BEYOND EARTH SYMPOSIUM

Crafting the Policies that Will Enable Humanity's Future in Space

OCTOBER 12-13, 2022

University of Arizona Center for Outreach & Collaboration
Washington, DC

PROGRAM & ISSUE BRIEFS

BEYOND EARTH INSTITUTE

Welcome to the Inaugural
Beyond Earth Symposium

October 12, 2022

Dear Symposium Attendee:

Welcome to the **Beyond Earth Symposium 2022**, an inaugural event presented by the Beyond Earth Institute.

We thank Dr. Vishnu Reddy, Professor of Planetary Sciences and Director of the University of Arizona Space Safety, Security and Sustainability Center, and the University of Arizona DC Center for Outreach and Collaboration, and its exceptional staff, for their generous support and partnership in this event.

By attending this landmark event, you are helping shape the future of space commerce and the potential for human participation in the space experience. Clearly, significant technical and policy/legal/regulatory challenges face us as we address the future course of civilization into the high frontier.

The Beyond Earth Institute was founded two years ago by a cohort of experienced space policy and legal experts who believe that now is the time to develop the policy framework that will enable economically vibrant communities beyond Earth. In the intervening months, we've produced papers and engaged in virtual events, including a range of senior government, industry, and academic speakers, to explore the issues that affect this desired future, from property rights in space to economic drivers to the changing role of NASA to Advanced financing.

Today's Symposium challenges us to look at policies that will impact near and long-term commercial space development. We are releasing four issue briefs (contained in the program book) that complement the topic sessions and include concrete policy recommendations that we hope will contribute to ongoing space policy deliberations.

We are extraordinarily fortunate to welcome more than 25 space industry and government leaders to help frame and lead our program, including Naren Shankar, showrunner for the popular Sci-Fi series ***The Expanse***.

We also want to thank our generous sponsors, without their support, this event would not be possible. And finally, we want to thank the extraordinary Beyond Earth team members who have worked tirelessly on this Symposium and have given so much to the organization over the past two years. In particular, we need to single out Courtney Stadd, who has served as unofficial co-chair of this Symposium; he's opened doors, made connections, and rolled up his sleeves to help bring this event into being. The full list of Sponsors and Team members is listed in the program.

So, we invite you to take this one day and think big, REALLY BIG about the potential for human expansion into space and what we need to do as drafters of public policy to make it happen.

We have one word of instruction for you today, spoken often by my favorite starship captain, "Engage!"

Ad Astra,

Steven Wolfe

President & Co-Founder
Beyond Earth Institute

Simon "Pete" Worden (Brig. Gen., USAF, Ret.)

Honorary Symposium Chair
Chairman, Breakthrough Prize Foundation

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BEYOND EARTH SYMPOSIUM

AGENDA

October 12, 2022

6:00 – 8:00 PM Welcome Reception & Stargazing
Fireside chat with Naren Shankar, Exec Producer/Showrunner, The Expanse

October 13, 2022

7:30–9:00 AM Registration and Light Continental Breakfast

9:00–9:15 AM Welcoming remarks
Steven Wolfe, President & Co-Founder, Beyond Earth Institute
Dr. Simon Peter "Pete" Worden (Brig. Gen., USAF, Ret.)

9:15–9:35 AM Keynote: **Kathy Lueders, Associate Administrator for Space Operations, NASA**
"Beyond Boundaries"

9:35–10:35 AM **Policy Challenges of Commercial Space Stations**

- Moderator: Michelle Hanlon, Co-Director, Center for Air and Space Law, University of Mississippi
- Kathy Lueders, Associate Administrator for Space Operations, NASA
- Erika Wagner, Sr. Director for Emerging Space Markets, Blue Origin
- Mike Gold, Executive Vice President for Civil Space and External Affairs, Redwire Space
- Eric Stallmer, Executive Vice President, Government Affairs and Public Policy, Voyager Space
- Mary Lynne Dittmar, Chief Government and External Relations Officer, Axiom Space

10:35–11:00 AM Keynote: **Ezinne Uzo-Okoro, Assistant Director for Space Policy, OSTP**
"Policies that Will Enable the Wave of Commercial Space Development"

11:00–11:25 AM Break

11:25–11:35 AM **Daniel Oltrogge, Chief Scientist & Director, Center for Space Standards & Innovation, COMSPOC Corp**
"The Application of Standards For the xGeo Environment"

11:35–12:30 PM **Achieving Safety and Reliability in Human Spaceflight**

- Moderator: Josef Koller, Space Policy Strategist, The Aerospace Corp.
- George Nield, President, Commercial Space Technologies, LLC
- Jennifer Fogarty, Ph.D., Chief Scientific Officer, Translational Research Institute for Space Health, Baylor College of Medicine
- Olivia Gamez Holzhaus, Founder and CEO, Rhodium Scientific
- Scot Bryson, Founder and CEO, Orbital Farm
- Henk Rogers, Founder, International MoonBase Alliance

12:30–1:30 PM Lunch

1:30–1:50 PM Keynote: **Johann-Dietrich Wörner, President. German Academy of The Engineering Sciences**
"An International Moon Village For All"

1:50–2:45 PM **Toward a Cislunar Ecosystem with Human Presence**

- Moderator: Laura Forczyk, VP of Research and Analytics, Beyond Earth Institute
- Paul Stimers, Partner, K&L Gates
- Dr. Vishnu Reddy, Professor of Planetary Sciences and Director of University of Arizona Space Safety, Security and Sustainability Center
- John Mankins, Vice President, Moon Village Association
- Angeliki Kapoglou, Researcher, European Space Agency

2:45-2:55 PM **Dr. Scott Pace, Professor of the Practice of International Affairs, George Washington University**
"Further Thoughts on Policies to Spur A Cislunar Economy"

2:55–3:00 PM **Kenneth Hodgkins, Co-Chair, Off-World Approach, Hague Institute for Global Justice**
"A New Off-World Approach"

3:00–3:20 PM Break

3:20–3:40 PM Keynote: **Bhavya Lal, Associate Administrator for Technology, Policy, and Strategy, NASA**
"Developing A Strategic Purpose for the Human Spaceflight Program"

3:40–3:50 PM Special Message: **Tory Bruno, CEO, United Launch Alliance (pre-recorded)**
"Commercial Pathways to Human Expansion into Space"

3:50–4:50 PM **Advance Financing Models for Large Scale Space Infrastructure and Habitation**

- Moderator: Michael Castle Miller, CEO, Politas Consulting
- Hoyt Davidson, Founder and Managing Partner, Near Earth LLC
- Carissa Christensen, Founder & CEO, BryceTech
- Nathan Whigham, President, EN Capital
- Robert Brumley, CEO, Laser Light Communications

4:50–5:00 PM Closing remarks

BEYOND EARTH INSTITUTE

Policy Challenges Of Commercial Space Stations

The First Rung Toward Space Habitation

This paper was prepared as background for a panel of the same name presented at the **Beyond Earth Symposium**, on October 13, 2022. The content of this paper was informed by but does not necessarily represent the views of any of the speakers on the panel or their employers.

By Lauren Andrade
Edited by Jonathan Thorvilson

I Introduction

Orbiting just 250 miles above the Earth, the International Space Station ("ISS") has operated as a collaborative project between five space agencies: NASA, Roscosmos, JAXA, ESA, and CSA.[1] Since its launch in 1998, the ISS has provided the international community with a platform for invaluable research. The ISS was and remains an incredible feat, both from a collaborative and technical perspective. The project, which called upon the cooperation of 15 countries, required 42 launches to assemble the 356-foot structure.[2]

While the contribution of the ISS to science, research, and as a testbed for further space exploration is settled, it is also undeniable that a new era of commercial space exploration is upon us. Congress has extended NASA's commitment to supporting the ISS through 2030. This seems to be in concert with NASA's stated goal of transitioning away from a government-run space station model, but it is not entirely clear if this is Congress' intent.

The push to commercialize outer space is by no means a novel concept. The space industry that was once tightly controlled and funded by national governments has expanded into a multi-billion-dollar market-driven industry (it may be worth noting that, at this point, the market is still largely government-driven). With clearly established commercial crew and cargo transportation to Low Earth Orbit ("LEO"), NASA is looking to the private sector to take the lead in establishing commercial space habitats in earth orbit in public-private partnerships - the precise terms of which are TBD.

[1] International Space Station Intergovernmental Agreement, 80 Stat. 271, T.I.A.S. 12927, entered into force Jan. 29, 1998
[2] https://www.nasa.gov/feature/facts-and-figures

II Background: The Advent of Commercial LEO Destinations

Space activities are technologically demanding, cost-intensive, and often cost-prohibitive. In the early years of space exploration, the industry was controlled and funded mainly by governments. However, the significant infusion of private capital in the space industry has opened the door for rapid innovation. In particular, NASA's Commercial LEO Development (CLD) Program seeks to foster the establishment of privately owned and operated space stations, or "destinations," that are freely available for use. These CLDs demonstrate the transition toward a commercial space economy in which NASA and other national space agencies act as customers rather than owners and operators.

Commercial LEO Destinations

In January 2022, NASA published the International Space Station Transition Report ("Transition Report"), which outlined a plan to transition LEO activities away from the ISS and onto CLDs by 2030.[1] This shift is to take a two-phase approach in which commercial actors first work in tandem with NASA to design CLDs with the ultimate goal of transitioning to commercially-operated space habitation.

Two major steps have already been taken to realize the first phase of this transition. In February 2020, NASA contracted with Axiom Space "to provide at least one habitable commercial module to be attached to the [ISS]."[2] Then, in December 2021, NASA announced that it had signed agreements with three companies–Blue Origin, Nanoracks LLC, and Northrop Grumman Systems–to design "free-flyers."[3] Unlike the Axiom contract, these space stations are intended to bypass the ISS entirely, going directly into orbit.

NASA has awarded over $555 million for CLD contracts to establish a functioning LEO space environment when the ISS is decommissioned.[4] The public-private partnership model allows NASA to provide decades of research and experience to private companies and creates a symbiotic relationship between both parties. Alongside this initiative, Axiom is working on and seeking to implement cutting-edge technologies through investor, and revenue-driven, capital.

For the private sector, the benefit of CLDs goes far beyond the contractual relationship with NASA. In implementing a public-private partnership model, government and private entities share the decision-making power. The companies that develop these space stations ultimately own their intellectual property and have the potential to expand far beyond the government market.

III Challenges to Commercial Space Stations

At present, a fully commercial space station is uncharted territory that brings with it a slew of hurdles that must be overcome in order to fully realize its potential. The policy challenges that a fully commercial space station may face are numerous; however, they can be loosely divided into three categories: environmental, regulatory, and international.

Environmental Challenges

LEO offers immense commercial opportunities; however it is not without significant risk. As LEO increasingly becomes the subject of commercial ventures, the area risks dangerous overcrowding. Space debris—"[e]ven tiny paint flecks"—remains a serious issue that threatens to turn LEO into a "heavenly junkyard."[5] The Kessler Syndrome describes the genuine possibility of debris collision resulting in a cycle of continuous fragmentation and, ultimately a "self-sustaining cascading collision of space debris" that would make LEO unusable.[6] While space debris is by no means a challenge faced exclusively by CLDs, it is nonetheless a serious concern as the LEO environment rapidly populates.

The problem with space debris is that it requires two avenues of mitigation: elimination and prevention. While attempting to move the international community forward, the Space Debris Mitigation Guidelines are merely an assembly resolution and are entirely at the discretion of states to implement.[7] The growing and largely unmitigated presence of space debris adds to the long list of potential hazards for space stations. Additionally, should an accident occur, it would exacerbate the space debris situation dramatically.

Regulatory Challenges

The establishment of CLDs presents domestic regulatory challenges. Space activities are regulated by various agencies including NASA, Federal Aviation Administration ("FAA"), the Federal Communications Commission, and the National Oceanic and Atmospheric Administration.

Export Controls - In the United States, export controls are government-sanctioned restrictions on sharing certain technologies with foreign actors. While export controls evince an interest in preserving national security, it has historically limited the flow of commerce. The International Traffic in Arms Regulations ("ITAR") operates under the jurisdiction of the Department of State and is administered by the Directorate of Defense Trade Controls.[8] ITAR authorizes restrictions on the "export and import of defense articles and defense services" to ITAR-prohibited countries.[9] The National Defense Authorization Act for Fiscal Year 2013 initiated overdue yet limited, export control reform, authorizing the removal of satellites and other space-related items from the United States Munitions List ("USML").[10] Now, dual-use items, including those found on the ISS, are governed by the Export Administration Regulations ("EAR").[11]

ITAR has been routinely criticized for hindering the ability of American companies to engage in the global market, leading to significant efforts in the last decade to relax export controls relating to commercial satellites. The USML maintains a list of ITAR-covered articles and services and makes certain "carve-outs" for some space-related activities.[12] Specifically, Category XV details that exports intended for use on the ISS are subject to EAR jurisdiction.

1 https://www.nasa.gov/sites/default/files/atoms/files/2022_iss_transition_report-final_tagged.pdf, 3.
2 https://www.nasa.gov/press-release/nasa-selects-first-commercial-destination-module-for-international-space-station
3 https://www.nasa.gov/sites/default/files/atoms/files/2022_iss_transition_report-final_tagged.pdf, 3.
4 Axiom Space ($140 million); Blue Origin ($130 million); Nanoracks LLC ($160 million); Northrop Grumman ($125.6 million).
5 Humaid Alshamsi et. al., As the Grapefruit Turns Sixty, It's Time to Get Serious About Clean Up in Outer Space (2018), 48.
6 Id. at 51.
7 Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (2007).
8 22 C.F.R. § 120-130.
9 Id. at § 120.1.
10 Pub. L. No. 112-239 § 1261(a)(1) ("Section 1513 of the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999...is amended by striking subsection (a)").
11 15 C.F.R. § 730 et. seq.
12 22 C.F.R. § 121.

International Challenges

Commercial space stations present a unique challenge to the structure of international law, which governs relations between countries. As such, treaties like the 1967 Outer Space Treaty[1] and the 1972 Liability Convention[2] bind States party to the treaties rather than private actors.

Liability - Liability in outer space is grounded in international law. Article VI and VII of the Outer Space Treaty mandate that states party to the treaty "bear international responsibility for national activities"[3] and are "internationally liable for damage."[4] It is clear that the international legal framework has not contemplated a commercialized outer space. Following on the heels of the Outer Space Treaty, the Liability Convention assigns liability to the "launching state." On the one hand, the concept of the "launching state" poses some serious problems when considering the complexities of modern commercial enterprises as the term may apply to 1) the State that launches; 2) the State that procures; 3) the State whose territory a space object is launched from; or 4) the State "from whose…facility a space object is launched."[5]

Moreover, under international law, the legal obligation is owed by a state because of the obligation to "authorize and continuously supervise" space actors.[6] Absent a clearly defined regulatory framework, there remains a question as to whether CLDs are continuously supervised within the purview of Article VI of the outer space treaty. At present, there is a regulatory gap for on-orbit commercial activities that needs to be filled.

End of the ISS Barter System - The 1998 ISS Intergovernmental Agreement ("IGA") established the terms and framework for the partnership between the partner countries.[7] A critical aspect of the ISS IGA was the right of any Partner to "barter or sell any portion of their respective allocations."[8] In practice, this provision allowed the Partners to provide goods and services without financial compensation, which benefited nations with lesser space-faring capabilities. Outside the cooperative realm of the ISS, many nations and space agencies may be limited in their ability to engage with foreign markets. For example, the ESA's 2025 Agenda explicitly outlines an interest in supporting European space companies.[9] Therefore, the end of the barter system not only runs the risk of limiting access to outer space but also may lead to strained relations between the former partners of the ISS.

IV Solutions/Policy Recommendations

With a timeline that anticipates a transition toward commercial space stations in under a decade, the challenges the CLD project faces are numerous. Despite this, it is essential to remember that this transition doesn't eradicate the existing frameworks, as noted below, that have allowed the private space sector to flourish for decades. Ultimately, both public and private players have a vested interest in the success of CLDs.

Utilizing the Public-Private Partnership

As with any public-private partnership, both parties have invested time, money, and resources into the project's success. In the Transition Report, NASA states its "intention to ensure continued collaboration with Partners on a U.S. CLD through government-to-government, government-to-industry, or industry-to-industry arrangements."[10] NASA may act as a broker between commercially owned and operated CLDs and foreign entities in situations where parties cannot or will not do business with the private sector. In certain situations, this model may bridge the gap in the transitional period between the ISS and a largely commercialized LEO.

Whole-of-Government Approach to Regulation

The success of commercial space stations will require a whole of government (WoG) approach rather than the discrete implementation of regulations across a vast array of federal agencies. Recent efforts to streamline the private space sector suggest a willingness to adopt a WoG approach to continue to foster commercial growth. For example, consolidating commercial launch and reentry requirements into Part 450 "increase[d] flexibility for launch and reentry vehicle operators" by mandating only a single license for all commercial launch and reentry activities.[11]

A fully commercial space station will necessarily require a regulatory framework that spans agencies to ensure compliance at a domestic and international level.

Drawing on Existing Models of Private Sector International Cooperation

The success of the ISS IGA makes manifest the need for a cooperative international framework moving forward. While there are clear benefits to working within the traditional governmental structure, it would be wholly inaccurate to assert that the private space sector has been operating absent any sort of global cooperation thus far. In fact, the private sector has long been filling in the gaps where government actors could not or would not act.

Many space-related companies have resorted to cooperative data sharing due to a lack of reliable space situational awareness ("SSA") data sharing at the national level. The Space Data Association ("SDA"), a nonprofit focused on providing SSA data globally, was formed in 2009 by three satellite companies: Inmarsat, Intelsat, and SES.[12] The goal of the organization is to improve the safety of space operations by increasing participation in a single data sharing network and also serves a normative function to help all satellite operators "[a]dopt best practices across [the] industry."[13]

In addition to playing a key role in the ever-present challenge that space debris and related liability pose for any space venture, the SDA structure provides a framework for the private sector to act as an independent broker. The space sector is rife with fruitful competition between space companies, yet it also means that there is an abundance of shared goals and interests. Members of the private space sector are stakeholders in the space economy. Their desire to keep their products and investment interests safe is the utmost priority. At its core, the immense success of the ISS has established a baseline proof of concept for the feasibility of commercial space stations.

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1 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, preamble, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 (entered into force Oct. 10, 1967)
2 Convention on the International Liability for Damage Caused by Space Objects, 961 U.N.T.S. 187, entered into force Mar. 29, 1972.
3 OST, art. VI.
4 OST, art. VII.
5 Liability Convention, art. I.
6 OST, art. VI.
7 International Space Station Intergovernmental Agreement, 80 Stat. 271, T.I.A.S. 12927, entered into force Jan. 29, 1998.
8 Id. at art. 9.
9 https://esamultimedia.esa.int/docs/ESA_Agenda_2025_final_EN_executive_summary.pdf.
10 Transition Report, 21.
11 Fact Sheet – Streamlined Launch and Reentry Licensing Requirements (SLR2) Rule, FAA (October 15, 2020), https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=25400.
12 Home, SPACE DATA ASSOC., https://www.space-data.org/sda/ (last accessed Sept. 4, 2022).
13 Jean-Luc Froelinger, An Overview of the Space Data Association and its Services, available at https://swfound.org/media/206314/froeliger_keynote.pdf.

BEYOND EARTH INSTITUTE

Achieving Safety And Reliability In Human Spaceflight

The Basic Requirements For A Human Existence Beyond Earth

The paper was prepared as background for a panel of the same name presented at the **Beyond Earth Institute**. The content of this paper is not meant to represent the views of any of the speakers on the panel or their employers.

By Ian Ching
Edited by Jonathan Thorvilson

I Introduction

In this age of renewed space exploration, where humans will travel further away from home, safety and reliability will be the paramount consideration for engineers, policymakers, and industry leaders. The Beyond Earth Institute envisions a future where thousands of people will eventually work in outer space, fostering a vibrant economy with permanent settlements.

The last sixty years of human spaceflight have built a rich foundation of experiences and knowledge on safety and reliability. Safety and reliability hinge on policies and engineering decisions in each journey's planning stages. The knowledge from these experiences informs the ongoing research and development about safety and reliability. Such R&D, in turn, will drive and shape government and industry practices for decades. As the industry shifts to a new age of space exploration and settlements beyond Earth, there will be a need to consider what policies have worked, what policies need to be changed, and what new policies need to be developed.

The future of safe and reliable space exploration and habitation will require new ideas, technologies, and the right policies, including rethinking the relationship between industry and government and relations between international partners. Policymakers and industry leaders will have to consider the effect of rules and regulations while encouraging innovation and supporting research and development. It will also be incumbent on space-faring nations to establish good conduct and norms of responsible behavior in space.

II Data & Risk Assessment

The discussion on safety and reliability in human spaceflight must be framed in the context of its unique risks. In 2020, scheduled U.S. air carriers operating under 14 CFR 121 flew more than 4 million flights and suffered no fatal accidents.[1] The accident rate for the Space Shuttle was 2/135 (1.48%). According to one assessment, If airlines suffered the same accident rate as the Space Shuttle, there would be 270 daily accidents.[2] Yet such direct comparisons do not reflect acceptable risk postures for similarly risky endeavors. The inherent risks to space travel are not substantially different from those of extreme sports or other risky activities. The importance of participant consent elevates accurate risk assessments as a necessity. Determining the appropriate Risk acceptability will also inform policymakers and regulators in approval of standards in commercial space travel. For space travel to truly become safe, it will require orders of magnitude better rates of accidents. Such safety developments will likely develop in tandem with the expansion of private and commercial space. With the expiration of the 2004 commercial space regulatory moratorium coming up in October 2023, this is the perfect time to renew discussions on when and what regulations will be necessary for a more open and accessible space future.

[1] National Transportation Safety Board, "U.S. Civil Aviation Fatalities and Flight Activity Decreased in 2020," U.S. civil aviation fatalities and flight activity decreased in 2020, November 17, 2021, https://www.ntsb.gov/news/press-releases/Pages/NR20211117.aspx#:~:text=The%202020%20fatal%20accident%20rate,to%202019%27s%20rate%20of%201.064.

[2] Alan Levin, "If Planes Failed like Space Shuttles, 272 Would Crash Daily," The Seattle Times (The Seattle Times Company, October 31, 2014), https://www.seattletimes.com/life/travel/if-planes-failed-like-space-shuttles-272-would-crash-daily/.

Commercial providers have recently conducted missions demonstrating the potential for private citizens to travel to space and participate in essential research.[1] Those providers have also earned international headlines for allowing people of all ages and backgrounds to travel to space. While these achievements are laudable, such missions still involve risks—both well characterized and those less understood. Hazards in space include the effects of microgravity, partial gravity, space radiation, and isolation. These risks elicit biological and psychological, which have both short-term and long-term health impacts.

Communication of risk and exposure to hazards, yet to be fully characterized, to potential passengers is one of the most important aspects of forming an ethical framework to assess safety and reliability. Like any dangerous activity, participants sign waivers with a clear understanding of the risks or unknown risks they take. For example, the death rate for wing-suiting is 1/500, a number garnered from thousands of jumps over decades.[2] The lack of sufficient data poses an initial obstacle to creating an accurate risk assessment for new space systems, one that will be overcome through time and experience.[3] (Only a total of 635 people have gone into space as defined by FAA criteria.) There is also the added difficulty of assessing different vehicle types, different destinations, and different body types.

Shared Database

The policy of a shared safety and reliability database among industry members should be adopted. Such a database may be modeled after the FAA's near accident reporting database or the Aviation Safety Information Analysis and Sharing (ASIAS) program.[4] The ASIAS is a database jointly funded by the FAA and Aviation Industry run by a third-party non-profit organization. ASIAS data is collected from dozens of airlines, industry partners, and government agencies. The information collected removes any information on the operator to ensure privacy and peace of mind. These non-punitive reports help industry and regulators proactively identify problems in aviation. Such a program should be encouraged and applied to the space industry.

As casual travel to space becomes more common in the coming decades, it becomes ever more important to research the effect of space on the human body. It would also be essential to obtain medical information for future space passengers who would not have the same health status as NASA astronauts. Such medical information should also be made available in a shared database to better inform all parties on the impact of space travel on different types of human physiology. The opportunity to gather aggregate data is critical to determining the criteria for reliability in human spaceflight.

The Translational Research Institute for Space Health (TRISH) has developed a medical research program for commercial space passengers. To enable research, the goal is to host human and vehicle data from all commercial spaceflight missions. This program was first deployed on the 2021 Inspiration 4 SpaceX flight which lasted three days, and continued data collecting with the Axiom 1 missions. In partnership with NASA's Human Research Program, TRISH funds research to reduce health risks to passengers.[5] The TRISH model may inform how much medical and human research data can be gathered and de-identified.

Funding for a centralized database could be provided by the government, industry, or both. Nevertheless, each option has its obstacles. It may be politically questionable to use taxpayer dollars for what many in the public consider a billionaire's venture. Private enterprise may be reluctant to share data it feels proprietary information. A hybrid system where government invites companies to provide information voluntarily would seem best but would only work if larger companies also commit. However, such a program could also be seen as disproportionally beneficial to smaller and new firms which lack safety and reliability experience. With this in mind, it may be difficult to guarantee the participation of larger firms in such a program.

III Regulations & Government

The role of government in the future of space exploration is drastically changing. NASA has been a designer, developer, owner, and operator of space systems, giving it a leading role in U.S. space exploration. It is also a focal point for spaceflight and contracts organizations to perform specific tasks such as design.

Since the shuttle program's retirement, the commercial space sector has flourished, especially under the public-private partnership model. As more private space providers (commercial & human) enter the market in the coming decades, taking a ride on commercial rockets will likely become safer, more economically viable, and more reliable. Further, as the industry develops its space systems, such as in-space habitats, repair, and servicing missions, NASA will be economically encouraged to hand over the responsibility of significant space developments to the private sector.

Nevertheless, NASA will still have a significant role to play in space exploration. NASA has specialized in projects that are fascinating but not necessarily marketable. Projects such as the James Webb Telescope, deep space probes, and Mars rovers have captured the public's attention. However, these scientific activities are not profitable ventures that the industry would take over. In a commercially active space future, these awe-inspiring large-scale, one-off undertakings will likely remain under the purview of government agencies.

When the Human Landing System contract was awarded to SpaceX, it demonstrated confidence in the private space industry to carry on the legacy of human space exploration. NASA still de-risks and is an excellent validator of space development and technologies. By flying NASA missions that rely on commercial space providers, the agency lends credibility to that private sector service provider. This endorsement can serve to bolster confidence in new space systems.

NASA's role will still be significant in the decades to come. In partnership with industry, it will assist with developing appropriate standards for space conduct, especially regarding international interactions in the space domain. These standards should not reflect a prescriptive government solution but guide the stated intent of new systems, to encourage the development of innovative designs. The Artemis Accords, signed by 20 space-faring countries, is a start for the government and industry to pursue frameworks that will serve the greater goal of establishing international norms and rules of conduct for space activities.

The FAA is the primary governing body that regulates commercial launches and reentries. However, a regulation moratorium from 2004 has prevented the FAA from issuing new regulations intended to ensure the safety of crew or space flight participants. This constraint is currently scheduled to end in October 2023. Once the FAA promulgates rules governing crewed commercial space missions (should they do so), the conversation will revolve around what risks the government should allow and how risk assessments are performed and communicated.

One of the most critical factors in ensuring safety and reliability is the risk of debris impact and microparticle damages. This danger with space travel and prolonged exposure to space vehicles help inform safety standards, including the Loss of Crew (LOC) ratings. With 60 years' worth of derelict rocket parts and dead satellites continuing to orbit the Earth, the chance for space hazards has increased and is at the forefront of sustainable space policy. The long-term dangers of space debris is triggering the Kessler Syndrome, a chain reaction of collisions that destroys low earth orbit's usability. The U.S. tracks 25,000 pieces of debris in space larger than 10 cm in diameter and estimates that there are 900,000 pieces of debris less than 10 cm.[6] The dangers of space debris have manifested in an increased need for satellite and satellite and space station collision avoidance maneuvers.

1 Elizabeth Howell, "Axiom Space AX-1 Mission: The First All-Private Crew to the International Space Station," Space.com (Space, March 9, 2022), https://www.space.com/ax-1-axiom-space-station-mission.

2 Andrew Bisharat, "Why Are so Many Base Jumpers Dying?," Adventure (National Geographic, May 3, 2021), https://www.nationalgeographic.com/adventure/article/why-are-so-many-base-jumpers-dying.

3 Kris Annapurna, "Wingsuiting: A 1 in 500 Chance of Death ," Explorersweb, June 6, 2022, https://explorersweb.com/wingsuiting-dance-with-death/#:~:text=Since%201981%2C%20more%20than%20400,1%20death%20per%20500%20jumps.

4 National Business Aviation Association, "Sharing Aviation Safety Data Is a Good Thing: NBAA - National Business Aviation Association," NBAA, June 5, 2017, https://nbaa.org/aircraft-operations/safety/statistics/sharing-aviation-safety-data-good-thing/.

5 Kaylee Dusang, "Space Health Institute Launches First Commercial Spaceflight Medical Research Program," Baylor College of Medicine, September 7, 2021, https://www.bcm.edu/news/space-health-institute-launches-first-commercial-spaceflight-medical-research-program.

6 Secure World Foundation, "SPACE POLICY AND SUSTAINABILITY" (Secure World Foundation, December 2020), https://swfound.org/media/207084/swf_space_policy_issue_briefing_2020_web.pdf.

NASA has led the development of technical standards through the Inter-Agency Orbital Debris Coordination Committee and implemented them through the Orbital Debris Mitigation Standard Practices.[1]* These standards outline quantitative limits on debris released per flight, probability limits on explosions, and reliability thresholds for post-mission disposal. Each U.S. Agency must apply these standards for their missions and commercial launches. While these standards have been recently updated, there is a distinct lack of motivation from both industry and government to invest in debris cleanup.

The current framework for authorizing, licensing, and managing space has been criticized as inconsistent, raising concerns about ensuring long-term safety and reliability. The U.S. Government entity charged with granting frequency licensing for communications satellites and regulating space debris mitigation is the Federal Communications Commission (FCC).[2] In the absence of action by other regulatory agencies, they have also issued requirements relating to satellite disposal and space debris.

A significant challenge is ensuring consistent rules overseeing orbital debris among the various federal agencies responsible for different parts of the space domain. For example, in addition to the FCC and its role in licensing communications satellites, the US Department of Commerce licenses imagery satellites and thus reviews potential debris issues associated with these satellites, the Office of Space Commerce has been proposed as the lead agency for Space Traffic Management (a role that is still undergoing debate in Congress). As noted above, the FAA licenses commercial launches and reentries, while NASA and DoD oversee their respective spacecraft. In 2018 Swarm Technologies launched four CubeSats via an Indian launch provider, despite not having been granted a frequency by the FCC. This unauthorized launch highlighted growing concerns with current launch practices.[3] It showed that foreign launch providers had no obligations to enforce or adhere to U.S. policies and regulations, precisely the guidelines on debris mitigation. That said, the FCC ultimately fined SWARM owners $900,000 for failing to comply with the FCC rules.

Currently, there is a lack of clarity on which government entity is responsible for overseeing non-government activities in space. This leads to confusion and problems such as the Swarm Technologies incident, which may hinder future commercial investments in space. Ideally, a regulatory framework that centralizes debris mitigation and space traffic would benefit commercial space and space sustainability. Without a solid regulatory framework, these issues will impact the development of safety and reliability. The centralization of regulations and government oversight should provide common guardrails and create a stable environment for industry to flourish. Standardizing space regulations across civil, military, and commercial sectors will further enhance reliability and safety.

IV Building Infrastructure

Throughout history, governments have spearheaded the development of new inventions, often paving the way and building the fundamental technologies for such industries. In the 1800s, the U.S. government funded railway construction across the country, allowing cross-continent commerce and settlement. Computers and the internet are such examples of technology borne from government funding. In the context of the space age, government-funded infrastructure could develop and maintain spaceports, ensure space situational awareness, and manage space traffic. The United States should continue this tradition of critical infrastructure support and development.

It should be a top priority for the U.S. to form an overarching policy for space infrastructure maintenance and development. Ensuring continued maintenance of critical space infrastructure will be crucial for developing a burgeoning commercial space sector. These critical infrastructures include spaceports, securing the cyberspace domain, spectrum access, and supply chains crucial for the industrial base.[4]

V International Space Governance

Space diplomacy is crucial to ensuring safety and reliability in human space flight. The United States, through multilateral and bilateral efforts in concert with foreign partners, is attempting to establish what constitutes responsible norms of behavior in space. With countries joining the space-faring club, the United States should utilize its leadership in space to continue fostering international policies that improve space safety and reliability.

In a time of renewed geo-political competition with China and a resurgence of a hostile Russia, America's role in space takes on renewed importance. American leadership in space means leading by example in commercial, civil and military space affairs.[5] The Artemis missions will not only build a cislunar station but also build a coalition of nations. If the United States does not maintain its leadership role, competitive powers like China will set space policy and international standards. The Artemis Accords will also continue the tradition of international space cooperation, as exemplified by the International Space Station over the past two decades.

There are still many safety policy areas that would benefit all parties. The Liability Conventions and Rescue Agreement have governed space activities for the past half-century. The 1968 Rescue Agreement binds all signatories to provide all necessary aid to astronauts in need. This duty-to-rescue principle is also well established in maritime law.[6] Cooperation on this issue is crucial for saving lives and creating a viable commercial environment. China's adoption of the International Docking Standard signals a good direction for this principle.

The growing congestion and competition in space will inevitably lead to more near-collision incidents. It is prudent for the United States, China, and all other spacefaring (or aspiring spacefaring nations) to cooperate on the sustainable use of orbital space. Ensuring that U.S. tracking agencies and companies can rapidly communicate dangers to international partners is crucial to keeping orbit safe and sustainable.

Such efforts to ensure space sustainability and common infrastructure will serve to benefit all parties in the development of future human spaceflight.

VI Conclusion

Safety and reliability in human spaceflight is a priority issue for humanity's future in space. There are countless technical and policy hurdles to making space safe. It is incumbent on the United States Government and industry to formulate the right policies in concert, ensuring sustainability and reliability in human spaceflight. The United States must lead the world in developing policies for a safer and more reliable future in human space exploration.

Space has always been fraught with challenges, but it is also the inherent desire of humanity to go beyond the current possibilities. That will to try, and sometimes fail, is what drives the groundswell of support, and capital for private space developments. The issue of safety and reliability will always be a cause for concern in space flight, as it is for any other activity, but this emerging space sector must be allowed to flourish without undue burden. Finding balance in achieving safety and reliability in human spaceflight is the key to humanity's successful future Beyond Earth.

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1 Orbital Debris Mitigation Standard Practices (2019).

2 "TRESPASSING ON THE FINAL FRONTIER: REGULATORY CHALLENGES FOR NEW SPACE ENTRANTS," TRESPASSING ON THE FINAL FRONTIER: REGULATORY CHALLENGES FOR NEW SPACE ENTRANTS (Center for Space Policy and Strategy, n.d.).

3 Mark Harris, "Swarm Seeks Fresh FCC Satellite Launch Clearance While Still in Penalty Box," IEEE Spectrum (IEEE Spectrum, June 24, 2021), https://spectrum.ieee.org/company-behind-illegal-satellite-launch-seeks-fresh-orbit-clearance-before-fcc-hands-down-penalties.

4 White House, "United States Space Priorities Framework - White House," UNITED STATES SPACE PRIORITIES FRAMEWORK (whitehouse.gov, December 2021), https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.

5 Secure World Foundation, "SPACE POLICY AND SUSTAINABILITY" (Secure World Foundation, December 2020), https://swfound.org/media/207084/swf_space_policy_issue_briefing_2020_web.pdf.

6 Irini Papanicolopulu, "The Duty to Rescue at Sea, in Peacetime and in War: A General Overview," International Review of the Red Cross, August 1, 2016, https://international-review.icrc.org/articles/duty-rescue-sea-peacetime-and-war-general-overview.

BEYOND EARTH INSTITUTE

Toward A Cislunar Ecosystem With Human Presence

The Underpinning For Permanent Lunar Communities

The paper was prepared as background for a panel of the same name presented at the **Beyond Earth Institute**. The content of this paper is not meant to represent the views of any of the speakers on the panel or their employers.

By Laura Forczyk
Edited by Jonathan Thorvilson

I Sustainability

Space can be considered a new frontier, a free and open domain for humanity to create and innovate for the betterment of Earth and humankind. As we travel outward, we bring with us our human values. Governments have a responsibility to promote the values they wish to preserve and propagate beyond Earth. This is especially true as the international community expands en masse to our nearest celestial neighbor: the Moon.

Timing is key. Government responses to technological development tend to be ill-timed. Top-down systems often struggle to keep up politically and technologically as the world changes more rapidly than governmental institutions can react to such change. As much as is feasible, policies should be created from the bottom-up rather than top-down with multiple stakeholder involvement from governmental and non-governmental entities alike.

Similarly, policies can also be created too soon, leading to stifling growth, limiting potential, or driving direction the wrong way. As mentioned, timing is crucial in policy implementation, and this is a reality that is only exacerbated in the space domain.

Sustainability is one of the main goals of NASA's Artemis program[1]. Space sustainability is often defined as political, economic, and environmental. Sustainability needs to be proved in the short term before it can be assessed in the long term.

Whereas former NASA Administrator James Bridenstine defined sustained lunar exploration as the ability to access the Moon anytime we wish to[2], we of the Beyond Earth Institute believe the US should strive for more. It should be noted, however, that former Administrator Bridenstine was working within budget and government constraints that limited what is actually feasible regarding space endeavors. Bridenstine would have likely advocated for much more in the way of sustainability without such constraints. That said, the US can and should commit itself to the goal of creating and nurturing a cislunar ecosystem with a permanent human presence.

[1] NASA's Plan for Sustained Lunar Exploration and Development, https://www.nasa.gov/sites/default/files/atoms/files/a_sustained_lunar_presence_nspc_report4220final.pdf
[2] The Space Foundation's Symposium365, Space Matters, July 14, 2022

II Political Sustainability

Until recently, change was a constant at NASA's human exploration directorates from presidential administration to administration. The George W. Bush administration's Vision for Space Exploration[1] was discarded in favor of the Barack Obama administration's Journey to Mars[2] and Asteroid Redirect Mission[3] which was later discarded in favor of the Donald Trump administration's Artemis program, with numerous examples of earlier transitions.

The cycle appears to have been broken with the Joseph Biden administration. The current administration has largely kept the course, promoting and funding the Artemis program it inherited from the previous administration. This has allowed NASA to save time and resources by not needing to greatly modify its plans, mission architectures, and hardware to fit a new goal.

Political sustainability is obtained with bipartisan support. Only by establishing an enduring national interest and articulating the "why" of space exploration in general and the Artemis program, in particular, can NASA and the White House maintain political sustainability. This stated national interest may be in the form of economic, political, or security priorities. Congress can support political sustainability by passing NASA authorization bills and matching appropriation bills.

Programmatic sustainability can augment/bolster political sustainability. Whereas Apollo was not programmatically sustainable, Artemis can be designed to be so. This may be accomplished by gradually extending Artemis' mission from shorter six-day expeditions to six months or one year, similar to International Space Station expeditions.

Commercial partners should be used to a maximum extent for cislunar and lunar infrastructure and operations. For example, SpaceX's super-heavy-lift vehicle Starship could be used to create surface infrastructure to allow for longer lunar expeditions. NASA has contracted SpaceX to modify Starship to carry astronauts to and from the surface of the Moon for Artemis 3. Its volume and carrying capacity are large enough to transform into a significant piece of Moon base infrastructure. Government missions can benefit technologically and financially by leveraging what the commercial sector is already doing or proposing to do.

III Economic Sustainability

The Artemis program will probe whether lunar activity is economically sustainable, that is, whether it is affordable and profitable for the private sector. This will largely depend on whether there is a market for cislunar commodities and services and if in-situ local resources can be used primarily or instead of relying on Earth resources. Investor commitments and private sector activities will also depend on the clarity of policies, regulations, and norms of behavior, especially regarding the safe and responsible use of cislunar space and lunar resources.

The US-led Artemis Accords[4] are multilateral agreements with 21 countries (at the time of this writing) on acceptable norms of behavior in space, largely based on the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space[5] (hereafter called the Outer Space Treaty). However, these agreements are still high-level. There is still work to be done to gain consensus on many topics outlined within the Artemis Accords.

Technology to enable a permanent presence and safe operations on the Moon, such as the development of landing pads or tracking capabilities for cislunar space situational awareness, should be encouraged.

The US may need to develop and fund additional missions for lunar mapping and resource prospecting, especially to better understand regions of great interest to the wider scientific and commercial space community.

Article II of the Outer Space Treaty forbids "national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." Some nations interpret this article as forbidding ownership of property, including mined or collected lunar resources. Other nations, such as the United States, have recognized celestial property rights in law.

Although this issue is settled within US law, it may need to be addressed in more detail to develop a global consensus. This will especially become important once mined lunar regolith or processed lunar regolith materials become a commodity to use in space or return to Earth for commercial purposes. For example, the completion of NASA contracts with three companies to purchase collected lunar regolith on the lunar surface may lead to additional policy and legal discussions on lunar property rights.

Certain lunar locations may be more desirable for mining and in-situ resource utilization (ISRU) operations. Disputed locations of interest may be the lunar south pole, where there are higher concentrations of water, permanently shadowed craters where water ice is less likely to have boiled off, and peaks of eternal light, which may be beneficial for solar power facilities.

A better understanding or consensus must be developed to understand how these regions of interest may be used. A "first come, first use" or "finders, keepers" mentality may not be looked upon favorably by the global community. Agreements between the international community on the use of these special regions may need to be better defined.

Additionally, there may be disagreements between the scientific community, who prefer a more pristine or underdeveloped lunar environment for surface research and deep-space radio astronomy, and the commercial space community, who prefers more lunar development.

Archaeologists and historians may also desire to protect areas of human heritage on the Moon. These heritage sites are protected under the Artemis Accords, and a proposal has been submitted for protection under the United Nations (UN)[6]. Which areas are set aside for protection and what this protection entails, as well as enforcement, need to be better defined.

Gaining a better understanding of cislunar space domain awareness is important for safe operations and national security. Improved satellite registration, coordination, tracking, trajectory analysis, and data verification are needed so proper conjunction analysis can be performed.

The UN maintains the Register of Objects Launched into Outer Space[7]. Some states are slow to provide information to the UN to update this registry after launches. It will become increasingly important to maintain a list of space objects in cislunar space as activities increase and the area becomes more congested, as we've seen with activities in Earth orbit.

Similar to the diplomatic work underway regarding Earth orbit operations, norms of behavior need to be developed and followed for cislunar and lunar operations. It is essential for all parties, especially adversarial states, to understand which maneuvers or close-approach operations are acceptable, for what reasons, and under what circumstances, as well as when to share information about these maneuvers and operations.

1 Vision for Space Exploration, Feb. 2004, https://www.history.nasa.gov/Vision_For_Space_Exploration.pdf
2 NASA's Journey to Mars: Pioneering Next Steps in Space Exploration, Oct. 2015, https://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008_508.pdf
3 Asteroid Redirect Mission Reference Concept, https://www.nasa.gov/sites/default/files/files/Asteroid_Redirect_Mission_Reference_Concept_Description.pdf
4 https://www.nasa.gov/specials/artemis-accords/index.html
5 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205
6 https://www.forallmoonkind.org/
7 https://www.unoosa.org/oosa/en/spaceobjectregister/index.html

Cislunar space domain awareness is also vital to mitigate the proliferation of space debris. Unlike Earth, the Moon does not have a true atmosphere. Atmospheric drag allows for deorbit burns of satellites and other space objects in low-Earth orbit (LEO), which are then burned up in Earth's atmosphere. Larger space objects that survive atmospheric reentry are often targeted to hit an area unpopulated by humans, such as the ocean.

In lunar orbit, there is no atmosphere to burn up space debris and other objects. Although the Moon is currently unpopulated, impacts onto the lunar surface can spray regolith widely and may even send ejected particles into lunar orbit, posing a danger to other objects in the vicinity or in orbit. Accidental and purposeful creation of space debris in the cislunar and lunar environment should be avoided where unintended consequences could cause harm.

The Moon's low-gravity and vacuum environment allow disturbed regolith to spread widely. Surface operations may eject enough regolith to disturb unrelated operations elsewhere on the surface of the Moon or in lunar orbit. The concept of "safety zones" or "keep away zones" has been proposed but undefined. More work may need to be done to reconcile protected lunar areas of activity with Article II of the Outer Space Treaty's prohibition of national appropriations.

Safety zones could be established based on technical, physical, and operational considerations rather than arbitrarily defined. For example, safety zones with landing pads and other mitigation measures could be based on the minimum safe distance that regolith or rocks of a specific size might be ejected outward from a landing vehicle or an area of surface activity. The technical community, rather than a governance body, could develop the criteria to assess safety considerations and set boundaries. Basing safety zones on physical properties and the promotion of responsible operations may increase the international community's willingness to accept zoning precautions as a norm.

The Outer Space Treaty calls for the avoidance of harmful contamination of the Moon and other celestial bodies. NASA classifies most areas of the Moon in its lowest protection classification, Category 1[1]. However, the lunar polar regions (north of 86 degrees north latitude and south of 79 degrees south latitude) and areas around human heritage sites are classified as Category 2, a classification that requires documentation.

With this in mind, the US Government may need to develop more robust and/or broader payload registration and review processes and trajectory tracking requirements. Under Article VI of the Outer Space Treaty, the US has certain obligations for authorization and continuing supervision of non-governmental US entities operating on or near the Moon.

IV Environmental Sustainability

To keep the Moon as a destination and resource for all humanity down through the generations, environmental sustainability must be considered and planned for from the start. This includes mitigating against the creation and proliferation of cislunar space debris and surface trash due to wasteful or careless operations.

Regulations may be needed to lessen the creation of waste on the lunar surface due to industrial processes and other activities and to avoid specific materials that may be difficult to recycle or dispose of.

We have the opportunity to create a Moon base or larger human habitats with more efficiency than typically seen on Earth. Excessive surface infrastructure can be minimized with advanced planning and new technology. For example, developing power beaming technology may be more efficient than laying power lines.

The Federal Communications Commission (FCC) has proposed a new rule requiring US and US-market-operating satellites in LEO to deorbit within five years of the completion of the satellite's mission[2], down from the non-binding 25-year guideline. A similar rule may need to be put in place in lunar orbit, with the added challenge of how to safely deorbit satellites onto the lunar surface or raise satellites into a lunar "graveyard orbit." Enforcement of these rules and guidelines is another area to be explored.

The US Government should evaluate the need for defunct space object salvage laws and/or support such laws should international partners propose them. This is of particular interest for the recycling or reuse of objects in Earth orbit. However, such laws could also benefit the cislunar and lunar environment by allowing for a potentially profitable way for companies to assist in the cleanup of cislunar and lunar objects no longer in use.

The lack of ability to dispose of near-Moon objects in an atmosphere may make near-Moon human-made object salvage rights even more of an imperative to keep the lunar and cislunar environment free of space debris and allow for safer and more sustainable cislunar operations.

V United States Leadership to Create a Cislunar Economy

The US has taken the lead to return to the Moon with a human presence, this time sustainably. Through NASA's Artemis program, supporting defense initiatives, and the Artemis Accords, the US is leading the way to creating a cislunar economy with a human presence.

NASA is a US tool of diplomacy. The Artemis program may be the right opportunity to promote a more open, transparent sharing of data, especially scientific data or data that might benefit scientific missions. Although the Wolf Amendment prohibits direct cooperation between NASA and China, some exceptions have been made over the past decade when it comes to sharing data for scientific purposes or scientific missions. The US may be able to use this period of renewed lunar exploration as a means of creating additional diplomatic bridges between the US, China, and other adversarial nations.

[1] https://planetaryprotection.jpl.nasa.gov/missions

[2] FCC Chairwoman Proposes New Rules to Address Growing Risk of Orbital Debris, Sept. 9, 2022, https://docs.fcc.gov/public/attachments/DOC-387071A1.pdf

Advanced Financing Models For Large Scale Space Infrastructure And Habitation

This paper was prepared as background for a panel of the same name presented at the **Beyond Earth Symposium**, on October 13, 2022. The content of this paper was informed by but does not necessarily represent the views of any of the speakers on the panel or their employers.

By Steven Wolfe
Edited by Jonathan Thorvilson

I Introduction

We are in the midst of a new space economic renaissance, with investment money flowing from private and public sources like never before. This investment is spurring a new wave of space innovation and applications that will benefit the world economy. But, while these investment trends are enabling such growth in the space-related markets, it remains unclear how we will eventually finance the construction of large-scale space infrastructure elements needed to support extensive cislunar activities, such as in-space servicing, assembly, and manufacturing (ISAM), mining and other in situ resource utilization (ISRU) operations, space-based solar power, and large-scale human habitats. The current funding mechanisms for space development are insufficient to meet this next stage challenge, which could be upon us within this decade.

In this paper, the Beyond Earth Institute will consider the financing options that could be made available to the developers of large-scale space infrastructure and habitat projects. Sooner or later, future space development planners will have to confront how to finance such mega projects.

We hope the financing options and models examined in this paper, many of which helped finance terrestrial infrastructure projects, might apply to the space environment. These options are not meant as an all-inclusive roster. There are undoubtedly even more novel models worth pursuing that match the audacious ambitions of establishing economically viable communities beyond earth. Of course, identifying a large enough customer base to justify the appropriate upfront non-recurring capital investment is fundamental to any successful financing model. To that end, the authors of this paper recognize that translating the vast potential of space-based markets into reality is still very much a work in progress. But, given the rapid upsurge in private and government-financed innovative space ventures seeking to commercialize the benefits of space, it is not too early to explore equally innovative large-scale financing models.

II What is Meant by Large-Scale Space Infrastructure and Habitats?

We are rapidly developing the means to access the solar system's resources that will, by the end of the century, create a space economy many orders of magnitude larger than any near-term space market estimate. This growth will result from extensive in-space mining, manufacturing, and habitation activities. Examples include but are far from limited to:

- Advanced high density and low latency communications satellite networks
- Advanced power generation sources for in-space and planetary surface operations
- Capability to mine water and minerals from the Moon, Mars, and asteroids
- Ability to efficiently transport resources to the desired location throughout the cislunar environment, including earth
- Capacity for in-space mining operations that will feed in-space manufacturing of finished and semi-finished goods for delivery to locations in space and on Earth
- Large-scale human habitats on the Moon, Mars, and in free space for semi-permanent occupancy

The above projects would have seemed too far out just a decade ago. Today, they are generally accepted as reasonable future initiatives. But financing these projects will require tens of billions of dollars or more, far exceeding the appetite of private and public investors, with few exceptions. As we anticipate implementing such mega space projects, it's appropriate to ask, 'how are we going to pay for them?' What will the structured project financing models look like?

This future is emerging. The only question is whether or not our national and international policies are willing to accept and support this future or remain an impediment to it. The nations and private investors who embrace this future will reap the rewards.

III Traditional and Advanced Financing Options

Historically, the U.S. government has wholly sponsored space research and technology development. Direct U.S. appropriated funds have paid for the Apollo moon program, the Space Shuttle, and the International Space Station. Only in the past decade or so has NASA looked to systematically share the development costs with the private sector. Private investment is also changing the calculus of space research and development. SpaceX, Blue Origin, Virgin Galactic, Sierra-Nevada, Northrop Grumman, L3 Harris, Voyager Space, and many others are making massive investments to drive space technology and expand the capability to new levels.

As we look ahead to the massive investment that will be needed for in-space infrastructure and habitation, it's clear that the availability of direct government funding is limited. NASA's budget in Fiscal Year 2022 is $24 Billion, short of the 7% increase proposed by the Biden Administration, and we can only expect incremental gains over time. DOD and the U.S. Space Force are also increasing investments in space capability. But, even these levels are nowhere near sufficient for future challenges alone.

Fortunately, various creative, innovative mechanisms can be employed to structure the necessary financing for even the most expansive space projects. What follows is a menu of options that the U.S. government, the international community, and investors can consider as part of a comprehensive financing plan.

Public Private Partnerships

Until the mid-aughts, NASA primarily contracted with industry partners on a cost-plus basis for all hardware developed. While there are benefits to this kind of contracting, it creates a strong disincentive to bring down the cost of space systems and launch critical elements in the potential for space commerce. In 2006, NASA experimented with a dramatically different approach under the Commercial Orbital Transportation Service (COTS) agreement. The program was an unqualified success. For an investment of just $800 million, COTS resulted in "two new U.S. medium-class launch vehicles and two automated cargo spacecraft." The subsequent Commercial Resupply and Commercial Crew programs to deliver supplies and astronauts to the International Space Station were equally successful. NASA has also applied this Public Private Partnership (PPP) model to lunar exploration programs, such as CLPS, Volatiles Investigating Polar Exploration Rover (VIPER), and the Artemis Human Landing Systems. NASA will continue to utilize this model. Indeed, there is solid bi-partisan interest across the government, including with DOD, to employ PPP to achieve technical goals.

The key drivers of this success were that these PPP programs not only shared the cost of system development with the private sector, allowing investors to achieve an acceptable risk-adjusted return on investment, but they also offered large initial markets for the services to be provided by these space systems. Reducing early-stage market risk is critical for successful large-scale infrastructure financings. The PPP programs also differed from past practice by funding two or more capabilities, thus creating new industry sectors to compete and innovate into the future versus one time government-funded, sole-source capabilities with a limited life.

For a mega space program, PPP could be part of the financing mix, assuming that such a project was a priority for the partnering nation(s). But, considering the limits to which partnering nation states may be willing to invest, PPP should be regarded as just part of a large mix of financing elements.

Private Investment

Data from Space Capital shows investors poured nearly $15 billion into the sector in the first half of 2021 alone across 230 deals, $37 billion since 2013. Such growth is immensely encouraging for entrepreneurs and investors in the space sector. Quality Analytics associate Jeff Thoben said space investment is "reaching near-manic levels" as private equity consolidator activity also ramps up in the market.

The investment environment for space ventures has never been better. Most investors are appropriately focused on relatively near-term ROI from low Earth orbit investments.With that said, the authors recognize that the current investment climate is dealing with "headwinds" such as inflation, rising interest rates, continuing effects of the recent pandemic, and recessionary fears that might, in the near term, cause some pullback by the investment community. But we remain confident that the fundamental long-term trend lines for space investment will continue on an upward slope - notwithstanding the occasional downturns due to macroeconomic business cycles.

Any sound business model showing a suitable investment return will attract investors.

It is not likely that private investment alone could be raised for mega space projects such as lunar infrastructure or large human habitats. Such investors

would want to know how much government contribution (either in direct funding or as an anchor tenant) or other project financing elements were involved in helping manage the risk. Again, while private investors will ultimately be part of the mix in financing large-scale space projects, they will likely seek as much public support as is available for the foreseeable future.

SPAC - Special Purpose Acquisition Company (SPAC)

A SPAC is a shell corporation with no active business operations and whose primary asset is cash to make an acquisition of an existing company. SPACs are used as a financial instrument to raise capital from investors through the channels of an initial public offering (IPO). The funds raised from the IPO are then used within a one-to-two-year period to finance ventures, such as acquiring private firms and taking them public or merging with startups to provide them access to long-term affordable capital to finance infrastructure development and expansion. The importance of SPACs has been an initial opening of the public capital markets to commercial space investment. The public capital markets provide liquidity, creating a perpetual source of capital. In contrast, most private equity financings come with investment horizons where investors seek an exit within generally 5 – 10 years, a period often too short for the space markets to have developed sufficiently to provide a satisfactory risk-adjusted return on capital.

In recent years, they have initiated a boom in the space startup sector, placing startups within reach of additional funding and enabling a smoother trajectory to public listing through mergers or SPAC deals. In 2021, nine space companies went public through SPAC mergers.

Enthusiasm for SPAC as a vehicle for a rapid cash infusion to space ventures decline in late 2021. Dampening interest are new regulations issued by US Securities and the Exchange Commission (SEC) that have added complexities that investors see as an added risk to the model and the poor stock trading performance of many of the SPACs that have made their acquisitions and begun operations. This has sparked uncertainty, resulting in delays, additional paperwork for the IPO processes, and a lower current investor appetite for new space-focused SPACS.

SPACs will likely remain an option for commercial space projects. (For example, Intuitive Machines just announced it would list on the Nasdaq after merging with the SPAC Inflection Point Acquisition Corp for a valuation of $815 million.) SPACs have already injected billions into the space market, a positive development. As more advanced mega space projects are initiated, some commercial elements of such projects will likely be financed via SPAC IPOs.

Government Debt Guarantee, Subsidies, Tax Incentives, and Direct Lending

The employment of debt guarantees, subsidies, tax incentives, and direct lending are ways the U.S. government has supported industries and business types to meet many objectives. Such options could similarly be employed to support space activities.

Loan/Debt Guarantee - A loan/debt guarantee is a contractual obligation between the government, private creditors, and a borrower—such as banks and other commercial loan institutions—that the Federal government will cover the borrower's debt obligation if the borrower defaults. Government loan/debt guarantees eliminate the default risk to the lender by shifting it entirely to the government, enabling the borrower to obtain much more favorable loan rates. Often, without the guarantee, the loan would not have been approved at all. In other cases, the interest rate would have been higher. The question is how much debt the government would be willing to take on to support space infrastructure development. The Transcontinental Railroad was financed in part with such government guarantees and subsidies.

Subsidies - A subsidy is a benefit given to an individual, business, or institution, usually by the government. The subsidy is typically given to remove some burden, and it is often considered to be in the overall interest of the public, given to promote a social good or an economic policy.

i. Low-interest loans, tax incentives, and many government welfare programs are indirect subsidies

ii. Examples of Subsidies - a payment from government to private entities, usually to ensure firms stay in business and protect jobs. Examples include agriculture, electric cars, green energy, oil and gas, transport, and welfare payments.

Tax Incentives - The tax code could be used to stimulate space development. Utilizing the tax code can be attractive to some lawmakers because of its simplicity to manage; however, in the past, other lawmakers have argued that the space industry should not be singled out over other important emerging industries. Any eligible entity can claim the incentive when filing their taxes. In the current space investment environment, the parameters for eligible projects may need to be defined as those that extend beyond low Earth orbit, as the LEO economy is experiencing a boom not requiring such incentives. Forms of tax incentives include:

i. 'Zero tax for zero G' has been a popular recommendation among space advocates. If a business involves putting assets into space, it would not have to pay taxes on its profit. Perhaps the slogan could be modified to 'Zero tax beyond LEO.' Actual corporate tax liability is currently so low in the U.S. it is hard to see how such an incentive would motivate extensive investment beyond what is already taking place as it does not share upfront development costs or lower market risk.

ii. Corporate tax credits would be a more significant stimulating effect, as certain expenses would be deducted from the tax liability and potentially result in a tax refund. But, again, we would want to define the kind of expenses that would be eligible clearly. There is no need to stimulate a burgeoning market further.

Direct Lending - Direct lending is the provision of credit directly to small and middle market companies (SMEs) for growth or acquisitions. Government is able to take higher risks than traditional lending institutes. It's a variation on loan guarantees that could reduce the overall cost to the government. It also creates a bureaucratic challenge that lawmakers may not want to put on existing agencies. For example, loans from Export-Import Bank (Ex-Im Bank) provide debt for satellite financings are well established.

i. Ex-Im Bank loans are generally lower cost than what is available in the traditional commercial lending market but do come with lots of restrictions and a high up-front cost in fees and due diligence. Since Ex-Im loans have been in the hundreds of millions of dollars, they would be stretched to fund projects requiring billions.

ii. Ex-Im loans generally have maturities of 8 years or so, which has been a long enough period to generate sufficient positive cash flows in the satellite industry to cover debt servicing. Some space infrastructure projects involving less developed markets might require much longer maturities, such as the 12 years frequently offered by the US International Development Finance Corporation (DFC). More details regarding the DFC are below.

These government-sponsored mechanisms could come into play for large-scale investment. These are not likely to be employed until there is an obvious project definition, which will be necessary in order for the terms of the government programs to be drafted. These mechanisms will likely place restrictions to benefit the sponsoring countries.

Again, these favorable funding sources are part of the long-term financing mix and not likely to account for all the total needed financing.

Lunar Development Cooperative[1]

The US can lead in the creation of a public-private partnership infrastructure company that would enable public and private entities to cooperatively and affordably gain access to locations and resources on the Moon. We call this the "Lunar Development Cooperative" (LDC). The U.S. Government would supply an initial capital equity investment to start the LDC. The US would also invite other nations to make similar equity investments, with developing countries eligible to purchase stock options. It would invite private-sector investors to take up a majority of the LDC's stock, including companies, high net worth individuals, and even regular citizens of any financial means. These investments would have a long-term rate of return, allowing the government investors to generate a profit to refund taxpayers while also de-risking the investment for private-sector parties.

The LDC generates income from the rise in the value of locations in space, benefiting from its shared infrastructure over time. For instance, if the LDC built a landing pad on the moon, alongside a power supply, shared-use habitat, and closed-loop life-support systems, it would earn revenue from this infrastructure over the long run through the rise in the use value of the locations on the Moon benefiting from the infrastructure. This long-term value would be captured through market-priced service-access licenses that require the user to pay for the market-determined rental value of the location they occupy while using LDC services.

Strategic Propellant Reserve[2]

One way to stimulate the space market is through the creation of a strategic propellant reserve. It can be propellant, water, minerals, or any other valuable and sought-after resource, strategically located in orbital space or on the lunar surface. In the event of an in-space shortage for such 'commodities,' authorities would have access to these reserves so as not to disrupt the flow of activity. The strategic reserve could be made available to government and industry as needed. Similar to the Strategic Petroleum Reserves, which acts as a buffer against any sudden disruption in the oil market. Strategic reserves can be financial in nature or even stockpiles of finished goods considered strategically important.

According to SSR leading proponent, United Launch Alliance CEO Tory Bruno, a Strategic Propellant Reserve by 2050 could stimulate a space-based economy of $3 Trillion, of which the propellant activities alone would account for $630 Billion. All of this, he says, could be made possible with a government investment of about $20 Billion.

Strategic Space Reserves and Space Commodity Exchange[3]

The Space Commodities Exchange is an idea promoted by Bruce Cahan of Stanford University. Part of the appeal is that the required government obligations would largely consist of legislative approval, regulation, and oversight versus significant funding. A space commodities exchange would allow buyers/users and sellers/producers to enter into forward contracts for the purchase and delivery of commodities in space at various defined locations. As Cahan wrote in a recent report:

"Space commodities allow the space economy to evolve and rely on standardized definitions of the goods and services they produce and need to operate in, from and to space orbits and regions of interest. The Exchange would reveal detailed levels of demand for specific space commodities in Earth orbit, near-Earth asteroids, cislunar, and beyond. Space companies would be permitted to earn cash flow via commodity contracts sold now for delivery in the future and would create a level playing field of Exchange Member Rules by which competitors agree to abide. The Exchange would allow for more open bidding that would drive better price/performance ratios for government and private sector users. Furthermore, if a customer were to buy too much of a given space commodity, the Exchange would allow for the re-sale of the commodity to achieve liquidity and flexibility in planning and adjusting future space operations. The Exchange would speed government acquisition of generic, commercial off the-shelf (COTS) space commodities at lower technology readiness and reliability risk to ensure the functional use of specific space commodities …The Exchange will, among other things, require the US government to better understand and forecast its aggregate demand for space-based commodities."

In general, however, commodities exchanges work best when there is first a known and mature market for the commodities being exchanged. As such, a space commodities exchange may work best when coupled with a strategic space reserve as a major anchor customer to generate initial market demand. Strategic space reserves could support NASA exploration initiatives, future anticipated needs of the U.S. Space Force, and similar needs of other space agencies and countries.

Flow-through shares (Canada)[4]

The flow-through share program in Canada that supports their oil and mineral exploration companies is a possible model to support space infrastructure and large-scale habitat financing.

Flow-Through Shares are a special issue of common shares where the early losses from prospecting, infrastructure development, and initial operations are passed directly to shareholders as tax deductions and then become regular common shares after the tax deduction is completed. Corporations that issue FTS typically generate Canadian Exploration Expense (CEE) which is a 100% deduction against income.

Flow-through shares are a financing tool available to a Canadian resource company that allows it to issue new equity (shares) to investors at a higher price than it would receive for "normal" shares, thereby assisting it in raising money for exploration and development. This then reduces the investor's Canadian taxes. The U.S. and other governments have resisted this idea, fearing that other industries would demand similar treatment. In addition, the U.S. has different ways of supporting oil and gas exploration.

Flow-through shares is an exciting model that could potentially support space infrastructure projects.

Development Finance Corporation Model[5]

The United States International Development Finance Corporation (DFC) is the development finance institution of the United States federal government, primarily responsible for providing and facilitating the financing of private development projects in lower- and middle-income countries. A DFC devoted to financing space projects could similarly be created.

This DFC Model for space has been proposed by the National Space Society called the Outer Space Private Investment Corp. (OSPIC), which mirrors the very successful Overseas Private Investment Corporation (OPIC) funding for infrastructure investments in emerging economies. The idea was that you could replace "overseas" with "outer space" in the OPIC charter without altering any other aspect. Space would simply be viewed as another geographic area of importance to the U.S. that had an economy too risky to attract private investment in much-needed infrastructure. In the OPIC case, investment in roads, hospitals, utilities, water treatment, telecom, and other primary infrastructure necessary for the economy to support its population and business development for stable markets to emerge and grow.

The question for OSPIC is whether it could evolve to sufficiently cover the cost of major infrastructure and habitat projects in space. DFCs are well suited

[1] More on the LDC concept can be found at https://www.thespacereview.com/article/3928/1 or at https://youtu.be/qP8hGoNY9dk (accessed on July 19, 2022)

[2] Users' Advisory Group. (2020, September 3). National Space Council. Assessing the Utility of a U.S. Strategic In-Space Propellant Reserve: Economic Development. Retrieved from https://www.nasa.gov/sites/default/files/white_paper_on_strategic_in space_propellant. (accessed on July 19, 2022)

[3] B. Cahan. "Space Commodities Futures Trading Exchange: Adapting Terrestrial Market Mechanisms to Grow a Sustainable Space Economy" New Space Magazine https://www.liebertpub.com/doi/abs/10.1089/space.2017.0047 (accessed on July 19, 2022)

[4] Suarez, Steve. (2021). Mining Tax Canada. Flow-Through Shares: Executive Summary. Retrieved from https://www.miningtaxcanada.com/flow-through-shares/ (accessed on July 19, 2022)

[5] Position Paper: Outer Space Private Investment Corporation (OSPIC), National Space Society https://space.nss.org/wp-content/uploads/NSS-Position-Paper-Outer-Space-Private-Investment-Corporation.pdf (accessed on July 19, 2022)

for investing in smaller companies and projects and may not be well suited to massive investments in space.

DFC can also invest directly in infrastructure funds focused on emerging companies as debt capital up to 30% of the total size of the investment fund. This low-cost debt capital allows the 70% equity capital to achieve a higher return on capital for these riskier markets. If nothing else of the OSPIC idea is achievable legislatively, this one aspect would be beneficial.

Space Trade Agreement

The Administration has the authority to request the US Congress grant the US Trade Representative "Fast Track" Trade Promotion Authority (TPA) to commence negotiations with our international space & trading partners, e.g., the European Union, UK, and Japan, the purpose of which is to establish the "Rules of the Road" for the trade and investment in off-planet commerce.

A Space Trade Agreement (STA) should include all interested current and future spacefaring nations. The STA should address all the economic and jurisdictional/enforcement issues today, providing the needed certainty for popular investment and business expansion tomorrow. This STA should effectively bring all off-planet business activities into the international trading system. It should also seek to mitigate future disputes among nations competing for scarce space resources through the World Trade Organization in lieu of conflict.

Inmarsat model[1]

Inmarsat is a private British satellite telecommunications company offering global mobile services. Inmarsat, however, began as an intergovernmental non-profit organization in 1979 created to establish and operate a satellite communications network for the maritime community. Twenty-eight nations joined in forming and funding the independent entity because of the common need to provide communications over the oceans and emergency alerts. Eventually, Inmarsat was privatized and into a private company that provides telephone and data services to users worldwide.

Space infrastructure and habitats could benefit from a similar model. An entity could be created as a joint project among many nations. It would have a clear mandate to build out prescribed space infrastructure in space, including habitable structures. It could be funded in part by the participating nations, as well as collecting fees from users and stakeholders. Like Inmarsat, we could envision such an entity going private and independent at some point.

The difference with the LDC concept above is that this IGO would be owned initially only by the signatory entities of participating governments. In the Intelsat and Inmarsat cases, this accelerated initial investment and system deployment but created monopolies with little incentive to innovate and lower costs.

Tennessee Valley Authority[2]

Like Inmarsat, the Tennessee Valley Authority (TVA) was established to meet specific needs in rural Tennessee. The TVA is a federally-owned company created in 1933 to control floods, improve navigation, improve the living standards of farmers, produce electrical power along the Tennessee River and its tributaries, and economic development in an area of the US particularly hard hit by the Great Depression. Today, the TVA is the largest public utility in the country, with revenues of more than $11 Billion. The TVA does not receive any funding from the U.S. government, nor does it pay state, local, or federal taxes. The TVA has yet to be privatized.

The formation of a TVA-like company to support space development could help accelerate space industrialization. With a clear mandate to develop space infrastructure and the ability to raise user fees, such an entity could be self-sustaining, providing for ongoing infrastructure development into the indefinite future.

IV Conclusion

A robust space ecosystem is emerging that, sooner than later, will lay the groundwork for large-scale space infrastructure and eventual habitats beyond earth. Whether that is measured in decades or generations, it is not too early to explore the range of financing models required to support such an audacious undertaking. As such, a review of the financing options helps to demystify what it may take to structure such large-scale complex financing mechanisms. If we can show concretely that even seemingly prohibitively high-cost space projects can be successfully capitalized, that may help, in turn, stimulate the preparation of viable business plans for seemingly out-of-reach ventures such as asteroid mining or solar power orbiting stations.

This paper is a culmination of our initial investigation into the financing options. Beyond Earth will continue to identify and explore traditional and novel financing options that can be applied to large-scale space systems.

V Recommendation

The U.S. Department of Commerce (DoC) should undertake a comprehensive study of government-enabled financing mechanisms that could be activated to finance large-scale, in-space infrastructure projects that exceed $10 Billion in total cost. In doing so, the DoC should consider specific project options that have high potential ROI value for both government and private stakeholders. The study should engage government, academia, and industry project financing experts.

[1] Sukawaty Andrew. (2019, March 18). Inmarsat Corporate. Enabling Connectivity Business Models. Retrieved from https://www.inmarsat.com/content/ inmarsat/corporate/documents/ (accessed on July 19, 2022)

[2] Editor. (2017, August 3). TVA. Tennessee Valley Authority Act Of 1933. Wikipdia. Retrieved from https://en.wikipedia.org/wiki/Tennessee_Valley_Authority (accessed on July 19, 2022)

Speaker Biographies

Beyond Earth Institute Leadership

Steven Wolfe

President and Co-Founder, Beyond Earth Institute

Steven Wolfe is Beyond Earth Institute President and Co-Founder. He is also the Global Spaceport Alliance's Deputy Executive Director and a CWSP International partner. He is on the Board of the Global Entrepreneurship Network – Space. He is on the Board of Editors for the Journal of Space Philosophy. Steve served in Washington as the executive director of the Congressional Space Caucus and drafted the Space Settlement Act of 1988. The bill was signed into law as part of the NASA Authorization bill. Steve is the author of *The Obligation: A Journey to Discover Human Purpose on Earth and in the Cosmos.*

Simon "Pete" Worden (Brig. Gen., USAF, Ret., PhD)

Chairman, Breakthrough Prize Foundation

Simon Peter "Pete" Worden, (Brig. Gen., USAF, Ret., Ph.D.) (born 1949, in Michigan, USA) is the Chairman of the Breakthrough Prize Foundation and Executive Director of the foundation's 'Breakthrough Initiatives.' He holds a Bachelor of Science degree in Physics and Astronomy from the University of Michigan and a Ph.D. in Astronomy for the University of Arizona. Prior to joining the Breakthrough Prize Foundation, Dr. Worden was Director of NASA's Ames Research Center at Moffett Field, California, USA, until his retirement on March 31, 2015. He has held several positions in the United States Air Force and was research professor of astronomy at the University of Arizona, Tucson, USA. He is a recognized expert on space and science issues – both civil and military, and has been a leader in building partnerships between governments and the private sector internationally.

Courtney Stadd

VP of Ecosystem Engagement, Beyond Earth Institute

Courtney Stadd is Founder/President, Capitol Alliance Solutions, LLC, a Washington, DC based management consulting firm whose clients include a wide range of pioneering commercial space actors. For nearly 40 years, Stadd's career path has been a mix of senior government leadership and corporate executive jobs – primarily focused on encouraging the removal of policy and regulatory barriers to the emergence of a competitive American-led commercial space marketplace. Courtney has held multiple senior positions at the US Department of Commerce, the US Department of Transportation, the White House, and worked directly for three NASA Administrators, including as Chief of Staff/White House Liaison.

Sean W. Hadley, Esq.

Chief Operating Officer and Co-Founder, Beyond Earth Institute

Sean W. Hadley, Esq. is Beyond Earth Institute's co-founder and Chief Operating Officer. He is an Attorney, Lecturer, and Legislative Policy Advisor with over two decades of experience helping organizations reach their public policy goals. He is also a member of the Board of Directors. Mr. Hadley's background includes frequent work on Capitol Hill, where Members of Congress regularly call upon him to review legislation and provide timely policy input. He also serves as Associate Faculty at Rutgers University, where he teaches law, public policy and international affairs. Mr. Hadley holds a Masters of Science Degree in Public Policy from the Bloustein School of Planning and Public Policy, where he was a fellow at the Eagleton Institute of Politics at Rutgers University.

Keynote and Featured Speakers

Tory Bruno

CEO, United Launch Alliance

Salvatore T. "Tory" Bruno is the president and chief executive off¬icer for United Launch Alliance (ULA). In this role, Bruno serves as the principal strategic leader of the organization and oversees all business management and operations. Prior to joining ULA, he served as the vice president and general manager of Lockheed Martin Strategic and Missile Defense Systems. He also managed the corporation's responsibilities in Atomic Weapons Establishment (AWE) Management Limited, a joint venture that produces and safely maintains the U.K.'s nuclear weapons.

Bhavya Lal

Associate Administrator for Technology, Policy, and Strategy, NASA

As the associate administrator for technology, policy, and strategy within the office of the NASA Administrator, Bhavya Lal is responsible for providing evidence-driven advice to NASA leadership on internal and external policy issues, strategic planning, and technology investments. She also provides executive leadership and direction to the newly created Office of Technology, Policy and Strategy within the office of the administrator. Dr. Lal is currently the acting chief technologist of NASA, the first woman to hold the position in NASA's 60+ year history. Dr. Lal holds bachelor's and master's degrees in nuclear engineering from the Massachusetts Institute of Technology (MIT), a second master's from MIT's Technology and Policy Program, and a Ph.D. in Public Policy and Public Administration from George Washington University. She is a member of both the nuclear engineering and public policy and public administration honor societies and has published more than 50 papers in peer-reviewed journals and conference proceedings.

Kathy Lueders

Associate Administrator for Space Operations, NASA

Kathryn Lueders serves as the associate administrator of NASA's Space Operations Mission Directorate (SOMD), overseeing the International Space Station (ISS), the Commercial LEO Development Program, Space Communications and Navigation (SCaN), Launch Services Program (LSP), Human Spaceflight Capabilities, and operations of crewed Artemis missions. She previously served as the first female associate administrator for the Human Exploration and Operations Mission Directorate, managing the agency's full human spaceflight portfolio.

Before joining NASA Headquarters, Lueders was the manager of the Commercial Crew Program (CCP) at NASA's Kennedy Space Center. She began her NASA career in 1992 at the White Sands Test Facility in New Mexico, where she was the Shuttle Orbital Maneuvering System and Reaction Control Systems Depot manager. Lueders holds a bachelor's degree in business administration finance from the University of New Mexico and bachelor's and master's degrees in industrial engineering from New Mexico State University.

Daniel Oltrogge

Chief Scientist and Director, Center for Space Standards and Innovation, COMSPOC Corporation

Dan Oltrogge is the Director of the Center for Space Standards and Innovation, Director of Integrated Operations and space policy expert at the Commercial Space Operations Center at COMSPOC Corporation, program manager of the Space Data Center, founder and administrator of the Space Safety Coalition, U.S. Head of Delegation to ISO TC20/SC14, academician of the International Academy of Astronautics, technical author, and the author of numerous international space standards and best practices.

Scott Pace

Professor of the Practice of International Affairs, George Washington University

Dr. Pace rejoined the faculty of the Elliott School of International Affairs in 2021 after serving as Deputy Assistant to the President and Executive Secretary of the National Space Council from 2017-2020. He previously served as the Associate Administrator for Program Analysis and Evaluation at NASA from 2005-2008 and Deputy Chief of Staff for the NASA Administrator from 2002-2003. Prior to NASA, he was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy. From 1993-2000, he worked for the RAND Corporation's Science and Technology Policy Institute, and from 1990-1993, he served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Master's degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Naren Shankar

Executive Producer/Showrunner, The Expanse

Naren Shankar is the Executive Producer/Showrunner of the critically acclaimed television adaptation of the international best-seller science fiction novel series, The Expanse, an Amazon Prime Original Series from Alcon Television Studios. Naren spent eight seasons as a Writer-Executive Producer and Co- Showrunner of the most-watched show in the world, CSI: Crime Scene Investigation. Prior to CSI, Naren was an Executive Producer on the SyFy Channel cult hit series Farscape for The Jim Henson Company, and spent three seasons as a writer-producer on Showtime's The Outer Limits. Naren began his career as a writer and science consultant for Star Trek: The Next Generation, and he holds a PhD in Applied Physics & Electrical Engineering from Cornell University.

Ezinne Uzo-Okoro

Assistant Director for Space Policy, White House Office of Science and Technology Policy

Ezinne Uzo-Okoro determines civil and commercial space policy priorities for the White House Office of Science and Technology Policy. Her portfolio includes Orbital Debris, In-space Servicing, Assembly, and Manufacturing (ISAM), Earth Observations, Space Weather, Aeronautics, and Planetary Protection. In 17 years at NASA, she contributed to over 60 missions and programs – as an engineer, technical expert, manager and executive – in earth observations, planetary science, heliophysics, astrophysics, human exploration, and space communications, which represent $9.2B in total program value. She holds an undergraduate degree in Computer Science from Rensselaer Polytechnic Institute; master's degrees in Systems Engineering, Space Robotics, and Science & Technology Policy from Johns Hopkins University, MIT, and Harvard University, respectively; and a PhD in Space Systems from MIT, on the robotic assembly of satellites. Her immigration story is profiled in President George W. Bush's book, 'Out of Many, One'.

Johann-Dietrich Wörner

President, German Academy of The Engineering Sciences

Johann-Dietrich "Jan" Wörner is President of Germany's National Academy of Science and Engineering. From 2015-2021, he was Director General of the European Space Agency (ESA). He chaired the Executive Board of the German Aerospace Center (DLR) from 2007 to 2015, and served as President of TU Darmstadt from 1995 to 2007. A civil engineer by training, Jan Wörner was previously Professor, Head of the Test Research Institute, and then Dean of Civil Engineering at TU Darmstadt. Jan holds numerous awards, including honorary degrees from the State University of New York, Technical University of Moldova, Politehnica University of Bucharest, Saint Petersburg State University of Economics, École Centrale de Lyon, and Mongolian Technical University. He has received the Federal Cross of Merit of the Federal Republic of Germany (Grand Cross 1st class) and is a Knight of the French Légion d'Honneur.

Special Session Panelists

Petr Bohacek

Space Strategy Manager, TRL Space

Petr Bohacek is co-owner and space strategy manager at TRL Space Systems, where he works on identifying new opportunities and ambitious missions to advance human presence in and knowledge of space. Petr has worked on developing laser applications for space at the Czech Institute of Physics, and as a space policy researcher at the European University Institute and Charles University, focusing on space mining and planetary defense. He has a background in the think tank industry and private intelligence as an international security analyst.

Robert Brumley

CEO, Laser Light Communications

Bob Brumley is the Senior Managing Director at Marble Arch Partners, LLC. He currently serves as Chairman and CEO of the Laser Light Companies. He was CEO of TerreStar Corporation (formerly Motient Corp.) from 2006 to 2008, and CEO of TerreStar Global and TerreStar Networks Inc., from 2005 to 2008. He led these firms into the emerging field of hybrid mobile satellite and terrestrial communications, raising over $1B in private investment. He is a former senior executive with Deutsche Telekom and Bell Atlantic International (now Verizon). He was appointed by President Reagan as Chief Legal Officer of the Department of Commerce and Senior Policy Advisor to the Secretary of Commerce and he chaired the Reagan Administration policy working group that privatized commercial space transportation.

Holds a bachelor's degree in mechanical engineering from the California Polytechnic State University, in San Luis Obispo, California, and has completed graduate courses and management programs at Harvard University, Santa Clara University, the Wye River Institute, San Jose State University and the Defense Acquisition University.

Michael Castle-Miller

CEO, Politas Consulting

Michael is a governance consultant who has served as an advisor to governments, international organizations, civil society, and private investors in over 32 countries. He specializes in the legal and public policy frameworks for special jurisdictions -- such as special economic zones and semi-autonomous areas -- that improve institutional governance for developing countries. He has drafted laws and regulations, helped create administrative agencies, design policy reforms, and structure public-private partnerships. He is the Founder and Executive Director of Politas, which provides innovative legal and policy solutions to help cities and special jurisdictions achieve inclusive growth.

Carissa Christensen

Founder and CEO, BryceTech

Carissa Christensen is the Chief Executive Officer and founder of BryceTech. She is an internationally-recognized expert on R&D processes, technology forecasting, and the space industry. Carissa is currently a member of the National Research Council Space Technology Industry-Government-University Roundtable, which advises NASA. She has served on the World Economic Forum Global Future Council since 2018. She is a Senior Advisor to the annual US Air Force Schriever Wargame. She also serves on the Advisory Council of the Aerospace Corporation's Center for Space Policy and Strategy.

Hoyt Davidson

Founder and Managing Partner, Near Earth LLC

Hoyt Davidson is the founder and Managing Partner of Near Earth LLC, an investment bank focused on the satellite industry, commercial space and the Internet of Things. Clients include major companies and institutional investors in those industries, and early stage entrepreneurial firms seeking private equity capital or new homes for their companies. Hoyt received a Physics degree from MIT and upon graduation spent six years in the Space Systems Division of Lockheed, before returning to MIT for an MBA. In the mid-1990s, he co-founded the Space Finance Group, the first coverage group focused on the commercial satellite industry. This group had a #1 ranking for the sector for many years and raised over $15 billion for commercial satellite companies. In 2002, he started Near Earth LLC, to continue helping space-related companies grow.

Mary Lynne Dittmar

Chief Government and External Relations Officer, Axiom Space

A national influence in space policy and programs for more than two decades, Dr. Mary Lynne Dittmar directs Axiom's work with local, state, and federal government authorities. As Axiom is a key partner in NASA's Low Earth Orbit Commercialization strategy and the leading commercial space company in Space City, she liaises directly as a thought leader with the U.S. government's executive and legislative branches. Mary Lynne founded and was most recently President & CEO of the Coalition for Deep Space Exploration, an industry trade group of more than 60 companies supporting NASA's programs in human exploration and science and promoting space commerce and the development of space technology. Her previous experience includes roles as Senior Policy Advisor for the ISS National Laboratory, Member of the Board of Directors at the American Astronautical Society, and managing the Flight Operations Group and serving as the Chief Scientist for Commercial Payloads on the ISS Program at Boeing.

Jennifer Fogarty, PhD

Chief Scientific Officer, Translational Research Institute for Space Health, Baylor College of Medicine

Jennifer Fogarty, PhD is the Chief Scientific Officer for the Translational Research Institute for Space Health (TRISH) at Baylor College of Medicine and the Director of Applied Health and Performance at Sophic Synergistics LLC. With more than twenty years of experience in medical physiology and human health and performance in extreme environments, her mission is to increase access to high-quality healthcare in space and on Earth, by empowering astronauts, patients, and medical providers with evidenced-based precision medicine and technology. As Chief Scientist of TRISH, Dr. Fogarty leads an innovative, high-risk research and development portfolio to address space exploration's most challenging human health and performance risks. Dr. Fogarty received her PhD in Medical Sciences from Texas A&M University College of Medicine.

Laura Forczyk

Executive Director, Astralytical

Laura Forczyk is the VP of Research and Analytics for the Beyond Earth Institute. She is also the founder and Executive Director of space consulting firm Astralytical, specializing in space science, industry, and policy, offering space career coaching services and publishing industry reports. Prior to forming her own company, she ran the Florida office of an international startup working to establish parabolic and suborbital flight at Kennedy Space Center and globally. She has also worked as a scientific analyst for a nonprofit facilitating over 50 experiments on the International Space Station for the benefit of life on Earth. Laura is the author of Rise of the Space Age Millennials (2020) and Becoming Off-Worldly (2022). She runs the private online community Becoming Off-Worldly Together and serves as an advisor for For All Moonkind.

Mike Gold

Executive Vice President for Civil Space and External Affairs, Redwire Space

Mike Gold is the Executive Vice President for Civil Space and External Affairs at Redwire Space. In this role, Mr. Gold supports the company's business development efforts as well as government and media relations. Prior to joining Redwire Space, Mr. Gold was NASA's Associate Administrator for Space Policy and Partnerships and also served as Acting Associate Administrator for the Office of International and Interagency Relations and Senior Advisor to the Administrator for International and Legal Affairs. At NASA, Mr. Gold led the development and implementation of the Artemis Accords which establish norms of behavior to ensure a peaceful and prosperous future in space for all of humanity. Before joining NASA, Gold was Vice President of Civil Space at Maxar Technologies and General Counsel for the company's legacy Radiant Solutions Business Unit.

Michelle Hanlon

Co-Director, Center for Air and Space Law, University of Mississippi

Michelle is co-founder and President of For All Moonkind. She leads all legal efforts, with particular emphasis on space law. Michelle is also Co-Director of the Center for Air and Space Law and an instructor of aviation and space law at the University of Mississippi School of Law. She is also the President of the National Space Society. Michelle received her B.A. in Political Science from Yale College and her J.D. magna cum laude from the Georgetown University Law Center. She earned her LLM in Air and Space Law from McGill University where the focus of her research was commercial space and the intersection of commerce and public law.

Kenneth Hodgkins

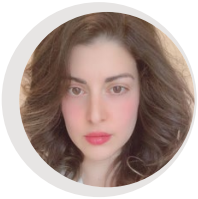
Co-Chair, Off-World-Approach, Hague Institute for Global Justice

Ken Hodgkins is a globally recognized strategic thought-leader on international space policy and law and the application of the Outer Space Treaties to new commercial ventures. Throughout his 40 years in government service, Mr. Hodgkins has been a driving force for multilateral and bilateral initiatives focused on improving transparency, predictability, interoperability, resiliency and the safe and responsible use of space. Mr. Hodgkins brings a unique perspective to international space endeavors having dealt with every aspect of the use of outer space at the diplomatic and agency levels for economic growth, national security, scientific discovery, foreign policy and improving the quality of life for the global community.

Olivia Gamez Holzhaus

Founder and CEO, Rhodium Scientific

Olivia Gamez Holzhaus is the Founder and CEO for Rhodium Scientific, charged with advancing the company's biotech commercialization strategies within the low Earth orbit economy. Olivia oversees science, engineering, and QA strategies at Rhodium Scientific to ensure discoveries made in microgravity translate into products utilized by regulated consumer, manufacturing, and life science industries. Ms. Holzhaus has positioned her company as an official Commercial Services Provider to multiple national laboratories, including the International Space Station (ISS), and has led the creation and implementation of Rhodium Scientific's Quality, Industry-Compatible (QuIC) Space Process, a trade secret process ensuring industry-standard quality controls are incorporated into spaceflight missions, allowing for reproducibility and standardization for biotech and biomanufacturing investigations. She has over 20 years in research.



Angeliki Kapoglou

Researcher, European Space Agency

Angeliki Kapoglou is part of ESA's Human Robotic Exploration Strategy and Innovation team. Her research is focused on the emerging commercial lunar ecosystem, ESA's new space resources strategy, and assessing future lunar surface exploration scenarios; while developing European priorities and activities for a sustainable future on the Moon. Angeliki is also contributing to ESA's Post-ISS commercialization strategy for Low Earth Orbit and ESA's Moonlight initiative (Lunar Communications & Navigation) Commercialization Team. She was recently part of the newly established ESA SOLARIS team, assessing the potential of Space-based Solar Power for contributing to Europe's energy security and Net Zero goals. Angeliki has also spent two years at one of the world's leading centers for innovation, the Hasso Plattner Institute of Design (the d.school) at Stanford University.

Josef Koller

Space Policy Strategist, The Aerospace Corp.

Dr. Josef Koller is a systems director for the Center for Space Policy and Strategy at The Aerospace Corporation, where he serves as a senior analyst and team leader on topics that cut across policy, technology, and economics. Koller is also the co-founder of The Aerospace Corporation's Space Safety Institute, which leads and advances spaceflight safety across the space enterprise from human spaceflight safety, launch, reentry, space operations, space situational awareness, cyber, and spectrum. Prior to joining Aerospace, Koller served as a senior advisor to the Office of the Secretary of Defense for Space Policy, where he directly supported key national and international strategy efforts for space-related U.S. government and DOD policy matters. His portfolio included commercial remote sensing, space traffic management, and related congressional affairs. He has more than 20 years of experience in space science, space policy, astrophysics, and strategy development and has authored more than 50 peer-reviewed scientific publications, with over 1,400 citations.

John Mankins

Vice President, Moon Village Association

John C. Mankins is President of Artemis Innovation Management Solutions LLC and of Mankins Space Technology, Inc., and a Director of Solar Space Technologies Ltd. Pty. He is Vice President of the Moon Village Association, and is a Dean and Professor at the on-line Kepler Space Institute. While at NASA and JPL, Mankins held numerous positions, including in the Office of Space Flight, Assistant Associate Administrator for Advanced Systems (acting), and Chief Technologist for Human Exploration and Development of Space. He received the NASA Exceptional Technology Achievement Medal. He holds a B.S. (Harvey Mudd College), an M.S. (UCLA) and an MBA (Claremont Graduate University). He is a member of the American Association for the Advancement of Science, the IEEE, Sigma Xi, and the International Academy of Astronautics. Mankins is known for writing the definitions of the Technology Readiness Levels and as the world's leading expert in the field of "Space Solar Power".

George Nield

President, Commercial Space Technologies, LLC

Dr. George C. Nield is the president of Commercial Space Technologies, LLC, which he founded to encourage, facilitate, and promote commercial space activities. He also serves as the Chairman of the Global Spaceport Alliance. In March of 2022 he flew to space as a private astronaut onboard Blue Origin's New Shepard rocket. He had previously been the associate administrator for the Federal Aviation Administration's Office of Commercial Space Transportation and was responsible for licensing and regulating all commercial launch activities. Earlier in his career, he held engineering roles at the Air Force Flight Test Center and the Orbital Sciences Corporation, and he was an assistant professor and research director at the U.S. Air Force Academy. Dr. Nield also served as the manager of the Flight Integration Office for NASA's Space Shuttle Program. A graduate of the United States Air Force Academy, he holds an M.S. and Ph.D. in Aeronautics and Astronautics from Stanford University, and an MBA from George Washington University.

Vishnu Reddy

Professor of Planetary Sciences and Director of University of Arizona Space Safety, Security and Sustainability Center

Vishnu Reddy is a Professor of Planetary Sciences at the Lunar and Planetary Laboratory and the Director of Space Safety, Security and Sustainability Center at the University of Arizona (UArizona), in Tucson. Prior to serving as a faculty member at the UArizona, he was a research scientist at the Planetary Science Institute in Tucson, Arizona, from 2012-2016. Since 2005, Prof. Reddy has been using the NASA IRTF on Mauna Kea, Hawaii to spectrally characterize small NEOs that make close flyby of the Earth. In addition to his work with NASA, Prof. Reddy is part of the Space Domain Awareness (SDA) program at the University of Arizona where he has developed a network of optical and RF sensors to characterize orbital debris and space objects in cislunar space for the United States Air Force Research Laboratory (AFRL).

Henk Rogers

Founder, International MoonBase Alliance

Henk B. Rogers is a Dutch-born entrepreneur, and a clean energy and space exploration visionary who has dedicated the past decade of his career to the research, development, advocacy, and implementation of renewable energy sources in his adopted home of Hawai'i and beyond. In 2007, after learning about the global threat of man-made environmental damage, Rogers founded the Blue Planet Foundation. Its goal: to end the world's dependence on fossil fuels. Blue Planet's efforts led to Hawai'i Governor David Ige signing a bill in 2015 that directed the state's utilities to solely generate 100-percent of electricity sales from completely renewable sources by 2045. Now Rogers turns to his next mission: building a backup of life on Earth.

Eric Stallmer

Executive Vice President, Government Affairs and Public Policy, Voyager Space

Eric Stallmer is the Executive Vice President for Government Affairs and Public Policy for Voyager Space Holdings Inc. Eric leads Voyager's Washington, DC office and is responsible for representing the interests of Voyager to key government institutions including Congress, the White House and several federal agencies that impact the success of Voyager and its subsidiaries. Prior to joining Voyager he was the President of the Commercial Spaceflight Federation (CSF). Under Stallmer's leadership, CSF worked tirelessly to craft the modern Commercial Space Launch Act, as well as to promote innovation as a national policy to spur the economy and create high technology jobs. Eric serves on both the Defense Innovation Board, Space Advisory Committee as well as the Federal Aviation Administration's (FAA) Commercial Space Transportation Advisory Committee (COMSTAC).

Paul Stimers

Partner, K&L Gates

Paul Stimers is an attorney in the Washington, DC office of K&L Gates, a global law firm, where he co-leads the public policy practice. He focuses on working with Congress and the Administration on issues related to commercial spaceflight and other disruptive technologies. He helped draft and pass the 2015 Commercial Space Launch Competitiveness Act, and has been involved in all major space-related federal legislation since 2008. His commentary on property rights in space has been published by the Wall Street Journal, the Orlando Sentinel, and the Space Review.

Erika Wagner

Sr. Director for Emerging Space Markets, Blue Origin

Dr. Erika Wagner serves as Senior Director of Emerging Market Development for Blue Origin, a developer of vehicles and technologies to enable human space transportation. Prior to joining Blue Origin, Dr. Wagner worked with the X PRIZE Foundation as Senior Director of Exploration Prize Development and founding Executive Director of the X PRIZE Lab@MIT. Previously, she served at MIT as Science Director and Executive Director of the Mars Gravity Biosatellite Program, a multi-university spacecraft development initiative to investigate the physiological effects of reduced gravity. Dr. Wagner's interdisciplinary academic background includes a bachelor's in Biomedical Engineering from Vanderbilt University, a master's in Aeronautics & Astronautics from MIT, and a PhD in Bioastronautics from the Harvard/MIT Division of Health Sciences and Technology. Her research spanned both human and mammalian adaptation to microgravity, partial gravity, and centrifugation; as well as organizational innovation and prize theory. She is also an alumna of the International Space University and an Associate Fellow of the American Institute of Aeronautics and Astronautics.

Nathan Whigham

President, EN Capital

Nathan Whigham is the Founder and President of EN Capital. He has been placing debt and equity across all types of commercial real estate since 2006 and has been involved in the origination of over $800M of commercial real estate finance. Prior to founding EN Capital he was the Senior Director of Business Development for CleanFund Commercial PACE Capital for Southern California. Before his tenure as a commercial PACE lender he was Senior Vice President at Nebo Capital, a boutique commercial real estate capital advisory firm. Nathan has also developed over six megawatts of large commercial renewable energy projects and has been involved in a variety of entrepreneurial ventures. He holds an MBA from the Marshall School of Business at the University of Southern California and a BS in Systems Engineering from the University of Arizona.

About the Beyond Earth Institute

The Beyond Earth Institute is an IRS-recognized tax-exempt non-profit corporation. BE differentiates itself in the space community by its status as a non-partisan think tank that focuses on the pragmatic policy and legal issues and challenges associated with advancing human's long-term expansion into space.

Beyond Earth's focus is on technology readiness, worldwide public support, and related public policy enactment, including recommendations for policy initiatives. Beyond Earth conducts primary and secondary research, then consolidates and publicizes reports to be delivered and presented widely throughout the space policy community in the U.S. and internationally.

The Beyond Earth Vision is simple. A time when coming generations will have the opportunity to live and work in economically vibrant communities beyond planet Earth for the benefit of all humanity. Today we are focused on helping to create a workable legal and policy framework that addresses the unique challenges of the emerging space-based industry. By doing so, we strengthen the economic underpinning that will eventually enable the creation of communities beyond Earth.

Beyond Earth engages the stakeholder community through regular webinars, workshops, and conferences. These activities inform our research reports and public policy recommendations that we make available to policy influencers in government, industry, and the advocacy community.

You are invited to get involved...

To achieve the goals of the Beyond Earth Institute, we need your support. Please help us make the mission of Beyond Earth the mission of our nation's leaders and their global counterparts. You can lend your expertise to our efforts or donate generously to this cause.

If you want to make a difference, send Steve Wolfe, Beyond Earth President, a message at steve@beyondearth.org. Our growing team looks forward to hearing from you.

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Crafting the Policies that Will Enable Humanity's Future in Space

October 12-13, 2022

University of Arizona Center for Outreach & Collaboration

Washington, DC

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