2021 SPACE TRAFFIC MANAGEMENT

DIVERSE DOZEN

17 November 2021

There are a growing number of state actors and new satellites in space, as well as an accelerating drive for space commerce and exploration.

On a recent trip to Alaska, Moriba Jah, an astrodynamicist and space environmentalist, experienced an inner shift in perspective on sustainability and recognized how the indigenous peoples of our world have important lessons and tenets to share that may serve as a basis for us to thrive in space, while doing so in a sustainable way. What seems to be missing from the space community writ large is an inclusive conversation about how best to go about doing these things as one humanity.

In an effort to address this, and coming from a space of honoring and respecting the relationships and relatedness among all things, as well as of acting with compassion, Moriba Jah has partnered with ASCEND to create a first-of-kind annual event that invokes **diverse and unique voices from humanity** to tell the world about salient issues in space safety, security, and sustainability.

The ASCEND Diverse Dozen represent a profile of human constituents with thoughts worth sharing!

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Ilaria Cinelli // ITALY

Space Healthcare and Business Developer, AIKO

Space Traffic Cooperation Helps Human Spaceflights and Disaster Management

International space traffic management does not meet the current needs of space traffic operators as accessibility to resources is not widely available. In 2021, countries around the globe realized the impact of weak international cooperation when dealing with hard-to-track space debris. In April, a piece of space debris passed unexpectedly close to a Crew Dragon capsule. The astronauts of SpaceX's Crew-2 mission could have lost their lives. Then, in June, China's dead rocket re-entered the Earth's atmosphere around the Maldives and uncertainties prevented the world's top experts from accurately predicting possible impact sites. These events prove that current measures taken in space traffic management do not enable multilateral coordination in possible emergency scenarios.

I stress that safety in space is not just for who or what is in space. An international consensus does not exist regarding specific safety aspects related to space traffic, making it nearly impossible to predict possible consequences.

The exponential growth of the commercial space sector is not accompanied by consistent investments targeted to address existing regulatory gaps, making space resource utilization instability inevitable. A human disaster in space may drastically slow down the current economic growth, which could result in a stalled economy in a worst case scenario. Moreover, safety in commercial spaceflights may be compromised without proper government oversight. Any collision in space can lead to an avalanche of new debris that cannot be stopped and could damage the International Space Station and satellites, for example.

Additionally, very little interest has existed in updating disaster management procedures for guaranteeing the safety of people on the ground when a threat from space cannot be stopped. The current progress in disaster management suggests that any risk level must be within an acceptable range. China's dead rocket flew over several populated countries. There were no known evacuation procedures implemented to protect the local population beyond warnings (e.g., "Stay home far away from windows"). I wonder how efficient international cooperation would have been if that dead rocket, the size of a school bus, had hit a city.

Space is not an isolated domain. Space traffic coordination aims to strengthen the link with space activities and closely related Earth-based mechanisms established to protect the people and our planet. Such coordination might be the starting point for having a multilateral space traffic management system.

The lethargy of the regulation-making processes, the foundation of space traffic management, can be overcome by developing an information-sharing system built on leading-edge technologies or artificial intelligence (AI) techniques. To date, nations have started investing in data repositories; yet, data are not often entirely disclosed to the public. AI techniques shall enhance existing resources for connecting information (not necessarily raw data) across the international community, including civil activities. Here, such technology acts as a neutral platform for risk evaluation. It could be accessed by a community that shares similar interests, such as those with a focus on stability of operations and planetary protection.

That is a feasible way to promote coordination through information sharing as a first step toward norm generation and multilateral cooperation. Moreover, it encourages openness and transparency around the globe, in line with the principles of the Outer Space Treaty.

Such a platform allows stakeholders to contribute to developing most societies' economic progress, opening up infinite opportunities. The contribution of space enthusiasts and students can have a massive impact to guarantee continuous updates of publicly available data. Such public engagement can help raise awareness of the importance of safety for citizens and space travelers, persuading nations to invest in multilateral cooperation. In such a way, the space sector can become the most useful for our species' prosperity and truly be "for all," conforming to the United Nations Office for Outer Space Affairs mission.

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The Earth System and Outer Space

New forms of access to remote areas of the Earth and outer space are increasingly facilitated by technological and scientific advances now combined with growing privatization. There are many firms launching satellite constellations and planning future microgravity platforms. A benefit of this space technology is the delivery of data that is crucial for monitoring climate change in remote regions of the Earth, such as the Arctic. The theoretical premise of my work, though, is that the non-human phenomena (even if anthropogenic), like greenhouse gases and orbital debris, are unpredictable and disruptive agents and causing the ongoing environmental degradation of outer space. The phenomena are unintended results of human activities, and in turn, have the capacity to affect all planetary life (human and non-human). They are human created but also act in accordance with non-human laws (e.g., physics, chemistry, etc.). In other words, atmospheric chemistry is affected by humans, but does not much care for human-made laws. A new understanding of the cosmic and post-anthropocentric politico-juridical space—or the "cosmolegal"—might provide an alternative framework.[1]

Here are some observations.[2] First, the outer space sector orientation toward innovation and future tends to often use hyperbole in the everyday language. Phrases such as "the leader of," "the innovative thinker," and "the future world builder" when referring to those running the firms bringing these technological and scientific advances are problematic because the vanguard of progress can easily argue that this is all they do, even if the costs are high (environmental, human labor, etc.). If the cost is permanent, such as the environmental degradation of orbital space, then such progress has limits. And the limits are already evident in space debris proliferation.

Second, outer space is not spared the political conflict on Earth—for instance, the resurgence of political populism. Populism frequently claims that scientific or expert views are "empty language games," with the common misconception that they are not "for the people." One prominent example is the denial of scientific evidence on climate change. STEM education should be accessible to all and required in early education, which would equip everyone with knowledge on space.

Third, and related, violence begins with language and many of us who have observed the onset of a civil war, the violence of populist language during and after the war, can provide ample examples. We can see violence deeply embedded in how humans approach space. Consider the frequent usage of the word "conquest." Language does not just influence violence and oppression; it creates it, perpetuates it, and sustains it.

Therefore, 1) If there is a vanguard, futurist thinking, "innovative" sector, which is bringing humanity to outer space and the future, this means that those who are not doing that are left "behind" and dealing with issues of no consequence. 2) If the outer space "talk" is more populist, bombastic, hyperbolic, it necessitates an abundance of excess. And excess also means endless appropriation of what are deemed to be non-human worlds, spaces, surfaces: Mars, moon, asteroid mining, etc. It is the new colonialism.

However, there is also a solution and a different possibility where this extraterrestrial environment remains a place of scientific exploration, expansion of knowledge, and benefit to "all humanity"—but also, not all "humanity." A different ontology is needed, which no longer makes clear distinctions between human and non-human and recognizes biological and material agency. A human body, for instance, is host to bacteria, viruses, or parasites. What is in the interest of a human body and its survival is not necessarily represented in the ontology of the dominant Western thought (e.g., is commercial gain more important than clean air and water, a decluttered orbit?). The problem then is not merely "anthropocentric" (i.e., a human body acts to survive like any other organism); rather it is the established ontology of artificial mind-body and human/non-human binaries, which has not been shared by all human societies. We need a new ethic, for both the Earth system and outer space, which does not see the human as the center of the universe.

[1] Further elaborated in Cirkovic, Elena. "The next Generation of International Law: Space, ICE, and the COSMOLEGAL Proposal." *German Law Journal* 22, no. 2 (2021): 147–67. https://doi.org/10.1017/glj.2021.4.

[2] Cirkovic, Elena. "Hyperbole: Outer Space." In *Research Handbook in Law and Literature*, edited by Peter Goodrich, Daniela Gandorfer, and Cecilia Gebruers. Edward Elgar, 2022. See also Billings, Linda. "Ideology, advocacy, and space flight – evolution of a cultural narrative." In *Societal Impacts of Space Flight*, edited by Steven J. Dick and Roger D. Launius, pp. 483-500. (NASA SP-2007-4801). National Aeronautics and Space Administration, Washington, DC, 2007. Available online at http://history.nasa.gov/sp4801.pdf, p. 483.

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A Bottom-Up Approach to Space Sustainability

This year, we celebrate 21 years of continuous human presence in space aboard the International Space Station. Over two decades of international cooperation, inspiration, and discovery is certainly a tremendous achievement. However, our access to space is not just about astronauts in spacesuits. Access to the space environment is an enabler of daily life on Earth with currently around 5,000 active satellites in Earth's orbit and ambitious plans for satellite mega-constellations that promise to revolutionize connectivity on Earth, reaching the remotest of places.

Hence, we are all users of space either directly or indirectly. Yet, how many of us self-identify as space-users? Your monthly online rent payment or ATM transactions are enabled by time synchronization technology based on space systems. Your last Uber ride was likely enabled by satellite navigation, as is your access to other forms of transport across air, land, and sea. Your ability to plan your day based on the weather forecast is also thanks to space systems applications with their privileged orbital insight. Cell phones, the internet, electronic banking, navigation, communications, and broadcasting are just a few examples of technologies enhanced by satellite-derived applications and services that we daily benefit from here on Earth.

Given that space systems are so deeply embedded in our modern infrastructure, why are we mostly just passive consumers of them? We are often dazzled by space, viewing it as a place to explore, far removed from us, and accessible to only a select few. However, maybe it's time we instead see it as a finite resource that is readily being exploited for our common benefit. How we disseminate the kinds of activities we carry out in space has the potential to impact our collective sense of awareness and willingness to better steward the space environment. It also provides an opportunity to better engage with the public to make us all shareholders in our space future – something which would represent nothing short of a paradigm shift in space sustainability.

Promoting a collective consciousness of both space traffic management and space sustainability issues, whereby global citizens see themselves as users of space, has significant potential. With heightened sensitivity comes increased investment in the issue worldwide that can, in turn, generate a critical mass of informed citizens able to spur policy discussions on a local and national level. This could ensure this topic remains high on the policy agenda, leading to the integration of sustainable practices in space from a national regulatory standpoint.

Furthermore, such activity could also serve as a driver to attract talent toward initiatives that focus on identifying space traffic management and space sustainability solutions such as citizen science activities and student-led groups, amongst others, which could model and be test beds for data-sharing practices prior to broad implementation.

To this end, an "International Day for Space Sustainability" would be a further means to gain traction and generate discussions that emphasize the essential nature of the space environment for daily life on Earth and the importance of transparency and data-sharing as new norms of behavior are established. The aforementioned activities could serve to empower currently non-spacefaring nations to act as active advocates of space sustainability measures to preserve the space environment that already suffers from persisting space debris and increasing space traffic particularly in the congested low Earth orbit (LEO) and geosynchronous equatorial orbit (GEO). Their advocacy could prevent further degradation of Earth orbits to preserve space access for tomorrow's spacefaring actors, ensuring equitable access to global and economic development through space.

It is clear that our reliance on space is ever-increasing, leading to heightened tensions between the rapidly growing space sector and our collective "ability to maintain the conduct of space activities indefinitely into the future." [1] This is not too dissimilar to what we are already experiencing as a result of industrialization here on Earth, which is often associated with negative impacts on the environment.

It would seem reasonable, therefore, to assume that the more actively citizens engage with both the criticality and finite nature of the space environment, the greater the possibility for responsible stewardship of this resource. For this reason, it is upon us as space actors, individually and holistically, to engage with a wider, non-industry audience to establish dialogues through which we can jointly determine and lay out our sustainable future in space.

[1] "Guidelines for the Long-term Sustainability of Outer Space Activities." UN Office for Outer Space Affairs, 2018. https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf.

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From Lone Travelers to Traffic Participants – An Argument for Basic Rules of the Road for the Emergent Traffic System in Low Earth Orbit

We stand at the dawn of humanity's second space age. The new dawn's warm rays of human ingenuity, innovation, and curiosity nurtures industry and science alike and inspires hope for new leaps in human development. We are a global community of spacefaring nations with diverse actors entering space with a flowering diversity of goals, motivations, cultures, technologies, and ethos. However, as the rockets take off in ever-increasing numbers and fill the void beyond the skies with an abundance of inventive human contraptions, a new issue has arisen – the final frontier is getting crowded.

The exponential growth in the population of satellites in low Earth orbit (LEO) is fundamentally changing the orbital environment. The frequency of conjunctions, i.e., situations where satellites pass near each other with potential for collision, is rising, demanding better and more frequent coordination between operators. The boon of the increasing diversity of cultures accessing space has a price, as operators increasingly need to communicate across cultural and linguistic barriers. We hold the shared aspiration of sustainability and safety in space and most agree that better coordination between space actors is urgently needed.

The urgent situation seems to call for an international agreement instituting a global traffic regime to ensure sustainable use, equitable access, and benefit-sharing of our orbital commons. A solution with an international treaty has many advantages, but one fatal disadvantage – it is unlikely to become reality any time soon. It has been decades since the enactment of the last broadly supported space treaty. Geopolitical tensions, militarization, commercial interests inter alia, makes a globally supported convention unlikely. Even if the global community agrees to start negotiations, the process could take years or decades and we do not have the luxury of time. A shocking catastrophe, like a satellite hitting the International Space Station (ISS), might speed things up, but that is a scenario too ghastly to contemplate. We must move forward with other solutions, rather than waiting until a disaster strikes.

The Emergence of Traffic

Traffic is an emergent property. It emerges when a sufficient number of independent actors interact without central coordination and without complete information about each other. If you drive across the desert and by chance meet another traveler, you are not in a traffic situation. When you are caught in rush hour on the motorway, you are a participant in a giant traffic system. LEO is changing from desert to motorway. And it's a motorway without traffic rules.

Motorways with no rules of the road are obviously unsafe, but just as important, they have much lower traffic capacity, speed, and efficiency. We can travel fast and close together on the motorway with minimal coordination because we know that we follow the same basic rules. It creates a predictable environment and makes it possible to exchange the most relevant information with very low broadband, e.g., blinking for lane-shift.

Starting with the Rules of the Road

Looking to other now well-regulated traffic domains, we can see that basic traffic rules have often preceded the complex treaty systems in place today. For road, sea, and air, basic customary rules of the road emerged in response to traffic issues long before the international community managed to agree to an actual treaty regime. For example, only a few decades after the Wright brothers took to the skies at Kitty Hawk, basic rules of the road had emerged to guide interactions between airplanes. We can sidestep many of the thorny geopolitical issues blocking international agreement about Space Traffic Management by focusing on specific, practical traffic rules for safe handling of conjunctions.

Most metrics of satellites relevant for traffic coordination cannot be determined without uncertainties. The rules of the road in orbit must be able to encompass these uncertainties. We should aim for brief and simple when formulating the rules, in the style of right-of-way provisions, safety distances, and similar concepts known from other traffic domains. Getting them right will take crossdisciplinary thinking across fields from international law to astrophysics. A challenge for the usefulness of even basic traffic rules is that safe space operations require access to advanced technology and capabilities. Actors lacking the technical capacities to comply with the rules will undermine the safety and usefulness of the rules for the whole space community. Therefore, rules of the road in orbit must be complemented by capacity-building initiatives evening out the knowledge and technology gaps among spacefaring nations.

Today operators handle traffic incidents on an ad hoc basis and there is little sharing of best practices about how it is done. If a number of operators and regulators are willing to adhere to some basic rules of the road and share their learnings, we can start evaluating and improving. With a bit of luck, these basic rules can become the seeds of the comprehensive Space Traffic Management system of the future. We must not let our dreams of an ideal global Space Traffic Management Treaty stop us from taking the small practical steps that might make spacefaring safer and more sustainable today.

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Bringing the Best of the Earth into Space

We are experiencing a true paradigm shift in space operations. "New Space" has brought about a new era of space solutions for an increasing number of industrial sectors (e.g., telecom, transport, and agriculture). This has resulted in a significant growth in the number of satellites launched into space each year. Back in the early 20th century, an unexpected boom in the automobile industry brought about a commensurate increase in the number of traffic jams, incidents, and accidents on the roads. As nonsensical as it would have been then to forbid people to buy cars as a measure to prevent accidents and risks, so is it now nonsensical to prohibit satellite operators from launching new spacecraft. Instead, we might look at our experience here on Earth and bring our lessons learned up into space.

Space assets are typically operated with a "single-use" mindset, assuming a lifetime limited by the amount of fuel onboard, mission needs, or the time before a severe malfunction incapacitates the functionality of a satellite. Once a satellite is launched into space, there is little that can be done to inspect, refuel, or repair it in orbit. This effectively forces satellite operators to abandon out-of-fuel, failed, or damaged spacecraft, which results in more space debris and, thus, increased risk to the operational satellite population. It would be insane to treat our personal cars as single-use vehicles and leave them on the highways once their fuel tanks were empty or they had issues with their engines. Following this reasoning in space, I foresee a switch from disposable space vehicles in favor of "reusability" — refuellable, recyclable spacecraft —to maximize exploitation of space assets and reduce the number of dead satellites speeding along the orbital highways.

However, an obvious question arises: "How do we refuel or refurbish assets if there are no gas or repair stations in space?" Indeed, the majority of space missions are currently developed taking into account that satellites cannot be serviced as it is typically done to cars. It is somewhat "a chicken and egg problem" — satellites are not supposed to be serviced because there is no infrastructure in space to do it and there is no infrastructure because satellites cannot be serviced. To break this cycle, the development of a flexible and reusable in-space robotic servicing infrastructure might be a possible solution to initiate the transformation of the space environment and facilitate sustainable space exploration.

I envision this infrastructure as a system of servicing assets performing rendezvous and docking with customer satellites to provide maintenance support directly in orbit as well as depots supplying these servicers with fuel and necessary tools. Satellite operators could request services such as satellite refueling if one is out of fuel, refurbishing if one is damaged or malfunctioned, and relocating if one took an incorrect orbital trajectory instead of having to replace a satellite with a new one. Moreover, the infrastructure might include additional features such as a satellite inspection system, just like surveillance around our cities and towns, which would provide regulating authorities with real-time data on the current situation in orbit to control the traffic. Active debris removal as a persistent part of the in-space infrastructure would become another feature to ensure effective space debris management by capturing and deorbiting debris in a controlled and safe fashion.

There is no one-size-fits-all solution to the issues that our near-Earth outer space ecosystem is facing today. The introduction of in-space servicing infrastructure, obviously, might not be the best one related to traffic management issues. Some may even claim that there are dozens of issues related to the regulation of service activities that would become a severe obstacle to implementing the infrastructure and it's certainly a topic for a few more op-eds. The main point is that we need to look at the experiences we have already had on Earth, such as how we tackle surface, maritime, and air traffic management, and bring the best solutions into space. We shall either learn how to be flexible and adapt to the challenges of sustainable space exploitation or discard the ideas of space exploration overall.

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Recruiting Empathy: The Case for Storytelling in Sustainable Space

Satellites are an essential part of our everyday lives. The Global Positioning System (GPS), phones, internet, banking: our society depends upon objects in orbit. Satellites are also vital components of intelligence gathering and weather predictions--issues of key importance to militaries and governments. And yet, despite decades of forewarning about the impending catastrophe of excessive space debris, there is no effective international solution. There have been small steps taken here and there by disparate groups but these small steps, while forward progress, often are lacking in specifics and have limited feasibility.

To make the giant leaps needed to prevent orbital debris from contributing to a tragedy of the commons, we need to focus on recruiting empathy from all the stakeholders. There is already technology developed for on-orbit servicing, life extension, and clean-up and there are detailed national and international policy solutions. What's missing is empathy recruitment to explain to the public and to policy makers why on earth they should care enough about tiny pieces of metal floating around above the earth to devote time and money to the problem.

There has been Nobel prize winning work showing that instead of making decisions based on rationality, humans are most sensitive to the framing of issues. For example, the framing of climate change as a scientifically contentious issue has resulted in decades of debate with limited action---a clear example of the power of a compelling story to affect the actions of decision makers and public opinion and effectively alter the future of the planet. The same phenomenon has played out with the COVID-19 vaccines—framing of the issue as political and not scientifically settled has divided policymakers and prolonged the pandemic.

Storytelling is powerful because it appeals to the limbic brain, the first part to form over the course of human evolution. It calls to our gut and feelings of trust and loyalty as opposed to relying on the neocortex, the rational part of the brain, to make decisions. We know that telling convincing stories is effective at producing change. For example, a pioneering project in Tennessee took on the massive task of reframing how residents thought about the effects in adulthood from adverse childhood experiences--a nebulous topic that has concrete impacts on society. They tested different messaging strategies, developed carefully chosen metaphors, and focused on feasibility instead of innovation. As a result, the culture around early childhood experiences in Tennessee has shifted as measured by the kinds of investments happening throughout the state.

Finding a solution to space traffic management requires collaboration of industry, academia, and essentially every country's government. To bring all those groups to the table to negotiate, let alone to settle on a solution, requires everyone to understand the importance of sustainability in space and be committed to achieving that goal. To do that, we need a compelling story.

Companies like SpaceX and One Web who are launching mega-constellations have different priorities than emerging space-faring nations. Politicians are beholden to their constituents who are, quite reasonably, more likely to be concerned with issues of healthcare, jobs, and education, than with developing practical, transparent, evidence-based strategies and methods for space traffic management. That's why the solution is a story, a framing, that shows why everyone should care about the spider web of satellites soaring around our planet.

To be clear, I am not arguing for a return to the Apollo myth of space as inspiration for greatness as the framing with which to engage decision makers; we need a new story to reflect the new world we live in. In the past seventy years, space exploration has shifted from something we do for political reasons, to something we do for scientific reasons. And now, we are entering a third phase of space exploration, one that combines the awe-inducing power of the Apollo phase and the technical expertise of the second phase. In this new phase, we must explore for the sake of urgency and empathy. It is no longer exploration because we can; it is exploration because we must.

The "why space?" story we tell must change as we enter this new era. It must reflect the priorities of the new generations who are living under the worst ever levels of income equality, facing climate-change induced disasters, and battling a global pandemic. It cannot be a story of white men climbing into capsules and shooting into space under the stars and stripes. It needs to be a story that represents the new era. As the next space generation, we have the deep privilege of authoring the next chapter of space exploration. May we honor that privilege by writing a story grounded in intersectionality, diversity, and sustainability.

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Incentivizing Space Sustainability

The space industry is facing a "pacing problem"—a notion referring to the rapid advancement of technological change that outpaces social, economic, and traditional government oversight systems and regulations that, in comparison, change incrementally. The projected growth of space actors, miniaturization of technology, rise in commercial space activities, and lower satellite and development launch costs are in stark contrast to the pace of development of regulatory guidelines and norms of behavior. As technology becomes more complex, the number of stakeholders involved in regulatory processes increase, thereby potentially slowing the ability for rapid regulatory actions.

In 2019, the UN Committee on the Peaceful Uses of Outer Space adopted 21 guidelines for the long-term sustainability of outer space activities. These guidelines were the result of the establishment of a working group in 2010 to propose a set of voluntary, non-binding guidelines to address the long-term safety, security, and sustainability of the space domain. During the nine-year development phase to reach internationally agreed consensus, a number of actions were taken by operators that directly contradict the efforts of the working group (e.g., ASAT tests, launches without federal license). While it is crucial to build international consensus and agreement of long-term sustainability, the downside is the slow progression of regulatory initiatives resulting in delayed policies that can be fragmented, incomplete, and open for interpretation.

Over the past two years, an international and transdisciplinary consortium consisting of the World Economic Forum, Space Enabled Research Group at Massachusetts Institute of Technology (MIT) Media Lab, European Space Agency, University of Texas at Austin, and BryceTech have been working on the design and development of the Space Sustainability Rating (SSR). The SSR is a tool to assess and recognize missions that are designed to be compatible with sustainable and responsible operations that reduce the potential harm to the orbital environment and the impact on other operators. Formulated as a composite indicator, the SSR consists of six modules highlighting key related decisions faced by space operators in all phases of the mission. These include 1) the mission index to calculate the space traffic footprint; 2) collision avoidance capabilities; 3) ability and willingness of the operator to share data on the mission; 4) the mission's detectability, identification, and tracking; 5) operator's compliance with standards and regulations; and 6) commitment to use or demonstration of use of on-orbit servicing and external services.

Sustainability rating systems, such as the LEED (Leadership in Energy and Environmental Design) that offer a global definition of sustainable design and practices in all aspects of construction projects, have been successfully used in other industries as an effective strategy to encourage and reward actors through financial or structural incentives, which in turn spurs further innovation and demand for sustainable technologies. Initiatives such as the SSR put in the spotlight responsible operators, and shift the attitude toward compliance assessment that can serve as positive examples of technological and operational solutions that have been successful in terms of debris mitigation. In efforts to make long-term sustainability a mainstream standard practice, these tools help define sustainability and subsequent sustainability metrics to support regulatory mechanisms such as the UN Long-term Sustainability Guidelines and Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, allowing actors to clearly demonstrate their actions to pursue and abide by current successful operational practices. With a common definition of sustainability and transparency in how rating scores are achieved, policymakers have insight into manufacturers' and operators' motivations in choosing specific criteria and certifications in designing their mission to achieve a high rating or improve their existing rating. Additional incentives include financial and economic drivers that have the potential to reduce insurance premiums and modified procurement processes, as well as enhanced brand recognition and public perception in pursuing sustainability that showcase corporate social responsibility considerations.

As space technologies such as debris removal and refueling services continue to rapidly mature and successfully be demonstrated, the SSR serves as a bridge between new technology adaptions and yet-to-be-defined regulatory policies. By providing an unbiased, scientifically-based initiative to recognize actors for their efforts toward sustainability, the SSR has the ability to support, shape, and implement new approaches to regulatory frameworks and close the pacing-gap to adopting timely regulations to address advancing technologies.

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The Rise of Satellite Constellations: Current Considerations for a Safe, Sustainable, and Intergenerational Use of Space

Observing space and celestial events has been a source of wonder and scientific discoveries for humanity for centuries. Unfortunately, outer space is now full of junk, 3,000 dead satellites to be exact, and over 34,000 pieces larger than 10 cm in size. This figure is only expected to grow exponentially with the rise of satellite constellations.

Satellite constellations are networks of two or more satellites used for various purposes, from navigation to Earth observation. The first larger known satellite constellation, pioneered by Iridium, was conceived in 1987 to provide cell phone coverage in the United States. Sixty-six satellites were placed into orbit, a large number of which have since become defunct, and a lesser number have been successfully deorbited. Today's constellations are far larger than their predecessors. For example, the Starlink constellation, operated by Elon Musk's SpaceX, has launched over 1,700 satellites in a grand global internet coverage initiative. And there are plans for tens of thousands of satellites to be launched by many more operators in the coming decades.

Despite the benefits that such activities could bring to humanity, these also have generated numerous societal concerns. On the one hand, the plan for these constellations would improve the quality of life, especially in isolated communities, by providing internet connectivity on a larger global scale. However, on the other hand, these operations constitute real commercial challenges, increase the level of congestion of Earth's orbits, particularly LEO, and raise critical issues for the sustainability of the terrestrial and space environment.

Some of the most pressing concerns come from the astronomy community, whose observations are massively impacted by the growing number of objects in orbit, with satellite trails crossing the field of view of optical telescopes or interfering with radio observations. This is not the first time the observation of the pristine night sky has been threatened and the study of celestial objects potentially hindered. In 1961 and 1963, MIT's Project West Ford aimed to create an orbiting belt of hundreds of millions of copper wires around Earth to form a secure global communication system. It was one of the first cases where the scientific community expressed concern about the impact these kinds of space activities could create on optical and radio astronomy. In 2001 the International Astronomical Union, considered the detrimental effect of obtrusive space advertising on astronomical observations. On that occasion, it was emphasized how, with increasing commercial and noncommercial activities in space, an imposing qualitative change in the environmental conditions for astronomy took place, causing a gradual loss of the possibility of observing a pristine sky. Although there have been discussions about how to protect the night sky for astronomy in international fora, we are facing similar concerns today.

We need to consider to what extent constellations will disrupt the dark and quiet skies and impede astronomy research. And since satellite constellations already occupy substantial portions of valuable orbits, their use will be limited for actors that today do not yet have access to space. How can we guarantee tangible equity that can allow the exploration and use of space for the needs of developing countries, as prescribed by the Outer Space Treaty, the Magna Charta of space activities?

From an international law perspective, outer space is free for everyone to access, use, and explore. There are, however, some limitations to these freedoms that cannot be neglected: the exploration and use of outer space should be the province of all humankind. They should happen for the benefit and in the interest of everyone, including developing countries—and in the interest of future generations.

In the past couple of years, several discussions have addressed the impact of satellite activities on the environment, astronomy, and cultural practices. I have been actively involved in the recent international efforts to coordinate the interests of astronomers, satellite operators, policymakers, legislators, and community representatives. One thing is clear: the space sector has evolved, and the number of stakeholders exploring and using outer space has increased. Today, there is an urgent need to acknowledge the different concerns involved and consider several segments of humanity impacted by space activities.

These confrontations have produced compelling recommendations, but there are still some steps needed to guarantee a harmonized coexistence of uses of outer space:

- International guidelines to implement existing principles of international law recognizing today's most urgent concerns
- A continuous engagement with stakeholders and discussion with the industry for their better involvement in decision-making processes
- A more remarkable coherence of policy objectives across the space sector

Suppose a solution is not immediately found to satellite constellations' impacts on ground-based and space-based activities. This could lead to the end of the observation of the dark skies as we have always experienced in the past centuries as we inevitably increase the number of objects in orbit, producing an ever more unstable and unsafe space environment.

This challenge is urgent and compelling, as it requires attention from multiple perspectives. From a technological point of view, we need to define and mitigate the effects deriving from the deployment of hundreds of thousands of space objects; from legal and political aspects, the coordination of national and international instruments should provide well-defined guidelines and rules to satellite operators; and from a business angle, the creation of an efficient market in compliance with the limitations provided must be allowed. Only through combined and prompt consideration of these aspects will it be possible to envision a more safe, sustainable, and intergenerational use of outer space.

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Past, Present, Future: Listening to Indigenous Australian Governance Practices for Long-Term Sustainability of Space A Growing Multitude of Anthropogenic Space Objects

Space is, according to the 1967 Outer Space Treaty, the "province" of all humankind. This treaty guarantees the right of access to and use of space for all nations, and provides that space activities shall benefit all. Space is often described as a "global commons," but we face a potential tragedy of the commons as more nations exercise their right to access and use space, and more commercial entities compete to provide space-based services. Today there are approximately 3,800 operational satellites in orbit around the Earth, and an estimated 128 million pieces of debris. By the end of this decade there will be at least 100,000 operational satellites, and it is impossible to predict how much debris. This amount of space traffic is unsafe, threatens the space-based services we all depend on, and is entirely unsustainable.

If space really is the province of all humankind, then there is a group of voices who deserve to be heard, and a cultural wisdom that deserves to be tapped into. Indigenous Australians have been practicing sustainable management of a challenging environment for 60,000 years according to deeply embedded notions of intergenerational equity and by understanding their dependence on a balanced use of resources.

You and I are dependent on space for multiple financial, navigational, and communications activities per day, and our governments are dependent on space for military, security, and civil safety. If we do not manage the orbits and frequencies that satellites use – which are finite natural resources – we risk losing our space services in the near term. Moreover, we would deny future generations the same access to space, which will set the human race back in time.

In 2019, the UN Committee on the Peaceful Uses of Outer Space adopted 21 "Guidelines for the Long-term Sustainability of Outer Space Activities," [1] most of which are dedicated to debris mitigation. Most important, some guidelines call for cultivating a culture of sustainability in government agencies and companies, which requires some major shifts in thinking and operating. While it might seem esoteric, the most important lesson to be learned from First Nations Australians is that we need to see ourselves as existing in space and dependent upon it. Indigenous Australians understand that everything has a role in the greater order, despite Australia's harsh aridity, dramatic dry and wet seasons, and many dangerous species. Similarly, rather than seeing space as a hostile environment, we need to understand how it functions as an ecosystem of orbits and frequencies, what its limits are, and find our place in it.

Second, custodianship should be the cardinal principle of all space activities. Space companies could be taking the lead in this, as there are many launch sites, tracking stations, and other ground-based space infrastructure on Indigenous lands around the world or which impact Indigenous populations. By partnering with Indigenous groups, and cocreating operating principles of custodianship of the lands and of our near-Earth environment, a very different commercial ecosystem can emerge – one which is still competitive and profitable, but which is also sustainable. In Australia, some mining companies operating on Indigenous lands have demonstrated how powerful cogovernance can be.

The third lesson is that of intergenerational equity. Each generation of First Nations Australians is taught the importance of managing the environment and its resources for the long term. If resources are misused, damaged, or not cared for in a way that future generations can still benefit from, it is a punishable breach of many traditional laws. This is how seriously we should be taking the long-term sustainability of space. National agencies should move away from the outdated 25-year rule (that satellites must have a de-orbit or debris mitigation plan 25 years after launch) and put in place technology-specific time limits, long-term tracking infrastructure, and strict sanctions for failing to de-orbit at the end of the life of a satellite. There should be tax incentives for sustainable designs and heavy taxes on unsustainable ones.

Finally, First Nations in Australia have learned when to reap the food and resource stocks of rainforests, rivers, oceans, mountains, and deserts and when they are being overburdened. Agreements about who can access resources and when are critical to maintaining these resources. We need to spend time and money on better understanding the carrying capacity of certain orbits and finding more sophisticated ways to allocate access.

Space traffic management is an urgent issue with no simple solutions. But partnering with Indigenous peoples on whose lands ground-based space infrastructure exists and incorporating these governance principles seriously can lead to truly sustainable policies, practices, and laws.

[1] "Guidelines for the Long-term Sustainability of Outer Space Activities." UN Office for Outer Space Affairs, 2019. https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf.

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Creating a Circular In-Orbit Economy: An Interdisciplinary Approach to the Multidimensional Orbital Debris Crisis

The question of whether we need faster, more reliable, and more robust space-based services, or a more sustainable orbital environment is nonbinary. Space is not just a remote destination—much like air, land, and sea, it is a domain in which we operate to generate critical services for the benefit of humanity. However, as the demand for these services surges and the supply strives to keep up, the very operations that enable these services are in danger of being severely disrupted as the probability of collisions increases, potentially destroying satellites or forcing them to veer off of their intended orbits. The solution to this dilemma is threefold—creating sustainable technology standards, commercial incentives, and business models that would urge space actors to be more responsible without stifling innovation and hampering business operations.

Space is essential business. The national and commercial assets we operate in orbit do not just create services for billions of global consumers, they are also of paramount importance to our national security, the backbone of our modern economy, and instrumental in tackling climate change and disasters to say the least. Responding to growing market needs, the number of active satellites quadrupled from 1,033 to over 4,600 over the last decade. On top of that, there are over 60 SmallSat constellations [1] constituting 107,000 spacecraft [2] planned to launch by 2029,[3] that is a 2,226% increase from 345% over the last decade.

Consequently, we are facing an orbital resource depletion. Adding fuel to the flames, objects over 10 cm have grown by over 72% in the period 2007–2021. The total mass of all objects has grown by 51% from 2004 to 2021, and by 850% since 1974.[4] Inactive satellites that have ceased operations and reached their end of life (EOL) have accumulated to 2,920, which led to at least 570 total breakups, explosions, or anomalous events.[5]

The five dimensions adding fuel to the orbital debris crisis are 1) surging demand and exponential supply, 2) lowering barriers to entry attracting actors with varying standards and levels of development, 3) growing numbers and threats of orbital debris potentially resulting in more catastrophic on-orbit collisions,[6] as well as posing greater risks to people and property on the ground, 4) ineffectiveness of non-binding regulations,[7] and 5) proliferating destructive counterspace capabilities, notably anti-satellite (ASAT) weapons and weaponized dead satellites.[8]

Entropy, the degree of disorder, tends to increase with time. That is, as space gets more congested and contested, the probability of debris-generating collisions will naturally keep increasing with time, which would significantly reduce expected mission lifetimes, disrupt services, and result in significant revenue losses.

Penalize or incentivize, that is the question. The Space Sustainability Rating (SSR) is a decentralized incentive system that quantifies the individual contribution of space actors through peer pressure rather than soft law or legally binding instruments by a centralized government or authority. Scoring operators on multiple factors that contribute to sustainability, it is the perfect multipurpose vehicle to increase transparency, accountability, and credibility, empowering investors, insurers, and regulators to incentivize best practices and call out irresponsible behavior.[9] Registering objects with the UN Registry, purchasing liability insurance, adopting standard interfaces and platforms, sharing orbital data, having a deorbit or life-extension plan/provider, and respecting orbital protective zones should receive higher SSR. Moreover, SSR can promote space environmentalism and spur sustainable business competition. Displaying SSR on space-based products would empower the public and urge actors to embrace responsible behavior to maintain a competitive edge. At the state level, a more comprehensive definition for space debris and more structured property laws allowing salvaging and transfer of ownership of space objects need to be regulated to enable new service providers to clear strategic orbits and prevent them from being cluttered with space junk.

"Executives often fail because they study the wrong product and customer data," said the Harvard Business School Professor Clayton Christensen.[10] With on-orbit servicing and manufacturing (OSAM) and refueling, a new orbital economy is taking off. Until more traditional space actors adapt to the dynamically changing value chain of the space sector, the real competition in these nascent markets could be the status quo option. Commercial OSAM actors need to explore synergies and create business models that create sustainable new services, ultimately overcoming the "Tyranny of Launch," turning waste into profit rather than creating more thereof.

Some would argue that orbit is not running out of space. At the other end of the spectrum, others would argue that we need binding laws. While the former is a legitimate argument based on the total mass in orbit, it neglects key pieces of evidence highlighted above, such as catastrophic impacts of even tiny objects, exponential growth of space junk, and increasing probability of collisions.[11] As for the latter argument, it takes decades for states to reach a consensus, and mostly this will set high standards that would prevent developing countries from accessing space. On the other hand, binding laws would hinder the progress of commercial actors. Kranzberg's first law states that "Technology is neither good nor bad, nor is it neutral," so it comes down to the user's intent and how they would use the technology. Why not influence users through incentives and peer pressure instead of policing them?

Space does not exist in a vacuum. It has become ubiquitous in our daily activities. Therefore, diligent and innovative efforts like SSR that do not increase the polarization among space actors and are efficiently implemented not only directly benefit all space industry stakeholders, but also prioritize the hopes and needs of our modern society—which is increasingly and profoundly reliant on space. If you neglect the long-term sustainability of the space environment, you pull the plug on all of this.

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Creating a Circular In-Orbit Economy: An Interdisciplinary Approach to the Multidimensional Orbital Debris Crisis (continued)

[1] The Space Foundation Space Report 2021
[2] FCC Filing List, https://fcc.report/IBFS/Filing-List/
[3] ITU Filing List, https://www.itu.int/ITU-R/space/asreceived/Publication/AsReceived
[4] Department of Defense (DoD) Space Survey Network (SSN)
[5] Space Environment Report, ESA SDO, May 2021
[6] NASA's Efforts to Mitigate the Risks Posed by Orbital Debris, NASA OIG, January 2021
[7] Christopher D. Johnson, Legal Aspects of Space Debris, SWF, September 2021
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[9] WEF Space Sustainability Rating, https://www.weforum.org/projects/space-sustainability-rating
[10] Clayton M. Christensen, Know Your Customers' "Jobs to Be Done"
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A Systematic Approach to Tackle the Issues of Space Traffic Management

The Space Age is here and we should be ready to embrace it. Humans have long been empowered with satellite technology, which has opened new pathways and opportunities worldwide. This boon to humankind has now become a problem because overcrowding in the outer space region.

Space exploration began in the year 1957 when the Soviet Union launched the first-ever beach ball-sized satellite, Sputnik 1. Since then plans for space exploration by space agencies and commercial satellite operators have changed and evolved. After the launch of the first-ever communication satellite, TELSTAR 1, in 1962 by Bell Labs, no solid framework has existed to measure and monitor the development in the space environment. In the last two years alone, the number of active and defunct satellites in low Earth orbit (LEO) has increased by over 50%, to about 5,000 (as of 30 March 2021. This exponential increase indicates an exploitation of the common space. Because of the overuse of LEO there are concerns of runaway space debris (the Kessler syndrome). We cannot afford an accident in orbit and even a minor anomaly could have grave repercussions. An effective way to tackle the space debris problem is to update the existing space laws on multiple levels.

I believe space is for all and it should be available to all and not be hampered by the power play of countries like the United States, Russia, China, or even India and Africa. My recommendations cater to the urgency in the field of space traffic management focusing on different sustainable options, which in turn will also help streamline the existing process of sending satellites into space.

- **Barcoding of Satellites:** This would be used to catalog satellites, which is a long overdue process that would help us to identify the models using KYP (Know Your Payload) details of any existing satellite (launch date, expiry date, and other details).
- **Sharing Data:** Satellite data is vital for Earth observation, geospatial mapping, telecommunication, navigation disaster management, and much more. Excluding the confidential satellites that no nation acknowledges, the data collected by developed nations should be available to developing nations as sharing of data would reduce the need for future launches by different entities with similar objectives.
- **Proper Code of Conduct:** Currently, there is no restriction to what the payload contents of a satellite are as long as the launch requirements are fulfilled. There should be a central body that would carefully review the payloads irrespective of the country/company launching them.
- **Corporate Social Responsibility:** Corporations should be asked to show social responsibility by pledging to declutter the orbital environment and work toward a common goal of net-zero debris as a part of future contingencies.

The issues of space security, space sustainability, and space traffic management not only affect spacefaring nations but also have become vital for the survival of humanity

The space revolution is not about contaminating and damaging space, but focusing on different dimensions of development and being responsible citizens of our planet Earth.

The 2021 cohort of the Space Traffic Management Diverse Dozen are influential thinkers and emerging leaders from around the globe. Led by Moriba Jah from the University of Texas at Austin, these authors are also the featured speakers in a series of rapid-fire lightning talks that highlight the most important issues surrounding safety, security, and sustainability in the context of space traffic. What needs to happen in order for space to be more transparent, more predictable, and to have a globally accessible pool of evidence to help people make decisions and hold them accountable for their behaviors in this shared domain?

Find out by watching their ASCEND session at
www.ascend.events

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