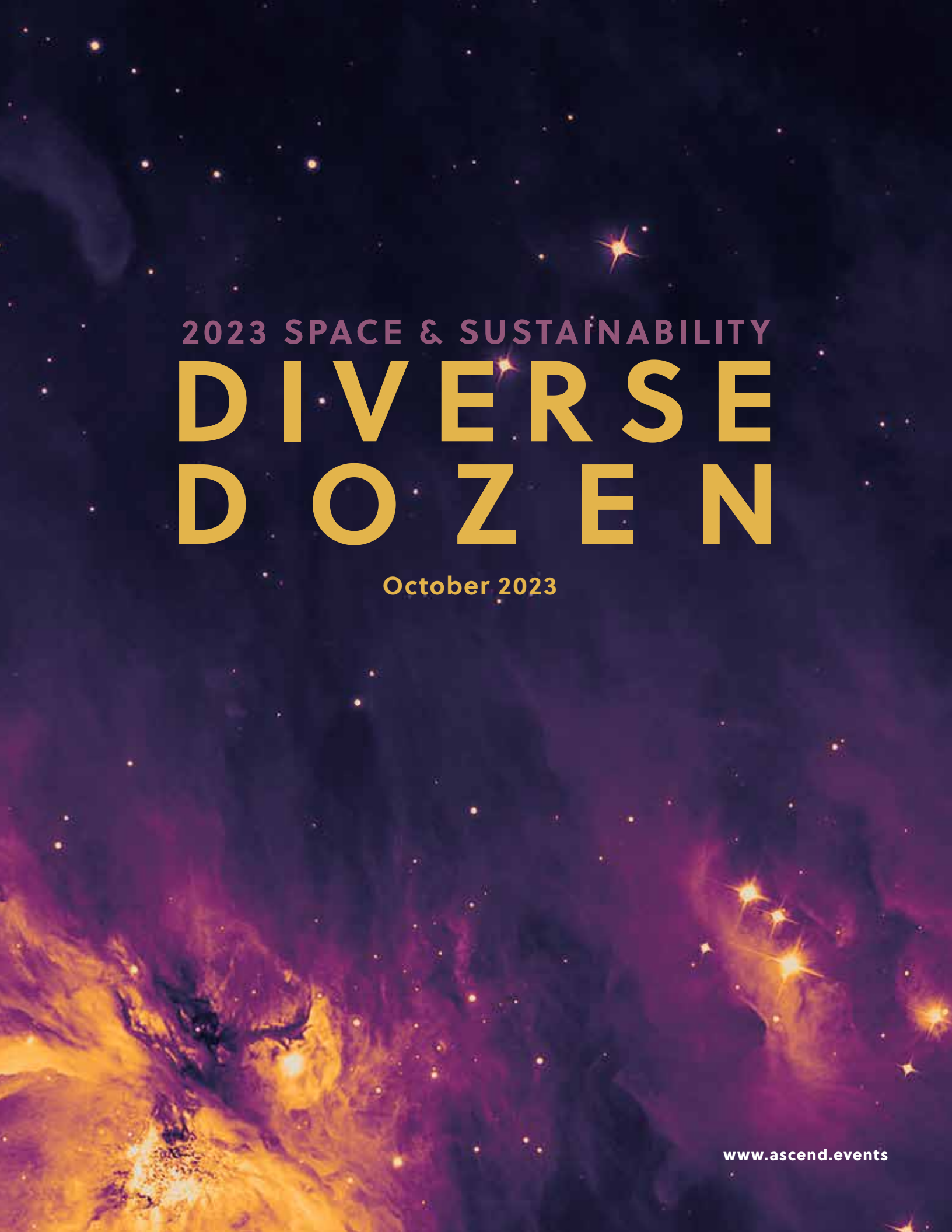

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2023 SPACE & SUSTAINABILITY

DIVERSE DOZEN

October 2023

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

Several years ago on a trip to Alaska, Moriba Jah, an astrodynamicist and space environmentalist, experienced an inner shift in perspective on environmentalism and sustainability, and recognized how certain indigenous peoples of our world have important lessons and tenets to share in this regard. In essence, we must embrace the belief that all things are interconnected and we must embody stewardship because our lives depend on it. These indigenous peoples live each day in acceptance that they are in an existential crisis and that their way through this is by having a successful conversation with the environment. This perspective may serve as the basis for us to thrive in space in a sustainable way. What still 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 topic, and coming from a place 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 one-of-a-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!

Mustapha Agbadi // UNITED KINGDOM
Bismerk Solicitors

Ubuntu and Emerging Space States: Fostering Space Sustainability in the Global Governance Framework

In our effort to venture further into outer space – the vastness where the secrets of the cosmos lie, science must prioritize space sustainability, despite an insatiable thirst for knowledge. Taking into consideration the consequences of unguarded activity like the use of anti-satellite weapons (ASAT) in space on our world, emerging space states of the Global South, with burgeoning space programs and diverse motivations, hold a key role in shaping the future of space sustainability.

Ubuntu is an Indigenous African philosophy whose main tenets purport interconnectedness – shared responsibility to act as stewards and centurions of all living things with shared values. For example, in the Zulu tribe the word Ubuntu means "a person is a person through other persons" [1], which has further been explained by John Mbiti to mean "Whatever happens to the individual happens to the whole group, and whatever happens to the whole group happens to the individual. The individual can only say: 'I am, because we are and since we are, therefore I am'" [2].

Just as Ubuntu emphasizes the interdependence of humans and the ecosystems that support us, space sustainability must underscore the interdependence of our celestial bodies because the path to space sustainability is not solitary. As we contemplate the trajectory of space exploration and the depth of what space sustainability means, a roadmap emerges guided by Ubuntu's wisdom and tailored to the contributions of the emerging space of the Global South. I propose a series of actionable recommendations to propel us toward this future.

Ubuntu's emphasis on collective responsibility resonates with the collaborative efforts needed to address sustainability challenges. The global community must transcend geopolitical divides and forge inclusive partnerships that harness the expertise of all nations, whether established space powers or emerging contenders. In this interconnected journey, knowledge-sharing becomes a currency that enriches us all, paving the way for a harmonious and sustainable future. African countries with their unique perspectives offer a fresh lens through which we approach the challenges and opportunities of space exploration. Their participation, characterized by a blend of ambition and cultural responsibility, would inject new vitality into the global pursuit of space sustainability.

Recommendations

- Strengthening international frameworks and agreements, rooted in Ubuntu's ethos of interconnectedness, will cultivate a shared commitment to space sustainability.
- Promoting awareness and education about Ubuntu's principles can inspire a cultural shift toward responsible space activities. These needs are necessary to safeguard outer space from irresponsible space activities that could undermine years of innovation in space science and technology.
- Encouraging emerging space states to identify their values, and collaborate and engage more actively in global forums such as the United Nations Office for Outer Space Affairs (UNOOSA) to bring in more diversity and space diplomacy capable of galvanizing international collaboration for safe, secure, and sustainable use of outer space.

Conclusion

In this pivotal moment, as we gaze toward the heavens with hope and curiosity, let us remember the wisdom of Ubuntu and the promise of emerging space states. Their journey mirrors our own – an exploration of the unknown, guided by shared responsibility and a commitment to a brighter, more sustainable future. As we embark on this voyage together, hand in hand, let us forge a path toward the stars that embodies the very essence of Ubuntu – an ethos that speaks to our interconnectedness, our collective potential, and our profound duty to safeguard the cosmos for generations yet unborn.

[1] A Hilliard et.al, "The Role of the African Value of Ubuntu in Global AI Inclusion Discourse: A Normative Ethics Perspective," Patterns, 3(4) 2022 https://www.sciencedirect.com/science/article/pii/S2666389922000423>Accessed 6/10/2023.

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Sahil Bhatia // INDIA

University of Bremen

A Moonshot for Space Sustainability

On 23 August 2023, the success of the Indian Chandrayaan-3 mission sparked the global imagination, serving as a testament to the growing excitement surrounding lunar exploration. Around the world, space entities are in a race to the moon. A 2021 report by PwC predicts the lunar economy surpassing a value of €142 billion by 2040 [1]. As access to space becomes more affordable, emerging nations and private entities alike see the moon as an arena to demonstrate their technological capabilities, hoping to orbit and land spacecrafts. This resurgence of interest in lunar exploration raises a vital question – sustainability – a concern not limited to the moon but to all space endeavors.

Current State of Lunar Operations: "We Came, We Saw, We Littered"

The short film, "An Incomplete List of Things We Left Behind on the Moon," made by Arlen Parsa, humorously portrays the artifacts left behind by the Apollo missions [2]. These include photos, golf balls, boots, and dozens of bags of human waste. In fact, since Luna 2, the first spacecraft to reach the moon in 1959, we have left behind a staggering 200 tons of debris on the moon. Proper planning and disposal of mission hardware still seem to be an afterthought in the current age. For instance, in March 2022, an abandoned upper stage from the Chang'e-5T1 mission impacted near the Hertzsprung crater on the moon [3]. The recent surge in lunar lander missions also revealed the risks of mission failure, as failed landings can scatter debris hundreds of kilometers across the lunar landscape. Another instance of negligence features the 2019 crash of the Beresheet lander, which introduced microscopic organisms called tardigrades to the lunar environment [4], sparking concerns as this is against the Committee on Space Research's (COSPAR) Planetary Protection Policy [5].

Moving forward, with ambitions to return humans to the lunar surface by the mid-2020s, supporting this endeavor, the demand for high-resolution data, communication, and GPS-like infrastructure will increase lunar traffic significantly. Additionally, the prospect of lunar tourism, such as the planned SpaceX dearMoon mission, compounds concern regarding environmental impact. Historically, lunar end-of-life strategies offered three options: lunar surface impact, abandonment in deep space, or Earth reentry [6]. Each strategy presents distinct challenges, such as endangering lunar scientific and historical sites, risking damage to space infrastructure, or the potential for reentry of overpopulated or ecologically sensitive areas on Earth.

To minimize our impact and ensure the long-term viability of human activities, a philosophy for sustainable space activities emphasizes responsible operations, monitoring traffic, disposal and debris management, resource-conscious utilization, and measures to prevent further disruption of orbital and surface environments.

The Path Forward: Does a New Lunar Space Race Hold Answers to Space Sustainability?

A gold rush approach among spacefaring entities could drive some players to prioritize dominance and commercial value over cooperation and sustainable operations. However, embracing this competitive drive could be useful in accelerating the adoption of responsible practices in space. Key technologies, such as debris removal and satellite life extension (including refueling and repairs), would benefit from the advancements in autonomy required for lunar missions – not to mention the added economic incentives of extending useful lifetimes of space assets [7-9]. Similarly, monitoring traffic in the lunar domain with improved radar, optical telescopes, and in-space monitoring could enhance our ability to catalogue debris in orbits around Earth.

Parallelly, space policy must adapt to these developments. The Artemis Accords lay out cooperation principles through peaceful operations, safety zones, and resource management. However, the Accords lack specifics to address traffic management and hardware disposal. Defining acceptable standards is vital considering our increasing focus on sustainability. For instance, in addressing the disposal of hardware on the moon, the Global Expert Group on Sustainable Lunar Activities (GEGSLA) advocates for the establishment of a designated Space Debris Landing Zone [10-12]. Although this would address a major concern, determining the viability and long-term sustainability of such an approach is essential.

In closing, as we dare to dream of ambitious lunar missions, we must also implement audacious sustainable actions hand in hand. As the adage goes, we do not inherit the Earth from our ancestors; we borrow it from our future generations. As stewards of the space environment, we must put this philosophy into practice and preserve our space environment today.

[1] PwC, "Lunar market assessment: market trends and challenges in the development of a lunar economy," 2021. [Online]. Available: https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf.

[2] An Incomplete List of Things We Left Behind on the Moon. [Film]. 2013. Available: https://in.mashable.com/science/5651/heres-how-tardigrades-were-secretly-smuggled-to-the-moon.

[3] NASA, "NASA's Lunar Reconnaissance Orbiter Spots Rocket Impact Site on Moon," 2022. [Online]. Available: https://www.nasa.gov/feature/goddard/2022/nasas-lunar-reconnaissance-orbiter-spots-rocket-impact-site-on-moon.

[4] C. Taylor, "Here's How Tardigrades Were Secretly Smuggled To The Moon," 2019. Available: https://in.mashable.com/science/5651/heres-how-tardigrades-were-secretly-smuggled-to-the-moon.

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Pablo Carlos Budassi // ARGENTINA

Awe infographics

Charting Space Sustainability: A Navigational Perspective

In the grand cosmic expanse, humanity has embarked on a journey that transcends our earthly confines. Space exploration and utilization have brought us a quite interconnected everyday life at many levels, but the feeling that Earth's orbit and the universe are a part of us is not quite there yet. Space isn't just a part of us; it's also home to us, and you don't throw dangerous trash inside your home.

Similar to early historical maps, small objects in low Earth orbit (LEO) and medium-sized objects in geosynchronous Earth orbit (GEO) remain as blank uncharted areas. Naturally, there is ample space and comparatively few objects in GEO. Providing life extension services there could serve as a sustainable means to keep it this way. Most urgently, LEO, a precious and limited resource, is becoming increasingly congested and needs our full attention and urgent

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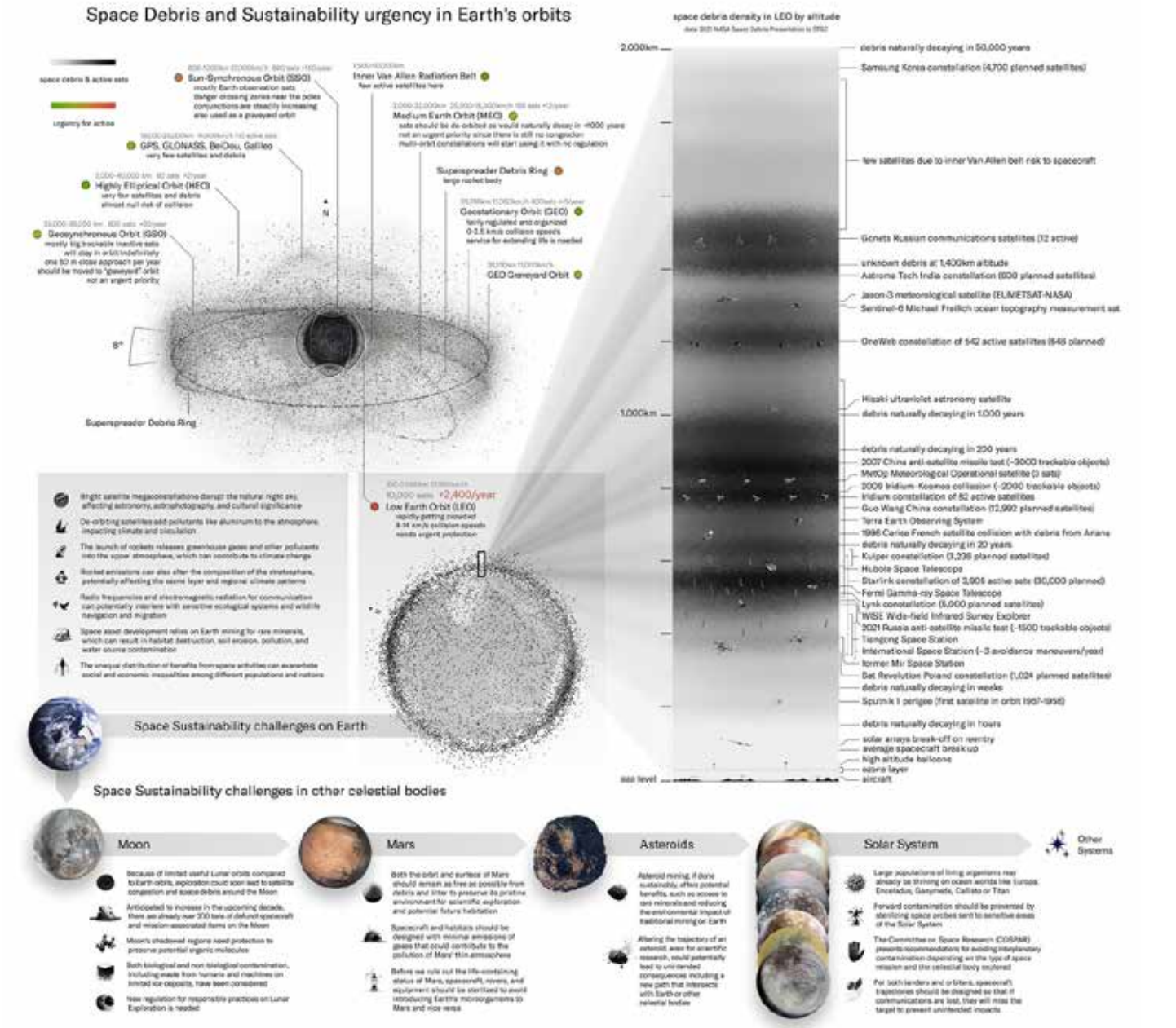

Figure 1: Overview of key space sustainability issues under consideration in 2023. Solar System objects images credit: NASA/ESA/UAESA

Continued

action. Megaconstellations are suddenly altering the night sky, impacting scientific research, cultural heritage, and more importantly: climate and ecology. De-orbiting satellites bring pollutants like aluminum into the atmosphere, affecting Earth's circulation in ways we cannot quite predict. Rocket launches introduce greenhouse gases and pollutants into the upper atmosphere, potentially influencing the ozone layer and other climate patterns.

Mapping Our Cosmic Priorities

Some argue that our current environmental challenges on Earth should take precedence over space sustainability efforts. They suggest that focusing on issues like climate change and biodiversity loss should be our primary concern. This is true, but we should not underestimate the interconnectedness of these spaces. Space sustainability isn't just about protecting outer space; it is about recognizing how our actions in space can exacerbate problems on Earth. Addressing these problems can lead to innovative solutions that benefit both our planet and our cosmic endeavors.

The blueprint for space sustainability is not a static diagram. As we incorporate more data and integrate machine learning into our situational awareness, and as space exploration continues to advance, new issues will undoubtedly emerge. Ideally, we should be prepared to address them. Setting a goal to make this map reasonably navigable within the next decade would be a worthwhile objective. Achieving relatively clean and organized LEO orbits may only be possible if we start taking deliberate action today.

Celestial Guardianship Through Every Step of the Course

As we venture beyond Earth's orbit and set our sights on celestial neighbors, responsible exploration becomes the only acceptable modus operandi. Lunar exploration must be conducted in a collaborative and respectful manner to prevent the creation of another landscape spoiled by orbital congestion and debris.

While sustainable space mining may be theoretically achievable, we should refrain from altering the trajectories of asteroids for any purpose to ensure the safety of Earth and other celestial bodies from unintended anthropogenic-caused impacts. Exploring other worlds that we believe could potentially harbor extraterrestrial life also necessitates the utmost caution on our part.

A Shared Responsibility as One with the Universe

Shared human existence can be conceived as a cosmic symphony. We must not lose sight of our interconnectedness with the universe. Our actions resonate far beyond our planet. While for the moment all decisions are being made from Earth's surface, our ethical footprint is boundless.

Yes, we will strive to address pressing environmental and social issues on Earth in the next decade, as well as environmental and social issues in the heavens. Yes, it is challenging to agree and work together in a competition-driven model of a world. We should begin by acknowledging that our choices today have ripple effects across time and space, impacting many generations yet to come.

Allen Herbert // UNITED ARAB EMIRATES

Space Agrifood Advocate

Sustainable Space Agrifood Commercialization: Impact on Space Debris, Earth's Food Security, and Climate Change

In the ever-expanding domain of space exploration and settlement, a pressing issue looms large – the challenge of space debris. While discussions primarily center around orbital clutter, another equally significant concern awaits our attention: the management of organic waste. This issue not only presents challenges but also opens up opportunities. As space becomes increasingly commercialized, so too will the field of space agrifood development. As we look toward a future of extended space habitation and exploration, this challenge demands proactive commercial solutions that resonate both in space and on Earth

In the visionary words of Jeff Bezos, who envisions, "millions of people living and working in space," we can foresee a future where human presence in space extends beyond brief missions. This envisaged reality brings with it the need for substantial resources, including a vital necessity – food. However, the implications of sustaining such an in-space population extend beyond the procurement of supplies; they encompass the intricate challenge of managing the waste generated in this new frontier in orbit and on celestial bodies, calling for innovative commercial strategies.

While much of the discourse about space debris revolves around defunct satellites and discarded rocket stages, the impending concern of organic waste has largely remained underexplored. Yet, as humanity prepares to establish footholds on the moon, Mars, and beyond, the significance of this issue cannot be understated. A multitude of waste, organic and some nonorganic (such as packaging), will accumulate in the unique microgravity environments of these extraterrestrial destinations. This accumulation holds the potential to become as problematic as traditional space debris, posing a threat to operational spacecraft and future missions [1].

Addressing this challenge necessitates embracing the ultimate in recycling technologies. In space habitats, waste reutilization is not merely an option; it is an imperative. Every resource, from packaging materials to human waste, must be recycled and repurposed to ensure both the sustainability of space operations and the prevention of the proliferation of space debris. Several pioneering initiatives are already exploring these possibilities.

The importance of these endeavors extends beyond the realm of space. The technologies and methodologies devised for managing organic waste possess considerable relevance on Earth as well. They offer solutions to waste management challenges, resource limitations, energy efficiency, and sustainability issues. This dual utility highlights the critical role of collaboration between industries and the sharing of expertise. This approach holds the potential to make substantial contributions to both food security and climate change mitigation, emphasizing the significance of a circular economy model.

The urgency of tackling this challenge lies in its potential impact on future space endeavors, including those involving interplanetary travel and settlements. As we expand our presence beyond our current space stations, the opportunities to dispose of waste by burning it up in orbit will diminish. Instead, we must equip ourselves with the means to manage and repurpose waste for valuable applications, both in space and on Earth, which opens up the opportunity for a closed loop circular economy in space and on Earth [2].

The path to efficient management of organic debris requires taking proactive steps, and some initiatives have already been set in motion:

1) **Initiate Research**: Begin immediate research efforts to develop practical solutions that address the unique challenges of managing organic waste in space.

2) **Cross-Industry Collaboration and Investment**: Foster collaboration between space agencies, research institutions, private companies, and the public sector to leverage expertise and resources.

3) **Dual-Use Technology**: Explore how mitigation techniques can be adapted commercially for use on Earth to enhance waste-to-resource technologies, and thus expand the market for the technology.

4) **Sustainable Funding**: Allocate increased funding to institutions and initiatives focused on organic waste management research, reflecting the urgency of the issue.

5) **Commercial Ventures**: Encourage the private sector to invest in the development of technologies that turn space waste into valuable resources, thus driving sustainable commercialization.

6) **Waste Reutilization**: Transform waste into valuable resources like water, oxygen, fuel, and pharmaceuticals [3].

7) **Packaging**: Support initiatives in pioneering reusable packaging solutions designed to accommodate various packaging needs, including those for food and essential materials.

8) **Specialty Space Appliances**: Innovate specialty food cooking appliances tailored to space conditions.

9) **Awareness and Advocacy**: Elevate the conversation around organic debris mitigation in space to ensure it remains a priority among stakeholders. Introduce dedicated sessions on organic debris mitigation at space conferences to facilitate innovation.

As conversations surrounding space sustainability and debris mitigation gain momentum, it is essential to underscore the importance of tackling traditional debris and also the impending challenge of organic waste. The promise of a thriving spacefaring future hinges on our ability to pioneer innovative waste management solutions that transform the discarded into the invaluable. By aligning our efforts across commercial industries, we can ensure the sustainability of space activities and also contribute to a greener, more sustainable Earth [4].

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Malkia Kelelue // KENYA

Kenya Space Agency

The Role of Diversity and Inclusion in Safeguarding Space Sustainability

Diversity and inclusion (D&I) are familiar terms in today's workplaces, communities, and society, and concepts of underestimated significance to space sustainability.

Current statistics [1] show that first world countries dominate the space sector. Other nations have some involvement, but are significantly less concentrated. Men, the dominant gender in engineering and science positions, also hold the majority of leadership positions in the industry. Cultural and racial minorities are also underrepresented and people with disabilities are greatly excluded. While some organizations strive to accommodate minority groups, studies [2] have revealed that they often face discrimination and inadequate accommodation in their workspaces. Evidently, a notable percentage of the world's population have little or no access to information, opportunities, and resources in space matters.

If these statistics prevail, the future space industry will remain dominated by a specific group of individuals. The inadequate space traffic regulations will likely give rise to the Kessler effect [3]. For developing countries, a polluted orbit and space environment will hinder the use of satellite technologies for crucial activities such as agriculture and disaster monitoring. With the projected advancement of the climate crisis, technologically advanced groups may migrate to the other celestial bodies, altering the skies and affecting cultures centered around these objects. People with disabilities and the elderly will not have access to space-related opportunities due to the lack of accommodating technologies. Summarily, individuals from underdeveloped countries and minority groups will be left on a dying planet surrounded by a polluted space environment.

Limited perspectives, skills, and interests arise from a limited group of players. Without a multifaceted approach to space exploration and exploitation, the future of the sector and the planet may be at risk. For instance, in 2019, NASA had a groundbreaking plan for an all-female spacewalk [4]—a historic mission to encourage women and girls to envision their own potential for space exploration. Regrettably, the mission was cancelled due to a shortage of spacesuits on board to fit women. If one of the leading space organizations struggled with something as fundamental as astronaut attire and equipment, what more pivotal aspects of D&I are being inadvertently overlooked? Addressing the need for D&I is important because it can prevent negative and biased trends from becoming norms, ensuring that space can be used by all people, not just the major players and technologically sophisticated ones.

EVONA, a company that recruits exclusively for the space ecosystem, has outlined a business case for D&I in the sector with statistics [5] that show increased revenue and profitability, enhanced collaboration, engagement and decision making, and strengthened reputation and market position for organizations that prioritize D&I. In one key example, a study by the Boston Consulting Group in 2018, showed that companies with a higher level of overall diversity experienced a 19% increase in innovation revenues and a 9% rise in EBIT (Earnings Before Income and Tax) margins on average [6]. This finding is especially significant in the space industry, where success largely depends on innovation and the use of state-of-the-art technology. These statistics further show that a diverse and inclusive space sector translates to a more cost-effective and productive sector that is more likely to ensure space sustainability.

While there are global efforts toward creating a just, equitable, diverse, and inclusive space sector [7], these initiatives are still scarce and often focus on gender and ethnicity rather than addressing socioeconomic disparities, physical capabilities, and racial and cultural representation, and there is still the challenge of discrimination.

If all players pursue an active role in promoting D&I, the aforementioned projections become more hopeful. The future space industry will be richly diverse and accommodating legislations will be enforced leading to enhance space traffic management. Developing nations will quickly advance in space-related research and technologies. Celestial bodies will remain protected allowing cultures centered around these objects to retain their heritage. With all individuals working to avert the climate crisis, solutions will be devised to ensure the health of the planet. All-inclusive technologies will be developed, and everyone will be able to explore and exploit space. Diversity and inclusion must therefore be prioritized so that all people can have a secure place in a sustainable space sector.

[1] https://www.visualcapitalist.com/visualized-which-countries-are-dominating-space.

[2] https://defence-industry-space.ec.europa.eu/system/files/2023-01/UoE_Leaflet_Survey%20Results_final.pdf.

[3] http://www.castor2.ca/07_News/headline_010216_files/Kessler_Collision_Frequency_1978.pdf.

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[5] https://www.evona.com/blog/business-benefits-diversity-inclusion-space-industry.

[6] https://www.evona.com/blog/business-benefits-diversity-inclusion-space-industry.

[7] https://jedispace.org.

Michelle Lucas // UNITED STATES

Higher Orbits

To Fill Our STEM Workforce in Aerospace, We Must Go to a New Well

Repeatedly we hear from aerospace companies about their needs to hire hundreds or thousands of individuals to fulfill all the work they have. And consistently we hear of their difficulties in finding enough people to fill these slots.

We can't solve the big problems facing us like space debris if we don't have the workforce, so we must first face the problem of workforce.

Einstein said the definition of insanity is doing the same thing over and over and expecting different results – yet it seems that's what a lot of companies are doing – the same thing.

To fill empty jobs, companies need to stop going to the same well with the same tools.

In the ever-evolving landscape of STEM, especially in our dynamic space industry, the quest for talent has become a challenging endeavor as there are more jobs to fill than ever before, including jobs to fill that have never existed previously. As we strive to keep pace with rapid advancements, the search for students in STEM must extend far beyond familiar territories. According to the U.S. Bureau of Labor Statistics [1], the number of jobs in STEM is projected to grow 8% by 2029, and the number of STEM occupations are projected to grow 10.8% from 2021 to 2031 as compared to 4.9% growth for all other careers. It is anticipated that this fast growth will leave nearly 3.5 million unfilled positions.

The narrative of STEM excellence has long been associated with certain regions and institutions. This perspective not only limits the growth of STEM fields but also perpetuates inequalities by inadvertently excluding talented individuals from different corners of the universe literally and figuratively.

I see companies going to the same places they traditionally have to recruit, and while these sources are tried and true, they also aren't bringing in much more than they have in the past. It is my experience that there is a perception, and a valid one, that students feel if they don't go to the "right" school the space industry won't even look at them. We must look to more than the typical "tried and true" universities and better explore community colleges and trades schools, etc.

STEM event outreach is a great way to inspire your future workforce. According to a recent study [2], underrepresented students who participate in an extracurricular STEM program boosted their chances of later earning a STEM degree. Clearly, STEM outreach works, BUT if you are only engaging in the same events as usual, you aren't bringing in enough students. The traditional activities in rocketry, robotics, and coding, etc., that have been organized in the past are wonderful opportunities for students, but they are ones that typically attract students who we would already have matriculated in our workforce. These students are already "geeked out" on STEM and have an eye on an education that will support our STEM workforce needs. We must find new ways to inspire other students to study STEM.

We also must show students role models that resonate with them. Sally Ride said, "You can't be what you can't see." Students need to see themselves in our industry. A study by Microsoft revealed that 73% of girls who personally knew a woman in STEM knew how to pursue a degree and career in STEM as opposed to 51% who don't personally know women in STEM [3].

To open the aperture for students about the variety of opportunities that exist for them in our industry we must first open ours to the variety of different individuals who might fill these openings.

We also must stop thinking that if we don't have students interested in STEM before high school ends, we have lost them. Many companies don't want to invest in initial STEM outreach to students in high school because they think they are not a viable option for a STEM degree if they aren't already properly set up. Is the road more challenging in this instance? Sure. Is it still achievable? YES! Let's bring these students to the STEM side!

If we don't have the workforce to tackle the problems of yesterday, we certainly don't have the workforce to tackle the problems of today and tomorrow. To be sure, it's no small task to fill our workforce needs, but we have space at our fingertips. There are two things that all students love at some point, space and dinosaurs! If we can't use our expertise in space to inspire our workforce beyond the usual suspects, we are doing it wrong.

[1] U.S. Bureau of Labor Statistics. (2023, September 6). Employment in STEM occupations. U.S. Bureau of Labor Statistics. https://www.bls.gov/emp/tables/stem-employment.htm.

[2] Cohodes, S. (2022). STEM summer programs for underrepresented youth increase STEM degrees. National Bureau of Economic Research. https://doi.org/10.3386/w30227.

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Yumna Majeed // PAKISTAN

Exploration – Cosmos to Classroom

Nurturing Space-Age Environmentalists: Fostering a Sustainable Cosmic Future Through Science Communication

Humanity's impact on Earth's vital resources – water, air, and land – is well documented through various mediums, yet often ignored until crises arise. This tendency to act only when faced with dire circumstances seems rooted in our nature. The research carried out by scientists often falls on deaf ears that can be attributed to the science communication gap, where vital information isn't effectively conveyed from scientists to the wider public and acted upon. Additionally, the disconnect between immediate concerns and future impacts is due to a generation gap, as the projected drastic impacts are set for 20 to 30 years in the future. Will it also apply to safeguarding the space environment?

Science communicators and educators play their role in overcoming the gap by igniting curiosity in young minds and encouraging them to explore space. Do these young minds truly understand how space affects our society and how our activities impact space? Are they aware of the orbital debris left by previous generations? Our upcoming generations have to address the challenges of climate change and space debris. We must prepare them for discovery while instilling a sense of responsible stewards of space. They should be equipped with both knowledge and emotional connection to Earth and space, motivating them to preserve these resources. This brings us to the concept of nurturing Space Age environmentalists – an idea extending beyond the regulation of space traffic management and debris.

Communicating observational science to children is often difficult because you cannot bring the entire cosmos to the classroom. However, we possess a powerful tool to bridge this gap: Science Communication: Art of Storytelling. Through this tool, we have the capacity to craft compelling narratives and tales that allow students to appreciate the marvels of space while we instill a profound sense of connection and understanding of their role in protecting it.

There are hardly any interactive educational resources in the current STEM education practices that combine space exploration excitement with lessons on space sustainability and responsible practices. If our aim is to inculcate responsibility for space in students, we should offer learning experiences that go beyond technical knowledge to shape young minds for conserving our environment both on Earth and in space. Leading aerospace companies, with their expertise in space debris solutions, can collaborate with skilled science communicators and educators to develop and deliver innovative STEM education approaches for fostering environmental consciousness in young space explorers. Through hands-on experiments, participants grasp challenges and solutions. Use visuals, interactive 3D graphics, and demos for clarity, engaging and aiding comprehension. By leveraging the art of storytelling, they can also create narratives that inspire bonding with Earth's preservation and the guardianship of our cosmic surroundings.

We know that Carl Sagan, a renowned science communicator, undeniably left a profound and lasting impact, serving as a driving force for countless astronomers, scientists, educators, and communicators passionate about exploring and sharing the wonders of the universe. By using stories in both written and visual formats, science communicators can inspire students to engage in age-appropriate projects that blend science and citizenship, closing the gap between understanding and taking action. Additionally, this education must encompass the global nature of space exploration. Young minds need to understand that space is a shared resource, and the actions of one nation or organization can impact the endeavors of others.

Ecosystem disruptions caused by climate change have replaced once-enjoyed natural pleasures like pristine beaches and stargazing with erosion and light pollution. Just as the coral bleaching of the Great Barrier Reef didn't happen overnight, the same holds true for the orbital junkyard. Unlike the tangible effects of climate change we witness around us, the consequences of space activities are often plain sight.

Educators can play essential roles in preparing responsible space custodians. As space utilization increases, more debris clutters our orbits, raising collision risks. It underscores the significance of fostering upcoming space stewards – young individuals who not only have a deep passion for space exploration but also possess the knowledge and skills to make well-informed decisions and empathy to ensure that their explorations don't harm the very environment they're eager to investigate. Effective education on space sustainability can prepare a generation to contribute to a safer and sustainable cosmic future.

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Claire Nelson // UNITED STATES
OASEAS at the Space Futures Foundation

How We Share Space? Fueling Sustainability with SMART Foresight

Imagine the Headlines... 12 April 2035 – "Air traffic control systems have been down for the last eight hours, grinding global air travel to a halt. Signal jamming problems with satellites controlling air traffic remain unresolved as space traffic management experts scramble to identify the key contributing factors using a digital twin simulation model developed by the Global Space Futures Collaboratory as the global protocol on space traffic management have gone unratified."

Imagine a future where the status quo remains unchanged. The race for space is on with countries and companies big and small, striking out to claim their piece of the sky. The Index of Objects Launched into Outer Space, maintained by the United Nations Office for Outer Space Affairs (UNOOSA) reports 11,330 individual satellites orbiting the Earth at the end of June 2023 with experts predicting the number to reach over 60,000 by 2030 [1]. Additionally, experts report approximately 25,000 pieces of debris larger than 10 centimeters tracked in orbit and many more untracked, which also pose a problem for the safe operation of satellites. Orbital crowding, space debris mitigation, responsible use of space resources, space traffic management, long-term sustainability of space infrastructure, environmental protection of celestial bodies, and negative impacts of space weather and natural phenomena are all issues in the space sustainability complex.

The space exploration ecosystem is a volatile, uncertain, complex, and ambiguous (VUCA) environment and leads to decision-making quandaries such as: What constitutes space sustainability policy? and How can our global policymaking instruments service the multiple, rapidly evolving, and often competing agendas? Accountability often takes a back seat to questions of sovereignty as the spacefaring elite – permanent members of the UN Security Council – place themselves outside the control of the very governance mechanisms that they establish to corral others. How we share space – a global common and a common good – will determine how humans thrive, and possibly survive. It is vital that the design of the space exploration ecosystem be underpinned by value systems that are deeply rooted in a sustainability paradigm. Further decision support systems should enable sustainable design.

Application of the SMART Futures Design Framework would offer decision-making capability to help create sustainability in space as on Earth through engaging our capacity to imagine the future and use the future to make improved decisions in the present [2]. The framework would address the complex and often conflicting demands of the ecosystem by applying five SMART questions to the future. How do we:

1) Develop space governance systems that can speak to the complex issues of sustainability?
2) Design space technology, engineering, and financial systems that recognize metrics that matter for a circular economy, building systems for durability, and bucking the trend to just move fast and break things?
3) Get space actors to address the sustainability aspiration, and go beyond what they are legally required to do versus what is right to do?
4) Design space sustainability governance that represents a multi-actor, sector-wide approach that is resilient, being emergent, and iterative?
5) Use technology in a transformational way to achieve teleologically effective solutions to the third-order consequences of the problem under study?

The framework adopts an approach that takes account of the sometime competing interests of the various actors in the ecosystem. Thus, all space actors – rocket scientists, engineers, lawyers, investors, policymakers, and so on – must be imbued with the capability to design plans, products, policies, and decision-making processes for space sustainability.

The establishment of a Global Space Futures Collaboratory (GSFC) – transnational, transdisciplinary, and multisectoral – would provide an environment for cooperative problem-solving, research, innovation, learning, and skill development. The Collaboratory would advance knowledge in ways that individual efforts will not achieve, through futures research and engagement tools – simulation, digital twins, gamification, technology foresight modelling, scenario planning – which enable the exploration of VUCA environments and the first-, second-, and third-order consequences of the decisions under consideration. The architecture of the GSFC, unlike the institutions of the past, would be designed as an emergent space of evolving partnerships that iterate as needed by the problem under study, and to enable decision makers to rehearse the future and explore problems as or before they emerge.

There will be opposition to the notion of yet another global institution, but keeping Earth's orbit a sustainable environment should be a key priority for all those with a vested interest in access to space. Developing global space sustainability standards and agreements will not be easy as evidenced by the Space Sustainability Rating (SSR) introduced by the World Economic Forum Global Future Council on Space Technologies [3]. Establishing a Global Space Futures Collaboratory would be a prudent, necessary, and sufficient condition to help us achieve space sustainability.

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Chau Nguyen // UNITED STATES

NYSA LLC

Diversity Gathering of Residence Space Object Data

The U.S. Space Surveillance Network (SSN) maintains a worldwide network of sensors that catalogs and tracks man-made orbital debris as small as 5 cm in diameter. The residence space object (RSO) data is made available through the Space Trek website. The RSO data is made available to registered owners or operators. The data provided are basic orbital data from the unclassified satellite catalog [1– 2] National Research Council. 1995). LeoLabs' network, a commercial RSO data provider, tracks and monitors orbital debris in the growing commercial sector of low Earth orbit (LEO) [3]. Data from all LeoLab's radar sites are collected and processed into higher level data products, including ephemerides, conjunction data messages (CDMs), and orbit change events. The data are delivered via a web-based API (application programming interface) and platform at https://platform.leolabs.space. Collectively, RSO data from SSN and LeoLab can provide space operators with a good set of data to use and monitor potential collisions in space. However, to get the data the space operators must enter into a data-sharing agreement and apply for the rights to obtain the RSO data.

Establishing a crowdsourcing process to obtain RSO data from all space operators, academics, scientists, and individuals is a means to obtain the best RSO data in a timely fashion. Waze is a crowdsourcing traffic mobile application that enables users to share real-time traffic information. Waze users agree to share data. The data collected includes passively collected speed data and actively reported user reports about current traffic conditions [4]. Prior to Waze, traffic data was collected using an Intelligent Traffic Management System (ITMS) [5]. ITMS required installation of probes and detectors along the streets in specific intersections.

The open source RSO data community can use the crowdsourcing philosophy of Waze application users to obtain more RSO data. In addition, the community can champion for greater in-orbit data gathering of RSO data. Today, the main systems used to gather RSO data are primarily ground base systems. There are efforts underway to augment existing satellites with new sensors to assist with tracking orbital debris. Tiny devices on satellites will soon be able to detect pieces of space debris as small as 1 inch that are invisible to existing space junk monitoring systems [6].

In the future, the supplier of RSO data will be the community of space operators with active satellites in space. The SpaceX megaconstellation Starlink can be equipped with new sensors used to detect and capture information about orbital debris. The data capture can be stored in an open source database for all space operators to use.

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[5] Nigam, N.; Singh, D.P.; Choudhary, J. A Review of Different Components of the Intelligent Traffic Management System (ITMS). Symmetry 2023, 15, 583. https://doi.org/10.3390/sym15030583

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Grecia Olano O'Brien // CANADA

Consortium for Research and Innovation in Aerospace in Quebec

A Multidisciplinary Approach to Space Sustainability

Satellites serve as the backbone of global communication, navigation, weather forecasting, disaster management, environmental monitoring, national security, economic activities, and scientific research, impacting diverse users across the world. However, the very services that satellites provide underscore the urgency of space sustainability. Sustainable satellite operations are crucial to ensure uninterrupted services for telecommunications companies, enabling people to stay connected. Moreover, in the realm of disaster management, uninterrupted satellite-based communication is vital for first responders and relief organizations, impacting the safety and well-being of individuals in affected areas. Furthermore, national security relies on secure satellite infrastructure, safeguarding nations and their citizens. Nevertheless, the issue of space debris and unsustainable practices threatens these crucial operations, making space sustainability a global challenge that demands a multidisciplinary solution to protect the interests of different users worldwide.

Environmental Perspective

As the global space industry continues to evolve, there is an increasing awareness among companies with respect to the importance of adopting environmentally responsible practices. However, assessing and addressing the complex environmental impacts of space activities, which span various domains and industries, presents a considerable challenge. Critical knowledge gaps persist in key areas of this field [1]. To navigate these hurdles effectively, space companies can turn to conducting life cycle assessments (LCAs). Undertaking LCAs is essential for space companies as it can provide them with a thorough understanding of the environmental, economic, and social impacts of their missions. LCAs allow companies to evaluate the entire life cycle of their space projects, from concept to disposal, providing insights into resource consumption, emissions, waste generation, and potential environmental risks at each phase. By identifying hotspots and potential areas for improvement, the space actors can optimize their processes to minimize negative impacts, both on Earth and in space, and enhance resource efficiency. Ultimately, by integrating LCAs into their practices, all space actors can make informed decisions and mitigate environmental risks.

Economics & Business Perspective

The exponential growth in satellites and space debris poses a significant risk to the operational environment in space. Currently, public and private satellite operators bear the burdens of space debris-related costs, including avoidance and mitigation. These costs are already substantial and vary depending on the specific orbit and type of spacecraft. One critical concern is the possibility of the Kessler Syndrome, a worst-case scenario in which certain orbits become unusable due to the proliferation of space debris. This outcome would have significant negative consequences, impacting government services, curtailing economic growth, and impeding the development of the space sector. Moreover, the adverse effects of such a scenario would not be evenly distributed, with some regions, especially rural areas reliant on satellite communications, bearing a disproportionate burden [2].

The establishment of a Space Sustainability Fund (SSF) would offer an innovative economic solution to alleviate the financial burdens on satellite operators and promoting collective action to ensure the long-term viability of space activities. By drawing support from high-net-worth individuals and private companies, as well as the public, this fund could provide financial resources to manage space debris, develop mitigation technologies, and support space sustainability efforts. Such a fund would help distribute the financial responsibility more equitably among all stakeholders.

Mandatory contributions could be integrated into relevant policies and regulations, ensuring a consistent inflow of resources. On the other hand, voluntary contributions could engage the public's enthusiasm for space exploration and environmental stewardship, offering an avenue for individuals to actively participate in shaping the future of space activities. This dual approach not only diversifies the funding base but also aligns the fund's objectives with a broader societal interest, strengthening the collective effort toward a more sustainable and secure space environment.

Awareness, Advocacy, & Outreach

Lastly, individuals, communities, and organizations outside the space sector must be engaged, informed, and inspired to contribute. This is where communicators, educators, and public engagement specialists enter the equation. By bridging the gap between complex technical concepts and public understanding, they empower individuals to grasp the urgency of the space debris challenge and actively participate in solutions.

Addressing the challenge of space sustainability demands a multidisciplinary strategy that surpasses the confines of individual fields. The intersection of technology, environmental science, business, and public engagement goes beyond mere expertise, it constitutes a collaborative effort that resonates with environmental stewardship, economic feasibility, and most importantly, shared responsibility.

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Kristen Price // UNITED STATES

Blue Origin

How Can the Space Industry Sustainably Continue to Grow?

By empowering and inspiring current and future generations of diverse stakeholders for the benefit of Earth.

What Do I Mean by Diverse Stakeholders?

Diversity is contextual. The diversity of stakeholder entities engaged in space industry activities and the diversity of the individuals within those entities and within their communities are all crucial for sustainably developing space.

Diversity of Entities

Space has historically been an industry mostly dominated by well-funded governments. Demonstrating American technological superiority fueled U.S. activities in space during the 1960s. Competition between nations drove the industry. That momentum of space industry development couldn't be sustained once the political motivation and unprecedented levels of government funding subsided. This is anecdotally observable through the state of NASA facilities[1].

A Space Foundation study that considered government spending and commercial revenue estimated the global space economy value at $546 billion for 2022 – projecting growth of another 41% over the next five years[2]. U.S. government space spending accounted for only about $68 billion. The landing of the Chandrayaan-3 spacecraft this past August is an historic accomplishment for India, but also evidence of a growing, more expansive, and diverse international space industry.

Non-government organizations (NGO) and academics are crucial stakeholders in sustainable space development. NGOs can advocate for responsible practices, influence policymaking, and foster international collaboration.

Diversity of Individuals

Workforce diversity is integral because diverse teams bring a wide range of perspectives and approaches to problem-solving, fostering innovation and creativity in space-related projects. Diverse workforces can better reflect the global nature of space activities and acknowledge the interests and needs of various communities and cultures. Inclusive workforce culture promotes collaborative and supportive environments, enhancing teamwork and productivity. Diversity also demonstrates inclusivity that can ultimately contribute to public engagement and the long-term success of space endeavors.

How Can Diverse Stakeholders Drive Sustainable Space Industry Development?

Compete

Competition fosters innovation, as each stakeholder strives to develop the most efficient technologies for space exploration and utilization. We've seen this throughout history between competing nations in space. Within industrial supply chains, competition can lead to the creation of more environmentally friendly systems, resource utilization techniques, and sustainable manufacturing processes. Competition drives commercial companies to seek cost-effective solutions, which can ultimately result in lower costs for space-related products and services.

Partner

Government agencies can partner with private companies, international organizations, and research institutions to engage in knowledge-sharing, cosponsored initiatives, policymaking, and advocacy to foster the development and implementation of enabling technologies and practices. NASA's work in this area is notable given the breadth and depth of facilities, resources, and experience within the agency.

Collaborate

More broadly, the industry can collaborate to establish joint research and development initiatives focused on sustainability objectives, efficient resource utilization, and space debris management. The Space Data Association is a collaboration between commercial satellite operators "to support the controlled, reliable, and efficient sharing of data critical to the safety and integrity of the space environment" [3]. The sharing of information about the orbits and movements of satellites can help prevent collisions minimizing additional debris generation.

Inspire

I feel incredibly fortunate to have this opportunity at ASCEND to learn from diverse colleagues doing incredible work advocating for the space industry and sustainability.

Inspiring future generations will serve as a catalyst to continue increasing diversity in the space industry. Blue Origin founded the nonprofit Club for the Future with the mission of inspiring future generations to pursue a career in STEM for the benefit of Earth. Club for the Future does this through four major priorities: increasing access to space through its Postcards to Space program, providing Club Ambassadors to schools to share their career path stories, partnering with organizations to reach underserved and underrepresented communities, and creating standards-aligned space-based lessons for K-12 students.

Call to Action

Each one of us brings a unique perspective to our roles at organizations and within our communities. Leveraging unique perspectives on the sustainable development of space to enrich our interactions with one another will enable the fulfillment of our collective responsibility to preserve humanity and Earth.

[1] https://arstechnica.com/space/2023/08/nasas-buildings-are-even-older-than-its-graying-workforce/

[2] https://fortune.com/2023/07/24/space-industry-revenue-growth-five-years/

[3] https://www.space-data.org/sda/

Alejandro J. Roman Molinas // PARAGUAY

Paraguayan Space Agency

Sustainability of Space: A Ticking Time Bomb

Humanity has always been fascinated by the marvels of the universe and drawn to the stars. Our interest in space has transformed over the last few decades into a more practical and ambitious industry: space exploration. The possibility of many of us leaving Earth is becoming closer as science and technology develop. However, among all the enthusiasm and development, we must address a crucial issue that is frequently disregarded. Space sustainability involves the prudent and responsible use of space for all countries, emerging and developed, ensuring that human activities in orbit and beyond do not jeopardize the future of space exploration or impede scientific progress.

The development of the space industry has brought many benefits to society, including satellite communications, Earth monitoring, and scientific research. For example, the proliferation of satellite constellations has revolutionized global connectivity and data sharing. As the number of satellites increases, so does the risk of collisions and space debris. Such collisions can create thousands of dangerous debris, leading to a catastrophic chain reaction known as Kessler syndrome, rendering some orbits unusable for decades or centuries. Space sustainability is a ticking time bomb that needs urgent attention. The accumulation of missing satellites, rocket stages, and debris in space significantly threatens active spacecraft and future space missions.

Initiatives such as active debris removal and the design of satellites with end-of-life disposal in mind are essential to mitigating this problem. However, these efforts must be supported by international agreements and cooperation to be effective.

International cooperation is the cornerstone of space sustainability. While space exploration has always been driven by competition between nations, the challenges we face today require cooperation, collaboration, and joint efforts. Establishing guidelines, standards, and effective practices can promote responsible behavior among spatial entities. Organizations such as the United Nations Committee on the Peaceful Uses of Outer Space (UN-COPUOS) and others are essential in fostering dialogue and cooperation to ensure that space remains a global common good.

Furthermore, sustainability extends to the moon, Mars, and other celestial bodies that may soon become targets for human exploration and resource use. As we envision future lunar missions and habitats, we must adhere to the principles of environmental protection on the moon. Avoiding pollution, protecting scientific sites, and preserving the natural heritage of these extraterrestrial bodies must be central to our approach.

Space exploration is an area that deserves special attention in pursuing space sustainability. Although mining resources from asteroids and other celestial bodies may seem lucrative, we must be cautious. Unregulated mining can lead to uncontrolled resource depletion and ecological damage on a cosmic scale. Establishing international frameworks and guidelines for managing space mining activities is crucial to prevent a rush to find gold that prioritizes short-term gains over long-term sustainability.

The sustainability of space requires an emphasis on responsible management of space traffic. As space becomes more crowded, it is essential to coordinate satellite orbits and maneuvers to avoid collisions. Integrating advanced tracking systems, automatic collision avoidance algorithms, and information-sharing mechanisms can significantly improve space traffic management and ensure our space efforts in the long term.

Also, the private sector has emerged as a significant player in the space industry, catalyzing innovation and lowering the cost of access to space. The challenge here is to find the correct balance between stimulating innovation and safeguarding space's sustainability that policymakers, industry leaders, and the scientific community must face together.

Investing in research and development is another essential aspect of space sustainability. Advances in materials science, propulsion, and manufacturing in space could lead to cleaner, more sustainable space missions. For example, applying solar electric propulsion for satellite navigation and orbit control could significantly reduce the environmental impact of space activities.

Finally, space sustainability is not just an abstract concept but an important aspect of our future in space. As we continue our journey through space, we must be mindful of our responsibility as the last defenders of the frontier. International cooperation, responsible space traffic management, regulatory frameworks, and investments in research and development are all essential elements of a sustainable space future.

Much evidence demonstrates sustainability concerns in space exploration and resource utilization. As previously noted, one of the major issues is the increasing accumulation of space debris in Earth's orbit. This threatens operational spacecraft and may impede future missions by endangering the space environment. It's clear proof of a problem that requires immediate and urgent attention. By working together, and with a strong commitment from all sectors, we can ensure that space exploration will benefit future generations while preserving the vast space for surviving as species and for wonders and discoveries to come.

The 2023 cohort of the Diverse Dozen are influential thinkers and emerging leaders from around the globe. Led by Moriba Jah from Privateer Space and 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 space safety, security, and sustainability. What needs to happen 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 attending their ASCEND session.

www.ascend.events

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Pablo Carlos Budassi // ARGENTINA
Awe Infographics

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Moriba Jah is the Chief Scientist and a co-founder of Privateer. Privateer is a data and intelligence platform empowering the future of space sustainability. As a renowned space environmentalist and astrodynamicist, Moriba brings a wealth of knowledge and expertise in space object detection, tracking, identification, and characterization, as well as spacecraft navigation to the Privateer team, where he is developing the first highly accurate space traffic map that aggregates multi-source data on Earth orbiting space objects, as a means to power the new space economy and make space exploration safe and sustainable. He is also an associate professor of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin where he is the holder of the Mrs. Pearlie Dashiell Henderson Centennial Fellowship in Engineering. At the University of Texas at Austin, he has worked with a team to develop ASTRIAGraph, an award-winning near real-time map of where objects are predicted to be located in space.