FORESIGHT INSTITUTE

Space Futures and Governance Workshop 2024

CHABOT SPACE CENTER, BAY AREA

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Foreword

The rapid evolution of space science and technology has opened new frontiers, which offer the risk of governance challenges but also the promise of an accessible, peaceful, and flourishing future beyond Earth.

The 2024 Space Futures & Governance Workshop, a collaborative effort between the Open Lunar Foundation and Foresight Institute, invited leading space-oriented scientists and technologists, as well as researchers and practitioners focused on governance, law, economics, and related areas to explore emerging opportunities at the intersection of space technology and governance. Held over two days at Chabot Space Center in Oakland, the event aimed to advance a shared vision of a future in space.

After introductory presentations, participants curated a shortlist of shared challenges and broke out into working groups to map out paths to progress before closing by discussing first possible steps along these paths.

Themes explored included:

- Economic incentives and challenges of space mining and manufacturing
- Technological and governance approaches to address space debris
- Increasing near-term access to space by lowering the cost to launch
- Initiatives and incentives to reinvigorate our mission to Mars
- Challenging walled garden assumptions and imagining open systems in space
- Ethical and social challenges for Lunar exploration: what can we learn from Earth?
- Space militarization technologies and related challenges and frameworks
- Emergent or existing catastrophic risks that could compromise human access to space

This report compiles summaries and recordings of the presentations and project collaborations. The corresponding presentations can be accessed by clicking on the play icons in the accompanying images.

We are grateful to all participants for their valuable contributions and collaborative spirit. Special thanks to our sponsors— Open Lunar Foundation, Protocol Labs, and Astro Mechanica —for their generous support, which enabled junior researchers to attend.

If you are a researcher, practitioner, or funder interested in advancing this critical field, we encourage you to reach out and join our efforts.

Best regards,

Allison Duettmann
FORESIGHT INSTITUTE

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Introduction

The Wright Brothers achieved the first powered, controlled, and sustained flight of a fixed-wing aircraft in 1903. Over the next sixty-six years, aerospace science advanced dramatically, culminating in the first human visit to the lunar surface in 1969.

Humans visited the Moon for the last time in 1972. Since then, fifty-two years have passed, during which time progress in aerospace has languished. There are bright sparks: the International Space Station has maintained a continuous human presence in orbit since 2000, and SpaceX has revolutionized spaceflight with reusable rockets that have dramatically reduced launch costs. Yet these achievements, impressive as they are, fall short of the bold visions of lunar bases and Mars missions that seemed within reach half a century ago.

How can humanity regain momentum in space exploration and development?

To address this question, the Space Futures & Governance Workshop 2024, organized by the Foresight Institute, brought together leading researchers, entrepreneurs, policymakers, and thought leaders. Over two intensive days, participants explored how to advance space development while avoiding potential pitfalls that could constrain or endanger humanity's future beyond Earth.

The discussions revealed a field characterized by both urgency and uncertainty. While technical capabilities for space development advance rapidly, questions about funding models, governance frameworks, and sustainable practices remain unresolved.

This report synthesizes the workshop's findings into three major sections. First, it examines the cross-cutting challenges that affect current space development efforts, including fundamental questions of funding, technical implementation, and governance. Second, it explores key tensions that emerged throughout the presentations and discussions, particularly regarding competing priorities between commercial, national, and international interests; balancing innovation with standardization; and managing the trade-offs between rapid development and sustainability. Finally, it presents harmonizing themes that suggest potential paths forward, focusing on infrastructure development, interdisciplinary integration, and democratization of access to space.

List of Participants

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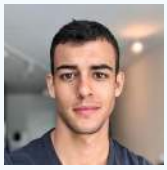

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Oluseun Taiwo
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FORESIGHT FELLOW

Victor Luo
NASA

Participants


FORESIGHT


Nanotech
Neurotech
Spacetech


Workshops


SPACE

About Foresight Institute

Founded in 1986, Foresight Institute supports the beneficial development of high-impact technology to make great futures more likely. We focus on science and technology that is too early-stage or interdisciplinary for legacy institutions to support, such as longevity biotechnology, molecular machines, brain-computer interfaces, multipolar AI, and space exploration. We award prizes, offer grants, support fellows, and host conferences to accelerate progress toward flourishing futures and mitigate associated risks.

Workshop Chair

Allison Duettmann

FORESIGHT INSTITUTE

Allison Duettmann is the CEO of Foresight Institute, directing programs in Intelligent Cooperation, Molecular Machines, Biotech & Health Extension, Neurotech, and Space. She founded Existentialhope.com, co-edited Superintelligence: Coordination & Strategy, co-authored Gaming the Future, and co-initiated The Longevity Prize. Duettmann advises companies such as Cosmica and serves on the Biomarker Consortium's Executive Committee.

Overview of Presentations

1. CROSS-CUTTING CHALLENGES

Building a world where development and operation in space environments is commonplace will not be easy. There are obstacles across the domains of economics, technology, and policy, and they reinforce each other. The initial costs for space initiatives are high, and there are few funding regimes to address them. The technical problems are daunting, and there are few feasible ways to test and iterate possible solutions. Uncertain governance hinders effective deployment of resources, and threatens confusion or instability in the future, deterring investment. Overcoming these challenges will require innovation and effort.

Funding and Economics

Space development faces significant economic hurdles. As Handmer, Terraform Industries (Mars Human Exploration Mission Planning) emphasizes, the high costs of space missions require novel funding approaches. Commercial lunar missions illustrate this challenge; Sarang, Open Lunar Affiliate (To the Moon and Beyond) notes that landing costs remain at approximately $1.2 million per kilogram, far above initial estimates. This creates a circular problem: high costs limit market development, but the fact that markets are limited inhibits the iteration and learning necessary to drive costs down.

Given this environment, traditional venture-capital models, with their emphasis on paths to exit and near-term returns, are unlikely to make space initiatives viable. Bennett, Spacecraft Business Unit (History's Guide to Space Settlement Economics), drawing on parallels to historical exercises in colonizing distant and forbidding environments, suggests that space-based initiatives will have to focus on long-term value creation, and the slow creation of new markets. Brettle, Keck Institute of Space Studies (Space Bottle Deposit) proposes innovative funding mechanisms that could help finance public good aspects of space infrastructure. That suggestion aligns well with the broader funding environment; if economic returns will not appear until the long term, then if they are to be gained, Earth's orbit must remain unpolluted by space debris.

Technical Implementation

The harsh realities of space environments demand unprecedented technical reliability. Siegler, Jet Propulsion Laboratory (NASA's Search for Life on Exoplanets) details the extreme precision required for space observation systems, where even microscopic imperfections can render equipment ineffective. These challenges extend to human factors. Reza, Astreas (Redefining Space Food) describes how basic processes like food preparation and consumption must be completely reimagined for microgravity environments.

Manufacturing presents particular difficulties. Johnson, Space Court Foundation (Whiskey in Space) demonstrates how even well-understood Earth-based processes require fundamental redesign for space applications. While practice will allow these processes to be refined and optimized, even creating conditions to permit iteration will be difficult. Pino, Volta Space Technologies (Lunar Power Standards) shows the need to determine standards for lunar power-distribution networks, but determining the standard in advance of operational experience is challenging. Similarly, Zea, Jaguar Space (Equitable Access to Space) proposes novel 'bio-mining' solutions to extract new raw materials from space environments, but acknowledges these remain untested, given the high costs of reaching and operating in orbit.

Governance and Coordination

Governance of space activity remains nascent. Johnson, Secure World Foundation (Space Policy: Challenges & Opportunities) and Salmeri, Lunar Policy Platform (Space Policy Futures and Lunar Development) each explore the Outer Space Treaty and find it a good start, but sufficiently imprecise that there are ample places for confusion or abuse. Johnson emphasizes the need, through the United Nations General Assembly or otherwise, to remove ambiguities, given the fact that early frameworks may establish conditions for decades to come. Salmeri seems to concur, noting that even basic definitions of space development lack international consensus, but that governance systems must retain the ability to evolve, given the uncertainties ahead, and the need for cooperation among nations to establish necessary lunar infrastructure.

The enforcement of agreements adds another dimension – Johnson, Secure World Foundation (Space Policy: Challenges & Opportunities) points out that traditional Earth-based enforcement mechanisms may prove inadequate in space contexts. Given the challenge identified by Siegler, Jet Propulsion Laboratory (Space Policy Considerations) that the needs of lunar colonists, scientific researchers, and commercial actors will need to be balanced, proactive policy development would seem to be required, to ensure harmony among these and other future actors.

These challenges—economic, technical, political—are interconnected. Technical development could improve economic viability; appropriate governance frameworks will encourage technical innovation and improve access to funding. Success in space development will therefore require that work proceed in all three arenas simultaneously.

2. KEY TENSIONS

Competing Interests: Commercial, National, International

Given the difficulties described in the previous section, to overcome them will require broad coalitions that can obtain the necessary funding, expertise, and policy outcomes. Assembling such coalitions may prove difficult, as competing interests within space development are increasingly in tension with each other.

Kaleagasi, Center for Space Governance (Commercial Space Stations) highlights the delicate balance between profit-driven development and public benefit in the context of commercial space stations. This tension manifests particularly in infrastructure development, where Kosak, Zitara (Lunar Landing Pad Mission) warns about the risks of any one actor exercising monopoly control over critical systems like landing facilities. Sarang, Open Lunar Affiliate (To the Moon and Beyond) notes the challenges of balancing the role of national space agencies like NASA against increasingly-active commercial firms operating in space, and determining the appropriate missions and responsibilities.

International dynamics further complicate the landscape. Salmeri, Lunar Policy Platform (Space Policy Futures and Lunar Development) and Johnson, Secure World Foundation (Space Policy: Challenges & Opportunities) both note that fundamental legal questions, including relevant and charged ones about matters like sovereignty and property rights, cannot yet be easily resolved, given the multitude of international actors, competing interests, and lack of straightforward ways of harmonizing competing legal traditions. Still, there is reason for optimism, given the tools of international law, and precedents of development in international territory like Antarctica.

Looking further ahead, Vollmer, Polaris Ventures (Post AGI Space Governance) raises concerns about value lock-in: how decisions made today, in favor of one constituency or another, might constrain future possibilities. Meanwhile, Walsh, Chapman University (Promoting Environmental Sustainability in Space) emphasizes the importance of preserving flexibility for future generations while meeting current development needs, identifying the possible competition of interests between the present and the future.

Innovation versus Standardization

The space sector grapples with balancing rapid innovation—necessary to make progress against difficult technical and policy problems—against the need for standardization, to permit the certainty necessary for new actors to enter the field. Pino, Volta Space Technologies (Lunar Power Standards) illustrates this tension through the lens of power systems, where premature standardization could stifle innovation, yet lack of standards impedes development. Linden,

Open Lunar Foundation (Complications of a Lunar Coordinated Time Scale) similarly highlights the challenges of establishing standards before operational experience exists. Gilbert, Payne Institute for Public Policy (Nuclear Technologies for the Moon and Mars) describes how integrating nuclear technologies requires careful balance between innovation and proven reliability.

However the case may be that lack of standardization hampers development, the need for innovation at the early stage remains critical; Luo, NASA (Non-Traditional Partnerships) advocates for unconventional partnerships for precisely this reason, to drive innovation better.

Speed versus Sustainability

The urgency of space development seems to conflict with concerns that too-hasty action could lead to permanent damage; as Rotola, Outer Space Institute (Outer Space Institute Space Sustainability) describes it, some space environments are irreplaceable, and "we cannot just stack our way out of the problems" that development might create.

An example of such fragile goods might be the heritage sites and objects that Walsh, Chapman University (Promoting Environmental Sustainability in Space) identifies, such as Apollo 11's Tranquility Base or Vanguard 1, the oldest human object still in orbit. Another might be an orbital layer around Earth free of dangerous debris. Kaleagasi, Center for Space Governance (Commercial Space Stations) suggested there would be future market demands for debris removal, while Brettle, Keck Institute of Space Studies (Space Bottle Deposit) proposes a regime to help minimize its production in the first place.

Both Rotola and Walsh identified the need to create frameworks for sustainable space development, with Rotola in particular arguing for learning from Earth's environmental history to avoid replicating past mistakes.

Against this view, several speakers emphasized the imperative for decisive and rapid space development. Handmer, Terraform Industries (Mars Human Exploration Mission Planning) argues that the technical capabilities for significant Mars development exist today, with the primary barriers being organizational rather than technological. Bennett, Spacecraft Business Unit (History's Guide to Space Settlement Economics) draws parallels to historical infrastructure development, suggesting that hesitation and over-caution can be as dangerous as recklessness; he points to how the defining characteristic of the early American colonies that helped them to succeed was a fast move to develop domestic manufacturing capabilities. Sarang, Open Lunar Affiliate (To the Moon and Beyond) notes that current launch costs to the lunar surface remain prohibitively high precisely because we lack the operational tempo and infrastructure that come with sustained, rapid development. Gilbert, Payne Institute for Public Policy (Nuclear Technologies for the Moon and Mars) emphasizes that while nuclear technology requires careful safety considerations, the greater risk lies in failing to develop these crucial power sources quickly enough to enable sustained human presence beyond Earth.

This moral tension, between the urgency to develop space for the good of humanity, and the urgency to avoid polluting space in ways that cannot be repaired, will not be easily resolved.

3. EMERGING SOLUTIONS

Infrastructure Development

There was an emerging consensus that foundational infrastructure is a critical enabler for sustainable space development, and building it should be a near-to-medium term objective. Pino, Volta Space Technologies (Lunar Power Standards) emphasizes the need for reliable power distribution systems, upon which the lunar microgrid that Arya, Stanford Aeronautics and Astronautics (Lunar Microgrid) would rely. Kosak, Zitara (Lunar Landing Pad Mission, and Lunar Landing Pad: Paving the Way) advocates for standardized landing facilities as essential shared infrastructure. Similarly, Gilbert, Payne Institute for Public Policy (Nuclear Technologies for the Moon and Mars) outlines how nuclear power could provide reliable energy infrastructure for lunar and Martian operations, though this requires careful integration of multiple technologies.

Interdisciplinary Integration

Success in space development increasingly requires combining diverse fields and approaches. Vora, Explore Mars (Explore Mars & Space Health Innovations) demonstrates how synthetic biology could revolutionize space manufacturing and life support systems, while Zea, Jaguar Space (Equitable Access to Space) explores biological approaches to resource extraction. Wong, Atomic-6 (The Moon as a Quiet Place) introduces the concept of the moon as a "quiet place" for scientific research, particularly in biology, taking advantage of the Moon as an ideal place to carry out work not aimed at space development, but rather to facilitate development of the Earth itself.

Novel perspectives yielded unexpected insights. Vollmer, Polaris Ventures (Post AGI Space Governance) examines how artificial intelligence might reshape space governance, while Johnson, Secure World Foundation (First Move Policy Games) describes how policy games and simulations can improve decision-making.

Democratization and Access

Finally, a common theme that emerged from the workshop was the need to broaden participation in space development. Riley, Itemfarm (Growing the Workforce of the Interplanetary Economy) emphasizes the importance of developing a diverse space workforce, while Rousset, Arizona State University (Space Technology for Good) describes educational initiatives to expand space-related opportunities. In a different vein, Sebastian, Foresight Fellow (Study Abroad in Space) proposes carrying out educational activities, as soon as 2035, on orbital platforms, to expand excitement and interest in space development to a broader audience.

Zea, Jaguar Space (Equitable Access to Space) proposes innovative cost-sharing approaches to make space research more accessible to developing nations. Reza, Astreas (Redefining Space Food) demonstrates how diverse perspectives can improve fundamental systems like space nutrition.

These harmonizing themes suggest pathways to address the field's challenges that may help to manage, or defuse, key obstacles and tensions. Shared infrastructure, interdisciplinary approaches, and broadened participation could help to encourage interest in the problems of space development, particularly how to do so quickly yet sustainably.

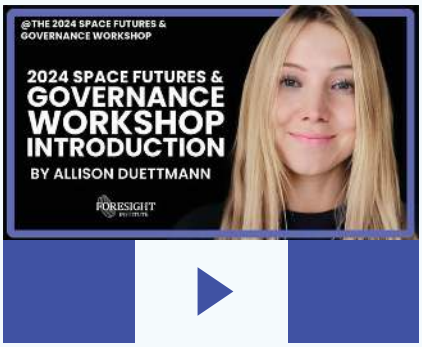
CONCLUSION

The Space Futures & Governance Workshop 2024 reveals a field at a critical juncture. The challenges are formidable: high initial costs, unprecedented technical requirements, and inadequate governance frameworks.

Yet the workshop revealed paths forward through these obstacles. Technical solutions influence economic viability, while governance frameworks shape both technical approaches and funding models. Success will require holistic approaches that acknowledge these interconnections while maintaining focus on both immediate progress and long-term sustainability.

The tension between speed and caution emerged as a central theme: the imperative to move quickly enough to establish viable space presence, while proceeding thoughtfully enough to avoid irreversible mistakes. The workshop suggests this balance might be achieved through shared infrastructure development, interdisciplinary collaboration, and broadened participation in space development. These approaches could help create the robust foundation needed for humanity's rapid expansion into space: building an exciting future for humanity while avoiding its past mistakes.

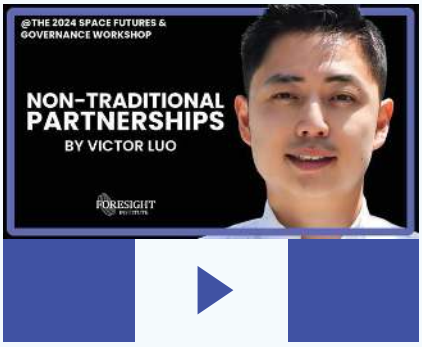
Talk Summaries



Opening Session

Allison Duettmann, Foresight Institute

Duettmann begins the workshop by outlining the Foresight Institute's role in supporting science and technology development that other institutions often find too narrow, too ambitious, or too interdisciplinary to fund. Since 1987, the Foresight Institute has offered fellowships, grants, and technical workshops in support of a variety of fields, including decentralized secure AI, molecular nanotechnology, longevity, and space. The latter has been a Foresight concern for some time. While past predictions regarding progress in this field may have been overoptimistic, they demonstrate a long-standing commitment to space development. She explains the workshop's structure, combining technical talks with collaborative sessions, aimed at three goals: learning about new frontiers, exploring challenges and opportunities, and developing practical project prototypes.



Non-Traditional Partnerships

Victor Luo, NASA

Luo presents innovative approaches to accelerating space development through unconventional collaborations, drawing from his experience with NASA, Amazon, and Toyota Research. He shares examples of successful partnerships, including NASA's collaboration with Xbox for a Mars Rover Landing game and work with Google Creative Labs on AR spacecraft visualization. A key case study focuses on Project Sidekick with Microsoft, which developed AR headsets for the International Space Station to enable real-time ground support for astronauts. The presentation emphasizes how these partnerships can reduce costs, increase efficiency, and accelerate space development beyond traditional government-agency approaches. Luo highlights the successful certification of consumer technology (like Snapdragon chips) for space use and advocates for more "weird experiments" in space through collaborative efforts.

Whiskey in Space

Nathan Johnson, Space Court Foundation

Johnson explores the cultural and technical challenges of making whiskey in space, framing it within the broader context of civilization development. He discusses historical precedents of distillation in major civilizations and argues for its importance in future space settlements. The presentation addresses technical challenges including launch costs, manufacturing capabilities, and microgravity considerations, alongside legal complications regarding trade jurisdictions and bourbon classification in space. Johnson reveals his 'Space Age Bourbon' initiative—to produce a trademarked product, initially on Earth—as a stepping stone toward space distillation, to attract attention and engagement to space initiatives more broadly. The talk concludes by highlighting how addressing these challenges could establish precedents for broader space commercialization.

Explore Mars

Tiffany Vora, Explore Mars

Vora discusses her role as VP of Innovation Partnerships at Explore Mars, focusing on synthetic biology applications for a sustainable presence of humans on Mars. She presents synthetic biology as a self-perpetuating, modular, and programmable manufacturing technology, highlighting its potential for creating a circular bioeconomy off-planet. Such a technology would offer advantages like flexibility in input materials and stable long-term storage. Vora connects this work to broader bioeconomy initiatives, including recent U.S. executive orders and international strategies. She outlines specific applications in NASA's technology taxonomy areas, emphasizing the shift from a "take" to a "make" philosophy in space resource utilization.

Redefining Space Food

Shahreen Reza, Astreas

Reza presents innovative approaches to space nutrition, focusing on developing high-functional chocolate truffles containing key micronutrients identified in NASA's Human Roadmap. The product addresses micronutrient deficiencies common in space while incorporating nootropics and adaptogens for cognitive enhancement. Using 64% Valrhona dark chocolate and algae oil, the product has already been tested in space via Virgin Galactic and SpaceX Crew 8 missions. Research with NCAA athletes demonstrates the product's ability to improve performance on identified metrics. The project emphasizes precision nutrition, recognizing individual dietary needs vary significantly. Additionally, Reza highlights successful testing on neurosurgeons performing AI remote robotic surgery, demonstrating practical applications beyond space travel.

NASA's Search for Life on Exoplanets

Nick Siegler, Jet propulsion Laboratory

Siegler discusses NASA's challenges in searching for life beyond our solar system, focusing on the technical difficulties of detecting exoplanets. He explains the "contrast problem" where starlight is billions of times brighter than reflected planetary light; the difficulty is analogous to detecting a firefly near a lighthouse, and doing so from across the country. Siegler offers two main approaches to finding exoplanets: internal coronagraphs and external star shades. He details progress in coronagraph technology at JPL's specialized lab, noting the facility is currently about an order-of-magnitude away from requirements for Earth-like planet detection. He concludes by discussing the Plans for the Habitable Worlds Observatory, designed for Earth-like planet detection and scheduled for late 2030s launch, including provisions for robotic servicing in space.

Mars Human Exploration Mission Planning

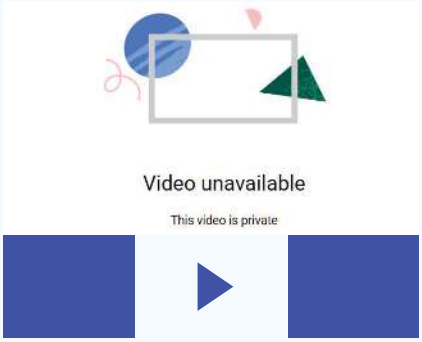
Casey Handmer, Terraform Industries

Handmer addresses the critical challenge of returning to Earth from Mars, emphasizing this as the most underestimated aspect of Mars missions. He explains the physics of orbital transfers using Hohmann Low Energy Transfer concepts and discusses the complications of plane changes between Earth and Mars orbits. Handmer analyzes the SpaceX approach versus traditional NASA mission architectures, highlighting how SpaceX's Starship development was motivated by the ability to return from Mars surface to Earth in a single stage. He emphasizes the importance of safe, routine access to low Earth orbit with reusable assets as a foundation for more ambitious missions.

Space Technology for Good

Jessica Rousset, Arizona State University

Rousset outlines the Interplanetary Initiative at Arizona State University, which focuses on rethinking university approaches to accelerate research and prepare future innovators. The initiative emphasizes interdisciplinary collaboration across sectors, bringing together experts from industry, government, and academia. Their interplanetary laboratory, run by students under professional supervision, supports various missions aligned with broader goals of access, inclusivity, and ethics. Rousset emphasizes the importance of engaging the public through arts and integrating social considerations into technical degrees from day one, highlighting recent NASA funding for space sustainability research projects.



X-Prize

Chris Lewicki, XPRIZE

This speaker did not permit their remarks to be made public.

Promoting Environmental Sustainability in Space

Justin Walsh, Chapman University

Walsh approaches space sustainability from an archaeological perspective, highlighting the importance of treating space as an environment requiring preservation. He demonstrates how archaeological principles can document and protect space heritage, from Vanguard 1 (the oldest object in orbit) to Apollo landing sites. Walsh presents several examples of exercises in space archaeology, including mapping of the Tranquility Base site with its 106 documented objects, and recent documentation of Mars 2020's entry descent and landing components. The presentation emphasizes the need for international treaties specifically addressing protection of human-heritage sites beyond Earth, arguing that protective frameworks for historical sites could serve as foundations for broader environmental protections in space.

Outer Space Institute Space Sustainability

Giuliana Rotola, Outer Space Institute

Rotola examines different frameworks of sustainability as applied to space, contrasting weak, moderate, and strong sustainability models. She argues that current space governance, including the Long-term Sustainability guidelines, represents a weak to moderate sustainability approach that may not adequately prevent replication of Earth's environmental mistakes. The presentation advocates for moving toward a strong sustainability framework that recognizes the intrinsic worth of space environments and the limits of technological solutions to space debris and other challenges. Rotola emphasizes the need for dynamic and holistic governance approaches that value ecosystem balance and shared stakeholder responsibilities.

Equitable Access to Space

Luis Zea, Jaguar Space

Zea presents his work making space research more accessible, particularly for researchers from nations with limited space program budgets. Drawing from his experience transitioning from aerospace engineering to bioastronautics, he describes innovative approaches to reducing costs through customer aggregation and shared payloads. His company helps multiple space agencies share costs while maintaining their own research objectives, streamlining safety review processes through experienced guidance. The presentation emphasizes practical solutions for broadening participation in space research beyond traditional participants.

Study Abroad in Space

Tommy Sebastian, Foresight Fellow

Sebastian proposes an innovative educational concept of "study abroad in space," arguing that space development needs diverse viewpoints and cultural perspectives. He outlines a vision for developing an interplanetary curriculum that goes beyond traditional science and engineering to include cultural aspects like storytelling and food preparation. By 2035, the proposal envisions a classroom section on orbital platforms where students can pitch and adapt ideas in the space environment. Sebastian emphasizes that this approach could help make space more accessible and real to people beyond the traditional space community, comparing it to how Earth-based study-abroad programs transform student perspectives.

Extracting Materials Using Synthetic Biology

Luis Zea, Jaguar Space

Zea discusses innovative approaches to bio-mining in space environments, highlighting that about 20% of Earth's copper and 5% of gold are currently extracted through biological processes. The presentation emphasizes that while these techniques haven't been implemented in space due to high orbital access costs, they represent significant potential for resource utilization. The approach centers on using oxygen-free (anoxic) environments where microbes interact with regolith oxides in a process similar to breathing. The microbes use the oxides as the final recipient of electrons in their metabolic cycle, and when the oxide accepts the electron, the metal is released into solution. This biological process effectively separates metals from the regolith, making them available for uses like 3D printing and manufacturing. The process could enable metal extraction for 3D printing and manufacturing in space, potentially reducing supply-chain dependence on Earth.

Space Policy Considerations

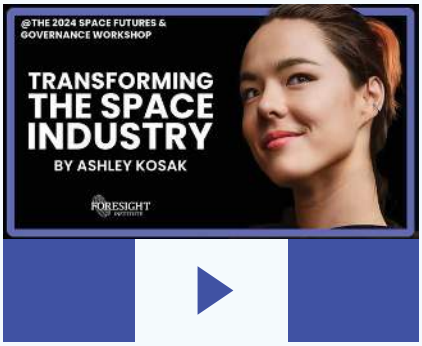
Nick Siegler, Jet propulsion Laboratory

Siegler offers a hypothetical scenario set in 2035 where lunar colonies, research stations, and space economies are established, then works backwards to examine how harmonious policy development could enable such a future. He presents a preliminary list of space policy considerations including sovereignty of space structures, property rights, space debris management, terraforming rights, and salvage rights. The presentation emphasizes the need for systems-view requirements in any guidelines, considering long-term implications of policy decisions. Siegler highlights the importance of developing these policies proactively rather than reactively, drawing parallels to how early regulation might have altered the environmental impact of gasoline consumption by automobiles.

Space Bottle Deposit

Harriet Brettle, Keck Institute of Space Studies

Brettle presents an innovative approach to the space debris problem through a financial incentive system modeled on terrestrial bottle deposit schemes. The concept requires satellite operators to place a down payment during the licensing process, which is returned only upon successful de-orbiting of their spacecraft. If the satellite becomes debris, the deposited funds would be used to support remediation efforts or fund “tow truck” services. The presentation acknowledges that humans have historically polluted the atmosphere and oceans, and argues for learning from these experiences to prevent similar outcomes in space. Brettle notes that while this approach is new for space, it builds on proven terrestrial models. The proposal includes discussion of how to quantify appropriate deposit amounts and potential tax incentives to encourage participation. Brettle emphasizes the importance of creating early incentives for responsible behavior, rather than waiting until debris becomes an insurmountable problem.



Transforming the Space Industry

Ashley Kosak, Zitara

Kosak addresses the need to transform the space industry from within, focusing on making it more intersectional and removing colonial mindsets. She critiques problematic language in the industry, from SpaceX's "colonize Mars" rhetoric to gendered technical terminology. The presentation outlines several key initiatives including prioritizing grants and funding to minority-owned and women-owned businesses, implementing diversity requirements in NASA funding, and developing education programs on socio-political impacts of space technology. Kosak emphasizes that a new space society shouldn't replicate existing power structures and proposes mechanisms for more inclusive industry development.

Space Distillation

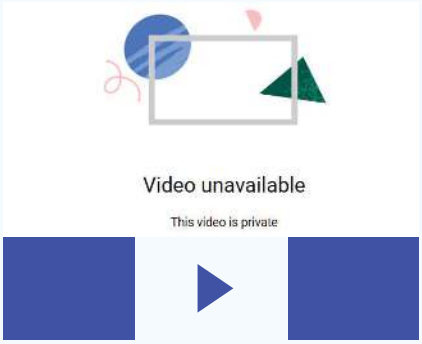
Nathan Johnson, Space Court Foundation

Johnson examines the history of distillation as a marker of civilization development, using this framework to discuss space settlement challenges. He analyzes the legal complications associated with producing bourbon in space, given its definition as a distinctly American product, and explores how space jurisdiction might affect trade classification. The presentation addresses technical challenges of distillation in microgravity and the current poor taste of space-aged spirits, noting Ardbeg's space experiments resulting in undesirable flavor profiles. Johnson proposes his "Space Age Bourbon" brand as a pathway to fund research and engage public interest in space development.

Lunar Power Standards

Paolo Pino, Volta Space Technologies

Pino examines the critical need for power standardization on the moon, using Japan's 2011 earthquake response problems (caused by incompatible power grids) as an illustrative example of standardization's importance. He surveys current global initiatives in space power standards development, identifying eight key technical areas requiring standardization. He addresses the challenge of developing standards without extensive lunar operational experience, proposing a dashboard approach for tracking candidate standards' development. Pino emphasizes the need to balance innovation with standardization and suggests methods for encouraging standard adoption through clear metrics and stakeholder engagement.



Lamps and Lunarsaber

Kevin Hubbard, Honeybee Robotics

This speaker did not permit their remarks to be made public.

Nuclear Technologies for the Moon and Mars

Alex Gilbert, Payne Institute for Public Policy

Gilbert presents advances in space nuclear technologies, focusing on both radioisotope power systems and fission reactors. As VP of regulatory affairs at Xenopower, he discusses the firm's innovative approach to packaging nuclear waste for space applications. The presentation highlights recent policy changes enabling commercial space nuclear development and details various projects including NASA's fission surface power initiatives. He emphasizes the critical role of nuclear power for sustained presence beyond low Earth orbit, particularly for surviving lunar nights and enabling Mars exploration. The talk includes discussion of supply chain developments and regulatory pathway improvements that are making commercial space nuclear more feasible.

History's Guide to Space Settlement Economics

James Bennett, Spacecraft Business Unit

Bennett critiques the common misuse of historical analogies in space settlement discussions, arguing that both advocates and opponents often cherry-pick historical examples without proper context. He particularly focuses on North American colonial development, and challenges the common narrative about export-focused settlement in the southern colonies with the observation that the northern colonies quickly developed manufacturing capabilities, such that 40% of British merchant fleet ships were built in North America by the American Revolution. Bennett draws parallels to current space development, particularly examining Elon Musk's approach with SpaceX as following the "Transcontinental Railroad model" of development-focused rather than transport-focused business strategy. Bennett argues that understanding these historical patterns correctly is crucial for developing sustainable space settlement approaches.

To the Moon and Beyond

Mehak Sarang, Open Lunar Affiliate

Sarang presents a critical analysis of commercial lunar-lander development, drawing from her experience at both Masten Space Systems and iSpace US. She highlights the transformative shift in NASA's operational approach through the Commercial Lunar Payload Services (CLPS) program, with its $2.8 billion operating budget. The presentation examines the fundamental challenge facing the commercial lunar landing industry: while NASA's theory anticipated commercial demand emerging similarly to SpaceX's evolution, the actual commercial market for lunar payload services remains minimal. Sarang presents data showing the stark contrast between CLPS payload mass and revenue versus minimal commercial demand, suggesting that lunar-lander companies may need to stimulate their own demand, as did SpaceX with its creation of Starlink. She discusses current cost challenges, noting that lunar payload delivery costs remain at approximately $1.2 million per kilogram, significantly higher than NASA's original estimates. Sarang concludes by examining how this high-cost barrier impacts the development of interesting and ambitious lunar activities.

Lunar Landing Pad Mission

Ashley Kosak, Zitara

Kosak presents a vision for a cooperative lunar landing-pad initiative, emphasizing the need to increase landing success rates from 50% to 80%. The presentation outlines various technical approaches to help achieve this goal, including blast shields, surface preparation, and communications systems. A key feature of this vision is democratic access and intergovernmental development rather than single-nation or corporate control. Kosak draws parallels to internet-infrastructure development, warning against potential monopolistic control of lunar-landing facilities.

Commercial Space Stations

Bartu Kaleagasi, Center for Space Governance

Kaleagasi discusses the transition from government-operated to commercial space stations, focusing on NASA's Commercial LEO Destinations (CLD) program. The presentation reviews various commercial station projects including Axiom Space, Starlab, and Orbital Reef, examining their different approaches and business models. Kaleagasi identifies funding constraints, regulatory pathways, and international cooperation as important matters to consider under any approach. The talk emphasizes the importance of developing diverse economic activities in orbit to sustain commercial stations beyond government contracting.

Post-AGI Space Governance

Jonas Vollmer, Polaris Ventures

Vollmer examines the intersection of artificial general intelligence (AGI) and space technology, arguing that AGI development could dramatically accelerate space-exploration timelines. He suggests that AGI by 2028 and superintelligence by 2030 could enable large-scale space exploration within decades rather than centuries. The presentation focuses on potential "value lock-in", namely that early space settlements will be hard to change once established, making initial governance decisions crucial. Vollmer proposes an illustrative framework for allocating the "cosmic endowment," suggesting the solar system be reserved for current humans, while dedicating most accessible space to reflection procedures that can adapt to evolving human values. He emphasizes the importance of establishing basic rights for both humans and sentient AIs in space governance frameworks.

Complications of a Lunar Coordinated Time Scale

Philip Linden, Open Lunar Foundation

Linden addresses the complex challenge of establishing Lunar Coordinated Time (LTC), explaining why Earth's UTC cannot be simply applied to lunar operations. The presentation demonstrates how relativistic effects cause perfect clocks on Earth and Moon to drift apart by 56 microseconds per day, potentially leading to navigation errors of up to 16 kilometers. Using visual aids to demonstrate the vast distances involved in Earth-Moon operations, Linden explains why GPS-style timing systems become problematic at lunar distances. The talk emphasizes practical considerations for distributing time signals on the lunar surface, suggesting that sharing time is more important than perfect accuracy. Linden proposes a three-part solution: requiring good clocks on spacecraft, establishing a basic public time service, and developing transparent systems for time distribution. He advocates for prioritizing practical timing solutions that can evolve with lunar development rather than waiting for perfect systems.

Space Policy: Challenges and Opportunities

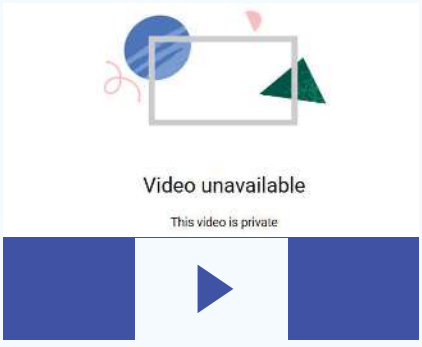
Chris Johnson, Secure World Foundation

Johnson applies deontic logic (the philosophy of obligations) to analyze space law, breaking down the Outer Space Treaty into permissions, prohibitions, and obligations. He demonstrates how these elements manifest in space law, using examples like the requirement to assist astronauts (obligation), the prohibition of military bases on celestial bodies, and the permission for free access to all areas of celestial bodies. The presentation explores legal gaps and ambiguities, questioning whether the 'Lotus Principle' applies: that is, that activities not explicitly prohibited should be considered permitted. Johnson emphasizes that international space law represents a unique legal framework distinct from both common and civil law traditions, requiring careful consideration of how to address emerging space activities not contemplated in existing treaties.

Space Policy Futures and Lunar Development

Antonino Salmeri, Lunar Policy Platform

Salmeri presents space law as a multi-level system requiring both international and national legislation. He emphasizes that the Outer Space Treaty remains relevant despite its age, as it provides foundational principles applicable to all space activities. The presentation outlines three development pathways for space policy: multilateral (through UN bodies), minilateral (between cooperating states), and multi-stakeholder (involving non-governmental actors). Salmeri highlights recent initiatives like the Working Group on Space Resources and the Action Team on Lunar Activity Coordination (ATLAC), emphasizing the need for governance systems that can evolve iteratively. He argues that lunar development requires cohesive policies addressing not just mining but also communication, landing pads, and other infrastructure needs. The talk concludes by advocating for a comprehensive approach that allows national development while maintaining international cooperation.



Space Governance on the Path to Artificial General Intelligence

Gustavs Zilgalvis, Center for Space Governance

This speaker did not permit their remarks to be made public.

Growing the Workforce of the Interplanetary Economy

Alder Riley, Itemfarm

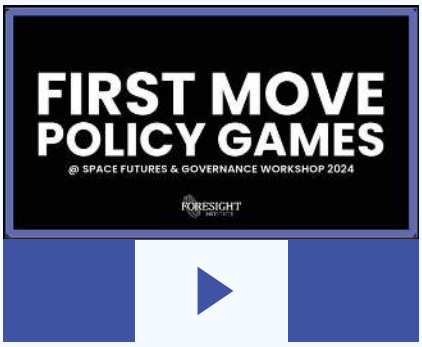
Riley addresses the challenge of developing a diverse workforce for future space development, emphasizing that most people who will live off-world haven't been born yet. The presentation uses interactive elements to demonstrate how different backgrounds and interests can lead to space careers, challenging traditional assumptions about who belongs in the space industry. Riley discusses his community work helping people from various backgrounds, from waitresses to policymakers, find their path into space-related careers. The talk emphasizes that space civilization will require diverse skills beyond traditional technical roles, arguing that cultural and memetic approaches are needed to counter anti-space expansion narratives. Riley advocates for radical inclusion in space workforce development, emphasizing that a true space civilization needs all types of people and professions.

The Moon as a Quiet Place

Adam Wong, Atomic-6

Wong highlights unique characteristics of the Moon—low gravity, extreme temperature deltas, low tectonics, and remoteness—as advantages for specialized research. He proposes conducting research below the lunar surface to leverage its low gravitonics, temperature noise, and electromagnetic noise, maximizing research value while minimizing visual impact on the lunar landscape. Two primary research areas are emphasized. Firstly, quantum research and particle physics experiments that would cost trillions to replicate on Earth could be conducted naturally in the lunar environment. With the global commercial R&D budget at $2.5 trillion annually, Wong argues that lunar facilities represent a worthwhile investment given their potential returns in the quintillions. Secondly, certain kinds of biological research, particularly gain-of-function studies, would be uniquely

appropriate on the Moon, as any lab leak would be neutralized by the harsh environment—a natural containment system. Wong compares potential organizational structures to CERN and the National Institute of Health, suggesting that public-private partnerships could effectively manage these facilities. He emphasizes that while governance details can be worked out later, established institutions have proven track records of managing large-scale scientific initiatives with 10–15 year horizons.



First Move Policy Games

Panel Discussion

The panel introduces an innovative tabletop exercise workshop focused on cislunar strategy, structured across multiple time periods. The exercise spans two days, with the morning session set in 2030, afternoon in 2035, and the following day's session in 2040. To create urgency and simulate real-world decision-making pressure, every minute of real time represents a week in the simulated timeline. Participants represent various stakeholders including commercial actors, scientific community, and state representatives, with some delegations having five people while others have just one person with backup teams. Players must enter the main room to announce decisions or moves, operating under time constraints that limit deliberation on treaty interpretations or scientific disputes. The exercise aims to identify points of contention, convergence, and areas of contestation to inform specific policy deliverables needed in 2024-2025. The organizers plan to run multiple parallel sessions, noting that ten more sessions are happening that weekend, allowing for comparative analysis of how different groups approach the same scenarios. This parallel structure enables the study of convergent solutions and major decision points that consistently arise across different groups.

Lunar Landing Pad: Paving the Way

Ashley Kosak, Zitara

Kosak outlines a proposal for developing reliable initial landing pads on the lunar surface, aiming to improve landing success rates from 50% to 80%. She discusses various technical approaches, including single-use deployment, laser sintering, on-vehicle deployment, and binder particle methods. She proposes a timeline from 2024–2030, starting with blast-shield demonstrations and progressing to operational landing-pad systems. The project emphasizes the need for standardized communication and geometric inspection systems, along with resource management strategies.

Lunar Microgrid

Manan Arya, Stanford Aeronautics and Astronautics

Arya presents a proposal for developing a power infrastructure at the lunar South Pole, focusing on serving multiple users including scouts, miners, and refiners. The project envisions deploying tall towers in permanently lit regions on Shackleton Crater's rim, equipped with photovoltaics and laser power delivery systems. The presentation addresses the 'chicken and egg' problem of power infrastructure by proposing initial use for high-bandwidth communications back to Earth. Technical challenges, including thermal management and safety considerations for kilowatt-class lasers, are discussed, along with potential dual-use concerns.

Project Closeout and Closing Remarks

Allison Duettmann Foresight Institute

In the closing session, awards were presented for the workshop's project proposals. Third place was awarded to BFL (Big Fricking Laser), while the lunar landing-pad project took second place. First place was awarded to First Move Policy Games, with discussion following about implementing this project, possibly at the next IAC conference. The session included practical considerations about venue logistics and timing for future implementations. Participants were encouraged to share their main takeaways from the workshop, particularly insights gained across different disciplines. The closing remarks emphasized the workshop's success in bringing together diverse perspectives and fostering interdisciplinary collaboration. Duettmann concluded by thanking participants and sponsors, encouraging continued collaboration through the WhatsApp group, and highlighting Foresight Institute's broader work across various technical tracks, including their end-of-year festival events.

Report writer: Andrew Miller, author of the newsletter on innovation, Changing Lanes

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