to support the infrastructure enabling autonomous vehicles and innovative solutions for supply chain tracking and management. In and beyond orbit, there are technologies being developed that enable energy generation off-Earth which could support for example, off-Earth manufacturing, agri-food sectors, life support systems, waste management, and resource extraction of water, minerals, and more. These developments could generate positive alternatives for living off-Earth thus supporting the sustainability of existing Earth societies while solving techno-economic issues down on Earth as well. That is for the half-full glass. This being said, the reality in decades to come is that space development activities are more likely to revolve around competition and congestion, in orbit and beyond. Looking at upcoming lunar activities and the acceleration of multiple nation's missions to the Moon, competition and congestion are expected due to driving objectives, such as natural resource exploration, mapping of the Moon (for practical purposes such as navigation, settlement planning, resources extraction, and overall safety and security of free access), and in-situ utilization, such as polar ice-water, volatiles, metals, rare earths, etc[12]. The steep increase of lunar missions with little to none coordination is a concern.

The legal, regulatory, and governance frameworks overseeing space activities have evolved throughout the Cold War, being based in the Outer Space Treaty (OST) along with other treaties and conventions. These were designed initially to manage competition between the United States and the Soviet Union, context which helps to illuminate the OST's historical and political Cold War origin[13]. It has become customary to derive outer space market projections from new use cases that can be divided into two broad categories: space-for-Earth applications, which facilitate terrestrial activities, and space-for-space applications, which only involve activities that occur in orbit, such as refueling and servicing, and tentatively waste and debris management[14]. And while most of the economically significant space activity in subsequent decades is likely to consist of in-orbit activities (either for Earth or space), the segment of space activities beyond orbit, based primarily on space resource utilization, could become an economically lucrative segment. These growing sectors are being taken seriously by governments, especially with regard to activities involving the Moon. For example, major space powers such as the U.S. and China, as well as Europe, Russia, Japan, India, and others are already active in these domains: one can witness these activities already with commercial missions to the Moon performed by iSpace from Japan[15]. While the OST already provides a far-reaching framework for space exploration and resource utilization, its relevance will be reinforced and newer domain specific frameworks will emerge as humanity considers economic activities on the Moon, asteroids, and beyond. In particular we will see these frameworks emerge to address issues revolving around resource extraction and utilization (mining). For example, the Global Space Law Center at Cleveland University College of Law, led by Mark J. Sundahl, remains committed to three primary goals: to promote the development of law for the peaceful use of outer space, to facilitate the growth of the commercial space industry, and to train next-generation space lawyers[16].

The OST, conventions and treaties, as components of 'space law', all operate under international law, thus warranting the relevance and involvement of the United Nations Office for Outer Space Affairs (UNOOSA)[17], the United Nations Committee for the Peaceful Utilization of Outer Space (UNCOPUOS)[18], and various other intergovernmental organizations. Nonetheless, space law and the OST are characterized as 'sovereign-centric', because any activity by any private operator falls under the responsibility of the nation state that backed and licensed the activity. However the OST Article II also states that *"Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty"*[19]. Any private operator, for the licensing of their space mission, will interface with licensing organizations of their nation state: in the US, it is the Federal Aviation Administration (FAAS) and its Office of Commercial Space Transportation[20], as well as relevant bodies for other functions[21]. Under the OST, and the Liability Convention[22], when a mission includes several operators from several countries, responsibilities and potential liabilities may be distributed between the 'launching state' and other responsible states involved in said mission[23].

However, these two governance layers, international and national, while still the dominant ones, do not represent the full picture. International treaties and legal instruments are legally binding to the countries which signed on to them, with gradations between hard and soft law enforceability[24]. National laws and regulations may focus on specific aspects such as resource utilization while subject to the state's characterization of its competitive national interest and obligations under international law. But this only constitutes one part of the tool set required for defining, verifying, and enforcing operators' behavior in a way that is conducive to "sustainable" space governance. Additional tools are required for governance, including non-legally binding instruments that are nonetheless upheld by an international consensus on "sustainability" goals and the means for their implementation, while ensuring no stakeholder will stray in the process of execution[25]. Starting with lunar activities, such a sustainable governance model could work only if there were a third layer of operators, through cycles of trial and error, agreeing on standards, meaning prioritized norms, operational procedures, and information exchange, even among geo-economic competitors. NGOs are strongly involved in this process currently in relation to the management of sustainable space resource usage and related activities. Following its final face-to-face meeting on November 11-12, 2019 in Luxembourg City, Luxembourg, the Hague International Space Resources Governance Working Group has adopted and released the *'Building Blocks for the Development of an International Framework on Space Resource Activities'*[26]. The Working Group offered these 20 building blocks to the international community as elements that should be considered in the development of international legal frameworks to enable space resource utilization[27]. These *Building Blocks* constitute a robust foundation for further international and national legal, regulatory, and governance work. However, the on-going acceleration of missions to the Moon in a context of space exploration and resource utilization, generates risk of friction and incidents that could threaten the safety and sustainability of lunar activities in the coming years and decades. The risk is sufficient enough to have warranted a concern for urgent practical concertation and solutions design in a multi-stakeholder context, and resulted in the Moon Village Association[28] launching in 2021 the Global Expert Group for Sustainable Lunar Activities (GEGSLA)[29], in

which this author is a participant. In February 2023, GEGSLA released '*The Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities*'[30] which is designed as a guide for well-balanced lunar projects and offers recommendations for how to implement safe and sustainable lunar activities through norm-setting, coordination, and management. This '*Recommended Framework*' builds on principles established in international space law, relevant UN outer space treaties and soft law documents.

While a third layer of industry operators developing standards is the direction that lunar activities appear to be going in the 2020's, anticipating the next couple of decades means that civil society needs to be included as well, and has already done so. We see this participation through for example, citizen participation in NGOs involved in this type of normative work for sustainable lunar activities including the Open Lunar[31] and Secure World[32] foundations, with a pervasive ethos of cooperation between participants involved in such creative ideation fora and collaborative solution design. The role of civil society is to contribute to the collaborative development of such standards, via inclusion of space domain experts and involvement of multi-stakeholder non-governmental organizations, in addition to industry operators, as seen in the above examples. This citizen participation and role of civil society isn't limited to the northern hemisphere and is significantly emerging all across the Global South: for example, Space Jano[33], led by Victorias Cocca y Esquivel, based in Argentina (in which this author participates), operates worldwide space domain information dissemination and a discussion platform across the whole of Latin America, including Brazil, a notable space actor. Similar organizations operate all across Africa and Western to Eastern Asia.

And while this doesn't amount to a major central consideration in this article, for the sake of fairness in societal assessment of current affairs, it is noteworthy that when it comes to consideration of inclusiveness in space domain governance related fora and initiatives, there is still a long way to go in terms of any form of relevant self-governed 'civic' initiative. In particular, when it comes from less favored quarters, from indigenous communities to women and girls having limited prospects for education and space domain careers in developing economies that are still struggling to emerge as space nations, this civic involvement is not yet seen operating at all levels of human-centered governance design. Especially when it comes to the inclusiveness of civil society vis-à-vis industry operators, government, and international organizations, whose decision-making process should be approachable, rather than opaque, it is an understatement to say that there is room for improvement.

Sustainable lunar activities and the practicalities of 'safety zones' on the Moon

It remains to be seen whether broadly assumed 'natural resources' on the Moon can be quantified as economically extractable 'reserves'[34], which is the whole purpose of the mining industry due process of exploration, mapping, qualification, and quantification, a data driven process that currently supports extraction and licensing on Earth. While various consultancies have recently attempted to evaluate lunar markets[35], the Moon Village Association Lunar Commerce and Economics Working Group,[36] in which this author

participates, released in November 2022 the first version of its Lunar Commerce Portfolio[37] in an attempt to realistically quantify emerging lunar markets in the current decade, and frame a set of scenarios for decades afterward. To be clear, on the Moon, as on Earth, environmental impact mitigation needs to be a priority in ensuring that lunar resource utilization has potential as a sustainable activity, which we can't be sure of yet. The half-empty glass view is that if the economic case for lunar resource utilization proves a dead-end or strongly challenging, the cost of not only environmental mitigation but all other sustainability enhancing measures, infrastructures, and processes could become a show-stopper. Inversely, neglecting sustainability measures means that we already know how that ends: destroying the Moon would eventually doom its utilization. *I place a bet that things will work out in the end.*

The situation described above implies that we need to determine whether "sustainability" on the Moon is even an investable activity segment to start with, because we don't know that yet. The need for economic viability and the fact that "sustainability" processes on the Moon are also going to be strongly data-driven processes, is a key reason to consider a certain degree of automatisation and autonomy as part of the techno-economically viable solutions for industry. Industry may operate under sole private sector Foreign Direct Investment (FDI) models on the Moon as well, under the responsibility of a nation state, as per space law. However, in order to de-risk the allocation of public and private capital expenditures, it also makes sense to consider Public Private Partnerships (PPPs) to develop infrastructure projects on the Moon[38]. Whether industry operates under private sector FDI or PPPs models, it matters that the cost of complying with sustainability objectives be itself economically sustainable. As lunar activities evolve toward a more mature phase leading to a steady state decades from now, it is possible to envision that sustainability objectives will be fully integrated as part of a resource utilization based lunar economy, even though that remains to be implemented and ascertained. Logistical aspects of sustainability such as waste treatment, traffic management, infrastructure mapping and safety zoning, to name a few, may deliberately be subcontracted by governments to the commercial sector, with an incentive to run cost-efficiently both material aspects and data-driven processes, subject to investable and viable business models.

But sustainability is not merely a long term concern for when lunar activities enter the steady state of a mature stage: there are indeed a lot of ways things could go wrong in the early stage of budding lunar activities, long before they reach a level when e. g. long term environmental destruction is of graver concern. For example, when spacecrafts land on the Moon's surface, low gravity makes it hard to control the ejection of particles: because when the crafts or landers eject gasses during landing and take off, gravels, particles, and dust will be projected upward and onward, over distances of several kilometers, instead of falling down immediately on the surface, as would happen on Earth. Why is that so? Because these gasses are being ejected at speeds 30-50% faster than Moon escape velocity[39], due to the Moon gravity being one sixth of the gravity on Earth. Therefore gravels, particles, and dust are being projected and accelerated at a speed that is higher than the speed at which they would need to move in order not to fall back on the surface immediately. So even if gravels and big particles move slower, there's nowhere safe on the Moon to shelter from a shower of particles and dust within

even a few hundred meters from any given landing and take-off location[40]. A primary mitigation measure is to build landing/parking/launching pads with protective berms[41]. A lack of consideration for this problem is immediately detrimental for safety and security, environmental sustainability, and commercialisation prospects: while ejected particles shower humans, habitat, equipment, and operations in the vicinity, they can also contaminate polar lunar ice or regolith that need to be scientifically studied by international missions, before being mined for resources that can be used commercially. The current average estimate of minimum safe distances between landing pads and other infrastructures is 2 kilometers[42], or 1.243 miles, a safe distance estimate also retained in the technical annexes of above mentioned *GEGSLA* '*Recommended Framework*'.

Another issue is the competitive *fait-accompli* resulting from the concept of "space power". Space power can be defined as "*the total strength of a nation's capabilities to conduct and influence activities to, in, through, and from space to achieve its objectives.*" and that includes both military and civilian elements[43]. The concept of influence of "space power" on past and future history is a key building block of "Space Power Theory", a topic dear to this author, which has been explored by leading experts such as Colin S. Gray[44]. As a matter of fact, in that historical context of power accumulation, alternating struggle with cooperation, nation states that develop and exercise that power are characterized as "space powers", and they can be both established (the U.S., Russia, China, Europe, the U.K., Canada, Japan) and emerging (Australia and many a Global South nation). In coming years and decades, every major space power (including and not limited to the U.S. and China) is going to compete (albeit perhaps with elements of cooperation) for the same lunar resources in the same areas, be it ice water at the south pole, or volatiles, metals, rare earth, and potentially Helium-3, in various locations[45]. As such, it is likely that, in the beginning, everyone will more or less land in the same geographical places, and won't venture very far early on. It will get crowded. Missions may not know who their neighbors are, making coordination for the building of infrastructure difficult. For example, if someone installs solar panels on a Moon crater's "peak of eternal light"[46] and someone else builds some kind of infrastructure that casts a shadow on the panels, what should be done? And practically, who can sue whom?

Then, assuming that a state and/or private sector operator, or an alliance of these, conduct scientific study, resource extraction, or any economic activity in a certain lunar perimeter, is there a way that this perimeter could be defined, formalized, and articulated to relevant parties? This articulation is also required for fulfillment of OST obligations, such as exercising "due regard" and avoiding "harmful interference" vis-à-vis other lunar activity stakeholders. While making sure to not turn a given perimeter into a de facto fenced exclusionary zone, which would be contrary to the non-appropriation non-exclusionary principle contained in Article II of the OST, and allow free, if regulated, passage[47].

The kind of friction or uncertainty described above will likely happen, so all stakeholders need to ask themselves how they should coordinate missions beforehand and establish certain rules in practice, starting by defining their perimeter of activity, in size and duration. The need to qualify and quantify infrastructures and activities, to coordinate missions, and record whatever happens, and in particular what could possibly go

wrong, suggests that preliminary exchanges of information, coordination efforts, deconfliction attempts, and post-facto potential litigations and settlements, all constitute intensive data-driven endeavors.

The above explicated situations form part of the motivation for defining what constitutes a "safety zone", as articulated in what is commonly referred to as "*The Hague Building Blocks*", first in the following contexts: the Hague International Space Resources Governance Working Group *'Building Blocks for the Development of an International Framework on Space Resource Activities'*[48], and the Artemis Accords[49]. More detailed definitions have since been explored in various fora, such as the above mentioned GEGSLA (in which this author participates), whose *'Recommended Framework'* deliverables were released publicly in February 2023[50]. Given that safety zones are for informational rather than legally binding purposes, they also need to take into account the limitations of information exchange due to legitimate interests of parties involved, and the obligation and extent to register one's activities. Thus, regardless of legally binding aspects, safety zones are a data-driven coordination endeavor, calling for multi-jurisdictional and cross-stakeholder collaboration.

How is Composable Governance relevant to the space domain and lunar activities?

Governance of space development and sustainable lunar activities is organized around three layers: international organizations, nation states, and industry operators. However, treaties, laws, and regulations, can only be adopted and enforced provided operators and investors with 'skin in the game' define and agree on effective operational 'standards'.

To these three layers mentioned above, I propose to add not a fourth layer but a transversal constituency, which is civil society holding all three layers to account through human-centered governance.

However, such a human-centered governance model doesn't necessarily take into account the impact of technology and data on governance. If law is to governance what engineering is to architecture, and (to use concepts from the MIT Computational Law Report)[51] [52], if any governance endeavor is built on a combination of business, legal, and tech architectures, then there is either a deterministic or probabilistic interaction with the human definition of standards.

Here I will illustrate a third hybrid interaction, thereby having three levels of interaction that go from deterministic to hybrid to probabilistic, considering the growing interaction of automated and autonomous systems with humans:

1. fully automated and autonomous systems not interacting with humans can have compliance engineered within themselves, provided algorithmic governance works.
2. automated and autonomous systems that require a significant interaction with human-centered decision loops (in- or -on the loop), still provide clear compliance data.

3. steering decisions and arbitrations that are based on human relativism and politics can nonetheless consider the available compliance data before allowing human decision.

These three levels of interaction are based on the premise that 'algorithm is policy[53]'. In that sense, Composable Governance relates to the algorithm-driven operationalization of policy within a system that has built-in engineered compliance. 'Algorithm is policy' as a process goes from deterministic to hybrid to probabilistic, a balancing act between the machine and the human. 'Algorithm is policy' represents a respectful evolution rather than an abrupt departure vis-à-vis the original concept of 'code is law' as per Lawrence Lessig first and second versions of 'Code and other laws of cyberspace', and further relevant works and discussions on 'code as law' or as regulatory technology[54]. Our purpose here is not to deep dive into yet another academic debate over the relationship between code and law, but simply to emphasize ways policy and therefore governance processes can be pragmatically represented by and engineered into data-driven algorithmic processes for our use case.

We described above a transversal constituency, which is civil society holding all previous three layers (international, national, operators) to account through human-centered governance. Rather than another layer, Composable Governance can also be seen as another transversal constituency, cutting across all three layers, facilitating policy as algorithm wherever relevant, and, inversely, developing algorithms that enforce policy in either deterministic, hybrid, or probabilistic fashion.

That data-driven Composable Governance constituency fully interacts with the human-centered governance constituency of civil society, in ways that could possibly reinforce each other, as *data is the tool by which civic power sustains itself.*

A Computational Jurisdiction to legally engineer Composable Governance

The concepts and building blocks used in this paper were either first introduced, or taken several steps further, by the MIT Computational Law Report, these include: '*Business-Legal-Tech*' three-layers architecture, as a software development concept conveniently adapted to legal engineering (often quoted in offline and online Telegram channel discussions), '*Automated and Autonomous Legal Entities*' (including DAOs)[55] [56] [57], the '*MIT Computational Law Sustainable Development Goals*'[58], built-in engineered compliance for automated and autonomous systems (MIT Telegram channel discussions), and, lately, '*Composable Governance*'[59]. Here I will focus on '*Computational Jurisdiction*', another concept created and introduced by the MIT Computational Law Report in my private email discussions with the Report leaders. I first came across this concept of '*Computational Jurisdiction*' in early 2021 as I was researching built-in engineered compliance for automated and autonomous systems. In particular, my use case was data-driven sustainability ratings and compliance within the space domain[60]. For this sustainability ratings' use case, I considered integrating technologies such as networked machines, deep learning, algorithmic decision making, distributed ledgers, computable contracts including and not limited to smart contracts. My past research on the topic having since

been enriched by additional experience working on lunar business model development[61], lunar activities adaptive governance[6263], and sustainable Moon bases and activities architectures[64], in space-related collaborative contexts with various teams outside MIT, I now revisit this concept of Computational Jurisdiction.

This time around, my techno-politically-agnostic approach focuses on the significance of this Computational Jurisdiction concept for the role of data-driven Composable Governance. However *I do not elaborate* on technical aspects such as decentralization and the integration of above mentioned technologies (Web3, AI, blockchain, etc.), and choose to focus on selecting a use case that would allow for a tentative validation of the relevance and limitations of the Computational Jurisdiction concept. To select the use case, I conducted an initial informal review of the variety of very practical concerns for sustainability one can encounter in the context of lunar activities.

Starting from the OST first principles, then the Hague International Space Resources Governance Working Group *'Building Blocks for the Development of an International Framework on Space Resource Activities'*[65], then the Artemis Accords[66], I ended up identifying several axes regarding sustainability issues. Next, further deep diving into the taxonomy of sustainability issues identified by the GEGSLA (in which this author participates), I gathered that the core '*Recommended Framework and Key Elements for Sustainable Lunar Activities*'[67], together with their technical annexes, easily led to a couple dozen potential use cases spread across Information Sharing, Safe Operations and Lunar Environmental Protection, Compatibility and Interoperability, Responsible Governance, a Sustained Lunar Economy, Human Interaction, Benefits for Humanity, etc. I then identified 'Safety Zones' as a use case that is relatively straightforward. If the 'Safety Zones' use case remains legally complex, I needed it to be still somewhat understandable for practitioners who, like me, aren't lawyers, and practical enough, so that readers may intuitively relate to it, simply because somehow, similar things could happen on Earth: debris falling on one's house, a neighbor's rover intentionally or not crashing into one's backyard, how far from a spaceport one should live and operate industrially, etc. I also hypothesize that a large chunk of the Computational Jurisdiction concept discussion for 'Safety Zones' can be extrapolated to other use cases, in case the concept would gain traction and appear more broadly useful, usable, and used.

I previously referred to the notion of 'algorithm as policy' as an evolution upon the concept of 'code is law'. Another question is what to do with the concept of cyberspace, and how best to extend it to the outer space domain. With the advancements in digital twining technologies, it is not unreasonable to suggest that we could one day have a functional digital twin of Earth, or at least various components of Earth such as individual cities or other easily mapped geographies. In fact this is already happening thanks to the European Space Agency (ESA) project working towards a Digital Twin of Earth[68].

Let's assume such a digital twin of the Earth could be expanded to the whole of an ecosystem comprising Earth, its orbits, cislunar space, and the Moon, as an initial step. Let's call this ecosystem the *Earth-Orbital-Cislunar-Moon Ecosystem* and use the acronym *EOCM-E* to refer to it. As missions, deep space internet,

industrial activities, and settlements develop that involve asteroids, Mars, and planetary bodies beyond, new layers of the expanded EOCM-E could be added to the digital twin. But for now and the coming decades, as far as the Moon is concerned, what matters is to build an equivalent of the known Earth internet into something that would encompass the whole EOCM-E. One "elephant in the EOCM-E room" is that it is not entirely clear how this will materialize techno-politically in a potential scenario where at least two major "blocs" respectively led by the U.S. and China, may compete for leadership and dominance from the Earth to the Moon and beyond. But by the time space communications and internet deployment have been built and secured for the whole EOCM-E, I hypothesize that this new infrastructure will warrant references to a concept of "cyberspace" beyond Earth relevant to the whole EOCM-E: and that could be problematic.

From my observation and research in the past couple of decades on the legal foundation and characterization of cyberspace (with a huge caveat since not being a lawyer), it strikes me that it is difficult to rigorously define or set parameters around what "cyberspace" is from a legal standpoint. For example, there are inherent difficulties in attempting to apply the concept of 'jurisdiction' to cyberspace in such a way that provides legal and operational clarity. Some workarounds have been attempted and rationale proposed to address these difficulties, such as: leveraging a form of territorial domain subject to international law, frameworks of conflict of law, effect test, etc.[69] Inversely, I looked at whether the concept of 'jurisdiction' is fit-for-purpose for defining a 'rule of law' in cyberspace, when applying the concept of 'rule of law' and 'jurisdiction' to 'cyberspace'. It is possible to find some degree of relevance to the concept of 'cyberspace' for governance of data and people's rights (or lack thereof) through online activities and transactions, but not for our context encompassing sustainable lunar activities and economic development in cislunar space and on the Moon.

Legal theory and practice currently dealing with "cyberspace" seem to fall short of considering complex system governance through built-in compliance. Furthermore, for the sake of composable governance within the space domain, it makes sense to look at the "*polycentric*" character of governance: the concept of *polycentricity* reflects a fragmentation of stakeholders' capacities and mandates in a context of practical interactions, and has already been explored e.g. by the Open Lunar Foundation.[70] In my review of cyberspace related literature, I didn't discover a definition of a polycentric governance framework in a way that aligned with concepts of a Computational Jurisdiction as the original concept suggested by the MIT Computational Law Report leadership in our email conversations back in 2021. Given that such a fit-for-purpose framework is seemingly unavailable, I attempt here to re-imagine what the features of a Computational Jurisdiction framework might look like, and how such a framework might function for sustainable lunar activities and safety zones.

Developing the features of a Computational Jurisdiction framework

I referred to the Cambridge Dictionary online in my analysis of the many definitions and meanings of the word 'jurisdiction'[71]: a jurisdiction can be defined as the authority of a court or official organization to make decisions and judgments, the official authority to make (esp. legal) decisions and judgments, the authority that

a particular court of law or official organization has to make laws, rules, or legal decisions, a country, state, or other area where a particular set of laws or rules must be obeyed, and all of the above with even more nuances and context. This analysis was a preliminary assessment of available definitions to determine features that could translate well within a Computational Jurisdiction framework. It is not intended to be a rigorous assessment of legal structures, and could benefit from further review by legal domain experts. Through this analysis I discerned the following three features as desirable for the engineering of a 'Computational Jurisdiction':

1) A Computational Jurisdiction should be clearly articulated with a physical domain of application

2) A Computational Jurisdiction should function effectively within relevant legal frameworks and their level of enforcement

3) A Computational Jurisdiction should be consistent with the relevant information architectures of any encountered lunar activity use-case, whose data may be fully or partially processed through human and/or computational intervention

Regarding point 3, what is meant by that is first that the data may exist under different formats on different physical substrates: a stone table, papyrus, or modern times paper, are among the most elementary forms of analog systems. I'm currently writing this text using the keyboard of a portable computer, under an operating system, with a word processor software, co-creating with my editor through a document sharing platform, which warrants a certain degree of interaction under a digital paradigm. But once I convert this word processing file into an e.g. "PDF" file format, even though the file is of "digital" nature, it will revert to a static, non-interactive artifact, in fact quite similar to a stack of paper printed with ink. It will take a few improvements until e. g. an extractive and generative AI can ingurgitate that PDF file and make it an interactive artifact that can intelligently interface with the ecosystem for which it is destined. We choose to call this a "*paper paradigm*". To further understand how painful a "paper paradigm" can be, just ask a junior lawyer how that feels to be tasked on a late friday afternoon with synthesizing information from a dozen boxes of legal archives, plus hundreds of stored pdf files for good measure, and report it all on monday morning.

Beyond the issue of a "paper paradigm", and in a legal technology adoption context, there is the tacit knowledge that in the legal profession, it is still challenging to organize flawless data sets in a seamlessly interactive digital fashion, and the space domain is no stranger to that state of things. The reality is often that the required data sets may not always be available, properly organized, or digitalized at all. However, in the space domain, if things are being done in an orderly, professional, and compliant fashion, the relevant object launched in space should have been legally registered and made permissible as per the OST and Registration Convention.[72] In some cases regulated by planetary protection rules under the FAA, it matters to make sure that either a launched or returning payload doesn't contain microorganisms or entities such as tardigrades[73]. Regardless of whether the space object adequately satisfies the OST and Registration Convention, there may be

issues with appropriate management and registration of data about, or generated by the space object. For example, the activity data, including nominal description, input-output, and post facto mission insights, might be unavailable. Or, such data about the activities might be available but its access restricted due to security or commercial reasons. And further yet data about both the object and its activities may be available and accessible, but the level of automation and autonomy through which it may be processed may vary thus creating potential difficulties with registration and licensing requirements, in case these would be extended from mere objects to detailed activities.

Let's see how these three desirable features would work in practice in the space domain:

1) A Computational Jurisdiction should be clearly articulated with a physical domain of application.

In this initial step, the physical domain of application may be defined as the environment embedded throughout the EOCM-E, in which the exchange of communications and data over satellites, other space objects, and computer networks occurs. This definition could be expanded later to include other planetary bodies, subject to internet access across and beyond the Solar System.

While some of the language may be reminiscent of the definition of 'cyberspace', I depart from this cyberspace concept due to the limitations that were previously reviewed. The physical domain of application of a would-be Computational Jurisdiction isn't divorced from material reality. Instead, it could be said that such a jurisdiction is anchored in a matrix of hardware and computer networks that presumably operate under some form of government oversight and alignment with corporate and individual stakeholders. Considering the set of terrestrial challenges with technology governance of current data systems, hardware, value chain management, even within well-defined Earth government structures, it is prudent to anticipate that similar governance challenges will emerge as a space economy develops.

2) A Computational Jurisdiction should function effectively within relevant legal frameworks and their modalities of application and enforcement where relevant.

As argued, while the 'cyberspace' concept doesn't seem sufficiently fit-for-purpose to deal with considerations of international public law and conflict of laws in purely terrestrial contexts, similar shortcomings, if they aren't first addressed and solved on Earth, are likely to manifest in the space domain. For almost half a century, the body of space treaties ("*Corpus Juris Spatialis*"[74]) ensured the legal environment in the space sector, addressing the principles of exploration and use of outer space. In other words, space missions operate under this *Corpus Juris Spatialis*, a fundamental yet evolving legal framework governing space activities under international law and relations between responsible states, built over time starting with the OST and implemented via subsequent treaty texts. In addition, a developing corpus of national space laws is being concurrently developed to govern responsible states activities in ways that are consistent with international space law, while being even more cohesive and legally binding.

However, a system-level understanding of space law[75] will show that the risk to a cohesive national regime is that the operators of different states will be bound by different, incompatible rules. This can be solved with a third regulatory layer[76], whereas the rules are made through inter-operator negotiation, public and private, or accepted by operators that opt in after the rules are fixed. In addition to operators, professional civil society organizations will contribute to a collective rule-making collaborative effort. For example, the Space Safety Coalition[77], the International Association for the Advancement of Space Safety[78], the GEGSLA[79], are examples of such civil society initiatives already performing such activities, through various and somewhat complementary methodologies. These examples show that an international and national space legal framework with various levels of binding instruments and interoperability, will underwrite adaptive governance of space activities, only on the condition that it can be effectively combined and harmonized, as previously mentioned, with a third layer of norms, standards, and codes of conduct. And that third layer involves both operators and professional civil society participating organizations. Therefore, and while future outcomes remain to be seen, if we intend for a composable component to become part of space activities governance under a Computational Jurisdiction, we need this to happen in ways that are consistent with existing legal and governance frameworks.

As such I would suggest this Computational Jurisdiction domain of application be set in a way that it includes functional articulations aligned with space law. Such an approach would *ipso facto* align with international public law and other relevant bodies of Earth-bound laws, including the national laws and regulation of relevant 'responsible states' operating in space: the U.S.[80], Japan[81], Luxembourg[82], and the United Arab Emirates[83] are primary examples of countries with national space law programs consistent with international space law. Otherwise, using 'cyberspace' would run the risk of adding a layer of confusion to the issue of legal interoperability across the EOCM-E. We do not definitely close the door on using the 'cyberspace' concept in the space domain either. The fact that regulations of the digital realm are actively being worked on with various national programs, legislative transformations, and governance practices, leaves open the possibility of eventually resolving shortcomings. Furthermore, we do not know how things will evolve in a matter of decades and centuries. For example, even if there is only a remote possibility that a governing body making up an independent jurisdiction of the Moon would be created, as if it was some kind of an 8th continent[84] where competing space powers should deal with their differences, it would be a blank slate, with the opportunity to rebuild and reformat, in ways that resolve all current 'cyberspace' structural incompatibilities mentioned above, such as conflict of laws and other issues already experienced on Earth. As a matter of principle, we should keep an open mind of whatever will be created and re-imagined for the space domain long after our generations are gone. The slow moving space domain is the quintessential trans-generational endeavor.

The OST Article VI derives a link between registration of space objects and liability, such that liabilities for damages or other circumstances involving space objects is the responsibility of the state of origin for those objects[85]. Precisely, in that space context, the issue of defining '*lex loci delicti*' (the "place of wrong") is further exacerbated in the context of the EOCM-E . The way in which this ecosystem is defined has a direct

impact on the relevant legal frameworks and their modalities of enforcement when considering a Computational Jurisdiction. In the EOCM-E Computational jurisdiction, the 'place of wrong' may not be where a problem geographically appears to occur at a given location in space. For example, the problem could be linked to any of the actors that are plugged into the ecosystem hardware and software, as its network unfolds through the space domain, and toward which a data trail may or may not clearly showcase under which circumstances or where and how something happened.

Let's consider two practical examples for a safety zone use case involving autonomous systems. In a first example, a swarm of mining robots extracting Moon South Pole ice water samples for further characterization by Party A overlap into an area where Party B operates. A computational warning can be triggered that generates a prompt "auto-correct" behavior by the Party A swarm and the payment of a fine is computationally canceled because Party A's swarm didn't cause any damage and corrected its behavior instantly, while also debugging its navigation process so that such incident doesn't happen again. In a second example, an autonomous lander misses its landing pad for some reason, fails to correct trajectory in time, and lands too close for comfort to facilities, generating damaging debris. In this case, even if all the evidence data is available, the damage-causing event couldn't be computationally managed, and the settlement of damage and liabilities is likely to be supervised and resolved through human assessment and expertise with only a partial computational input.

Therefore from these simple practical examples, it is easy to understand, and I would argue, that while some legal matters might seem straightforward enough to be resolved within a strictly computational environment (first example), other matters (second example) may require reverting back to the *'Corpus Juris Spatialis'* and to an Earth-bound (or in future possibly Moon-bound, which remains to be created) supra-national or national equivalent jurisdiction. In the latter case the Computational Jurisdiction would act as a point of obligated passage where data-driven litigation evidence may be assessed and processed. Yet, the relevance of the evidence and its use in court would only be possible if a Computational Jurisdiction is regulated as a valid framework within a litigation and arbitration process[86].

The relevance and effectiveness of using a Computational Jurisdiction could be graded at three levels[87]:

- High: a fully automated and autonomous dispute resolution system can be implemented
- Medium: a degree of human and algorithmic coordination is required for dispute resolution
- Low: a protracted and cumbersome "paper paradigm" process stifles effectiveness at scale

3) A Computational Jurisdiction should be consistent with the relevant information architectures of any encountered lunar activity use-case, whose data may be fully or partially processed through human and/or computational intervention

As mentioned before, law, interpreted as a data process, could be said to function on the basis that 'algorithm is policy' when considered in the context of Composable Governance. As such, the consistency and de facto functionality of any use-case relevant information architecture, as encountered within the framework of a Computational Jurisdiction, is an engineering problem related to the relationship between validated data and the rule of law.

The following further builds upon takeaways from MIT Computational Law Report concepts and workshops:

The 'Pathetic Dot' model by Lawrence Lessig[88] combines four forces: *Architecture, Market, Law, Norms*. It can be rearranged as a construct that regroups the former three forces (renamed as *Technology, Business, Legal*) interacting with a universe of *Norms and Policies*. And as one operates through such a *Business-Legal-Tech* construct interacting with a universe of *Norms and Policies*, one may see the consistency and de facto functionality of any use-case relevant information architecture, as boiling down to three capabilities:

- capability to *predict data-driven (yet human centric) legal outcomes*
- capability to *enable ex ante legal and normative compliance ("compliance by design")*
- capability to *keep score cards of "successive states" and a "record of intent"*[89]

And, note that these capabilities are for any given Business-Legal-Tech construct at any given time and in any EOCM-E location where this construct performs some operation.

Furthermore, engineering these capabilities into the systems (hardware and software) that perform relevant activities is a first step toward the engineering of compliance within systems with various levels of automation and autonomy, also known as "*compliance by design*".

"*Compliance by Design*"[90] has originally been defined in a banking context as applying a systematic approach to integrating regulatory requirements into manual and automated tasks and processes. This can be achieved by preemptively decreasing the occurrence and risk of non-compliant behaviors through appropriate checks, due diligence, and behavioral requests conditional for granting access and completion of transactions, and make these as automated as possible with minimum required human supervision of such processes. And when that doesn't work, there is at least a data trail available for post facto forensics and litigation when appropriate. This modus operandi and concept can be tentatively extended from human customers and human-led financial transactions, to the whole of hardware and software systems operations that are set to comply with laws, regulations, and norms, with minimal to no human "cruise control" intervention, knowing a human can also be a single point of failure, and certainly epitomizes the cryptographic ethos of "*don't trust, verify*".

There may be cases where the potential for the above listed capabilities is maximal, thus making a Computational Jurisdiction the most relevant architectural framework. There may also be cases where the above listed capabilities are little to none and the relevance of a Computational Jurisdiction is reliant on the

accessibility of the data trail and record of evidence, as in the case where intents are near 100% human-assessed. But in any case, it will still depend on the larger body of space law and other relevant legal frameworks to take this data and evidence into consideration. And that processes will be human-led and arbitraged, with a case-by-case extraction of data sets and argumentation under a relevant national jurisdiction, or possibly an international body of arbitration whenever relevant. Whereas the computational aspect plays a supporting role in the constitution of evidence and reconstruction of sequences of events, neither a trivial matter for data acceptability nor for how interpretation of such data is debated in court as it conflicts with human expert testimony and assessment.

Remaining areas of uncertainty in space law and governance

I introduce this section in an attempt to provide clarity ahead of the next section *"Preliminary conclusion on 'computational jurisdiction' and 'composable governance'"*. In the above developments I constantly referred to the need for functional consistency between the features of a Computational Jurisdiction and the current corpus of space law and governance. However, there are remaining areas of uncertainty in space law and governance, which include and aren't limited to arbitration, liability mechanisms, registration, and specific questions with regard to automated and autonomous systems in outer space. These areas of uncertainty are likely to be sorted out over time, in the coming years, decades, and centuries, as activities expand across areas of the EOCM-E, and specific situations are being addressed.

Sorting out such areas of uncertainty over time may provide more clarity as to which data sets and algorithmic policies should be reflected in the features of a Computational Jurisdiction.

The context of arbitration was already mentioned. Regarding liability issues, let's reiterate that based on Article VI of the OST and Articles II and III of the Liability Convention[91], a State launching objects is responsible for any activities in outer space, including involvement of non-governmental entities residing in that State, such as the commercial private sector. This State is also liable for any accident and consequential damages[92] [93] .

As for registration, the provisions of the Article VIII of the OST, reinforced by the Registration Convention[94], requires the registration of objects launched in space by responsible states. The conditions under which such registration is being performed and the quality of the provided data are factors which in particular affect the status of responsibility, liability, and effective dispute resolution mechanisms for private sector entities and their record of compliance[95].

Furthermore, the nature of lunar activities being performed on the Moon surface or in its vicinity directly impacts the risk of insufficient "due regard" and potential "harmful interference", if activities are conducted without any coordination before, during, and after they are being performed: as reviewed above, examples of what could go wrong include and aren't limited to: accidental landing, projections and debris ; accidental surface traffic : messy exploration, samples extraction, and mining ; badly planned construction of infrastructures that affect other operators in the immediate vicinity ; etc. Therefore it matters for coordination

purposes to have a minimum of information about the activity itself at various stages of planning and execution: nominal description (but that is much more specific on what it actually does, than a payload list of e.g. mining equipment), activity logs and input-output, mission post-facto insights, sound like desirable parameters required for a reasonable level of activity coordination that warrants risk minimization and deconfliction. However, the fact that so far, registration only concerns objects launched in space (a nominal description of payloads) and not activities data as we just schematically described it, are part of several limitations explored for potential solutions by the Registration Project[96] (2021-2022). A joint-endeavor by the Moon Village Association and the Global Space Law Center at Cleveland University, the Registration Project (in which this author participated) was set with the purpose of providing a neutral international platform for assessing the existing mechanisms for sharing information about space activities, and for making a recommendation for harmonized methods for sharing information about lunar activities.

To add another layer of complexity, there is the issue of liability for systems with various degrees of automation and autonomy, a problem domain that is emerging just now on Earth and as such is currently lacking solutions. In space we are likely to see an abundance of deployed automated and autonomous systems, and as such liability becomes a matter of concern not only for crewed spacecrafts[97], but also for example vehicles and swarm robotic mining systems[98]. A potential solution broadly defined as establishing a liability linkage between the (consequences of the) acts of an automated and autonomous system and a human-controlled legal entity (either government or private sector) is only a starting point. The issue is complex and has been long debated, whether that means dealing specifically with AI-driven self-learning systems[99] or defining liability in relation to robots and algorithm[100]. But that's not all: whether it's dealing with these issues in space or on Earth, each region and country may develop their own approach. For example, in parallel with on-going efforts to develop a European AI law[101], German lawmakers[102] are looking into differentiation such as considering that, *'...the addressee of strict liability should not only be the operator of the system, but also its producer. With regard to causal liability of the producer, however, a differentiation is required: The producer should only be the addressee of causal liability if, instead of the operator of the system, he plays the central role in controlling the risks emanating from the autonomous system.*' Finally, the issue of legal and ethical *"crumple zone"* in the interaction between humans and automated and autonomous systems remain: a "*crumple zone*" is a technical term to define the front part of a vehicle that is designed to bend easily in an accident so that the people inside are protected[103]. That concept and definition can be extended to the relationship between humans and autonomous systems, and whether or not there is a device to protect the humans who could be indiscriminately and unjustifiably affected, not only physically, but legally and ethically, by the (consequences of the) nominal or accidental actions of said autonomous systems. This concern starts from the observation that *'When algorithms mess up, the nearest human gets the blame'*[104]. This important and complex issue, including concepts such as "human-in-the-loop[105]" have long been explored, and the flurry of cautionary tales in human-robot interaction[106] warrants a prudent and conservative approach on Earth to start with, and ultimately all across the EOCM-E.

It will likely take years, decades, and in some cases centuries, to sort out all of the above complexities and uncertainties, as the techno-political context evolves on Earth and beyond. And, almost ironically, the development of human-machine relationships might compel humans to reckon with both the limitations and unexplored potentials of their own nature. Adopting more responsible behaviors and departing from a path of constant conflict and rampant destruction of the Earth ecosystem might keep the glass half-full for starters.

Preliminary conclusion on Composable Governance and Computational Jurisdiction

As a result of the above delineation, I would conclude that a Computational Jurisdiction as a concept would be relevant, useful, and supportive of a Composable Governance framework, if it were to be imagined and implemented within the space domain. However, the effectiveness of this framework would still depend on its functional relationship with the larger body of space law and how courts currently conduct space-related litigation, and would need to deal with potential cases of lunar domain litigation, which remains to be seen. It is fair to say that a Computational Jurisdiction is not a *chimera*, but neither is it a *panacea*: it would be unlikely to act as a silver bullet that solves remaining uncertainties and complexities as mentioned above in the evolution of space law and governance. But the layers of complexity and uncertainty that need to be resolved in above examples pertaining to space law and governance, warrant that potential features of a Computational Jurisdiction may function consistently with the existing corpus of space law and governance, only on condition that this corpus has resolved its own uncertainties and evolutionary shortcomings first. Therefore both potential areas, a framework for a Computational Jurisdiction, and an evolving corpus of space law and governance, might develop in parallel, while learning from their occasional interactions in areas where they can find commonly consistent joint-functionality. I would then argue that a “rock-bottom” functionality for a Computational Jurisdiction would be to foster activities data, including a “record of intents” and a “record of activity states” of relevant systems, in ways that support the monitoring of how well such systems support the exercise of “due regard”, prevent and mitigate potential “harmful interferences”, and facilitate rather than obstruct the resolution of physical frictions while optimizing deconfliction, warranting the implementation of robust activities data registration.

How would a Computational Jurisdiction pan out for ‘Safety Zones’ on the Moon?

Let’s review the role of data with reference to three initial examples of what could go wrong, and how these scenarios might be mitigated through a computational and data-driven approach.

In the first example, if a spacecraft lands in an area that isn’t compliant with the requirements of a landing related safety zone, this could lead to projections damaging the environment and other possible issues. In such a scenario, a data-driven computational infrastructure could be expected to do three things. First, to help manage compliance benchmarks such as where are the designated landing pad areas for nominal behavior, and

where are the excluded landing areas that lead to accidental behavior, with a gradation of related risks and damages. Second, to monitor probable outcomes, by, at any given time when the spacecraft approaches the surface, inferring the probability of where and how (speed, orientation) the spacecraft will land, together with the probability of an accident happening (nominal vs gradation of probable accident). Lastly, if the above is possible, such a computational infrastructure could support corrective actions to normalize landing parameters or at minimum reduce the risk of accident and pursuant damages. If the spacecraft is human-piloted, this incorrect landing is either a human error or a deliberate action for reasons that may widely differ, from justified emergency to less excusable motives. If the spacecraft is fully automated and autonomous, it could be a system failure or even an external hack. The data linked to that spacecraft, flight, and harmful landing can be analyzed to monitor compliance issues at each stage, examine the record of intent, and inform corrective steps. If this analysis is done in real time, technology could enable early detection of the harmful trajectory and programmatically implement preventative tactics, such as repositioning the spacecraft's trajectory toward a proper landing area. This would be a subset of Moon Traffic Management for surface approach and landing.

In the second example, if an operator starts building an infrastructure that encroaches on solar panels strategically located on top of a crater (known as 'peaks of eternal lights') it will cast a shadow, which would have been a deliberate architectural decision. This is problematic from a practical and legal standpoint. Practically, by casting a shadow on the affected party's solar panels, the offender generates a technical risk (disrupted power supply) and a financial risk (loss of revenues and investment return on power generation). Legally, the offender just demonstrated an inability to exercise "due regard", and created a clear case of "harmful interference", as referred to in Article IX of the OST. In addition, the fact that this situation occurs is likely to imply that the offender didn't perform the necessary duty of care which would have been to register objects and intentions linked to this infrastructure, whereas an architectural blueprint would have preemptively warned all concerned parties about any likely issues with projected shadows. Therefore the building of such an infrastructure should be stopped in its tracks, and it could, but only provided the operator accepts to cooperate. Alternatively, data could be retrieved and used for documentation to support a lawsuit if coordination fails. The infrastructure of a Computational Jurisdiction could help manage compliance benchmarks by supporting international coordination among relevant parties for architectural decisions and collaborative design, ahead of such costly mishaps happening.

The third example occurs as a state and/or private sector operator, or an alliance of these, conduct scientific study, resource extraction, or any economic activity in a certain lunar perimeter. In that case, the safety zone is defined by the space and time coordinates making up the perimeter of that activity (localization and duration) to be informed to relevant parties. Based on the relevant data, the governance model of a computational jurisdiction should be able to support the definition of compliance benchmarks. This could be done as follows.

First, with the OST Article IX practice of "due regard" and avoidance of "harmful interference", and the requirement for operators to hold international consultations to coordinate activities or to resolve matters if

harmful interference is likely to occur[107]. Then, with the OST Article II non-appropriation and free-access, non-exclusionary principle, it is made very clear that denying free access by "fencing" a certain area for an indefinite period of time, is nothing but a sneaky pattern on unlawful appropriation by *fait accompli*. Therefore, the analysis of available data should support verification that a given perimeter isn't a de facto exclusionary zone, being "fenced" by localization and indefinite duration[108]. While these compliance benchmarks would be at the level of international law, relevant compliance benchmarks could also be developed and managed through a computational infrastructure at a national level, and at an industry standards level. Further data-driven compliance benchmarks may be introduced transversally by a civic constituency, such as non-governmental organizations with space expertise, and other relevant civil society actors, as already mentioned.

From the above, we can draw three additional observations and needs: *for international coordination of lunar activities, information exchange protocols, and the models of adaptive governance (including a composable governance component) required to handle these cases.*

International coordination, information exchange, and models of governance

While international consultations are required by the OST Article IX for the exercise of 'due regard' and avoidance of 'harmful interferences'[109], the reality is that there is an urgent need for a narrower approach coordinating lunar activities at the international, national, and operator levels. While international standards and interoperability are needs and objectives that could be supported by a data-driven computational jurisdiction, the dialogues at diplomatic, governmental, and corporate levels that may take place would also need to be substantiated by validated operational data.

However, the exchange of information in the context of lunar activities isn't a trivial matter. According to the OST Article XI[110], the responsible states involved in lunar activities have an obligation to inform the office of the Secretary General of the United Nations, while keeping in the loop the international scientific community and the public. We previously introduced the concept of a "*paper paradigm*" for legal documents: that includes not only analog artifacts in archive boxes, but also files in digital storage, whose static and non-interactive format doesn't allow for an automated, intelligent, and quasi-autonomous treatment. As a matter of common sense, when faced with dealing with the millions of documents and data sets to be generated by space domain activities in the remainder of the 21st century and beyond, it is difficult to see how human staffers of the above mentioned office alone could deal with that information flow in real time. In other words, it is difficult to see how such an office process could *scale* under such a "paper paradigm" as activities expand exponentially. There is another avenue to make information available, which is the Registration Convention that complements the OST[111]. In reality it is mostly limited to the registration of objects rather than dynamic activities (nominal description, input-output, and post facto missions insights), so far mostly orbital rather than cislunar or on the Moon surface and vicinity. And it doesn't cover the construction of computational datasets for data-driven Composable Governance architectures engineered with a Computational Jurisdiction, since it remains stuck in

this 20th century "paper paradigm" pre-computational mindset, to put it mildly. Therefore there is a necessary evolutionary phase that needs to happen at this juncture and in due time.

There are also practical limitations to the exchange of information when confidentiality and business interests are involved, such as the need to protect proprietary information and returns on investment, and where to draw a line vis-à-vis the public interest. In that respect it would perhaps be useful to investigate how concepts and tools such as various forms of '*Zero-Knowledge Proof*' could verify compliance mechanisms while supporting confidentiality. Zero-Knowledge Proofs (ZKP) are a classical cryptographic primitive that ensures the validity of data and computations without compromising their confidentiality.[112] Yet, experiences of legal technology shows how difficult it is to build appropriate datasets, a tacit knowledge matter within the profession. It is certainly worth trying but it will not be trivial to develop functional lunar activities datasets that are relevant to a business-legal-tech construct, while remaining manageable by all parties involved at all levels. Furthermore, if one adds a transversal civic-computational joint-constituency, coordination will depend on the governance models that are being adopted.

So what do we expect active governance models to look like, such that they can both sufficiently master the business-legal-tech construct of lunar activities, while also deploying the necessary diplomatic leverage? Diplomatically, the governance model taking place under the auspices of the United Nations appears to be the most preferred. I hear though many who would argue the UN is quite weak with regard to legal structures, enforceability, etc, and also not so technically established. It is an understatement to note that the UN, in its current structure and modus operandi, is subject to challenging reconsiderations in some political quarters. The institution is in need of reform to better reflect the fact that the world has evolved since 1945, as, for example, the composition and modus operandi of the UN Security Council doesn't reflect the political, economic, and demographic reality represented e.g. by the emerging Global South. While there is room for improvement, there are however areas of satisfactory activities: since having with colleagues some 'skin in the game' of feeding the UN system with space domain governance-related inputs, I address the prevalent criticism not merely from a political angle, but from a pragmatic, professional practitioner stance.

First and foremost it is important to understand that the diplomatic, legal, and technical articulation between the UN and civil society in space domain governance affairs is primarily realized *through NGOs being granted Permanent Observer status at the UNCOPUOS.* This is similar to what is known in e.g. defense and security diplomatic dialogues as the articulation between Track 1 and Track 2 discussions. The half-empty glass view on this is that observers do not run the show. The half-full glass view is that they contribute substantive inputs that may be instrumental in developing new regulations and governance mechanisms[113].

During its 2022 session, the Legal Subcommittee (LSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) created a *Working Group on the Legal Aspects of Space Resource Activity* and gave it a five-year mandate to gather information, study the current legal framework, and "*assess the benefits of further development of a framework for such activities, including by way of additional international*

governance instruments." A survey was sent to the LSC's member states and official observers. *Eighteen member states and seven NGOs* with permanent observer status contributed inputs, and their responses were published in early 2023[114]. I contributed as co-coordinator of the Moon Village Association (MVA) response, whose input was led by the expert team at the Catholic University of Santos (aka Unisantos), São Paulo, Brazil, represented and co-coordinated by Brazilian academic and space lawyer Susan Cristina Malhadas: that input represented a voice from the Global South, focused on issues of access to and benefit sharing of lunar activities, including and not limited to targeted technology transfers and value chains inclusiveness[115][116]. Other NGOs made equally significant contributions that are being reviewed, on top of the member states that responded. And while it remains to be seen whether COPUOS five-year mission produces a new international governance instrument in outer space resources[117], the system appears to work, albeit at snail pace, for both member states and civil society, and the work is being done by professionals, including among permanent observers with 'skin in the game'. Further examples are provided as to the interventions and contributions by NGOs to the UNCOPUOS inputs, including and not limited to the MVA: this first quarter 2023 alone, the UNCOPUOS Technical Subcommittee in February, and the Legal Subcommittee just concluded in late March, witnessed substantive and practical contributions to on-going space domain governance issues, including and not limited to outer space resource utilization[118].

Therefore, it is with the quiet confidence of professional teams which perform a useful work of productive contributions for the betterment of humankind, that I would argue in favor of the quality and relevance of the work performed together with the UNCOPUOS ecosystem. And its growing offline and online contingents of friends and allies across member states and civil society include the rising Global South. Evidently, the issue of diplomatic snail space needs to be addressed, however this is precisely an area where civil society has consistently demonstrated, with the works quoted in reference, its ability to deal with the immediacy of issues through comprehensive, flexible, and substantive responses. I posit the UNCOPUOS and its ecosystem will remain relevant in designing the appropriate space domain legal and governance instruments in this decade and most likely the next, fostering the ability of states to develop their own national instruments, and leveraging civil society inputs, which aren't going away. I would moderate misinformed criticism heard by simply stating that it is both inaccurate and unfair to belittle the legal and technical ability of the UNCOPUOS in tackling issues: as demonstrated by the programmatic drive of the technical and legal subcommittees, the kind of leadership and expertise displayed by the panelists and audience is effectively taking the ecosystem to the next level of business-legal-tech acumen. The best misinformed critics could do is in fact to join the fray and get some 'skin in the game' by contributing to civil society's constructive work in that context, At the same time, I also would certainly not deny the fact there is evidently much room for improvement to sufficiently involve industry and operators at large. This issue is in the process of being solved by e.g. the GEGSLA having one of its vice-chairs and part of its on-going operationalization phase being squarely focused on the involvement of industry. The time required for a consensus among a hundred member states being a given constraint, I nonetheless gather that it is both desirable and productive to work on accelerating industry involvement.

Furthermore this works as another pathway to influence the crafting of *national* space legislation. The time required to reach consensus needs to be reduced from half-centuries to decades to years in order to move the needle, since we don't have that much time ahead to get our international lunar act together.

There are a number of successful national organizations with strong technical expertise, but they need better collaborative positioning to deal with policy, governance, and legal issues *in coordination with industry*. Finally, there are several past and present multi-stakeholder non-governmental organizations or working groups (we have mentioned some of them: the Open Lunar and Secure World foundations, and GEGSLA launched in 2021 by the Moon Village Association) that probably do a better job of gathering business-legal-tech expertise jointly with exercising diplomacy and policy making skills. However, while delivering useful content, these organizations remain confronted with the challenge of effectively prompting and nudging senior decision makers at international, national, and operator levels. Without a 'Mandate from Heaven', it remains an uphill struggle, in our siloed and hierarchized societies, to build things from the ground-up. As a result, the often-quipped concept of 'polycentric governance' is a reflection of the fact that any policy coordination attempt may start from a fragmented socio-professional base with some sort of linkage to the powers that be, and that linkage may perhaps be re-engineered. A component of data-driven composable governance engineered around a Computational Jurisdiction seems in that regard reasonably well positioned to contribute to improve governance of space affairs as a whole, while optimizing the efficiency of its human-centered, data-driven constituencies. This presents a challenge of business-legal-tech adaptation and adoption not only for the UN bodies, but for the whole of the space domain ecosystem, including governments, industry, and civil society.

Conclusion

In the context of sustainable lunar activities, I focused on the concept of 'safety zones' on the Moon. However, solution components may be extrapolated to many space domain issues. Composable Governance in the realm of space domain affairs is not a *panacea*, but it is not a *chimera* either. Its utility includes engineering of compliance within automated and autonomous systems, while dealing with consequences of various degrees of human-machine interaction. In that sense, the features of a Computational Jurisdiction can be designed to reflect the various roles of data-driven 'algorithm is policy' implementations, from maximal (autonomous compliant decision making) to minimal (the data is at least available as evidence and record of states and intents, in order to prepare for a potential litigation, subject to its receivability by the relevant judicial process). But the adoption of Composable Governance as an organizational feature is subject to the evolution of relevant techno-political contexts on Earth as in space. In addition, a Computational Jurisdiction construct would work only to the extent that current uncertainties, inconsistencies, shortcomings and yet to explore evolutions of space law and governance, can be tackled and resolved over time in an internationally collaborative fashion, that is sustainable and deconfliction[119]-minded- notwithstanding in parallel the complexities of dealing with automated and autonomous system liability mechanisms in a context of human-machine interaction and relationship. Furthermore, and considering the current and provisional state of space domain affairs, the role of

Composable Governance may potentially expand much beyond autonomous systems. However, besides space traffic management, space system architectures, and business models, the most urgent and complex problem we need to solve now, for the sake of sustainable space domain and lunar activities, is a staggering coordination task at international, national, and operators levels, on policy and legal. A 'half-empty glass' approach to this situation would point out the geopolitical and geoeconomic challenges that may stand in the way of international coordination in space. The often encountered concept of 'polycentric governance' conceals an understatement, which is that the many fragmented stakeholders and organizations involved only master a fraction of the expertise and mechanisms of senior decision making at above three levels. In that sense, a 'half-full glass' view would argue that a Composable Governance component might support the development of data architectures and datasets relevant to all parties and usable by stakeholders, thus improving the process of negotiation and decision making. To engineer it around a Computational Jurisdiction can help streamline information exchange processes (including some form of Zero-Knowledge Proof protecting confidentiality) and support the development of interoperability as well as common standards for operators' behavior. A 'half-full glass' approach to this situation might conclude that, ultimately, transversal civic and computational constituencies can join forces, in an effort to improve data-driven yet human-centered governance models. I have explored how, through multi-stakeholder engagement, civil society could already further develop functional relationships with practitioners and decision makers, at international, national, and operator level . Even lesser levels of digital data interactivity, automation, and autonomy, were taken into account, as well as the gradual adoption of technology in legal affairs. It turns out, in these diverse and unequal contexts, that a Computational Jurisdiction-based form of Composable Governance, combined with civic initiative, might contribute to support a safe, peaceful, and sustainable development of space activities, for the benefit of all humankind. Whether we, humans, fight each other toward planetary destruction, or cooperate on Earth and across the Solar System, to survive and evolve as a species, is our free choice, perhaps as part of an effort intended for '*space as a laboratory of peace*'[120]. To which extent our free choice may integrate technology to foster deconfliction mechanisms remains to be seen.

Post-scriptum

Current events

At the time of editing and publishing, the *sixty-second session of the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space (COPUOS LSC), coordinated and logistically organized by the United Nations Office for Outer Space Affairs (UNOOSA)*, was taking place during 20-31 March 2023 in Vienna[121].

The exchange of information and data was one of the major discussion topics across events, while safety and sustainability of peaceful space and lunar activities is a pervasive theme.

Several publications and organizational announcements were made, here are five of them.

1. *The Global Expert Group for Sustainable Lunar Activities - GEGSLA* presented its *Recommended Framework and Key Elements for Sustainable Lunar Activities*[122] which was published in February 2023 (and in which this author participates). The *GEGSLA* is an international multi-stakeholder platform, including a strong Global South outreach, with a practical purpose of de-risking future lunar missions and increasing global cooperation for lunar exploration and settlement. GEGSLA is supported by the Moon Village Association which has permanent observer status at the United Nations Committee on the Peaceful Use of Outer Space (UNCOPUOS). The operational goals of the GEGSLA are to prepare materials that will be submitted to the UNCOPUOS, to support the Committee's discussions and deliberations on critical issues surrounding increased lunar activity. The *GEGSLA Recommended Framework* is designed as a guide for well-balanced lunar projects and offers concrete recommendations for how to implement safe and sustainable lunar activities through norm-setting, coordination, and management. It builds on principles established in international space law, relevant UN outer space treaties and soft law documents, and designs recommendations in thoroughly practical and implementable terms.

2. *The Moon Village Association Lunar Commerce and Economics Working Group* presented the first edition of its *Lunar Commerce Portfolio*[123] (in which this author participates), which was published in November 2022. The "Lunar Commerce and Economics" Working Group (LCE) provides a forum for promoting an international and interdisciplinary discussion of all potential markets for goods and services that will form an essential part of the Moon Village operations. It provides a focus for businesses who are considering supporting lunar activities, and for government planners who seek to understand the timeframe of, and degree to which, commercial business will be able to contribute to the endeavor of developing the Moon. The WG develops a Lunar Commerce Portfolio (LCP) to be a valuable source of lunar commercial market opportunities data. The LCP compiles, to a standard format, the full range of potential lunar businesses, and their interactions, that are anticipated not only in the near term, but in the long term, not only on the Moon, but in lunar orbit. In this same document, moreover, are collected the best assessments of prices for commercial products and services on the Moon, and the resulting revenue projections.

3. *The Moon Dialogs* announced the release of their *'Lunar Policy Handbook'*[124]. *The Moon Dialogs* is a compact of organizations led by the *Open Lunar Foundation*, and comprising the *Secure World Foundation*, *For All Moonkind*, *the European Space Agency - ESA*, the *Space Generation Advisory Council - SGAC*, the ***MIT Media Lab Space Exploration Initiative***, among its stakeholders. The *Lunar Policy Handbook* is a reference guidebook for government personnel and private actors in the space industry. It is designed to be a high-level guide that is useful for a broad audience of space actors, outlining policy issues and operational considerations related to lunar activities.

4. *For All Moonkind* announced the launch of their *'For All Moonkind Institute for Space Law and Ethics'*[125]. The *Institute*, whose mission is to promote the articulation and development of an ethical foundation and framework for responsible space behavior, will serve as a platform for the exchange and innovation of ideas

regarding law, morality and ethics amplifying diverse thoughts on the interpretation and expansion of the law as it affects human space activities. The ultimate goal of *For All Moonkind's Institute on Space Law and Ethics* is to reduce the potential for conflict and assure the sustainable exploration and use of space and its resources for the benefit of all humankind.

5. *The International Association for the Advancement of Space Safety* - IAASS[126] has just announced a "Forerunner" proposal:

"The IAASS proposed the establishment by MoU of an open cooperation among interested countries for the development of space safety standards, based on the following key principles:

- Cooperation aimed to achieve the highest practical degree of uniformity in national regulations, standards, procedures, and organizations.

- Joint development of top-level space safety standards as reference for national regulations.

- MoU signature not generating any prerogative, right or obligation for individual nationals of the subscribing countries. Only national laws and regulations apply.

- Ultimate decision maker on implementation and enforcement is the national space authority.

- Secretariat of the standardization cooperation at UNOOSA."

(My comment, for reference only: whether such MoU is implementable remains to be seen.)

Above examples are a demonstration of activity and relevance for space law and governance proposals being made at international, national, operators and civil society stakeholders level.

This record of events is not intended for discussion of involvement of such initiatives in the context of this article topic, other than what has already been reviewed regarding the topic relevance and adoption of legal engineering for sustainable practice implementation purpose.

Future explorations: relevance and potential roles of Generative AI in composable governance of space domain affairs

Between the initial ideation and drafting steps of this article, and the editing and publication stages, Generative AI based on Large Language Models has re-emerged as a field gaining public traction and concern. This is due not only to competitive offerings by OpenAI, Anthropic and several field leaders, but the immediate concern for reliability and security issues surrounding a non-regulated, non-supervised, or too naïve use of the technology.

In the Fall 2022 - Spring 2023 time frame, The MIT Computational Report was among the first collaborative community-based producers of public goods, to understand this renewed interest, both the potential and issues of concern for Generative AI, and to quickly set up a number of initiatives, such as: a *Generative AI Sessions of the 2023 MIT IAP Computational Law Workshop* ; an *idea flaw session on Legal Prompt Engineering - Examples and Tip* ; and setting up a *Task Force on Responsible Use of Generative AI for Law*[127].

At the time of publishing, I suggested there might be some merit in looking at the relevance and potential roles of Generative AI in composable governance of space domain affairs. Taking into account opportunities, limitations, and responsible use considerations, there may be some potential from e.g. governance check-lists processing to scenarios assessments to decision support. The MIT Computational Law Report leadership mentioned interest in exploring such potential. While that topic goes beyond the scope of this opinion piece, it will be explored in later articles.

Acknowledgements

Thank you for making it that far. If you enjoyed reading this opinion piece, credit should go to the *MIT Computational Law Report* best editor Aileen Schultz, who further acted as a wise and effective adviser to the building of the argument. I warmly thank *The MIT Computational Law Report* leadership, as well as its online community which I joined in Fall 2018, for the creation and development of legal engineering (computational law) and Composable Governance building blocks used in this opinion piece, and for suggesting the concept of a Computational Jurisdiction in conversations back in 2021. This work would not have been possible without my active involvement with the *Moon Village Association* and *Global Expert Group for Sustainable Lunar Activities*: I am grateful to this business, legal, tech multi-stakeholders community, and its seasoned professionals and academics in the field of space law and adaptive governance, for the wealth of experience acquired in its various trans-disciplinary working groups. I also express gratitude to other organizations active in lunar governance, such as *Moon Dialogs*, including the *Open Lunar* and *Secure World foundations*, in addition to the *European Space Agency - ESA*, the *Space Generation Advisory Council - SGAC*, the *MIT Media Lab Space Exploration Initiative*, as communities interact and joint-webinars occur. While having collaboratively written about and studied space legal and governance issues for quite some time with the help of academics and practitioners, *I am not a lawyer!* Such efforts are merely a contribution to coordinating trans-disciplinary information exchanges, knowledge transfers, and collaborative solution design, among international people of good will, across all paths of life, for the sake of space and planetary governance. Therefore, in the legal field, as well as other aspects pertaining to space domain governance, errors, misunderstandings, and omissions are mine and mine only.

*Please see below the references section for “Useful Readings” and “A Handy Study-List of International Law and Space Law Treaties and Legal Instruments”

References

1. MIT Computational Law Report - Collected Works on Composable Governance, first batch, December 2022 < https://law.mit.edu/composablegovernance >
2. Idea Forum on Composable Governance, to 'explore the idea of composable governance in the contexts of legal tech, business automation, and web3' < https://law.mit.edu/pub/ideaforum-1/release/3 >
3. Principles of composability and modularity < https://increment.com/frontend/on-composable-modular-frontends/ >
4. Relationship between composability and modularity < *https://ptolemy.berkeley.edu/projects/cps/Modularity_and_Composability.html* >
5. Exploration of Composable Organizations, Bryan Wilson, 2022 < https://www.upside.gg/the-ledger/exploration-of-composable-organizations-part-1 >
6. Although not intended at the time of writing, our readers may find, in this prudent, conservative definition and techno-politically agnostic approach toward the concept of Composable Governance within a multilayered international context and construct, an echo of *The Stack - On Software and Sovereignty* by Benjamin H. Bratton < https://observatory.constantvzw.org/books/benjamin-h-bratton-the-stack-on-software-and-sovereignty-2.pdf >
7. In *Monoliths and Dimensions: Benjamin H. Bratton's The Stack as Theory-Fiction* < *https://plijournal.com/files/9JOSHUA-CARSWELL.pdf* >, Joshua Carswell writes: *"In the shadows of the behemothic, overbearing, and totalizing regimes of highly-tuned, postindustrial technocapitalism, Benjamin H. Bratton's appropriately lofty opus The Stack: On Software and Sovereignty proposes a new means of assessing the architecture of contemporary geopolitics, identity, autonomy, and subjectivity. The democratizing potential of new technologies promised to us around the turn of the new millennium, we learn early on, has proven itself post-2008 to be no more sustainable than the global economy, and yet such fallacious utopian sentiments continue to reign down heavy fire upon us, like the antiquated drones of Philip K. Dick's short story 'Autofac', built for a harmonious world which no longer seems achievable or even desirable. The new geopolitics is inextricably also a technopolitics; its sovereignty is not singular but universal, coming from above, below, without and within."*
8. Safety Zones for Lunar Activities under the Artemis Accords, Alex Gilbert, Open Lunar Foundation, 2022 < https://www.openlunar.org/library/safety-zones-for-lunar-activities-under-the-artemis-accords >
9. The full text of the OST, whose U.N. formal title is *"Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies"*can be found there, together with a handy narrative that sums up the OST's historical and political Cold War context: < https://2009-2017.state.gov/t/isn/5181.htm >. U.N. space law instruments, including and not limited to the OST, can be found there: < https://www.unoosa.org/pdf/publications/STSPACE11E.pdf > and we also provide a detailed list of relevant treaties and legal instruments at the end of this opinion piece.
10. The OST Article IX notions of "due regard" and "harmful interference": *"In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by*

*the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with **due regard** to the corresponding interests of all other States Parties to the Treaty. (...) If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially **harmful interference** with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. (...)"*

11. McKinsey analysts suggest the outer space market could exceed 1 trillion dollar by 2030 < https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/laying-the-foundations-for-a-space-economy > (such numbers are being controversially debated)
12. Northrop Grumman: Why on Earth Should We Be Mining the Moon? < https://now.northropgrumman.com/why-on-earth-should-we-be-mining-the-moon/ >
13. *bidem* OST full text together with a handy narrative that sums up the OST's historical and political Cold War context: < https://2009-2017.state.gov/t/isn/5181.htm >
14. McKinsey: How will the space economy change the world < https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/how-will-the-space-economy-change-the-world >
15. iSpace from Japan < https://ispace-inc.com/news-en/?p=4460 >
16. The Global Space Law Center at Cleveland University College of Law, Ohio, U.S., led by Mark J. Sundahl < https://www.law.csuohio.edu/academics/globalspacelaw >
17. The United Nations Office for Outer Space Affairs (UNOOSA) < https://www.unoosa.org/ >
18. The United Nations Committee for the Peaceful Utilization of Outer Space (UNCOPUOS) < https://www.unoosa.org/oosa/en/ourwork/copuos/current.html >
19. The Evolution of a New and Viable Concept of Sovereignty for Outer Space, Linda R. Sittenfeld, 1980 < https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=1027&context=ilj >
20. The Federal Aviation Administration (FAAS) and its Office of Commercial Space Transportation < https://www.faa.gov/newsroom/commercial-space-transportation-activities >
21. US Environmental Protection Agency (EPA) Aerospace Sector Information: The Department of Defense, Federal Aviation Administration, National Aeronautics and Space Administration and EPA are the agencies primarily responsible for regulating the aerospace sector. < https://www.epa.gov/smartsectors/aerospace-sector-information >
22. The Liability Convention < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html >
23. Wilson Center, 2021, The Global Legal Landscape of Space: Who Writes the Rules on the Final Frontier? < https://www.wilsoncenter.org/article/global-legal-landscape-space-who-writes-rules-final-frontier >
24. Hard law or soft law? The debate about the future of space law, Dennis O'Brien, 2020 < https://www.thespacereview.com/article/3918/1 >

25. National Implementation of Non-Legally Binding Instruments: Managing Uncertainty in Space Law? Alexander Soucek, Jenni Tapio, 2019 < https://kluwerlawonline.com/journalarticle/Air+and+Space+Law/44.6/AILA2019035 >
26. The Hague International Space Resources Governance Working Group's *'Building Blocks for the Development of an International Framework on Space Resource Activities'* < *https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/final-bb.pdf* >
27. Secure World Foundation, Final Building Blocks Released by Hague International Space Resources Governance Working Group, 2019, < https://swfound.org/news/all-news/2019/11/final-building-blocks-released-by-hague-international-space-resources-governance-working-group >
28. The Moon Village Association < https://moonvillageassociation.org/ >
29. The GEGSLA - Global Expert Group for Sustainable Activities (in which this author is a participant) < https://moonvillageassociation.org/global-expert-group-on-sustainable-lunar-activities-gegsla/ >
30. '*The Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities*', GEGSLA, 2023 < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ >
31. The Open Lunar Foundation < https://www.openlunar.org/ >
32. The Secure World foundations < https://swfound.org/ >
33. Space Jano, led by Victorias Cocca y Esquivel, based in Argentina (in which this author participates), operates worldwide space domain information dissemination across the whole of Latin America, including Brazil, a notable space actor. < https://www.linkedin.com/company/spacejano/?originalSubdomain=ar >
34. '*Mineral Resources*' can be defined as the concentration of material of economic interest in or on the Earth's crust, or, for that matter, the Moon, asteroids, or any planetary body in the Solar System and beyond. Whereas '*Ore Reserves*' are the parts of a Mineral Resource that can at present be economically mined. < https://www.mmg.com/our-business/mineral-resources-and-ore-reserves/ >
35. Lunar market assessment: market trends and challenges in the development of a lunar economy, PWC, 2021 < https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf >
36. The Moon Village Association Lunar Commerce and Economics Working Group (LCE WG, in which this author is a participant and co-chair) < https://moonvillageassociation.org/working-groups/lunar-commerce-and-economics/ > released in November 2022 the first version of its Lunar Commerce Portfolio < https://moonvillageassociation.org/downloads/lunar-commerce-portfolio-2/ >
37. The Moon Village Association (MVA) LCE WG first version of its Lunar Commerce Portfolio, 2022 < https://moonvillageassociation.org/downloads/lunar-commerce-portfolio-2/ >
38. Space economy beyond Earth orbit: the need for Public-Private Partnerships in infrastructures projects on the Moon, SEE Lab Bocconi, 2021 < https://www.wia-europe.org/2021/07/05/space-economy-beyond-earth-orbit-the-need-for-public-private-partnership-in-infrastructure-projects-on-the-moon/ >
39. Definition: escape velocity, in astronomy and space exploration, is the velocity needed for a body to escape from a gravitational center of attraction without undergoing any further acceleration.

< https://www.britannica.com/science/escape-velocity >

40. Understanding rocket exhaust effects in polar regions during powered descent on the Moon < https://www.lpi.usra.edu/announcements/artemis/whitepapers/2059.pdf >
41. Rocket exhaust blowing lunar soil and mitigation by construction of lunar landing pads < https://www.youtube.com/watch?v=NFBMuOww1mI >.
42. Imagining safety zones: Implications and open questions, Jessy Kate Schingler, 2020 < https://www.thespacereview.com/article/3962/1 >
43. Space Power and the Foundations of an Independent Space Force < https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-33_Issue-4/F-Townsend.pdf >
44. The influence of space power upon history, Colin S. Gray, 2007, https://www.tandfonline.com/doi/abs/10.1080/01495939608403082?journalCode=ucst20 >
45. Making the Moon Work: Governance and Safety in a New Environment < https://www.youtube.com/watch?v=LXafVU7ofgQ >
46. Peaks of Eternal Light: discovered in 1994 on Peary crater near the north pole of the Moon, the so-called peaks of eternal light are the only known region in the solar system where the sun never sets. This unusual condition arises because the Moon's rotational axis is barely tilted relative to the plane of its and Earth's orbit around the sun. < https://static.scientificamerican.com/sciam/assets/media/8-Wonders/07-PeaksOfLight.html >
47. The legal limitations of safety zones in Outer Space < https://medium.com/@NinoRosso/the-legal-limitations-of-safety-zones-in-outer-space-9faf949457be >)
48. The Hague International Space Resources Governance Working Group *'Building Blocks for the Development of an International Framework on Space Resource Activities'* < *https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/final-bb.pdf* >
49. The Artemis Accords (< https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf >
50. Global Expert Group for Sustainable Activities '*Recommended Framework and Key Elements for Sustainable Lunar Activities*' < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ >
51. The MIT Computational Law Report - '*Collected Works on Composable Governance'* - First batch, December 2022 < https://law.mit.edu/composablegovernance >
52. The MIT Computational Law Report - Defining '*Legal Engineering*' < https://law.mit.edu/pub/ideaflow13/release/2 >
53. Exploring the concept of 'Algorithms as Policy', Michael Zargham, Kelsie Nabben, 2020 < https://kelsienabben.substack.com/p/algorithms-as-policy >
54. Blockchain Technology as a Regulatory Technology: From Code is Law to Law is Code, Primavera De Filippi, Samer Hassan, 2018' < https://arxiv.org/abs/1801.02507 >

55. '*Automated and Autonomous Legal Entities - AALEs*' (including DAOs): Presentation and discussion session presented at the MIT Media Lab Symposium on Blockchain for Robotics and AI Systems on December 4, 2019 < https://www.youtube.com/watch?v=Gjh3umDGin0 >
56. MIT Brenden Maher records the AALE genesis across the MIT Computational Law Report community, including Brenden and this author < https://otonomos.medium.com/otoco-and-the-revolution-4b6ad3a4e50c >
57. On AALE Automated and Autonomous Legal Entities: 2019 MIT Computational Law Report community "Computational Law and Blockchain Festival CB+L" NYC Brooklyn @The Bushwick Generator ("The Bushwick Generator Event"). A starting point for the pegging of DAOs and other AALEs to U.S. jurisdictions. Featuring MIT CLR's Dazza Greenwood, Brenden Maher, et al. < https://clbfest.github.io/2019-NYC/ > ; < https://github.com/CLBFest/2019-NYC/blob/master/session-automated-legal-entity.md >
58. The '*MIT Computational Law Sustainable Development Goals*', 2020 release < https://law.mit.edu/pub/computationallawdevelopmentgoals/release/1 >
59. The MIT Computational Law Report '*Collected works on Composable Governance*' < https://law.mit.edu/composablegovernance >)
60. The Secure World Foundation: Space Sustainability Rating Launch< https://www.youtube.com/watch?v=uaLsH5YdvQk >
61. The Moon Village Association (MVA) LCE WG first version of its Lunar Commerce Portfolio, 2022 < https://moonvillageassociation.org/downloads/lunar-commerce-portfolio-2/ >
62. The Moon Village Association Adaptive Governance Working Group < https://moonvillageassociation.org/working-groups/adaptive-governance/ >
63. Global Expert Group for Sustainable Activities '*Recommended Framework and Key Elements for Sustainable Lunar Activities*' < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ >
64. The Moon Village Association Architectural Concepts Working Group: '*Podcast: 2045: Moon Bases, Power Satellites, Reusable Transportation System, a Multi-trillion Dollar Space Economy & Space Diplomacy*' < https://moonvillageassociation.org/podcast-2045-moon-bases-power-satellites-reusable-transportation-system-a-multi-trillion-dollar-space-economy-space-diplomacy/ >
65. The Hague International Space Resources Governance Working Group *'Building Blocks for the Development of an International Framework on Space Resource Activities'* < *https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/final-bb.pdf* >
66. The Artemis Accords < https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf >
67. GEGSLA - '*The Recommended Framework and Key Elements for Sustainable Lunar Activities*' < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ >

68. The European Space Agency (ESA) project is working towards a Digital Twin of Earth < https://www.esa.int/Applications/Observing_the_Earth/Working_towards_a_Digital_Twin_of_Earth >
69. Conflicts on the Net: Choice of Law in Transnational Cyberspace < https://scholarship.law.vanderbilt.edu/cgi/viewcontent.cgi?article=1841&context=vjtl >
70. Polycentricity for coherent, timely, effective, and equitable governance of lunar activities < https://www.openlunar.org/library/polycentricity-for-governance-of-lunar-activities >
71. Cambridge dictionary online: definitions and meaning of the word "jurisdiction" < https://dictionary.cambridge.org/dictionary/english/jurisdiction >
72. The Convention on Registration of Objects Launched into Outer Space < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html >
73. The curious case of the transgressing tardigrades, 2019 < https://thespacereview.com/article/3783/1 >
74. Space lawmaking, Lucien Rapp, 2018: definition of *"Corpus Juris Spatialis"* - < https://www.thespacereview.com/article/3523/1 >
75. A Systems-level Understanding of Space Law, Brian Israel, 2022 < https://www.youtube.com/watch?v=bGyzJirjVpo >
76. '*Space Governance 3.0*', Brian Israel, 2020 < https://digitalcommons.law.uga.edu/gjicl/vol48/iss3/7/ >
77. The Space Safety Coalition '*Best Practices for the Sustainability of Space Operations*' < https://spacesafety.org/best-practices/ >
78. The International Association for the Advancement of Space Safety < https://www.iaass.org/ >
79. The Global Expert Group for Sustainable Lunar Activities - GEGSLA < https://moonvillageassociation.org/global-expert-group-on-sustainable-lunar-activities-gegsla/ >
80. The U.S.' space law < https://www.spacefoundation.org/space_brief/us-space-law/ >
81. Japan's space law < https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/japan/nasda_1969E.html >
82. Luxembourg's space law < https://space-agency.public.lu/en/agency/legal-framework.html >
83. The United Arab Emirates' space law < https://u.ae/en/about-the-uae/science-and-technology/key-sectors-in-science-and-technology/space-science-and-technology >
84. How the Antarctic Treaty of 1959 Influenced the Outer Space Treaty of 1967, Bailey DeSimone, 2022 < https://blogs.loc.gov/law/2022/01/how-the-antarctic-treaty-of-1959-influenced-the-outer-space-treaty-of-1967/ >
85. The Origins of Authorisation: Article VI of the Outer Space Treaty and International Space Law ' < https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1068&context=spacelaw >
86. Currently in the space domain, disputes arbitration processes still remain to be designed and implemented, in part due to the sovereign-centric nature of space law, and whether or not an arbitration process is even relevant to activities and operators in context. A go-to reference in that domain is the Space Arbitration Association < https://space-arbitration.com/blog/ > whose webinars are supported by the media platform SpaceWatch Global < https://spacewatch.global/2022/08/spacewatchgl-opinion-what-is-space-arbitration/ >

87. I deliberately did not focus this article on being a dissertation about DAOs and other cybernetic forms of organizations. Nonetheless, there is a benefit in referencing DAOs etc. at this juncture of the article: this would be a relevant elaboration, as AALE Automated and Autonomous Legal Entities technology and organizational design keep evolving over time. Suffice to say that the space domain will first require the development of a physical infrastructure and material solutions. Then, there will presumably be a time, when everything that has been discovered, experimented, and matured with AALEs, will come to fruition and be useful in a space domain and lunar activities context- one that is heavy on machines, strongly data-driven, yet human-centered. When that happens, pegging any form of AALE Automated and Autonomous Legal Entities to a jurisdiction will be key.
88. The 'Pathetic Dot' model by Lawrence Lessig (< https://en.wikipedia.org/wiki/Pathetic_dot_theory >
89. By "successive states" is meant the parameters that define the operational process and trajectory of any business-legal-tech construct through the whole cycle of performance of its operations in the context of a mission, a data set that can be stored and/or hashed. By a "record of intent" is meant a data record of what such business-legal-tech construct expects its operation parameters to become in the immediate future and a longer timeline whenever relevant. Note that "intent" isn't to be seen through a human lens of "intention", having nothing to do with speculations about alleged machine "intelligence" or "sentience". It links to deterministic or probabilistic aspects of laws of astrophysics, orbital mechanics, and autonomous systems algorithmic stochastic decision making as they behave in-situ and in time.
90. "*Compliance by Design*" has originally been defined in a banking context as applying a systematic approach to integrating regulatory requirements into manual and automated tasks and processes < https://web-assets.bcg.com/img-src/Compliance-by-Design-Dec2017_tcm9-198779.pdf >
91. The Liability Convention (1972) < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html >
92. Understanding International Space Law and the Liability Mechanism for Commercial Outer Space Activities —Unraveling the Sources < https://journals.sagepub.com/doi/10.1177/0974928419874553 >
93. As the role of the commercial private sector expands in the context of lunar missions, it becomes necessary to focus on the impact of such expansion on space liability regimes and to ascertain the legal efficiency of the links between private sector entities and responsible state liability.
94. The Registration Convention (1974) < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/registration-convention.html >
95. Unsolved issues of compliance with the registration convention < https://www.sciencedirect.com/science/article/abs/pii/S2468896721000409 >
96. The Registration Project, a joint-endeavor by the Moon Village Association (MVA) and the Global Space Law Center (GSLC) at Cleveland University, Ohio, USA < https://moonvillageassociation.org/download/registration-poject-final-report-april-2022/ >
97. NASA - Autonomous systems < https://www.nasa.gov/consortium/AutonomousSystems >
98. OffWorld < https://www.offworld.ai/ >

99. Liability for Autonomous Systems: Tackling Specific Risks of Modern IT < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3195676 >
100. Liability for (Semi)Autonomous Systems: Robots and Algorithms < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3161962 >
101. EU Artificial Intelligence Act <https://artificialintelligenceact.eu/ >
102. German Law and Liability for Autonomous Systems < https://link.springer.com/chapter/10.1007/978-3-030-90513-2_3 >
103. The Britannica Dictionary, crumple zone < https://www.britannica.com/dictionary/crumple-zone >)
104. When algorithms mess up, the nearest human gets the blame - MIT Technology Review < https://www.technologyreview.com/2019/05/28/65748/ai-algorithms-liability-human-blame/ >
105. The Fallacy of the Human in the Loop: The Moral Crumple Zone < https://theheadway.pub/the-fallacy-of-the-human-in-the-loop-the-moral-crumple-zone-fc3cfa293caa >
106. Moral Crumple Zones: Cautionary Tales in Human-Robot Interaction < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2757236 >
107. Due Regard and Safety Zones: Understanding the Commercial Implications of Recent Policy and Legislation < https://www.nasa.gov/sites/default/files/atoms/files/space_portal_michelle_hanlon.pdf >
108. The legal limitations of safety zones in Outer Space < https://medium.com/@NinoRosso/the-legal-limitations-of-safety-zones-in-outer-space-9faf949457be >
109. OST Article 9 (OST < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html >) for the exercise of ‘due regard’ and avoidance of ‘harmful interferences’
110. OST article 11 (OST < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html >) for the duty of information
111. The Convention on Registration of Objects Launched into Outer Space < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html >
112. Zero-Knowledge Proof learning < https://zk-learning.org/ >
113. A 55 mn interview of Niklas Hedman, the former acting director of UNOOSA, sending a clear signal in favor of the private sector, operators, NGOs, and stakeholders at large, including the Global South. < https://spacewatch.global/2023/03/the-space-cafe-podcast-76-niklas-hedman-unoosa-exploring-the-intersection-of-space-industry-and-international-diplomacy-with-a-surprising-twist/ > The current director, newly confirmed in June 2023, is Aarti Holla-Maini < https://spacewatch.global/2023/06/aarti-holla-maini-to-become-unoosa-director/ >
114. A survey was sent by the UNCOPUOS Legal Subcommittee Working Group on space resources to member states and official observers. *Eighteen member states and seven NGOs* with permanent observer status contributed inputs, and their responses were published in early 2023 < https://www.unoosa.org/oosa/en/ourwork/copuos/lsc/space-resources/index.html>
115. Moon Village Association input, led by the expert team at the Catholic University of Santos (aka Unisantos), São Paulo, Brazil, represented and co-coordinated by Brazilian academic and space lawyer Susan Cristina

Malhadas: representing a voice from the Global South, focused on issues of access to and benefit sharing of lunar activities, including and not limited to targeted technology transfers and value chains inclusiveness < https://www.unoosa.org/documents/pdf/copuos/lsc/space-resources/LSC2023/PermObsResponses/Moon_Village_Association_LSC_WG_on_SR_and_Annex.pdf >

116. See also the Benefit Sharing Project, led by Suyan Cristina Malhadas and this author, under the umbrella of the Moon Village Association Adaptive Governance Working Group, 2022-2023 < https://moonvillageassociation.org/working-groups/adaptive-governance/ >
117. Will COPUOS five-year mission produce a new "international governance instrument in outer space resources, Dennis O'Brien (one of the contributors to the MVA input to the UNCOPUOS LSC), 2023 < https://moderndiplomacy.eu/2023/02/03/will-copuos-five-year-mission-produce-a-new-international-governance-instrument-for-outer-space-resources/ >
118. < *https://www.unoosa.org/res/oosadoc/data/documents/2023/aac_105c_22023crp/aac_105c_22023crp_31_0_html/AC105_C2_2023_CRP31E.pdf* > *In addition, the MVA attended with interest the meetings of the LSC Working Group on Legal Aspects of Space Resource Activities since the theme is of great relevance for human presence on the Moon. Moreover, the 62nd session of the LSC was another opportunity of engaging with delegates from other observer institutions who share an interest in the Moon and to attend the launch of the Lunar Policy Handbook* < *https://www.moondialogs.org/lunar-policy-handbook* >*, developed by the Moon Dialogs initiative. The handbook provides a comprehensive overview of space law and regulations relevant to lunar activities and identifies areas where insufficiency of norms, policies and governance could lead to potential risks. The complementarity of initiatives and approaches - for instance, the Lunar Policy Handbook and the GEGSLA Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities - are essential to advance the safety and sustainability of activities on the Moon with the immediacy required.*
119. "Deconfliction" has become an adopted concept in the governance of safe and sustainable space activities, for example used in the Artemis Accord. It includes active coordination and mitigation measures to avoid potential frictions or prevent these from festering into conflict. The use of "deconfliction" originates in the military coordination of flights, maneuvers, etc. between groups especially in areas where overlapping operations are occurring, in order to reduce the risk of accidents or incidents: *"Deconfliction is how friendly forces keep out of each other's way."* See < https://www.merriam-webster.com/dictionary/deconfliction >.
120. Space as a laboratory of peace: '*The Artemis Theory of Warfare*', Mark J. Sundahl, 2023 < https://bjwa.brown.edu/29-1/the-artemis-theory-of-warfare/ >)
121. The sixty-second session of the Legal Sub-Committee *of the Committee on the Peaceful Uses of Outer Space (COPUOS LSC), coordinated and logistically organized by the United Nations Office for Outer Space Affairs (UNOOSA)* < https://www.unoosa.org/oosa/en/ourwork/copuos/lsc/2023/index.html >, took place during 20-31 March 2023 in Vienna. The COPUOS Legal Subcommittee meets every year for two weeks to discuss legal issues related to the exploration and use of outer space. Furthermore, topics include the status and application of the five United Nations treaties on outer space, the definition and delimitation of outer

space, national space legislation, and legal mechanisms related to space debris mitigation. The Subcommittee also discusses international mechanisms for cooperation in exploration and peaceful use of outer space, among many others.

122. The Global Expert Group for Sustainable Lunar Activities - GEGSLA '*Recommended Framework and Key Elements for Sustainable Lunar Activities*', 2023 < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ >.
123. The Moon Village Association Lunar Commerce and Economics Working Group first edition of the 'Lunar Commerce Portfolio' < https://moonvillageassociation.org/download/the-lunar-commerce-portfolio-first-edition-november-2022/ >. Version 2 is targeted for 4th Quarter 2024.
124. The Moon Dialogs '*Lunar Policy Handbook*' < https://www.moondialogs.org/lunar-policy-handbook >
125. '*For All Moonkind Institute for Space Law and Ethics*' < https://www.forallmoonkind.org/institute/ >.
126. The International Association for the Advancement of Space Safety - IAASS < https://www.iaass.org/ >
127. Generative AI Sessions of the 2023 MIT IAP Computational Law Workshop: < https://www.youtube.com/watch?v=-cARPZAl_6Q > ; Idea flow session on Legal Prompt Engineering - Examples and Tip: < https://law.mit.edu/pub/ideaflow15/release/4 > ; Task Force on Responsible Use of Generative AI for Law: < https://law.mit.edu/pub/generative-ai-responsible-use-for-law/release/3 > *"The purpose of this Task Force is to develop principles and guidelines on ensuring factual accuracy, accurate sources, valid legal reasoning, alignment with professional ethics, due diligence, and responsible use of Generative AI for law and legal processes.*

Useful readings

Lunar governance in action: the Global Expert Group on Sustainable Lunar Activities (GEGSLA) has initiated three working groups as part of its Operational Phase, in order to address key aspects of lunar exploration and activities. The working groups, namely Lunar Environmental Protection (WG 1), Lunar Technical Coordination (WG 2), and Lunar Multistakeholder Coordination (WG 3), will focus on ensuring environmental preservation, coordinating technical aspects, and fostering collaboration among various stakeholders in lunar endeavors (source: GEGSLA newsletter, August 2023 issue).

[https://www.linkedin.com/pulse/gegsla-newsletter-august-2023-gegsla/]

The GEGSLA WG3 on Lunar Multistakeholder Coordination is forging collaboration across diverse stakeholders for a unified lunar future.

[https://www.linkedin.com/feed/update/urn:li:activity:7105859823031697408/]

Malak Trabelsi Loeb on envisioning space governance: Reframing Global Governance for Sustainable Development: A Vision for UN 2.0

[https://www.linkedin.com/pulse/reframing-global-governance-sustainable-development-trabelsi-loeb--1f/]

Dennis O'Brien in #SpaceWatchGL Opinion: UN-COPUOS space resources meetings reveal wide spectrum of opinions but also some consensus on scope of discussions

[https://spacewatch.global/2023/07/spacewatchgl-opinion-un-copuos-space-resources-meetings-reveal-wide-spectrum-of-opinions-but-also-some-consensus-on-scope-of-discussions/]

Indian PM Modi proposes Creation of a BRICS Space Exploration Consortium at the 15th BRICS Summit: upon witnessing live during the 15th BRICS summit on August 22nd-24th, 2023, the successful soft landing of Chandrayaan 3 on the Moon, Indian PM Modi went ahead with a declaration in which he proposed the creation of a BRICS Space Exploration Consortium. Acknowledging to be already working on a BRICS satellite constellation, the PM considers the Consortium as a next step under which BRICS can work for global good in areas like space research and weather monitoring. PM Modi also insisted on the need for cooperation in education, skill development and technology, since, "to make BRICS a future ready organization, we have to make our societies future ready. Technology will play an important role in this".

[https://www.narendramodi.in/prime-minister-narendra-modis-remarks-at-plenary-session-i-of-brics-summit-in-johannesburg-south-africa-573176]

In June 2023, United Nations Secretary-General António Guterres announced the appointment of Ms. Aarti Holla-Maini of the United Kingdom as Director of the United Nations Office for Outer Space Affairs (UNOOSA) in Vienna.

[https://spacewatch.global/2023/06/aarti-holla-maini-to-become-unoosa-director/]

In March 2023, Ian Grosner, the Brazilian Space Agency federal attorney, was elected the chair of the Working Group on the Definition and Delimitation of Outer Space of the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space (COPUOS) in Vienna, Austria.

[https://spacewatch.global/2023/03/ian-grosner-elected-as-chair-of-outer-space-lsc-working-group/]

SpaceWatch Global - miscellaneous articles on space domain development and sustainability.

[https://spacewatch.global/?s=bosquillon]

A handy study-list of international law and space law treaties and legal instruments

The Charter of the United Nations, 24 October 1945, 1 UNTS XVI
aka "UN Charter",
[https://www.un.org/en/about-us/un-charter/full-text]

United Nations Treaties on Outer Space:

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 27 January 1967, 610 UNTS 205, (entered into force on 10 October 1967)

aka "Outer Space Treaty",

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html]

Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 22 April 1968, 672 UNTS 119, (entered into force 3 December 1968)

aka "Rescue and Return Agreement",
[https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/rescueagreement.html]

Convention on International Liability for Damage Caused by Space Objects, 29 March 1972, 961 UNTS 187, (entered into force 1 September 1972)

aka "Liability Convention",

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html]

Convention on Registration of Objects Launched into Outer Space, 14 January 1975, 1023 UNTS 15 (entered into force 15 September 1976)

aka "Registration Convention",

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/registration-convention.html]

Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 5 December 1979, 1363 UNTS 3, (entered into force 11 July 1984)

aka "Moon Agreement",

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/moon-agreement.html]

United Nations Resolutions and Guidelines Related to Outer Space:

Declaration of Legal Principles Concerning the Activities of States in the Exploration and Use of Outer Space, GA Res 1962 (XVIII), UNGAOR, 18th Sess, UN Doc A/RES/18/1962 (1963)

aka "Declaration of Legal Principles",

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/legal-principles.html]

Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting, GA Res 37/92, UNGAOR, 37th Sess, UN Doc A/RES/37/92 (1982),

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/dbs-principles.html]

Principles relating to Remote Sensing of the Earth from Space, GA Res 41/65, UNGAOR, 41st Sess, UN Doc A/RES/41/65 (1986),

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/remote-sensing-principles.html]

Principles Relevant to the Use of Nuclear Power Sources in Outer Space, GA Res 47/68, UNGAOR, 47th Sess, UN Doc A/RES/47/68 (1992),

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/nps-principles.html]

Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries, GA Res 51/122, UNGAOR, 51st Sess, UN Doc A/RES/51/122 (1996),

[https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/space-benefits-declaration.html]

UNGA, Application of the concept of the “launching State”, UN Doc A/RES/59/115 (2005),

[https://www.unoosa.org/pdf/gares/ARES_59_115E.pdf]

UNGA, Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects, UN Doc A/RES/62/101 (2008),

[https://www.unoosa.org/pdf/gares/ARES_62_101E.pdf]

UNGA, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, 2010, [https://www.unoosa.org/res/oosadoc/data/documents/2010/stspace/stspace49_0_html/st_space_49E.pdf]

UNGA, Recommendations on national legislation relevant to the peaceful exploration and use of outer space, UN Doc A/RES/68/74 (2013),

[https://www.unoosa.org/oosa/oosadoc/data/resolutions/2013/general_assembly_68th_session/ares6874.html]

UNGA, Guidelines for the Long-term Sustainability of Outer Space Activities, UN Doc A/74/20 (2019), Annex III,

[https://www.unoosa.org/res/oosadoc/data/documents/2019/a/a7420_0_html/V1906077.pdf]

UNGA, Prevention of an arms race in outer space, UN Doc A/RES/76/22 (2021),

[https://documents-dds-ny.un.org/doc/UNDOC/GEN/N21/377/75/PDF/N2137775.pdf?OpenElement]

International Treaties Governing Telecommunications:

Constitution and Convention of the International Telecommunication Union, Collection of the basic texts adopted by the Plenipotentiary Conference Edition of 2019, March 2019

aka "ITU Constitution",

[https://www.itu.int/dms_pub/itu-s/opb/conf/S-CONF-PLEN-2019-PDF-E.pdf]

International Telecommunication Union, Radio Regulations, Edition of 2020, (entered into force on 1 January 2021)
aka "Radio Regulations",

[https://www.itu.int/pub/R-REG-RR-2020]

Other International Treaties:

Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, 5 August 1963, 480 UNTS 43 (entered into force 10 October 1963)

aka "PTBT",

[https://treaties.un.org/doc/Publication/UNTS/Volume%20480/volume-480-I-6964-English.pdf]

Convention on the Prohibition of Military or Any Hostile Use of Environmental Modification Techniques, 18 May 1977, 1108 UNTS 151 (entered into force 5 October 1978)

aka "ENMOD",

[https://treaties.un.org/doc/Treaties/1978/10/19781005%2000-39%20AM/Ch_XXVI_01p.pdf]

Vienna Convention on the Law of Treaties, 23 May 1969, UN Doc A/Conf.39/27, 1155 UNTS 331, (1969) (entered into force 27 January 1980)

aka "Vienna Convention on the Law of Treaties",

[https://legal.un.org/ilc/texts/instruments/english/conventions/1_1_1969.pd]

Footnotes

1. MIT Computational Law Report - Collected Works on Composable Governance, first batch, December 2022 < https://law.mit.edu/composablegovernance > ↩
2. Idea Forum on Composable Governance, to 'explore the idea of composable governance in the contexts of legal tech, business automation, and web3' < https://law.mit.edu/pub/ideaforum-1/release/3 > ↩
3. Principles of composability and modularity < https://increment.com/frontend/on-composable-modular-frontends/ > ↩
4. Relationship between composability and modularity < *https://ptolemy.berkeley.edu/projects/cps/Modularity_and_Composability.html* > ↩
5. Exploration of Composable Organizations, Bryan Wilson, 2022 < https://www.upside.gg/the-ledger/exploration-of-composable-organizations-part-1 > ↩
6. Although not intended at the time of writing, our readers may find, in this prudent, conservative definition and techno-politically agnostic approach toward the concept of Composable Governance within a multilayered international context and construct, an echo of *The Stack - On Software and Sovereignty* by Benjamin H. Bratton < https://observatory.constantvzw.org/books/benjamin-h-bratton-the-stack-on-software-and-sovereignty-2.pdf > ↩
7. In *Monoliths and Dimensions: Benjamin H. Bratton's The Stack as Theory-Fiction* < *https://plijournal.com/files/9JOSHUA-CARSWELL.pdf* >, Joshua Carswell writes: *"In the shadows of the behemothic, overbearing, and totalizing regimes of highly-tuned, postindustrial technocapitalism, Benjamin H. Bratton's appropriately lofty opus The Stack: On Software and Sovereignty proposes a new means of assessing the architecture of contemporary geopolitics, identity, autonomy, and subjectivity. The democratizing potential of new technologies promised to us around the turn of the new millennium, we learn early on, has proven itself post-2008 to be no more sustainable than the global economy, and yet such fallacious utopian sentiments continue to reign down heavy fire upon us, like the antiquated drones of Philip K. Dick's short story 'Autofac', built for a harmonious world which no longer seems achievable or even desirable. The new geopolitics is inextricably also a technopolitics; its sovereignty is not singular but universal, coming from above, below, without and within."* ↩
8. Safety Zones for Lunar Activities under the Artemis Accords, Alex Gilbert, Open Lunar Foundation, 2022 < https://www.openlunar.org/library/safety-zones-for-lunar-activities-under-the-artemis-accords > ↩
9. The full text of the OST, whose U.N. formal title is *"Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies"*can be found there, together with a handy narrative that sums up the OST's historical and political Cold War

context: < https://2009-2017.state.gov/t/isn/5181.htm >. U.N. space law instruments, including and not limited to the OST, can be found there: < https://www.unoosa.org/pdf/publications/STSPACE11E.pdf > and we also provide a detailed list of relevant treaties and legal instruments at the end of this opinion piece. ↩

10. The OST Article IX notions of "due regard" and "harmful interference": *"In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with **due regard** to the corresponding interests of all other States Parties to the Treaty. (...) If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially **harmful interference** with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. (...)"* ↩

11. McKinsey analysts suggest the outer space market could exceed 1 trillion dollar by 2030 < https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/laying-the-foundations-for-a-space-economy > ↩

12. Northrop Grumman: Why on Earth Should We Be Mining the Moon? < https://now.northropgrumman.com/why-on-earth-should-we-be-mining-the-moon/ > ↩

13. *ibidem* OST full text together with a handy narrative that sums up the OST's historical and political Cold War context: < https://2009-2017.state.gov/t/isn/5181.htm >. ↩

14. McKinsey: How will the space economy change the world < https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/how-will-the-space-economy-change-the-world > ↩

15. iSpace from Japan < https://ispace-inc.com/news-en/?p=4460 > ↩

16. The Global Space Law Center at Cleveland University College of Law, Ohio, U.S., led by Mark J. Sundahl < https://www.law.csuohio.edu/academics/globalspacelaw > ↩

17. The United Nations Office for Outer Space Affairs (UNOOSA) < https://www.unoosa.org/ > ↩

18. The United Nations Committee for the Peaceful Utilization of Outer Space (UNCOPUOS) < https://www.unoosa.org/oosa/en/ourwork/copuos/current.html > ↩

19.

The Evolution of a New and Viable Concept of Sovereignty for Outer Space, Linda R. Sittenfeld, 1980

< https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=1027&context=ilj >↩

20. The Federal Aviation Administration (FAAS) and its Office of Commercial Space Transportation < https://www.faa.gov/newsroom/commercial-space-transportation-activities > ↩

21. US Environmental Protection Agency (EPA) Aerospace Sector Information: The Department of Defense, Federal Aviation Administration, National Aeronautics and Space Administration and EPA are the agencies primarily responsible for regulating the aerospace sector. < https://www.epa.gov/smartsectors/aerospace-sector-information > ↩

22. The Liability Convention < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html > ↩

23. Wilson Center, 2021, The Global Legal Landscape of Space: Who Writes the Rules on the Final Frontier? < https://www.wilsoncenter.org/article/global-legal-landscape-space-who-writes-rules-final-frontier > ↩

24. Hard law or soft law? The debate about the future of space law, Dennis O'Brien, 2020 < https://www.thespacereview.com/article/3918/1 > ↩

25. National Implementation of Non-Legally Binding Instruments: Managing Uncertainty in Space Law? Alexander Soucek, Jenni Tapio, 2019 < https://kluwerlawonline.com/journalarticle/Air+and+Space+Law/44.6/AILA2019035 > ↩

26. The Hague International Space Resources Governance Working Group's *'Building Blocks for the Development of an International Framework on Space Resource Activities'* < *https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/final-bb.pdf* > ↩

27. Secure World Foundation, Final Building Blocks Released by Hague International Space Resources Governance Working Group, 2019, < https://swfound.org/news/all-news/2019/11/final-building-blocks-released-by-hague-international-space-resources-governance-working-group > ↩

28. The Moon Village Association < https://moonvillageassociation.org/ > ↩

29. The GEGSLA - Global Expert Group for Sustainable Activities (in which this author is a participant) < https://moonvillageassociation.org/global-expert-group-on-sustainable-lunar-activities-gegsla/ > ↩

30. '*The Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities*', GEGSLA, 2023 < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ > ↩

31. The Open Lunar Foundation < https://www.openlunar.org/ > ↩
32. The Secure World foundations < https://swfound.org/ > ↩
33. Space Jano, led by Victorias Cocca y Esquivel, based in Argentina (in which this author participates), operates worldwide space domain information dissemination across the whole of Latin America, including Brazil, a notable space actor. < https://www.linkedin.com/company/spacejano/?originalSubdomain=ar > ↩
34. '*Mineral Resources*' can be defined as the concentration of material of economic interest in or on the Earth's crust, or, for that matter, the Moon, asteroids, or any planetary body in the Solar System and beyond. Whereas '*Ore Reserves*' are the parts of a Mineral Resource that can at present be economically mined. < https://www.mmg.com/our-business/mineral-resources-and-ore-reserves/ > ↩
35. Lunar market assessment: market trends and challenges in the development of a lunar economy, PWC, 2021 < https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf > ↩
36. The Moon Village Association Lunar Commerce and Economics Working Group (LCE WG, in which this author is a participant) < https://moonvillageassociation.org/working-groups/lunar-commerce-and-economics/ > released in November 2022 the first version of its Lunar Commerce Portfolio < https://moonvillageassociation.org/downloads/lunar-commerce-portfolio-2/ > ↩
37. The Moon Village Association (MVA) LCE WG first version of its Lunar Commerce Portfolio, 2022 < https://moonvillageassociation.org/downloads/lunar-commerce-portfolio-2/ > ↩
38. Space economy beyond Earth orbit: the need for Public-Private Partnerships in infrastructures projects on the Moon, SEE Lab Bocconi, 2021 < https://www.wia-europe.org/2021/07/05/space-economy-beyond-earth-orbit-the-need-for-public-private-partnership-in-infrastructure-projects-on-the-moon/ > ↩
39. Definition: escape velocity, in astronomy and space exploration, is the velocity needed for a body to escape from a gravitational center of attraction without undergoing any further acceleration. < https://www.britannica.com/science/escape-velocity > ↩
40. Understanding rocket exhaust effects in polar regions during powered descent on the Moon < https://www.lpi.usra.edu/announcements/artemis/whitepapers/2059.pdf > ↩
41. Rocket exhaust blowing lunar soil and mitigation by construction of lunar landing pads < https://www.youtube.com/watch?v=NFBMuOww1mI >. ↩
42. Imagining safety zones: Implications and open questions, Jessy Kate Schingler, 2020 < https://www.thespacereview.com/article/3962/1 > ↩

43. Space Power and the Foundations of an Independent Space Force < https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-33_Issue-4/F-Townsend.pdf > ↩
44. The influence of space power upon history, Colin S. Gray, 2007, https://www.tandfonline.com/doi/abs/10.1080/01495939608403082?journalCode=ucst20 > ↩
45. Making the Moon Work: Governance and Safety in a New Environment < https://www.youtube.com/watch?v=LXafVU7ofgQ > ↩
46. Peaks of Eternal Light: discovered in 1994 on Peary crater near the north pole of the Moon, the so-called peaks of eternal light are the only known region in the solar system where the sun never sets. This unusual condition arises because the Moon's rotational axis is barely tilted relative to the plane of its and Earth's orbit around the sun. < https://static.scientificamerican.com/sciam/assets/media/8-Wonders/07-PeaksOfLight.html > ↩
47. The legal limitations of safety zones in Outer Space < https://medium.com/@NinoRosso/the-legal-limitations-of-safety-zones-in-outer-space-9faf949457be >) ↩
48. The Hague International Space Resources Governance Working Group *'Building Blocks for the Development of an International Framework on Space Resource Activities'* < *https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/final-bb.pdf* > ↩
49. The Artemis Accords (< https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf > ↩
50. Global Expert Group for Sustainable Activities '*Recommended Framework and Key Elements for Sustainable Lunar Activities*' < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ > ↩
51. The MIT Computational Law Report - '*Collected Works on Composable Governance'* - First batch, December 2022 < https://law.mit.edu/composablegovernance > ↩
52. The MIT Computational Law Report - Defining '*Legal Engineering*' < https://law.mit.edu/pub/ideaflow13/release/2 > ↩
53. Exploring the concept of 'Algorithms as Policy', Michael Zargham, Kelsie Nabben, 2020 < https://kelsienabben.substack.com/p/algorithms-as-policy > ↩
54. Blockchain Technology as a Regulatory Technology: From Code is Law to Law is Code, Primavera De Filippi, Samer Hassan, 2018' < https://arxiv.org/abs/1801.02507 > ↩

55. '*Automated and Autonomous Legal Entities - AALEs*' (including DAOs): Presentation and discussion session presented at the MIT Media Lab Symposium on Blockchain for Robotics and AI Systems on December 4, 2019 < https://www.youtube.com/watch?v=Gjh3umDGin0 > ↩
56. MIT Brenden Maher records the AALE genesis across the MIT Computational Law Report community, including Brenden and this author < https://otonomos.medium.com/otoco-and-the-revolution-4b6ad3a4e50c > ↩
57. On AALE Automated and Autonomous Legal Entities: 2019 MIT Computational Law Report community "Computational Law and Blockchain Festival CB+L" NYC Brooklyn @The Bushwick Generator ("The Bushwick Generator Event"). A starting point for the pegging of DAOs and other AALEs to U.S. jurisdictions. Featuring MIT CLR's Dazza Greenwood, Brenden Maher, et al. < https://clbfest.github.io/2019-NYC/ > ; < https://github.com/CLBFest/2019-NYC/blob/master/session-automated-legal-entity.md > ↩
58. The '*MIT Computational Law Sustainable Development Goals*', 2020 release < https://law.mit.edu/pub/computationallawdevelopmentgoals/release/1 > ↩
59. The MIT Computational Law Report '*Collected works on Composable Governance*' < https://law.mit.edu/composablegovernance >) ↩
60. The Secure World Foundation: Space Sustainability Rating Launch< https://www.youtube.com/watch?v=uaLsH5YdvQk > ↩
61. The Moon Village Association (MVA) LCE WG first version of its Lunar Commerce Portfolio, 2022 < https://moonvillageassociation.org/downloads/lunar-commerce-portfolio-2/ > ↩
62. The Moon Village Association Adaptive Governance Working Group < https://moonvillageassociation.org/working-groups/adaptive-governance/ > ↩
63. Global Expert Group for Sustainable Activities '*Recommended Framework and Key Elements for Sustainable Lunar Activities*' < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ > ↩
64. The Moon Village Association Architectural Concepts Working Group: '*Podcast: 2045: Moon Bases, Power Satellites, Reusable Transportation System, a Multi-trillion Dollar Space Economy & Space Diplomacy*' < https://moonvillageassociation.org/podcast-2045-moon-bases-power-satellites-reusable-transportation-system-a-multi-trillion-dollar-space-economy-space-diplomacy/ > ↩
65. The Hague International Space Resources Governance Working Group *'Building Blocks for the Development of an International Framework on Space Resource Activities'* <

https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/final-bb.pdf > ↩

66. The Artemis Accords < https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf > ↩

67. GEGSLA - '*The Recommended Framework and Key Elements for Sustainable Lunar Activities*' < https://moonvillageassociation.org/gegsla/documents/gegsla-recommended-framework/ > ↩

68. The European Space Agency (ESA) project is working towards a Digital Twin of Earth < https://www.esa.int/Applications/Observing_the_Earth/Working_towards_a_Digital_Twin_of_Earth > ↩

69. Conflicts on the Net: Choice of Law in Transnational Cyberspace < https://scholarship.law.vanderbilt.edu/cgi/viewcontent.cgi?article=1841&context=vjtl > ↩

70. Polycentricity for coherent, timely, effective, and equitable governance of lunar activities < https://www.openlunar.org/library/polycentricity-for-governance-of-lunar-activities > ↩

71. Cambridge dictionary online: definitions and meaning of the word "jurisdiction" < https://dictionary.cambridge.org/dictionary/english/jurisdiction > ↩

72. The Convention on Registration of Objects Launched into Outer Space < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html > ↩

73. The curious case of the transgressing tardigrades, 2019 < https://thespacereview.com/article/3783/1 > ↩

74. Space lawmaking, Lucien Rapp, 2018: definition of *"Corpus Juris Spatialis"* - < https://www.thespacereview.com/article/3523/1 > ↩

75. A Systems-level Understanding of Space Law, Brian Israel, 2022 < https://www.youtube.com/watch?v=bGyzJirjVpo > ↩

76. '*Space Governance 3.0*', Brian Israel, 2020 < https://digitalcommons.law.uga.edu/gjicl/vol48/iss3/7/ > ↩

77. The Space Safety Coalition '*Best Practices for the Sustainability of Space Operations*' < https://spacesafety.org/best-practices/ > ↩

78. The International Association for the Advancement of Space Safety < https://www.iaass.org/ > ↩

79. The Global Expert Group for Sustainable Lunar Activities - GEGSLA < https://moonvillageassociation.org/global-expert-group-on-sustainable-lunar-activities-gegsla/ > ↩

80. The U.S.' space law < https://www.spacefoundation.org/space_brief/us-space-law/ > ↩
81. Japan's space law < https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/japan/nasda_1969E.html > ↩
82. Luxembourg's space law < https://space-agency.public.lu/en/agency/legal-framework.html > ↩
83. The United Arab Emirates' space law < https://u.ae/en/about-the-uae/science-and-technology/key-sectors-in-science-and-technology/space-science-and-technology > ↩
84. How the Antarctic Treaty of 1959 Influenced the Outer Space Treaty of 1967, Bailey DeSimone, 2022 < https://blogs.loc.gov/law/2022/01/how-the-antarctic-treaty-of-1959-influenced-the-outer-space-treaty-of-1967/ > ↩
85. The Origins of Authorisation: Article VI of the Outer Space Treaty and International Space Law ' < https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1068&context=spacelaw > ↩
86. Currently in the space domain, disputes arbitration processes still remain to be designed and implemented, in part due to the sovereign-centric nature of space law, and whether or not an arbitration process is even relevant to activities and operators in context. A go-to reference in that domain is the Space Arbitration Association < https://space-arbitration.com/blog/ > whose webinars are supported by the media platform SpaceWatch Global < https://spacewatch.global/2022/08/spacewatchgl-opinion-what-is-space-arbitration/ > ↩
87. I deliberately did not focus this article on being a dissertation about DAOs and other cybernetic forms of organizations. Nonetheless, there is a benefit in referencing DAOs etc. at this juncture of the article: this would be a relevant elaboration, as AALE Automated and Autonomous Legal Entities technology and organizational design keep evolving over time. Suffice to say that the space domain will first require the development of a physical infrastructure and material solutions. Then, there will presumably be a time, when everything that has been discovered, experimented, and matured with AALEs, will come to fruition and be useful in a space domain and lunar activities context- one that is heavy on machines, strongly data-driven, yet human-centered. When that happens, pegging any form of AALE Automated and Autonomous Legal Entities to a jurisdiction will be key. ↩
88. The 'Pathetic Dot' model by Lawrence Lessig (< https://en.wikipedia.org/wiki/Pathetic_dot_theory > ↩
89. By "successive states" is meant the parameters that define the operational process and trajectory of any business-legal-tech construct through the whole cycle of performance of its operations in the context of a mission, a data set that can be stored and/or hashed. By a "record of intent" is meant a data record of what such business-legal-tech construct expects its operation parameters to become in the immediate future and a longer timeline whenever relevant. Note that "intent" isn't to be seen through a human lens of "intention",

having nothing to do with speculations about alleged machine “intelligence” or “sentience”. It links to deterministic or probabilistic aspects of laws of astrophysics, orbital mechanics, and autonomous systems algorithmic stochastic decision making as they behave in-situ and in time. ↩

90.

“*Compliance by Design*” has originally been defined in a banking context as applying a systematic approach to integrating regulatory requirements into manual and automated tasks and processes

< https://web-assets.bcg.com/img-src/Compliance-by-Design-Dec2017_tcm9-198779.pdf > ↩

91. The Liability Convention (1972) < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html > ↩

92. Understanding International Space Law and the Liability Mechanism for Commercial Outer Space Activities—Unraveling the Sources < https://journals.sagepub.com/doi/10.1177/0974928419874553 > ↩

93. As the role of the commercial private sector expands in the context of lunar missions, it becomes necessary to focus on the impact of such expansion on space liability regimes and to ascertain the legal efficiency of the links between private sector entities and responsible state liability. ↩

94. The Registration Convention (1974) < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/registration-convention.html > ↩

95. Unsolved issues of compliance with the registration convention < https://www.sciencedirect.com/science/article/abs/pii/S2468896721000409 > ↩

96. The Registration Project, a joint-endeavor by the Moon Village Association (MVA) and the Global Space Law Center (GSLC) at Cleveland University, Ohio, USA < https://moonvillageassociation.org/download/registration-poject-final-report-april-2022/ > ↩

97. NASA - Autonomous systems < https://www.nasa.gov/consortium/AutonomousSystems > ↩

98. OffWorld < https://www.offworld.ai/ > ↩

99.

Liability for Autonomous Systems: Tackling Specific Risks of Modern IT

< https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3195676 > ↩

100. Liability for (Semi)Autonomous Systems: Robots and Algorithms < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3161962 > ↩

101. EU Artificial Intelligence Act <https://artificialintelligenceact.eu/ > ↩

102. German Law and Liability for Autonomous Systems < https://link.springer.com/chapter/10.1007/978-3-030-90513-2_3 > ↩
103. The Britannica Dictionary, crumple zone < https://www.britannica.com/dictionary/crumple-zone >) ↩
104. When algorithms mess up, the nearest human gets the blame - MIT Technology Review < https://www.technologyreview.com/2019/05/28/65748/ai-algorithms-liability-human-blame/ > ↩
105. The Fallacy of the Human in the Loop: The Moral Crumple Zone < https://theheadway.pub/the-fallacy-of-the-human-in-the-loop-the-moral-crumple-zone-fc3cfa293caa > ↩
106. Moral Crumple Zones: Cautionary Tales in Human-Robot Interaction < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2757236 > ↩
107. Due Regard and Safety Zones: Understanding the Commercial Implications of Recent Policy and Legislation < https://www.nasa.gov/sites/default/files/atoms/files/space_portal_michelle_hanlon.pdf > ↩
108. The legal limitations of safety zones in Outer Space < https://medium.com/@NinoRosso/the-legal-limitations-of-safety-zones-in-outer-space-9faf949457be > ↩
109. OST Article 9 (OST < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html >) for the exercise of ‘due regard’ and avoidance of ‘harmful interferences’ ↩
110. OST article 11 (OST < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html >) for the duty of information ↩
111. The Convention on Registration of Objects Launched into Outer Space < https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html > ↩
112. Zero-Knowledge Proof learning < https://zk-learning.org/ > ↩
113. A 55 mn interview of Niklas Hedman, the acting director of UNOOSA, sending a clear signal in favor of the private sector, operators, NGOs, and stakeholders at large, including the Global South. < https://spacewatch.global/2023/03/the-space-cafe-podcast-76-niklas-hedman-unoosa-exploring-the-intersection-of-space-industry-and-international-diplomacy-with-a-surprising-twist/ > ↩

114. A survey was sent by the UNCOPUOS Legal Subcommittee Working Group on space resources to member states and official observers. *Eighteen member states and seven NGOs* with permanent observer status contributed inputs, and their responses were published in early 2023 < https://www.unoosa.org/oosa/en/ourwork/copuos/lsc/space-resources/index.html> ↩

115. Moon Village Association input, led by the expert team at the Catholic University of Santos (aka Unisantos), São Paulo, Brazil, represented and co-coordinated by Brazilian academic and space lawyer Susan Cristina Malhadas: representing a voice from the Global South, focused on issues of access to and benefit sharing of lunar activities, including and not limited to targeted technology transfers and value chains inclusiveness < https://www.unoosa.org/documents/pdf/copuos/lsc/space-resources/LSC2023/PermObsResponses/Moon_Village_Association_LSC_WG_on_SR_and_Annex.pdf > ↩

116. See also the Benefit Sharing Project, led by Suyan Cristina Malhadas and this author, under the umbrella of the Moon Village Association Adaptive Governance Working Group, 2022-2023 < https://moonvillageassociation.org/working-groups/adaptive-governance/ > ↩

117. Will COPUOS five-year mission produce a new “international governance instrument in outer space resources, Dennis O'Brien (one of the contributors to the MVA input to the UNCOPUOS LSC), 2023 < https://moderndiplomacy.eu/2023/02/03/will-copuos-five-year-mission-produce-a-new-international-governance-instrument-for-outer-space-resources/ > ↩

118.

UNCOPUOS Legal Subcommittee 62nd Session, as reported by Suyan Cristina Malhadas, Brazilian academic and space lawyer representing both the Catholic University of Santos, (aka Unisantos) and the MVA:

"*From March 20th to 31st, 2023, the Moon Village Association delegation attended the 62nd session of the Legal Subcommittee (LSC) of UN COPUOS. Delegates attended both in person and online. Being an institution with permanent observer status at COPUOS, the MVA had the opportunity to make a statement under agenda item 3 - General exchange of views, presenting its main activities during the past year and contributions to the development of space law and governance. Among those are:*

● *the Lunar Commerce Portfolio produced by the MVA Lunar Commerce & Economics Working Group;*

● *the Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities developed by the Global Expert Group on Sustainable Lunar Activities - GEGSLA;*

● *the Inputs for the Working Group on Legal Aspects of Space Resource Activities provided by the MVA Adaptive Governance Working Group and included in the paper A/AC.105/C.2/2023/CRP.23;*

● *the successful organization of the first International Moon Day on 20 July 2022, supporting the creation of several events worldwide in more than 23 countries, and the plans for the celebration in 2023.*

During the LSC session, the MVA distributed the report and hardcover copies of the GEGSLA Recommended Framework and Key Elements for Peaceful and Sustainable Lunar Activities and held a side event to present the document in detail to delegations of member States and observers. The side event took place on March 22nd in a hybrid format, where the experts also highlighted the urgent need for mechanisms to enhance

coordination and transparency for the safety and sustainability of activities on the Moon, considering that missions are already happening or planned for the next years. Watch the recording: < [*https://moonvillageassociation.org/watch-the-copuos-lsc-side-event-the-recommended-framework-and-key-elements-for-peaceful-and-sustainable-lunar-activities/*](https://moonvillageassociation.org/watch-the-copuos-lsc-side-event-the-recommended-framework-and-key-elements-for-peaceful-and-sustainable-lunar-activities/) *>*

On March 27, the Lunar Commerce and Economics Working Group made a technical presentation on the Lunar Commerce Portfolio, explaining the activities of the group, how the portfolio was developed to comprise different lunar markets, identify market drivers and produce revenue estimates for different lunar economic scenarios. In addition to the results achieved so far with the preliminary version of the Lunar Commerce Portfolio, the presentation also indicated the next steps and goals of such an ongoing effort. Download the Portfolio < [*https://moonvillageassociation.org/download/the-lunar-commerce-portfolio-first-edition-november-2022/*](https://moonvillageassociation.org/download/the-lunar-commerce-portfolio-first-edition-november-2022/) *>*

The MVA submitted a Conference Room Paper to the 62nd Session of the LSC, reporting the status of GEGSLA, its deliverables and plans for the implementation phase (A/AC.105/C.2/2023/CRP.31). It can be