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Conference Outcomes Report

Challenges in Sustaining Space as a Resource

June 24–25, 2025
Silicon Flatirons Center, University of Colorado Law School

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In Gratitude

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1 Introduction

Space is rapidly transforming from a frontier of exploration into an intensively utilized, and increasingly vulnerable, resource. Technological innovation continues to lower barriers to entry in space activity, improving both affordability and productivity. At the same time, unprecedented launch volumes and growing orbital congestion raise urgent concerns about the practical and physical limits of the space environment.

With the space economy and space regulation at a crossroads, the Silicon Flatirons Center convened leaders from the scientific, commercial, regulatory, and defense communities. Held on June 24–25, 2025, the *Challenges in Sustaining Space as a Resource* conference examined the challenges of sustaining space as a shared resource and explored solutions.

This moment is one of remarkable opportunity. Space activity has grown exponentially over the past decade. The global space economy generated approximately $400 billion in revenue in 2023, and by the end of that year, 9,691 active satellites were operating in orbit—an increase of 361 percent over five years.

Commercial competition continues to accelerate. Major operators are planning unprecedented deployments, with SpaceX targeting as many as 42,000 satellites, and the Chinese operator SpaceSail planning 15,000 satellites by 2030. These so-called mega-constellations represent a pace and scale of activity that existing regulatory frameworks were not designed to accommodate.

This rapid growth brings heightened risks, including harmful radiofrequency (RF) interference and physical collisions. The value of the space environment itself may be diminished by congestion, interference, cascading debris events, or other threats. Addressing these challenges will require timely and coordinated action by policymakers.

Effective space policy inherently depends on global cooperation. As Federal Communications Commission (FCC) Commissioner Anna Gomez noted in her keynote address, 31 agenda items at the upcoming World Radiocommunication Conference 2027 (WRC-27) focus specifically on space-related issues. This level of international attention underscores the need for enhanced coordination among operators, improved international dialogue, and reformed regulatory approaches.

This Outcomes Report captures the key insights and actionable recommendations that emerged from participants in the June 24–25, 2025 Conference.

2 Day One Morning Keynote: Anna Gomez

FCC Commissioner Anna Gomez opened the conference with an upbeat but urgent call to action, emphasizing that Colorado's growing space economy makes it an ideal place for critical space policy discussions. To put the sheer volume of commercial space activities into perspective, Gomez shared a few statistics: over 11,000 small satellites were launched between 2022 and 2024; a $293 billion global satellite market in 2024; and more than 8,000 U.S.-operated satellites. These numbers demonstrate clear opportunities for operators, while raising serious questions about spectrum congestion and orbital debris. This set the stage for a central message: policy must evolve as quickly as the technology it governs.

Building on this foundation, Commissioner Gomez outlined the FCC's four core responsibilities in space: 1) authorizing commercial systems; 2) facilitating efficient spectrum use; 3) ensuring responsible orbital-debris practices; and 4) coordinating with international fora.

2.1 The Need for Cooperation

Gomez stressed that space is inherently international, making domestic policy inseparable from global cooperation. Early, data-driven domestic compromises lead to stronger, and more unified U.S. positions abroad. Describing the extent of what is at stake, Gomez mentioned that 31 agenda items at the World Radiocommunication Conference 2027 (WRC-27) focus on space. This conference will test whether U.S. agencies can present a unified front, so Gomez encouraged early and inclusive collaboration between domestic agencies such as the FCC, the National Telecommunications and Information Administration (NTIA), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD).

> ***"Practices that demonstrate interagency cooperation breed cooperation globally. Policies that support competition domestically inspire competition globally."***
>
> – Anna Gomez

2.2 The Positive Role of Competition

Gomez highlighted competition's unifying role in space policy. Gomez argued that many domestic goals—bridging coverage, boosting national security, and maintaining a technological edge—depend on having multiple strong competitors. Gomez emphasized that regulation should balance the needs of startups and scientific users with those of larger players, driving innovation rather than stifling it.

2.3 Working Alongside Innovators

> ***"Sustaining space competition and leadership requires multiple healthy competitors. Our policy decisions cannot lose sight of that."***
>
> – Anna Gomez

Gomez recounted her recent "space tour" of U.S. commercial space innovators. Her visits to companies like Astranis, Rocket Lab, K2 Space, and Planet, as well as NASA's Ames Research Center, revealed a landscape of rapid experimentation and cutting-edge technological breakthroughs. To Gomez, these advancements demonstrate the sector's ingenuity while surfacing complex regulatory questions about the sustainable use of outer space, from daily Earth imaging and jumbo high-throughput satellites to solar sail propulsion and spacecraft swarms. This recent industry engagement underscored the FCC's challenge of encouraging innovation without compromising safety, competition, or international harmony.

2.4 Questions and Answers Session

The themes above were brought to the forefront in the subsequent Q&A session. Commissioner Gomez clarified that the upcoming mid-band satellite auction likely will not affect small-satellite startups unless shared-use rules apply. Next, she reinforced the critical need for continued interagency cooperation, acknowledged the difficulty of protecting scientific spectrum users in an increasingly crowded environment, and warned that the federal workforce cuts threaten the expertise necessary for effective policy. Gomez identified the Low Earth Orbit (LEO), Non-Geostationary Satellite Orbit (NGSO) boom, especially with China's aggressive entry and lunar communications as today's most significant "space races," highlighting the urgency of coordinated action.

2.5 Final Thoughts

By linking explosive industry growth with the necessity of adaptable regulation, Gomez left the audience with a clear takeaway: sustaining U.S. leadership in the space economy will require cooperation at every level: domestic, international, public, and private. This keynote positioned policy not as a brake on innovation, but as the framework that makes continued exploration and competition possible.

> ***"Space, by its very nature, is inherently international, and thus policy for space communications is inextricably tied to successful cooperation with international bodies and other nations."***
>
> – Anna Gomez

3 Topic 1: Resolving Spectrum Conflicts Between Active Users in Space and on Earth

3.1 Context

As innovation in satellite technology rapidly advances, more national and commercial actors are entering the space domain than ever before. With a record number of satellites operating in orbit in 2024, the demand for spectrum has intensified. Innovations in space-based communications, including mega-constellations and direct-to-device satellite services, are now outpacing the ability of domestic regulators and international bodies to manage spectrum conflicts using a traditional ex ante approach. From the competing uses of users in space versus those on Earth, incumbent users versus new entrants, operators of LEO versus Geostationary Earth Orbit (GEO) satellites, and the developing world versus the developed world, tensions will inevitably continue to rise.

The panelists argued that new approaches are urgently needed to address the conflicts that experts guarantee are inevitable. With space-related spectrum issues dominating the WRC-27 agenda, a unified and proactive regulatory framework is a high priority for the international community.

The panel discussed how a comprehensive regulatory framework, collaboration between commercial and international actors, and improved communication can address the growing complexity of shared spectrum use. Ahead of WRC-27, this discussion highlighted the urgent need for more adaptive, equitable, and efficient spectrum management that can withstand a rapidly changing spectral environment, continue to support innovation, and avoid harmful interference between actors.

Panelists echoed the global call for solutions to resolve disputes, promote equitable access, and ensure an interference-free coexistence in an increasingly crowded spectrum environment.

3.2 Panel Discussion

- Julie Kearney, Partner and Co-Chair of the Space Exploration and Innovation Practice at DLA Piper (Moderator)
- Kimberly Braum, Head of Regulatory at Astranis
- Thomas Dombrowsky, Vice President of Engineering and Technology Policy at T-Mobile
- Rich Lee, CEO of Posi, Inc.

Panelists brought industry, regulatory, and technical expertise and experience to the table to discuss managing the increasingly competitive spectral environment. The conversation asked how industry leaders and regulators can collaborate to ensure efficient spectral coexistence for users across the globe.

Rising Demand for Spectrum Across Sectors

> ***"At the end of 2024, a total of 11,539 satellites were operating in Earth orbit compared to just 3,371 in 2020."***
>
> *– Julie Kearney, sharing statistics from the 2025 Satellite Industry Association Industry Report.*

Commercialization of space and a booming space economy has quickly created an unprecedented demand for spectrum internationally. Julie Kearney kicked off the discussion with a staggering statistic illustrating the explosive growth in space-based spectrum use. The rising demand for scarce spectrum is a topic of growing concern for all users. Traditional rules must be updated to reflect the massive demand for access to spectrum bands from commercial, government, and scientific actors.

FCC Licensing Reform

The licensing regime for GEO and NGSO systems requires a clearer, more adaptive policy that promotes fair access and coexistence for new and incumbent users. The FCC currently has two separate licensing regimes for GEO and NGSO satellites. On the one hand, GEO licensing for particular locations are administered on a first come first serve basis. On the other hand, the FCC holds processing rounds for NGSO licensing whereby interest is sought from anyone who wants to use the same radiofrequency band at the same time. This forces a process even if the band is already in use. The first-come first-serve basis for GEO licensing favors operators of older satellites and creates difficulties for new entrants. By virtue of operating an old satellite, incumbent users are able to avoid certain FCC requirements like putting up a bond surety to maintain rights, even if it is no longer commercially viable. This creates another barrier for newer entrants.

> ***"It's critical to be looking at ways spectrum is used efficiently, being sure there are opportunities for newcomers to acquire spectrum."***
>
> *– Kimberly Baum*

Within NGSO licensing, panelists advocated for a more efficient system that encourages reuse of existing spectrum assets. One panelist noted that operators targeting new NGSO LEO systems are already looking at ways to share spectrum with GEO systems.

WRC-27 Agenda Items

> ***"80% of the agenda items at WRC-27 are space-related."***
>
> – Julie Kearney

Revising Equivalent Power Flux Density (EFPD) Limits. One panelist explained that EPFD limits were developed in the late 1990s as a means to protect GEOs from interference from NGSOs. It enabled NGSOs to use the same frequency bands without coordinating with each and every GEO. Today, however, these limits no longer serve their original purpose and instead have become constraints on NGSO systems. The U.S. played a key role in the discussions surrounding revising EPFD limits to allow for greater flexibility for NGSOs while maintaining protections for GEOs.

Equitable Access

Several agenda items addressing equitable access will be visited at the WRC-27. Over the years, the International Telecommunications Union (ITU) developed several different approaches to promote equitable access to orbital slots and spectrum for developing countries. However, the modern spectral environment has rapidly evolved since the 1970s and 1980s when the first approach to ensure equitable access was implemented. Tensions continue to exist between guaranteeing access to space for countries without existing systems and continuing to encourage innovation and development by countries creating global systems. Difficult questions regarding the correct means to ensure equitable access while continuing to promote innovation and growth by key players remain unanswered.

Coexistence in Spectrum Between Terrestrial and Satellite Use.

A highly-contested WRC-27 agenda item suggests allowing satellite use of existing terrestrial allocations between 698 to 2700 megahertz (MHz). Terrestrial mobile operators like T-Mobile argue satellite use of this band should be secondary to terrestrial operations. One panelist raised concerns about potential problems between satellite systems and co-channel terrestrial operators and adjacent operators.

Recommendations

Panelists called for improvements in regulation and policy that effectively manages competing spectrum uses by satellite and ground systems. On an operator level, commercial entities should take substantial steps to optimize frequency use and reuse wherever possible. Process improvements should positively impact industry, rather than de-incentivize responsible use.

To mitigate interference issues, one panelist recommended the FCC turn to privatizing monitoring and enforcement, as the FCC has done with certification of equipment.

Ultimately, rules should be reformed to promote competition and ensure fair access. Important progress can be made towards this goal by reevaluating and reforming the FCC's first-come, first-served model for spectrum licensing.

3.3 Summary

Thousands of new satellites are being launched into orbit today. Notably, more actors are launching LEO satellites than ever before. More satellites are crowding the available radio frequencies, and both space-based and Earth-based systems are attempting to use the same spectrum bands. Thus, all agree there is not enough spectrum to meet the needs of all commercial actors entering space under existing rules, and existing rules are not suited to navigate spectrum conflicts that are bound to take place.

Existing regulations, like those set by the FCC and ITU, were made for a different era, one that has long passed. These rules assume systems will be static and long-lived. But today, that is not the case. Satellite systems are mobile, and the latest systems are faster, cheaper, and more flexible than ever before. An FCC licensing regime that awards on a first-come, first-served basis can lead to inefficient spectrum use.

Collaboration between regulators, commercial operators, passive users, and international partners is crucial to managing growth efficiently and effectively.

4 Topic 2: Sustaining Orbital Space as a Resource

4.1 Context

Each year, near-earth orbit becomes increasingly congested. As of last year, roughly 12,500 satellites orbited the Earth, but about a quarter were inactive. The number of objects in orbit continues to grow rapidly. For example, 2023 alone saw the addition of 2,800 smaller, more advanced satellites. Alongside active spacecraft are an estimated 128 million debris fragments, together weighing over 10,000 tons. Each inactive satellite or stray fragment is a potential high-speed projectile, and collisions risk triggering cascading debris events that could cripple the space-based systems essential to modern life.

The challenge of managing LEO "carrying capacity" is complicated by its patchwork governance: responsibilities are split among national regulators, voluntary industry agreements, and evolving international standards. Without cohesive rules and meaningful enforcement, the probability of large-scale debris creating incidents grows, particularly as human activity expands beyond LEO to the Moon and beyond.

The panel convened engineering, space law, industry, and environmental law experts. Drawing on analogies from terrestrial environmental management, they examined how best to safeguard orbital space as a shared resource through improved data, effective governance models, creative incentives, and forward-looking standards.

4.2 Panel Discussion

- Keith Gremban (Moderator), Co-Director, Spectrum Policy Initiative, Silicon Flatirons Center
- Angel Abbud-Madrid – Director, Space Resources Program, Colorado School of Mines
- Jillian Quigley – Associate, Wiley Rein LLP
- Jonathan Skinner-Thompson – Associate Professor, Colorado Law
- Milo Medin – CEO, Logos Space Services

Building Trust and Capacity Through Data-Driven Traffic Management

Panelists began the discussion by reframing orbital congestion in LEO as data-quality and governance issues rather than a fixed physical limit. Drawing an analogy to transatlantic aviation, which evolved from wide physical safety margins to dense Global Positioning System (GPS)-guided corridors once high-frequency radios and oceanic control developed, panelists argued that precise, universally accessible satellite and debris tracking data could unlock additional orbital LEO capacity.

An improved, high-fidelity Space-Situational Awareness (SSA) system validated by independent radar, optical, and laser-ranging sensors would enable regulators to use this data to designate altitude "lanes," test traffic management algorithms, and simulate slot usage at different launch rates. Such a system could also assess whether satellite designs effectively reduce debris creation. A robust SSA system would allow researchers to determine whether current satellite designs reduce debris creation and flag aging spacecraft at higher risk of fragmentation.

Better data alone is not enough. It must be paired with an effective traffic management structure. The panel then argued for and against operator-led coordination and centralized coordination systems. The U.S.'s shift of civil SSA responsibility from the Department of Defense (DOD) to the Office of Space Commerce (OSC) signals a move toward open, commercially oriented management. Today, collision avoidance largely relies on operators' self-reported ephemeris data, an honor system with uneven participation and quality across nations. Here, each satellite owner is liable for creating its own avoidance maneuvers.

Advocates for operator-led coordination argue that market incentives already discourage reckless behavior, as no company wants to destroy its assets, and insurers raise premiums when collision risk rises. They proposed an open, independently validated catalog to enhance accountability without heavy-handed regulation. Proponents of centralized coordination countered that self-policing falters in crowded orbital shells or when national security exemptions permit the withholding of tracking data. They drew parallels to mixed civil-military airspace, where growing congestion and opacity eventually necessitated neutral air traffic controllers with authority to issue clearances, set right-of-way rules, and resolve conflicts in real time. They warned that the first major accident could trigger a regulatory backlash as harsh and disruptive as post-Crash air safety regimes on Earth without a similar arbiter in orbit.

> ***"The data is only as good as what you are giving it."***
>
> – Jillian Quigley

Both perspectives converge on a central truth: no traffic management model can succeed without universal participation, real-time communication updates, and independently verified positional data. When operators withhold updates or understate position accuracy, everyone else's risk models degrade, and current liability structures allow them to avoid responsibility for avoidance maneuvers, undermining the trust that safe and efficient orbital operations require.

Layered, Incentive-Based Regulatory Frameworks

When debating how to turn improved data into responsible behavior, panelists mapped out three regulatory layers: 1) International multilateral accords to establish baseline duties for registration, liability, and spectrum coordination, while mediating strategic competition among major spacefaring powers; 2) Domestic regulations, including licensing, insurance requirements, and disposal rules, to operationalize treaty commitments and enforce compliance; and 3) Industry-driven customary norms from best-practice design standards to voluntary data sharing, enforceable by commercial contracts. Panelists stressed that the most durable and effective stewardship would braid these layers together, using technology-neutral domestic statutes to backstop international principles and letting commercial self-interest accelerate compliance.

Recognizing that traditional treaties are slow and technology-specific rules quickly stale, the group highlighted alternative models to address the quickly evolving nature of outer space. A flexible framework treaty in the style of the United Nations Convention on the Law of the Sea (UNCLOS) could provide a neutral forum for states, industry, and civil society to hash out these evolving standards. Similar to how the International Maritime Organization (IMO) refines shipping codes under UNCLOS.

Even the best frameworks falter without enforcement teeth. Unlike terrestrial environmental law, where agencies levy fines and order remediation, space has no global equivalent. Existing institutions divide the workload: the ITU allocates spectrum and orbital slots; the United Nations Office for Outer Space Affairs (UNOOSA) maintains the space object registry and studies resource issues through its subcommittee; and the Liability Convention sets post-incident arbitration channels. However, when nations violate norms (such as the widely cited antisatellite test that forced evasive maneuvers on the International Space Station (ISS)), responses remain limited to "name and shame" style diplomacy. To ensure this framework does not become symbolic, panelists advocated for stronger verification tools (e.g., mandatory sensor corroboration of self-reported maneuvers) and clear steps to tangible economic penalties, such as higher insurance premiums.

> ***"Just because there aren't treaties in place or treaty bodies that handle these issues internationally, doesn't mean that there isn't-- there are rules of the road. And so just because it's not written down on paper, that doesn't necessarily mean it doesn't exist in practice."***
>
> – Jillian Quigley

Debris as a Resource: From Orbital Liability to Circular Value

Shifting from governance models to opportunity, the panel spotlighted the economic potential of in-orbit space junk recycling. One-centimeter fragments possess grenade-level energy in orbit, yet the material locked in defunct hardware, such as aluminum and titanium, holds substantial value. Capturing and reusing these materials already in orbit avoids the high costs of launching new materials from Earth. Even with today's early robotic technology, recycling is less expensive than fresh launches.

> ***"Physics has the last vote, but economics has the second-to-last vote."***
>
> – Milo Medin

The discussion on how to utilize this value started with pre-emptive engineering, since the least expensive piece of debris is one never created. Panelists highlight "design-for-disassembly" standards for constructing satellites so their parts stay attached but can be unplugged later instead of snapping off. Engineers also place small satellites in lower orbits and let electric thrusters carry them to their final altitude. This is intentionally done so if something fails early, the craft reenters Earth's atmosphere within months instead of decades, burning up safely rather than contributing to the debris cloud.

However, prevention alone cannot address the estimated 8,000 metric tons of mass already orbiting Earth, so the panel turned to emerging remediation services (clean up and recycling). Several start-up spacecraft can now rendezvous with dead or "zombie satellites." Once these satellites are captured, a small space tug can execute a controlled re-entry (shove the junk into Earth's atmosphere to burn up) or even berth it to an "in-space servicing and manufacturing" company. Panelists also described a closed-loop economy for debris removal that is already happening, starting with debris-removal companies like Astroscale. This self-reinforcing cycle scenario begins with a debris-removal firm's spacecraft delivering captured hardware from a defunct satellite to an on-orbital foundry, which recycles it into wire. A propulsion supplier buys this wire, sinters it into metal propellants, and sells the pellets back to the original debris-removal firm for its next capture mission.

> ***"How do you go from trash to treasure? Debris-to-delta-V is already on the test stand."***
>
> — Angel Abbud-Madrid

Financing this ecosystem benefits from a strict-liability regime. This means that regardless of fault or intent, if a party causes harm, they are liable for the damage caused, and all parties are expected to voluntarily avoid triggering liability in the first place. Panelists proposed an "Orbital Superfund" that would impose strict, no-fault financial responsibility on operators, letting private actors hash out reimbursements later. Mirroring the hazardous waste laws on Earth, this superfund could levy a small fee by weight into a shared pool that pays servicers by the weight of the mass removed or recycled. Because the money would be collected upfront, when a satellite generates revenue, it sidesteps the orphan-asset problem that plagues terrestrial cleanups. Insurers could even offer discount premiums for satellites outfitted with standardized refueling ports, creating a pricing loop that rewards recyclable design.

This hinges on removing remaining legal barriers, such as clear title transfer and liability hand-off rules. Under current international treaties, even one inch of a defunct satellite remains the property of the launching state unless expressly relinquished. This language deters services from touching hardware they do not own and discourages owners from admitting loss lest they incur cleanup costs. Panelists proposed solutions ranging from automatic "abandonment" classifications after prolonged inactivity to adopting maritime-style international salvage laws that hand temporary custody to the company that secures the debris. They also called for a simple online registry where nations can pre-approve their defunct satellite's recovery once they enter a declared disposal mode.

Preparing for the Future of Space Exploration

LEO functions as the on-ramp for every deep-space mission. Any spacecraft headed for GEO, the moon, or Mars and beyond must first pass through LEO's crowded traffic lanes. Panelists warned that if the international community fails to build forward-looking rules soon, today's congestion will migrate outward without clear, future-oriented pathways that cover launch corridors, disposal zones, and post-mission recycling. The group framed governance not as a static rulebook but as a living architecture that anticipates lunar landings, surface operations, and eventual decommissioning questions such as "Where does a lunar satellite go to die?" The urgency is palpable: governments across North America, Europe, and Asia all intend to establish lunar bases within the next decade. Establishing those precedents now, before permanent outposts materialize, was cast as the best way to avoid a replay of LEO's debris spiral on every new celestial step.

> ***"Maybe a lunar landfill is what's required."***
>
> – Milo Medin

4.3 Summary

LEO is a finite, shared resource under mounting strain. Governance remains fragmented across domestic regulators, voluntary industry norms, and evolving international standards, leaving significant enforcement gaps as activity accelerates in LEO and beyond. Panelists reframed the LEO congestion problem as a data and governance problem rather than a physical limitation. Panelists argue that a high-fidelity, independently validated SSA system that pulls from radar, optical, and laser ranging sensors to enable altitude "lanes," real-time traffic management, and better modeling of slot usage and launch rates. They debated operator-led coordination versus centralized control. But, whatever the model, universal participation, timely updates, and independently verified position accuracy are non-negotiable.

The panel outlined a layered regulatory approach. International accords would set baseline duties for registration, liability, and spectrum coordination. Domestic regimes would implement licensing, insurance, and disposal rules. Industry norms and contracts would operationalize best practices. Panelists highlighted flexible frameworks analogous to the maritime system, paired with real verification and consequences for enforcement. Tools like mandatory corroboration of maneuvers and economic penalties (e.g., insurance pricing tied to risk) are needed to increase compliance.

The discussion also recast debris as an economic resource. Design-for-disassembly, low-orbit staging, and early reentry can prevent new junk, while emerging servicing missions can capture defunct hardware for controlled deorbit or in-space recycling. To finance cleanup at scale, panelists floated the idea of an "Orbital Superfund" with strict, no-fault responsibility and small, weight-based fees collected during a satellite's revenue-generating life. Proceeds would pay removers for mass recovered and reward recyclable design through lower insurance premiums. Unlocking this market requires legal fixes, however, such as clear title transfers, liability hand-offs, and practical salvage rules.

Finally, the panel urged anticipatory governance beyond LEO. Today's congestion will otherwise migrate outward. Forward-looking standards should address launch corridors, disposal zones, post-mission recycling, and even end-of-life questions for lunar assets. With multiple nations targeting lunar bases within the next decade, setting these precedents now is the best way to avoid replaying LEO's debris spiral across the rest of the Earth-Moon neighborhood.

5 Day One Afternoon Keynote / Fireside Chat: Adam Cassady

Adam Cassady, Deputy Assistant Secretary of Commerce for Information and Telecommunications, and Deputy Administrator of the NTIA delivered the afternoon keynote.

Cassady's keynote made a compelling case for placing engineering at the center of modern spectrum policy. As commercial activity in space accelerates, he emphasized the need for clear, technically grounded policies that support innovation. Through stories, institutional critiques, and forward-looking proposals, Cassady outlined a path for smarter governance built on engineering fluency.

> ***"We want a world where we can see where interference will happen, before it happens."***
>
> – Adam Cassady

Throughout the keynote and fireside chat, Cassady emphasized his desire to be led by engineering. This captured both his leadership philosophy and his vision for more effective spectrum management.

Technical Leadership for a New Era. Cassady began with a story about visiting a Los Angeles radio station with FCC Commissioner Nathan Simington. He recalled seeing Simington pacing outside, memorizing Fourier transforms. It was a moment that stood out to him and inspired his belief that real policy leadership requires both legal authority and deep technical understanding.

He urged agencies to build teams that include people who understand both engineering and law. Both disciplines are required. Without both in the room, one side will get it wrong.

Making Better Use of NTIA's Technical Assets

Cassady highlighted the value of the Institute for Telecommunication Sciences (ITS), calling it a "world-class lab that people forget exists." He described an incident at the ITS Table Mountain site, where elk were interfering with spectrum equipment. What some viewed as problem, he saw as an opportunity, suggesting that these real-world challenges justify further investment in robust experimental infrastructure.

He emphasized the need for spectrum rules that engineers can model in advance.

Adapting Rules for Today's Space Landscape

> ***"We want rules that are parametrizable, that you can simulate before you launch a $200 million system."***
>
> - Adam Cassady

Cassady argued that today's regulatory frameworks were designed for a different time. They were not built with satellite constellations, asteroid mining, or microgravity manufacturing in mind. "Operators need to know what the rules are ex-ante," he said. In other words, companies need clear, predictable rules before they build or launch anything. Without that, they either overbuild to manage risk or avoid building entirely.

He also pointed to NTIA's support for the FCC's five-year orbital debris rule - a requirement that satellites in LEO be deorbited within five years of mission completion, rather than the decades-long window allowed previously. The rule is intended to reduce the buildup of debris that threatens both commercial and government spacecraft. But Cassady cautioned that standards like these must be grounded in technical reality. Orbital debris standards must be more than words; they need to be something engineers can model.

Leading from a Position of Strength

Cassady delivered a strong message about the United States' responsibility to lead global space policy. "We need to lead the international conversation," he said. "If we don't shape the rules, someone else will." While reaffirming that the U.S. has the world's most dominant space economy, he warned that dominance does not guarantee leadership. Without action, others may take the lead in setting norms.

He also raised concerns about startup companies seeking more favorable environments overseas. "If we make them wait, they're going to leave. They'll fly a flag of convenience somewhere else."

Smarter Policy for Small Space Operators

> ***"We're not trying to deregulate," he said. "We're trying to regulate more intelligently."***
>
> – Adam Cassady

Cassady called for faster and more accessible licensing processes, especially for small and emerging space companies. Current procedures are too slow and unpredictable for rapid innovation. He outlined ongoing NTIA efforts to modernize how applications are submitted and processed, with the eventual goal of enabling AI-supported frequency assignments.

Fireside Chat with David Redl

In his conversation with David Redl, former NTIA Administrator, Cassady expanded on the themes of his keynote and offered candid reflections on the challenges facing spectrum and space policy.

At the center of his approach is a simple principle - be led by engineering. Cassady acknowledged that policy inevitably involves tradeoffs but stressed that technical expertise should define the boundaries of policy. “If we can make the most technically supported policy choice and circumscribe the realm of what’s possible by the engineers, then we are doing our job,” he said.

Regulatory Processes

Cassady also emphasized NTIA’s role in the interagency process, which is sometimes overlooked. While the FCC issues licenses and other agencies safeguard national security equities, NTIA brings an economic lens to spectrum and space policy. Cassady framed NTIA’s job as finding ways to move the American space economy forward while respecting critical federal uses.

When asked about regulatory reform, Cassady pointed to process bottlenecks as the greatest barrier. Pre-coordination with federal agencies, he said, too often means sending emails into the void: “Sometimes there’s no one on the other side of the phone.” These gaps can delay launches, costing startups critical funding opportunities. For him, the solution is not just deregulation but smarter resourcing and collaboration.

Cassady was also careful to stress the balance between efficiency and safeguards. For example, he supported simplifying licensing for multiple ground stations but warned against cuts that erase agency flexibility to assess unique operations. The goal is to move toward parameter-based rules that operators can model, without undermining safety-of-life protections.

An Optimistic, Forward-Looking Approach

Looking to the future, Cassady returned to the theme of the government's role in “pushing from behind.” He encouraged startups and operators to share their real-world stories with policymakers, not just technical proposals. “The most powerful thing you can do is come in and say, ‘You delayed my launch, I missed my window, I didn’t raise my next round. What are you going to do about it?’” he said. Those lived experiences, he argued, should drive reform.

Cassady reaffirmed his optimism about U.S. leadership. While acknowledging bottlenecks, he reminded the audience that the U.S. already has the world's most dominant space economy, supported by unmatched talent and capital. In his view, the challenge is not capability but ensuring that regulatory processes keep pace with industry innovation.

Finally, when asked the classic "magic wand" question, Cassady offered a lighter but telling answer: he would eliminate the mountain of departmental clearance forms that land on his desk each day. The remark drew laughs, but his underlying point was serious; bureaucratic processes, not technology, are often the biggest brake on progress.

6 Topic 3: Navigating the Final Frontier: Contemporary Challenges in Space Governance

6.1 Context

As humanity continues to rapidly expand its presence in outer space, there is more unpredictability and uncertainty when it comes to space governance than ever before. The need for a robust framework to govern actors across the globe has never been greater. But today, no single entity is responsible for implementing and ensuring compliance with new rules in space. The question therefore remains: *Who should regulate, monitor, and enforce rules that govern international activities in space?*

With a fractured system of space governance domestically, the U.S. is struggling to lead by example. In addition, geopolitical tensions often hinder coordination efforts, resulting in decreased transparency and communication.

This panel brought together industry, agency, and academic perspectives to explore the evolving challenges in space governance.

6.2 Panel Discussion

- David Redl (Moderator) - Founder and CEO, Salt Point Strategies
- Jennifer Warren - Vice President, Global Regulatory Affairs & Public Policy, Lockheed Martin
- Lynna McGrath - Depute Associate Administrator, NTIA Office of Spectrum Management
- Daniel Baker - Director, Colorado Space Policy Center

There is an explosive demand for spectrum from terrestrial and satellite users worldwide, both commercial and non-commercial. With no additional spectrum supply, panelists raised concerns about existing means, or lack thereof, to resolve conflicts between federal, commercial, and scientific actors operating in space. Pressure is mounting as the space environment gets crowded and there is no uniform system of governance to guide global and commercial actors engaging in space activities. Panelists gave a chilling perspective on the risks of continuing our current course.

At the core of the panelists' concerns was the growing unease regarding who currently has and who *should* have authority over new space activities. No single international governance model exists. Instead, many non-governmental organizations (NGOs), government bodies, and international forums all contribute in various ways. The Moon Village Association, the Hague Institute of Global Justice, the ITU, the UNOOSA, World Economic Forum, and the Washington Compact are just a few of the international bodies participating and contributing to space governance. Even in the United States, there is no designated agency for emerging uses. A mix of federal agencies have stepped in to fill gaps in governance, like the Federal Aviation Administration (FAA), the FCC, the Department of Commerce (DOC), and the National Oceanic and Atmospheric Administration (NOAA).

There is overlap, contradiction, and inefficiency without a clear representation of where authority resides. Panelists called for a model of governance that can provide certainty and predictability for commercial entities that receive mission authorization. As one panelist said, "We're still sitting here without that clarity. … It would be really helpful for that predictability and certainty for us to be able, as a country, to move forward. But that requires everybody working together: the Hill, executive branch, and industry."

The Puzzle of U.S. Space Governance

> ***"The only way to win a race is to run faster than the competition. And I fear we're running slower and slower instead of running faster."***
>
> *– Daniel Baker*

The U.S. has 16 different venues for space and spectrum regulation. Voices from within the federal government echo industry concerns about the lack of direction coming from Congress and the executive branch. The responsibility of tracking and coordinating existing space systems, for example, has recently been taken over by the OSC within NOAA. But even when important progress is being made to improve one aspect of the governance puzzle, those working on system improvements face the risk of developing and enforcing rules that contradict another federal agency, leading to costly litigation. Overall, the panel called for the U.S. to be a leader in norm creation and operate with a more strategic approach to space governance. The NTIA Office of Spectrum Management (OSM)_is currently working on fixing the satellite coordination process to create a more efficient system. The first step is to figure out how to do so without clear direction.

International Cooperation

The United States is not alone in producing next-generation satellite operators. Space is an international venue, and many countries are contributing to the boom in satellite proliferation. A neutral forum is needed to accomplish the goals associated with space traffic management efforts and satellite tracking. Many of the governmental bodies attempting to fill gaps in governance are U.S. agencies. Global distrust in US-based systems continues to add complexity to globalizing a space governance model. A key question for decades has been how to develop a global uniform system of governance.

Space Traffic Management and Debris Mitigation

Panelists warned of the dangers associated with continued underdevelopment and underinvestment in space traffic management and debris mitigation systems. As unchecked satellite launches can result in overcrowding and catastrophic collisions, the development of a system to manage traffic concerns everyone acting in the space domain. Without global coordination on ephemeris data sharing, experts warn that catastrophic results are bound to follow.

> ***"We're one major catastrophe away from making things really, really bad. … There's so many things lurking in space that can't move, that can't get out of the way. I think there's a real danger lurking here. … Somebody's got to step up and take leadership."***
>
> *– Daniel Baker*

Researchers warn that systems promoting sustainability are developing too slowly to keep up with an exponentially increasing source function. A panelist shared the opinion that only governmental actors can increase the pace of development in sustainability solutions. However, cuts in funding and personnel are diminishing the ability of federal agencies to act.

In-space Servicing, Assembly, and Manufacturing (ISAM)

Existing licensing regimes have not adapted to suit new in-space activities like orbital refueling and satellite servicing. Commercial actors, including Lockheed Martin, advocate for the FCC's adoption of an activity-based authorization model for ISAM systems, rather than a customer-based model. ISAM systems are also currently under FCC supervision, despite lacking designation as the appropriate authority.

> ***"So, what happens when someone decides, 'Yeah, I'm going to go blow up somebody else's satellite because they're using that for surveillance?' Now what?"***
>
> – Lynna McGrath

War in Space

Geopolitical tensions are not just creating unease about a nonexistent governance model. Panelists could not ignore the fact that space is now a war-fighting domain. Deployment of commercial satellites with offensive and defensive capabilities presents a plethora of concerns for industry, academic, and government experts.

Further complicating this issue is the crossover of the commercial space industry heavily leveraged into the national security industry. When commercial satellites become a warfighting target, the fog of war will completely unravel governance efforts.

Making Space Safer: Connecting Operators

Although matters look especially grim for international cooperation, there are other ways commercial operators can step up and work together to create a safer and more stable space environment. One panelist flagged an idea that has been raised in other forums: developing a contact list for satellite operators. Something as simple as a contact list for satellite operators to create familiarity with one another, leading to the development of long-standing connections that can withstand change is a way for operators to work together to create safer operating and investment conditions for all.

Lunar & Cislunar Spectrum Governance

Governance of the lunar surface and spectrum is quickly becoming an urgent concern. Today, many countries, such as China, India, and Japan, are working on lunar landers. Although we are observing a race to the moon, one panelist pointed out that these countries work surprisingly well together, including the U.S. and Russia. Many of the world's space agencies convene as part of the Space Frequency Coordination Group (SFCG). WRC-27 Agenda Item 1.15 attempts to address the necessary requirements for lunar spectrum and lunar spectrum communications. Within the ITU, there are active conversations about the addition of lunar as an ITU Region 4. Many question whether the ITU should take this step.

As more private companies get involved, we are witnessing a significant change in how lunar spectrum governance is approached. A panelist with first-hand experience shared that companies trying to operate in the lunar ecosystem are creating an "interesting confusion" for spectrum conflict. Companies are actively trying to move terrestrial mobile technology to the lunar surface but maintain operations in the frequency bands optimized for Earth. One panelist argued that lunar and cislunar operations may have the potential to alleviate some of the existing spectrum wars. But, as another panelist commented, spectrum conflicts have already existed on Mars.

> ***"It's not when the first country lands on the moon, it's when the second one gets there that we're going to have problems."***
>
> – Lynna McGrath

The growth of commercial lunar activities continues to raise important questions about spectrum coexistence and the appropriate framework to govern lunar and cislunar operations globally.

Role of Passive Users

Passive users cannot be left out of consideration when developing a spectrum governance framework. Many crucial scientific measurements, like data used for weather forecasting, are derived from passive sensing. Today, passive sensing bands are under tremendous pressure as efforts continue to maximize the use of spectrum bands. For example, as of June 2025, a current FCC proceeding is considering putting terrestrial space services in an existing passive sensing band. However, the risks of degrading crucial public services due to insidious interference should not be minimized. If data for services like weather forecasting begins to degrade, the impact will be felt by all.

Unlike other frequency bands, existing passive sensing bands are not auctioned and not sold off for commercial services. These citizen services have no subscription cost, but services every individual on the planet. Panelists highlighted the challenge of not having an economic valuation on the types of citizen services that require passive sensing.

> ***"Passive users don't have a champion. or at least not a champion that is economically viable, or as loud or as well-heeled as other spectrum users … and until passive users find a way to make a better case for their uses as economic engines, they're going to suffer from the same deficit in advocacy."***
>
> – David Redl

Panelists cautioned that coordination between scientific needs and the allocation of commercial spectrum is essential to protecting the valuable passive uses of spectrum that impact our daily lives. Unfortunately, the public is often ill-informed of how vital space services are to everyday life. Improved advocacy and communication are necessary to make these vital services more "visible" to passive users.

6.3 Summary

Space governance is fractured, reactive, and lagging behind innovation. Commercial and government actors seek clarity, predictability, and efficiency in the rules that govern space operations.

The biggest challenge in moving towards a strong framework for global space governance is identifying the appropriate supervisory authority. Although domestic space agencies have banded together to make progress in particular areas of space governance, inconsistent rulemaking authorities can have negative consequences.

To develop a strong framework for space governance, the conversation must begin with identifying who should be responsible. Communication and coordination between commercial entities and intergovernmental organizations working towards shared governance goals must improve. International coordination is essential for a strong framework.

In the U.S., the 16 entities that play a role in space and spectrum governance must operate under more direction from both the legislative and executive branches for greater efficiency.

Commercial operations in space are expanding to include lunar and cislunar surface and spectrum. Some argue that the use of lunar spectrum will alleviate spectrum conflicts arising from competing terrestrial uses. Others argue that conflict is inevitable, given spectrum conflicts have even occurred on Mars.

To complicate matters, space is also a warfighting domain. Experts are warning of the negative consequences that will occur if space transitions from commerce to conflict.

Passive users and scientific interests risk being drowned out without stronger advocacy. Valuable public services, like radio astronomy and weather forecasting, are seriously threatened by efforts to reallocate passive sensing frequency bands for other commercial uses. Insidious impacts on scientific data derived from these passive sensing bands will affect everyone.

It is crucial to develop a strong governance framework before a major catastrophe forces a regulatory catch-up.

7 Topic 4: Historical Lessons for Governing the Final Frontier

7.1 Context

Outer Space may evoke images of limitless potential, but its lack of regulation is all too familiar. U.S. history demonstrates that initial standards, incentives, and governance decisions - more than technological advancements - influenced each wave of expansion. Panelists suggested that LEO's complexities resemble the path-dependent challenges seen during the railroad expansion that united the continent and when early broadcasting filled the airwaves. Early choices about spectrum sharing, traffic control, and infrastructure "commons" will determine who holds power, access, and market dominance for many years.

The stakes are only escalating. Increasing launch frequencies and large satellite constellations are intensifying physical and spectral constraints, while private entities are claiming orbital space faster than regulations can adapt. The panel argued that without proactive management, the current patchwork of temporary licenses and bilateral agreements risks repeating issues like duplication, interference, and expensive retrofits that affected previous terrestrial networks. If we learned anything from our past, we should act before legal disputes or actual collisions compel urgent fixes.

Panelists advocated adaptable, technology-neutral rules rooted in transparent allocation and safety standards. This approach aims to preserve competition while avoiding a destructive race in which no party benefits. The discussion sought to explore how to incorporate historical lessons into current rule-making, how stakeholders can balance innovation with interoperability and competition with collaboration, and how to ensure that this arena does not repeat some of humanity's greatest mistakes.

7.2 Panel Discussion

- JP de Vries (Moderator) – Director Emeritus & Distinguished Advisor, Silicon Flatirons
- Suraj Jog – Senior Research Scientist, Microsoft
- Carolyn Kahn – Distinguished Chief Spectrum Economist, MITRE
- Patty Limerick – Professor of History of the American West, CU Boulder

- Jennifer A. Manner – Senior VP, Regulatory Affairs and International Strategy, AST Space Mobile

Moving Beyond the "Last Frontier" Metaphor

Panelists cautioned against the reflexive habit of calling outer space the boundless "last frontier" or the "wild west." They argued that using frontier imagery in this context can obscure the hard-wired inequities that followed the Transcontinental Railroad boom. In the 19th-century United States, early infrastructure decisions fixed control of rail line profits, land, and labor in ways that persisted for generations. This speedy nation-building infrastructure was only possible due to the mass corruption, environmental damage, and blatant disregard for human lives, especially for indigenous peoples. Echoing this lesson, the panelists stressed that today's orbital policies will determine the long-term winners and losers that could entrench or correct power imbalances for generations.

> ***"Applied history is an anti-inevitability delivery system."***
>
> – Patty Limerick

The language used to discuss issues shapes the policies drafted about them. Panelists argued that similar path-dependencies will likely form around orbital "corridors" if equity, labor protections, and environmental safeguards are not embedded into these policies. The Law of the Sea and the post-war Chicago Convention on air-traffic coordination were offered as counterexamples where international norms matured early enough to channel competition into broadly accepted practices. That historical framing set the stage for a deeper dive into scarcity.

Managing Scarcity

> ***"Orbital slots are scarce. Some are better than others…Spectrum is scarce in bands where the physics lines up with space needs."***
>
> – Carolyn Kahn

Panelists agreed that space already has multiple, physics-defined bottlenecks. GEO slots, where a satellite can hover over a constant point on Earth, are finite, and some confer better coverage than others. Even launch windows and employee space aboard crewed stations have hard ceilings. Spectrum is limited to bands for which atmospheric attenuation and antenna size match mission needs. The panel noted that how spectrum resources should be prioritized differs significantly by country based on the robustness of their space economy.

Across these sectors, the theme is consistent - holders of scarce orbital real estate are required to prove they are putting it to productive use. On the ground, terrestrial wireless operators compete for exclusive licenses from the FCC at auction and can later trade or subdivide them in secondary markets. On the other hand, Satellite operators must post milestone bonds anytime they apply for a new constellation. If they go past their deadlines, they forfeit multi-million dollar guarantees. At the international level, orbital slot fillings move through a first-come, first-served queue at the ITU. Still, the right to a slot expires after seven years, allowing dormant paperwork to clear out before it jams busy longitudes.

Predictable, incentive-based systems can keep congestion below a crisis point. Once scarcity is acknowledged, the next challenge is designing governance that can evolve with technology rather than freeze it.

Governance and Incentives for Cooperation

Past catastrophes show that safety often unlocks coordination faster than lofty ideals. For example, after radio interference hampered distress calls from the Titanic, nations formed the ITU to standardize emergency channels. Today, every close approach that threatens damage to the ISS reminds governments that unmanaged debris endangers lives and multi-billion-dollar assets. Political pressure inside the ITU, where member states vet filings for satellites that could interfere with neighbors, already persuades people to follow norms. Yet the panel agreed that broader sustainability questions outstrip the ITU's narrow spectrum mandate.

> ***"Why not embrace the interference? Instead of slicing spectrum, let devices collide and separate signals with smarter processing."***
>
> – Suraj Jog

> ***"Even more important than treaties…you have got to have best practices, and they have to be technology-neutral."***
>
> – Jennifer Manner

The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) offers a wider forum, but its government-only structure limits private-sector expertise. Interim mechanisms are filling the gap. For example, the Artemis Accords outline voluntary norms for lunar exploration, and industry associations' public debris-mitigation handbooks to pre-empt heavier regulation. Panelists framed these efforts as "best practices" and cited historical analogies when best practices have also helped in resource management. Key examples cited included how the Law of the Sea helped to curb over-fishing, and air traffic norms which encouraged conflict avoidance/responsible behavior due to the Chicago Convention. In conclusion, until a comprehensive treaty becomes politically feasible, relying on technology-neutral best practices is the best way to keep commerce moving.

Engineering Paths to Expanded Capacity

Beyond governance, engineers on the panel suggest reframing spectrum scarcity altogether. Technological innovation can stretch finite resources if regulators allow for novel approaches. One panelist described dynamic spectrum sharing. Instead of dividing bands into exclusive allocations, multiple signals are transmitted simultaneously and separated later with advanced decoding. This concept builds on earlier terrestrial experiments such as TV whitespaces (reusing vacant broadcast channels in rural areas) and Citizens Broadband Radio Service (CBRS), a coordinated sharing system in the 3.5 GHz band.

In the satellite context, spatial diversity adds leverage. A single satellite footprint spans thousands of kilometers, so ground stations in different locations receive different mixes of interfering signals that can be recombined to recover each user's data. Embracing interference in this way shifts complexity from legal coordination to signal processing hardware, but it demands certification regimes nimble enough to approve unfamiliar designs.

Technologies are necessary for innovation, however, their expenses do not always justify their cost. The panel argued that it is important to weigh engineering ambition against long-term cost and financing strategies and prioritize plans for funding technology development and implementation.

Ethics, Public Legitimacy and Stewardship

Although physics sets hard limits and economics may rank priorities, panelists emphasized that ethics determines who benefits from the resource allocation decisions. However, historically, ethical considerations are mostly overlooked. Audience members asked the panelists for a clearer rank in where ethics falls in decision-making hierarchies. The panelists responded that every profession has a share of responsibility for ethical decision-making. Technologists must disclose risks honestly, economists must weigh equity alongside efficiency, and historians must keep society alert to unintended consequences.

Additionally, communication and knowledge campaigns to the general public are essential. Many consumers rely daily on satellite navigation (GPS) without realizing how the infrastructure is made and who is impacted by lack of resource availability. Greater visibility could build political support for sustainable practices in the same way Progressive-era industrialists once embraced regulation to restore public trust.

Ultimately the panel cast ethical review as a design specification, rather than a separate layer. Licensing conditions that require debris-minimization plans, data-sharing for collision warnings, and respect for scientific observation windows transform moral aspirations into enforceable obligations.

7.3 Summary

History informs us that the early frameworks that manage scarce resources, whether land grants, shipping lanes, or radio channels, shape markets and ecosystems for decades. The panel therefore urged spacefaring nations and companies to move simultaneously on three fronts: include scarcity-aware incentives into licensing regimes; institutionalize best-practices that can mature into formal law and treat ethical stewardship as an integral part of the systems architecture. The panel concluded that coordinated early action is the most effective means to maintain orbital spaces as open, competitive, and scientifically valuable as humanity's footprint continues to expand.

8 Day Two Keynote: David Goldman

Day Two began with a keynote speech delivered by David Goldman, Vice President of Satellite Policy for Space X. Drawing on his extensive experience working with the federal government, including as a key policy advisor with the FCC, Goldman focused on the growing mismatch between historically low-barriers of entry in cost and technology and the existing high-barriers of entry of the existing regulatory scheme, specifically in licensing. Goldman stressed that rapidly advancing space technology serves a substantial public interest and small innovators should not be disproportionately impacted by existing licensing requirements that are often inconsistent, unpredictable, and present high late-stage costs.

Starlink Helping Underserved Communities Come Online

Starlink operates a LEO satellite constellation that provides high-speed, low-latency broadband to over 6 million customers across 140+ countries. Roughly one-third of the world remains without access to the internet and is disproportionately located within Africa and Southeast Asia. Starlink is actively expanding into these regions where traditional broadband infrastructure is limited or nonexistent.

From operations in space to on the ground, Goldman shared how operating the world's most advanced satellite constellation directly benefits communities across 140+ countries. This advanced technology is being used to address social, health, and environmental issues across the world.

Example #1: Improving the Disproportionately Low-Survival Rate of Cancer in Southeast Asia Compared to 80% in the U.S.

First, David shared a story of Starlink terminals being used to improve the low-survival rate of cancer in the Philippines. The Polaris Dawn crew traveled to the Philippines with Starlink terminals to raise awareness of childhood cancer for St. Jude's Children's Research Hospital. The crew brought Starlink terminals to rural medical clinics across the country hundreds of miles from the central hospital in Manila. By supplying rural clinics with terminals, doctors were not only able to reach the central hospital in Manila, but anywhere in the world. With access to new technology, diagnosis and treatment speeds can increase, helping to improve the low-survival rate of children with cancer in underserved areas.

Example #2 & 3: Emergency Connectivity During the LA Wildfires & Power Outages in Spain and Portugal.

Then, David pointed to a recent example where Starlink terminals provided essential connectivity to those who had lost access due to natural disasters. In January of 2025 when devastating wildfires tore through communities in Los Angeles, California, 1,350+ user terminal kits were sent to Los Angeles to help public safety mobilize when the traditional connectivity infrastructure was unexpectedly damaged. The kits provided free high-speed internet and direct-to-cell services, allowing first responders to coordinate efforts despite downed cell towers, residents to locate missing loved ones and organizations to deliver aid to those who needed it most.

Similarly, Starlink terminals provided emergency internet access during blackouts in Spain and Portugal that left 50 million people without connectivity or communications for over 10 hours. Over those 10 hours, Starlink usage surged by 35% because it never went dark.

Example #4: Public use benefits in Kenya: Stories from the Kenyan Parks Department & surrounding villages.

> ***"[SpaceX] may be the first to do a lot of this, but we really got to make sure we're not the last and only."***
>
> – David Goldman

Goldman's final example was from an impactful trip he took to Kenya, where he spoke with the President and Head of the Parks Department about utilizing new technology. In Kenya, the proliferation of cutting-edge Starlink terminals within the country is helping government officials meet their goal of getting government services online while serving a great public benefit to communities and wildlife. By attaching Starlink terminals to cameras in national parks, officials can now proactively track down wildlife poachers. National Park access was also greatly improved, and park revenue was boosted 10x by enabling park entrances to accept cashless payment from entrants. All the while surrounding villages could access free broadband due to park terminals staying online 24/7.

Barriers to Entry

Goldman next focused on the disconnect between the low-barriers of entry in cost and technology and the high-barriers of entry created by the existing regulatory scheme. In 2025, access to space is cheaper than ever before. With launches at a record high and continuing to grow each year, innovation in existing technology creates more abilities to get to space. Goldman expressed the opinion that regulations are the bottleneck. In his opinion, existing regulations stand in the way of being able to take advantage of the low barriers of entry to encourage innovation.

Today, there are significant regulatory delays that affect small players, like startups, the most.

Theoretical Case Study: BUFFSAT

To illustrate existing regulatory barriers, Goldman presented a theoretical case study of a fictional space startup created by University of Colorado students called BUFFSAT.

He based this case study on real SpaceX launch customers that are often on SpaceX rideshares, like one transporter launched only a few days prior with 70 different satellites on-board.

Ridesharing is a key example of one-way space is *more* accessible than ever before. For real start-ups like "BUFFSAT," SpaceX rideshares allow smaller satellite operators to launch in a way that lowers the cost for everyone. Goldman estimated that BUFFSAT's total launch fee would be around $2 million for a spot on a rideshare for a small operator. On the other hand, Goldman estimates licensing fees for a BUFFSAT system without propulsion would cost around $2,250,000 over five years of a passive deorbit. If BUFFSAT filed for a license with the FCC in June 2025, based on historical FCC processing times, BUFFSAT likely would not receive funding until September 2027.

> ***"It shouldn't cost more to get your license than it costs to launch."***
>
> – David Goldman

Ultimately, the problem with existing regulations is that, in Goldman's opinion, it is currently easier to get something into space than it is to attain the license to operate it.

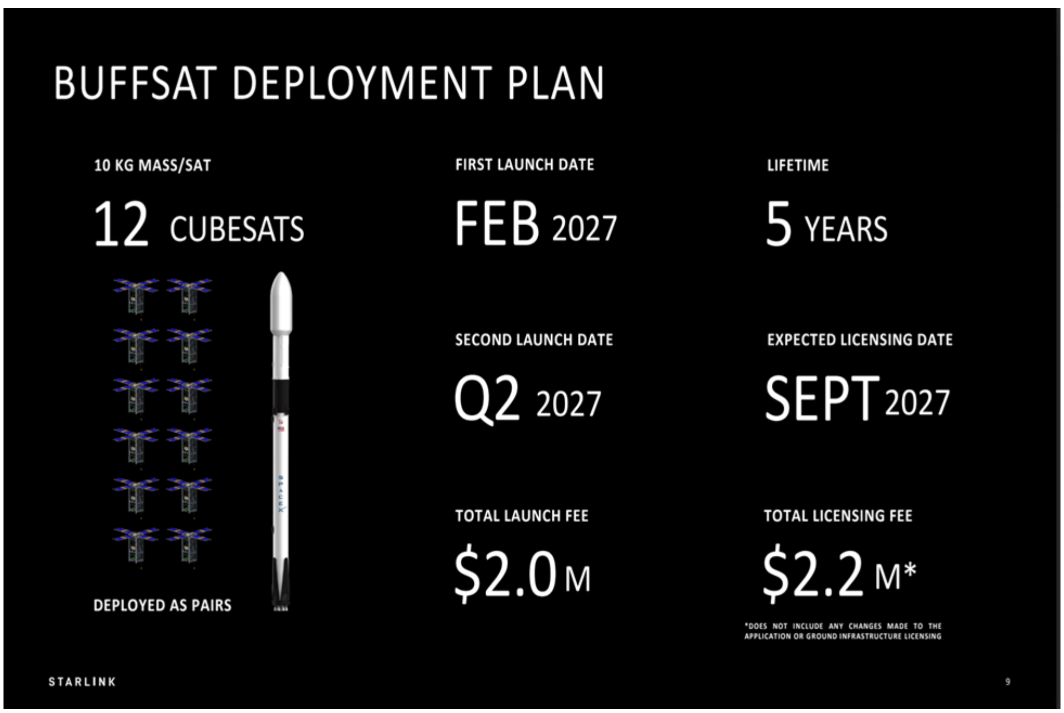

Figure 1: The deployment plan for a hypothetical BUFFSAT systems shows that licensing costs more and takes more time than building and launching.

Shortfalls of the Existing Licensing Regime: Favoring Large Players, Blocking Small Players

The FCC's habit of issuing long, unpredictable license conditions late in the process makes it nearly impossible for engineers to plan technical specifications for launch with certainty. As Goldman pointed out, by the time a license is received, the operator has already developed, built, and shipped satellites to the launch site. Given the time it takes to obtain a license, unpredictable conditions can present significant late-stage costs to small players relying on investor funding. According to an analysis performed by SpaceX legal counsel, licensing terms and conditions are highly unpredictable, rather than standard boilerplate. For instance, Goldman shared that a side-by-side license comparison revealed that some large satellite constellations did not receive the same space sustainability conditions as smaller satellite constellations.

Goldman used an image to illustrate the long and unpredictable FCC licensing conditions. and the 12-page license contained 26 lettered sections of conditions, from A to JJJJ. The last condition on the license imported all conditions from all licenses previously issued to SpaceX.

He emphasized this system favors large companies, like SpaceX, that can afford the legal burden of sorting through the licensing process, including understanding the attached set of conditions for a given license. This excludes small innovators, like the example startup, BUFFSAT.

Recommendations Going Forward

Goldman presented possible solutions to regulatory reform to encourage innovation on the ground and match the lower barriers of entry in cost and technology.

Standardization

First, regulations should be more standardized for improved clarity and predictability. Instead of surprising conditions in the late stages of launch preparation, state requirements upfront so engineers can design accordingly. Standardizing regulations would eliminate the massive inefficiency caused when engineers guess which rules they are working with when designing. At a minimum, this should apply to the initial rules actors encounter when applying for a license. It should be presumed that applicants who are consistently meeting the FCC's initial standardized requirements are in the public interest.

Ground Stations

Currently, ground stations are individually licensed. The FCC runs individual interference checks on each system, despite the risk of interference being minimal. This creates unnecessary burdens for the FCC. Goldman proposed a light-touch licensing model for ground stations by creating a simple database that provides users with spatial awareness in proximity to other ground systems. Doing so will drastically accelerate long processing times.

Sunsetting Outdated Incumbent Protections

Existing rules were designed to protect initial investments by incumbent users. However, these protections should be reviewed to promote spectrum sharing, reuse, and space for new entrants. SpaceX even suggested sunsetting the Starlink Gen. 1 initial protections to encourage a level-playing field.

Streamline Payload and Gateway Licensing Processes

Many existing rules push operators to develop their own independent systems, from top to bottom. First, the application process for payloads should be streamlined. This would reduce the traffic from independent satellites launching into orbit and encourage infrastructure sharing.

Improve Communication on Space Sustainability

Finally, addressing space sustainability can be addressed by working on communication. Transparency in satellite location and behavior improves coordination between operators and helps avoid collisions. In a universe with no clear and uniform space rules, communication is in the best interest of operators. Regardless, Goldman stressed the need for uniform, clear space traffic rules.

A Final Word to the Next Generation

David Goldman concluded with a call to action for students and the next generation of policy makers. Goldman urged students to continue challenging outdated assumptions in space policy and to tell him why he is wrong. He encouraged students to question whether we are doing the right thing and continue to ask if there is a better way things could be done.

> ***"100% of the time, there is some way to do it better. And we should be looking for those ways."***
>
> – David Goldman

9 Topic 5: Dark and Quiet Skies

9.1 Context

The night sky has inspired humanity for millennia as a source of scientific discovery, navigation, cultural storytelling, and spiritual reflection. In recent decades, however, it has become an increasingly contested and vulnerable resource. The rapid expansion of commercial satellite constellations such as SpaceX's Starlink and OneWeb promises global broadband coverage but also introduces new pressures to both optical and radio astronomy.

Astronomy depends on detecting extremely faint signals from distant cosmic sources. In optical astronomy, satellites can reflect sunlight into telescopes, creating bright streaks that ruin long-exposure images. In radio astronomy, satellites transmit in or near bands used for scientific observation. These signals can interfere with the ultra-sensitive receivers needed to detect natural emissions from distant galaxies, pulsars, and interstellar gas clouds.

The importance of preserving dark and quiet skies extends far beyond science. Many Indigenous, rural, and underserved communities hold the night sky as a vital part of their cultural identity and knowledge systems. For these communities, the sky is a shared heritage and a living connection to history, navigation, and storytelling.

Regulatory frameworks have not kept pace with the scale and speed of satellite deployments. In the U.S., the FCC licenses satellite communications, while the National Science Foundation (NSF) and other agencies work to protect scientific access to the spectrum. Internationally, the ITU coordinates frequency use, and COPUOS sets broad principles for space activities. However, none of these bodies currently offers comprehensive protections for dark and quiet skies in the era of "mega constellations."

The challenge before the international community is clear: how to balance the benefits of satellite-enabled connectivity with the preservation of an irreplaceable scientific and cultural resource. As the following panel discussion reveals, solutions will require coordinated action across technology, economics, regulation, and public engagement.

Figure 2: Mt John Observatory above Lake Tekapo. photograph, Lake Tekapo, New Zealand. Apse, J. (2023).

9.2 Panel Discussion

- Chris Anderson (Moderator), Theory Division Manager, Institute for Telecommunication Sciences
- Ashley VanderLey, Astronomer, American Astronomical Society (AAS)
- Jessica Kaim, Adjunct Research Fellow, University of Southern Queensland
- Kelsey Johnson, Associate Dean and Professor of Astronomy, University of Virginia
- Zack Donohew, Assistant Teaching Professor, University of Colorado Boulder
- Paul Kolodzy, Technical Fellow, Payload Engineering, Logos Space Systems

The panel brought together scientists, engineers, economists, and policy experts to examine the challenge of safeguarding the night sky while enabling the growth of satellite-enabled services. The conversation moved across scientific, cultural, economic, engineering, and regulatory dimensions.

Scientific Threats from Satellite Constellations

Optical Astronomy Impacts

Large-scale satellite constellations create unprecedented challenges for ground-based observatories. In optical astronomy, satellites can reflect sunlight, leaving bright streaks across astronomical images that astronomers must remove from their data. A few streaks here and there is not a new issue. Astronomers have long removed occasional streaks from their data, but thousands of satellites in view every night represent a dramatic shift in scale.

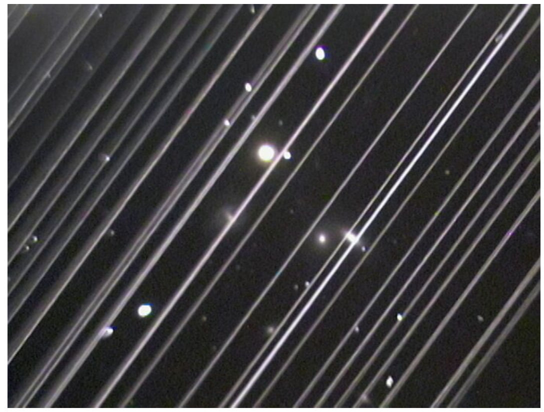

Figure 3: Lowell Observatory image of NGC 5353/4 galaxy interrupted by streaks created by Starlink Satellites

Instruments like the Vera C. Rubin Observatory, designed to capture wide-field, time-sensitive images for asteroid detection and other survey science, are especially vulnerable. A single bright satellite can saturate the world's largest astronomical camera, ruining an entire 15-second exposure. While streak-removal algorithms remain useful, they cannot compensate for images compromised by overly bright reflections.

Panelists emphasized that dimming satellites below a certain brightness threshold, originally thought to be around magnitude 7 (barely visible to the human eye) but now closer to magnitude 6–6.5, is critical. Achieving this goal requires collaboration with satellite operators to modify surface materials, orientations, or shielding to reduce reflections without compromising spacecraft performance.

Radio Astronomy Challenges

Radio astronomy faces a similar, equally complex challenge. Sensitive radio telescopes detect extremely faint cosmic signals, often billions of times weaker than those from terrestrial transmitters. As Chris Anderson explained, instruments like the Very Large Array can detect signals on the order of –300 dBm, which is so sensitive that it could, in principle, detect a cell phone on Pluto. This level of sensitivity means that even very low-power satellite transmissions, especially in bands near protected frequencies, can cause harmful interference. Passive scientific bands near 24 GHz, for example, are critical for measuring atmospheric water vapor and for maintaining global reference frames used in GPS. Disruption to these observations could affect weather forecasting, navigation, and timing systems.

> ***"The need for real-time, proactive cooperation is no longer optional. It is essential."***
>
> – Ashley Vandeley

One promising mitigation is the Operational Data Sharing System, now implemented between the NSF and operators like SpaceX. This system uses precise telescope schedules and satellite position data to coordinate "boresight avoidance." In practice, satellites momentarily cease or redirect transmissions when a telescope's line of sight intersects the satellite beam. Hundreds of such maneuvers occur weekly, protecting scientific observations without disrupting satellite service.

Cultural, Ethical, and Community Dimensions

Panelists stressed that dark and quiet skies are not only a scientific concern. They are also cultural, spiritual, and communal assets. Many Indigenous communities view the night sky as integral to knowledge systems, ceremonies, and storytelling. Yet these communities are often excluded from decision-making about satellite deployments that may alter that sky. Dark and quiet skies are part of a common cultural heritage, just like historic landmarks. Once they are gone, they are gone for good. This framing underscores the stakes - while technology can sometimes restore damaged ecosystems or repair infrastructure, there is no realistic way to restore an unspoiled night sky once it is lost. Once lost, it is gone for good.

> ***"We are watching the sky disappear before our eyes, and with it, a part of our humanity."***
>
> – Kelsey Johnson

Satellite-based broadband can bring important benefits to rural and indigenous communities, by providing essential services like telehealth, online education, and connectivity. However, panelists stressed that collaboration and consultation with community leaders on deploying these services must be central to an equitable approach. Respect for sovereignty and relationship-building must be central to any equitable approach. Panelists encouraged the community to move beyond inherited frameworks of entitlement, such as the colonial-era "Doctrine of Discovery," that implicitly justify resource claims based on who arrives first. Since profit doesn't always reflect the true value of what is owned, emphasizing respect for sovereignty and building relationships with these communities when developing solutions is crucial for fostering positive and sustainable change.

Economic Framing of Externalities

Panelists framed impacts as a classic case of externalities and market failure. Private actors gain from satellite services, while costs such as lost research quality, diminished cultural value, and increased atmospheric pollutants are borne by the public. Without clear property rights to the night sky, early users such as astronomers lack legal standing to demand compensation for these losses.

While acknowledging that not all values can be priced, panelists suggested gathering as much data as possible for quantifying harms. For example, dark-sky tourism in the U.S. Colorado Plateau generates an estimated $2.5 billion annually. Such valuations can inform policies like harm taxes, operator bonds, or mitigation rebates.

> ***"We do not have to put a price on the stars, but we do need to quantify the harm."***
>
> – Zack Donohew

Engineering Solutions and Systems Thinking

Other panelists reframed the challenge as one of entropy, the disorder created by random emissions, uncoordinated maneuvers, and uncontrolled debris. Reducing randomness across systems can make mitigation more predictable and effective. One panelist proposed technical measures such as: 1) Optical: Favor specular (mirror-like) reflectors over diffuse ones, so reflections occur in predictable directions rather than scattering broadly; 2) Radio: Use tighter beam control to limit stray emissions and reduce interference risk; and 3) Constellation management: Coordinate orbits, timing, and pointing behaviors to reduce unpredictability and allow for shared mitigation strategies.

Panelists stressed that incentives, whether regulatory, market-based, or collaborative, are essential to drive industry adoption of such practices.

Policy, Regulation, and Global Coordination

Several panelists argued that regulation lags far behind deployment. Current regulatory frameworks are reactive, rather than predictive, and lack the incentives necessary to increase the adoption of new practices. Dynamic coordination systems and life-cycle environmental assessments are rare, and most mitigation measures are voluntary. Without market-based or collaborative incentives, the likelihood of widespread adoption of these practices is slim.

However, forums are emerging to discuss tangible plans for action. COPUOS has launched a five-year agenda on dark and quiet skies, led by Chile and Spain. Meanwhile, in the U.S., early-stage legislation seeks to establish centers of excellence to that will evaluate satellite impacts and develop strategies to mitigate them.

> ***"We are using tools from a different era to manage tomorrow's challenges."***
>
> – Jessica Kaim

Life-cycle thinking was another recurring theme. Panelists raised concerns about the reentry of thousands of satellites, potentially releasing hundreds of tons of aluminum vapor into the upper atmosphere each year – orders of magnitude more than natural meteorite deposition. While the effects are not yet well understood, they could alter atmospheric chemistry and climate processes. Even seemingly benign exhaust products like water vapor can have unexpected impacts when released into upper atmospheric layers.

Public Engagement and Awareness

The panel agreed that public engagement is critical, yet challenging. The majority of people, 83 percent in the U.S., live in urban areas where light pollution hides most stars. However, the panel agreed that public engagement is critical, yet challenging. Some suggested first-hand experiences, such as visits to dark-sky parks, can help rekindle this lost connection. In contrast, others advocated for storytelling to connect the night sky to everyday life, culture, and heritage. Others noted that even simulated night skies in a planetarium can inspire awe and spark interest in science.

Some panelists suggested a publicity campaign to increase the public's knowledge of how these bright night skies impact their everyday lives, framing the issue through relatable adverse impacts, such as degraded hurricane forecasts or higher insurance costs from less accurate Earth

> ***"Let us tell a better story, one that includes everyone and everything the sky touches."***
>
> – Zach Donohew

observation data. Others advocated storytelling that connects the sky to everyday life, culture, and heritage.

Policy Implications and Path Forward

Panelists converged on the idea that sustaining dark and quiet skies will require action on multiple fronts: 1) Technical: Implement and standardize dynamic coordination, brightness reduction, and tighter emission controls; 2) Economic: Internalize externalities through market mechanisms, valuation studies, and shared mitigation funds; 3) Cultural: Engage communities, including Indigenous nations, as equal partners in shaping space policy; 4) Regulatory: Shift toward predictive, life-cycle-based frameworks and strengthen global coordination; and 5) Educational: Expand public awareness and access to dark-sky experiences.

The discussion underscored that this is not a choice between scientific integrity and commercial growth. With sustained collaboration, innovation, and governance reform, it is possible to preserve the shared heritage of the night sky while enabling the benefits of space-based services.

9.3 Summary

The panel on Dark and Quiet Skies brought together scientists, engineers, economists, and policy experts to address a rapidly growing challenge: how to safeguard the night sky as a shared scientific, cultural, and environmental resource while allowing the expansion of satellite-enabled services that support global connectivity and innovation.

Panelists emphasized that the issue is no longer confined to the astronomy community. While the number and scale of satellite constellations now present a direct risk to both optical and radio astronomy, satellites can disrupt deep-space observations and degrade the precision of critical measurements such as global reference frames, GPS accuracy, and Earth observation data for climate science.

The discussion made clear that the value of dark and quiet skies extends far beyond research. Indigenous, rural, and underserved communities have cultural, navigational, and storytelling traditions deeply rooted in the stars. These communities often lack a voice in space policy discussions yet bear a disproportionate share of the cultural and environmental costs when the night sky is altered. Several speakers argued that protecting the sky should be understood as an act of equity, respect, and stewardship, with meaningful participation from those most affected.

From an economic standpoint, panelists described the situation as a classic externality. Proposed solutions included creating market-based incentives for mitigation, establishing coordinated data-sharing systems between operators and observatories, and clarifying property or usage rights for scientific access to the sky.

Engineers contributed a systems-focused perspective, noting that much of the challenge stems from disorder in orbit. Engineering solutions could include designing satellites with reduced reflectivity, narrowing radio beams to minimize interference, and adopting predictable operational patterns that enable astronomy to plan around satellite activity.

The panel also stressed the importance of proactive, international coordination. The panelists called for updated regulations and collaborative initiatives that shift from theoretical modeling to testing and validating mitigation measures under real operational conditions.

In closing, the discussion clarified that preserving the night sky will require technical innovation, informed policy, economic tools, and a shared cultural commitment. As one panelist reflected, "We are watching the sky disappear before our eyes, and with it, a part of our humanity."

10 Topic 6: Beyond Earth: Extending Spectrum Management to Deep Space and the Moon

10.1 Context

The growth of commercial space activity is moving rapidly beyond Earth orbit. The Moon is emerging as the next major destination for exploration, science, and commercial enterprise. Plans for lunar mining, navigation infrastructure, surface bases, and scientific observatories are no longer theoretical. Missions by national space agencies are now joined by a wave of commercial operators, and filings for lunar spectrum access by private actors already exceed those of governments.

These activities depend on spectrum as a foundational resource. Reliable communication links are essential for command and control, navigation, coordination, and the transmission of scientific and operational data. In deep space, spectrum is also critical for safety. Without it, spacecraft cannot be tracked, coordinated, or warned of hazards. The challenge is that spectrum is finite and shared, and the Moon and cislunar space present unique technical and governance problems that differ sharply from those on Earth.

On Earth, spectrum use is governed by national regulators and coordinated internationally through the ITU. These terrestrial frameworks rely on national sovereignty, established enforcement mechanisms, and decades of precedent in managing interference. In lunar and deep space environments, no such enforcement authority exists. The 1967 Outer Space Treaty (OST) establishes broad principles, including that space is the "province of all mankind" and cannot be claimed by any one nation. Still, it provides few details for practical spectrum management among multiple commercial and governmental actors.

The technical environment is also more challenging. Communication links must overcome extreme distances, with significantly greater signal attenuation than in Earth orbit. Mobility is constant, as spacecraft in lunar orbit or on the surface must coordinate with one another in real time, often with limited visibility into others' operations. Certain locations, such as lunar poles or Lagrange points, are especially attractive, creating the potential for high-density activity. At the same time, new technologies such as optical communications promise higher capacity and reduced interference, but they lack regulatory frameworks.

Although these technological advancements are exciting, the risks are significant without coordination in spectrum policy. For example, harmful interference could jeopardize scientific missions, degrade navigation services, or disrupt commercial operations. Congestion in valuable lunar orbits could create conflicts between operators. Without agreed-upon enforcement tools, actors may push the limits of acceptable behavior, leading to disputes or operational failures. The stakes go beyond commerce. The Moon will be a proving ground for how humanity manages shared resources beyond Earth.

This panel explored whether terrestrial spectrum management concepts can be adapted for lunar and deep space use, where they fall short, and what new tools and governance models might be needed.

10.2 Panel Discussion

- David Reed (Moderator), Senior Fellow, Silicon Flatirons Center
- Gerald Adams, George Sharswood Fellow, University of Pennsylvania
- Rob Frieden, Academy and Emeritus Professor, Penn State University
- Carolyn Kahn, Distinguished Chief Spectrum Economist, MITRE Corporation
- Lynna McGrath, Deputy Associate Administrator, NTIA OSM
- Scott Palo, Professor, University of Colorado Boulder

Why Lunar and Deep Space Spectrum Policy Matters

Commercial activity beyond Earth is accelerating at a pace that was difficult to imagine only a decade ago. Lunar landers, rovers, communication satellites, and prospecting missions are no longer the sole domain of national space agencies. Filings for lunar spectrum access by commercial operators now surpass those by governments. This shift raises a pressing question: Can the terrestrial spectrum management frameworks that govern Earth-based communications be applied to the Moon and beyond?

Spectrum in space is both finite and shared. It underpins navigation, science, communication, and mission safety. In a congested lunar environment, uncontrolled interference could threaten not only commercial ventures but also essential scientific work such as radio astronomy and Earth–Moon navigation services. So, panelists argued that the current regulatory framework relies too heavily on "norms and discretionary compliance" to address the congestion to come.

The challenge is maintaining order in an environment with no sovereignty, no central enforcement authority, and no existing body with clear authority over lunar spectrum use. This creates a governance problem unlike anything faced in terrestrial spectrum policy.

Key Differences Between Earth and Space Environments

Distance and Path Loss

Signal strength decreases sharply with distance. The Moon is roughly 20 dB more attenuated than GEO, meaning the signal is about 100 times weaker, and deep space (beyond two million kilometers) presents even greater losses. Scott Palo emphasized that "it is not just about distance, it is about where you want to be and who else wants to be there." Certain locations, such as lunar poles and Lagrange points, are especially desirable, creating potential hotspots for congestion.

Mobility and Tracking

Unlike fixed terrestrial towers, spacecraft in lunar orbit or cislunar space constantly move, often with complex orbital dynamics. Landers and surface stations are also likely to be repositioned during operations. Tracking and coordinating these mobile users is far more complex than managing terrestrial systems.

Lack of Sovereignty

On Earth, national governments enforce rights through licensing and can exclude non-compliant operators from their markets. In space, this enforcement tool disappears. Rob Frieden asked the central question: "Who enforces when there is no sheriff?"

> ***"Without sovereignty in space, our ability to assign and enforce rights becomes tenuous at best."***
>
> – Gerald Adams

Gaps in the Current Legal and Regulatory Framework

The existing framework was designed for an era when space activity was almost entirely governmental. Today's rules do not fit the realities of commercial lunar operations: 1) *Federal vs. Non-Federal Allocations.* In the United States, the "space research" bands are federal-exclusive. Commercial lunar missions often need to use these bands because their hardware is already optimized for them. Lacking a regulatory home, they operate under experimental licenses or ITU Article 4.4 "non-interference" waivers. Lynna McGrath summarized the problem: "We are trying to squeeze things into a terrestrial allocation framework that may not fit for the lunar or cislunar environment." 2) *Fragmented Governance.* Coordination today happens through a mix of ITU processes, bilateral agreements, and informal norms. None of these provide secure, long-term expectations for operators. 3) *Enforcement Void.* There is currently no credible way to sanction or deter harmful interference on the Moon. Frieden warned that without a credible enforcement structure, operators may bypass existing processes entirely.

Risk of Norm Fragmentation

The absence of a single enforceable framework opens the door to multiple overlapping systems of rules, each driven by different governments or even private actors. While diversity can foster innovation, it also risks conflicting standards and competitive escalation.

Some governments and companies are already shaping norms on their own terms. The Artemis Accords, for example, bypass the 1979 Moon Agreement and its shared-commons philosophy, favoring bilateral arrangements. Panelists cautioned that this unilateral norm-setting, enables private actors to do the work of governments.

Cases such as Swarm Technologies launching without authorization and Dish Network failing to meet de-orbit commitments show that even on Earth, operators sometimes ignore rules when the perceived benefits outweigh the risks. Panelists noted that these are not just hypotheticals, there are actors willing to push the limits.

Externalities and Market Failures

Lunar and deep space operations create externalities, meaning costs are imposed on others without compensation. Interference, congestion, and debris affect all users of space, yet the responsible party may not bear those costs. Carolyn Kahn pointed out that "spectrum use can create externalities, interference, and congestion, and result in debris, and we are not pricing in all of those costs yet."

First movers may lock in prime spectrum and locations, leaving later entrants at a disadvantage. This raises equity concerns and may discourage competition or innovation. The panel stressed the importance of designing policies that balance innovation with fair access.

Technical Opportunities and Solutions

While governance is a major challenge, technology offers new tools to manage congestion and interference: 1) Optical Communications – Laser-based links have extremely narrow beams, that reduce the risk of interference and increase data rates. One panelist suggested that optical may be the key to managing congestion in deep space. However, regulatory structures for optical spectrum are still undeveloped; 2) Improved Propagation Models – Accurate lunar propagation models are still under development at the ITU and elsewhere. These models will be essential for predicting interference and guiding spectrum planning; and 3) Designing for Predictability – Coordination is easier when systems behave predictably. That means standardizing beam patterns, orbital slots, and timing plans where possible.

New Governance Approaches

The panel agreed that governance cannot just be a slogan. It must mean enforceable rules, predictable outcomes, and incentives for compliance.

> ***"We have to move beyond the romance of governance and start thinking about enforceable, durable frameworks."***
>
> – Gerald Adams

Potential approaches discussed included: 1) Club Membership Models – Operators agree to specific rules in exchange for benefits such as market access, coordination support, or reciprocal protections; 2) Quasi-Property Rights – Assigning use rights for specific frequencies, locations, or orbital slots even without sovereignty, to create stability; 3) Institutional Innovation – Creating new bodies or coalitions that can coordinate across governments and include private actors in meaningful ways.

Paths Forward: Shared Infrastructure and Trust. The panel explored ways to build trust and cooperation even without sovereignty: 1) Transparency – Publicly accessible repositories of orbital and spectrum-use data could allow mutual monitoring. Transparency in data sharing could help bridge the gap where enforcement falls short. 2) Cross-Disciplinary Coordination – Law, engineering, economics, and diplomacy must work together to design solutions; and 3) Incentives for Good Behavior – Market-based incentives, such as insurance discounts for compliant operators or shared technical resources, can encourage adherence to best practices.

Panelists acknowledged a need for incentive-compatible governance, not just compliance by fiat.

10.3 Summary

The discussion addressed a central question: *how can spectrum be managed fairly and effectively beyond Earth, where there is no sovereign authority and commercial activity is expanding rapidly?*

Panelists agreed that existing terrestrial frameworks provide a useful starting point but cannot simply be transplanted to lunar and deep space environments. The absence of sovereignty removes a key enforcement mechanism. Without it, spectrum coordination depends largely on voluntary compliance, informal norms, and ITU processes that were designed for an earlier era of state-led space activity. The risk is that high-value locations such as the lunar poles or specific orbital regimes could become congested without a clear process for conflict resolution.

Several governance risks were identified including: fragmentation of norms across different countries or private initiatives; unilateral action by powerful actors that sets de facto rules; and precedent-setting cases where companies have disregarded licensing requirements or operational commitments. Such behavior can undermine trust and create long-term challenges for cooperative management.

From a technical standpoint, panelists highlighted the need for accurate lunar propagation models to inform spectrum planning and reduce interference. Optical communications were discussed as a promising technology for future lunar and deep space missions, offering narrow beams and reduced interference risk. Predictable system designs, including standardized beam patterns, coordinated orbital slots, and planned transmission schedules, were discussed as ways to improve efficiency and reduce coordination burdens.

Economic and policy perspectives emphasized that spectrum use in space produces externalities such as interference, congestion, and debris, which are not fully accounted for in current market structures. Incentive-based mechanisms, shared data repositories, and transparency in operations were proposed as tools to align private incentives with the broader public interest.

In closing, the panel agreed that preserving the utility of lunar and deep space spectrum will require more than extending existing rules. It will demand new forms of cooperation that include both government and commercial actors, frameworks that are enforceable and adaptable, and the integration of legal, economic, and engineering expertise. The Moon may be humanity's first large-scale test of how to manage spectrum as a shared resource beyond Earth, and the lessons learned there will shape our ability to operate sustainably for decades to come.

11 Munch & Muse: Scouting the Speculative Frontier

11.1 Context

This forward-looking conversation brought together experts from law, policy, engineering, economics, and industry for a forward-looking conversation on the future of the space sector. The informal format encouraged open dialogue and cross-disciplinary insights, allowing participants to test ideas and challenge assumptions.

The session was structured around scenario planning, a method used to explore multiple plausible futures rather than predict a single outcome. This approach is particularly relevant for space policy, where technological change, market forces, and geopolitical dynamics can shift rapidly. Participants worked to identify the foundational parameters that will shape the next decade of space activity, the critical risks that could disrupt progress, and the governance tools that could influence outcomes.

Key issues that framed the discussion included the absence of comprehensive international rules for orbital conduct, growing commercial influence in setting operational norms, the tension between public interest science and commercial profitability, and uncertainty about how emerging technologies will impact orbital traffic and governance. Participants also discussed the limitations of current institutions and the need for stronger, more adaptable governance structures that can manage orbital congestion, address equity in access, and maintain the long-term sustainability of the space environment.

The conversation recognized that the choices made today will influence whether the next 10 to 15 years bring cooperative, sustainable growth in space, a fragmented and competitive "Wild West," a geopolitically divided Cold War-style environment, or a slower-paced but ethically grounded expansion.

11.2 Panel Discussion

Foundational Parameters for the Future

Regulatory Maturity

"Right now, there is a regulatory gap. We do not have global norms for what constitutes responsible behavior in orbit."

Participants consistently identified the lack of internationally agreed-upon rules for satellite operations, debris management, and orbital conduct as a critical vulnerability. The discussion acknowledged that while terrestrial communications benefit from well-developed institutions like the ITU, there is no equivalent with clear authority over orbital conduct.

Market Dynamics

The group examined how the balance of power between governments, large commercial operators, and startups will shape space governance. A central question was whether there would be true multilateral input, or whether a small set of dominant players would set de facto standards, potentially prioritizing their own interests over those of the public. There was broad concern that market concentration could leave smaller actors, especially from emerging space nations, without meaningful influence.

Public vs. Private Incentives

Several participants raised the tension between scientific and commercial priorities. Public interest science, such as space-based climate monitoring or deep space exploration, may not be profitable but serves critical societal needs. "

Technological Uncertainty

Emerging technologies like optical communications and autonomous collision avoidance could help reduce some congestion and interference risks. However, participants noted that they could also accelerate orbital activity and increase risks if governance and oversight do not keep pace.

Critical Risks and Disruption Factors

Orbital Congestion and Kessler Syndrome

The discussion returned repeatedly to the hypothetical risk of cascading collisions that could make entire orbital regions unusable for decades. This "Kessler Syndrome" scenario would not necessarily be triggered by a single catastrophic collision but by a chain reaction of debris impacts. The result of a chain reaction could be the entire loss of access to LEO.

Fragmentation of Norms

"There is a real risk of everyone doing their own thing, and no one being accountable."

There was strong concern that powerful nations or large private companies could bypass multilateral processes entirely, creating fragmented rule sets that undermine cooperation. The result can be forum-shopping and compliance arbitrage, where actors select the least-restrictive venue, undermining accountability and making reliable spectrum access harder for everyone.

Global Disparities

The group discussed the risk that orbital access, capacity, and benefits will increasingly be concentrated in wealthier nations. Without proactive measures, countries in the Global South could find themselves permanently excluded from meaningful participation. "

Four Scenario Archetypes for the Next 10–15 Years:

Scenario 1: Regulated Commons

In this optimistic future, space governance keeps pace with technology and market growth. Multilateral agreements set clear and enforceable rules for orbital conduct, debris mitigation, and spectrum management. Nations agree to treat orbital space as a shared global commons, much like the high seas, with transparent access and responsibility requirements.

Predictable norms make it easier for new entrants, including emerging space nations and smaller companies, to participate without being crowded out by early movers. Sustainable practices such as active debris removal and shared orbital traffic management services must become standard. International coordination bodies have enough authority to enforce compliance, reducing the risk of both accidental and deliberate interference.

Implication: Scientific missions thrive alongside commercial ventures, innovation continues without destabilizing the orbital environment, and global trust in space governance deepens.

Scenario 2: Commercial Wild West

In this high-risk trajectory, commercial innovation races ahead of policy. Dominant space companies and a handful of powerful nations set operational norms through sheer market presence, rather than formal agreements. These norms may prioritize speed, profit, and expansion over long-term sustainability.

Without robust oversight, collisions, spectrum interference, and light pollution intensify. Smaller space actors are forced to adapt to standards they did not help create or are shut out entirely. Public interest science struggles to secure orbital real estate and quiet spectrum for research. National regulators cannot keep up with the number and complexity of launches, and informal "gentlemen's agreements" replace enforceable rules.

Implication: Orbital space remains economically vibrant in the short term but becomes increasingly unstable, raising the likelihood of a major debris-generating event that could permanently alter access.

Scenario 3: Cold War 2.0 in Space

Geopolitical rivalry dominates this future, with two or more major blocs shaping distinct and incompatible space governance regimes. Each bloc prioritizes national security and dual-use technology, such as satellites that serve both civilian and military purposes. Access to certain orbits, resources, and frequency bands is restricted to bloc members, creating political "safe zones" and "no-go" areas.

International collaboration on space science is rare, and cooperative debris mitigation measures are difficult to implement across competing blocs. Military posturing raises the risk of deliberate or accidental interference, especially in contested orbital zones.

Implication: Space becomes less a shared commons and more a strategic arena. Smaller states and private actors must align with a bloc to survive, limiting their autonomy and reducing opportunities for global problem-solving.

Scenario 4: Ethical Renaissance

This deliberate, slower-growth scenario redefines the purpose of space activity. Expansion is paced to match sustainable orbital capacity, and governance incorporates ecological ethics, cultural heritage, and relational sovereignty. Policies are shaped with input from Indigenous communities, ethicists, scientists, and civil society alongside governments and industry.

There is a deliberate effort to respect nonhuman and ancestral claims to the night sky and celestial bodies. Technological adoption focuses on minimizing environmental impact, avoiding unnecessary launches, and maximizing the lifespan of orbital assets.

Implication: Economic growth in space is slower but more stable over the long term. Space remains accessible to a diverse set of stakeholders, and cultural as well as scientific values are given equal weight with economic ones.

Recommendations and Reflections

Build "Minimum Viable Governance." Participants stressed that perfect frameworks should not delay practical action. Even partial agreements on collision avoidance protocols, debris-generating activities, and orbital transparency could dramatically reduce risks. A baseline set of enforceable norms could serve as a foundation for more complex governance in the future. Early agreements could also prevent dominant players from unilaterally shaping long-term standards.

Strengthen Scenario Planning as a Policy Tool

Integrate structured foresight exercises into the work of agencies, research institutions, and international forums. Much like climate modeling, scenario planning would allow policymakers to rehearse responses to multiple plausible futures rather than react after the fact. This would require assembling cross-disciplinary teams, including technologists, economists, ethicists, and political scientists.

Public Engagement and Awareness

Participants emphasized that making space governance easy to understand and relevant to the public is crucial. Clear communication about the stakes, whether in terms of lost satellite services, environmental damage, or diminished scientific capability, can help build political will. Outreach efforts should move beyond technical audiences and include schools, community groups, and public forums.

Aligning Incentives for Good Behavior

Use and policy tools to encourage cooperation. Examples include reduced insurance premiums for operators who meet debris-mitigation standards, preferred licensing terms for transparent spectrum use, or public funding for shared infrastructure such as debris-tracking networks. Governance can attract voluntary participation by rewarding compliance rather than relying solely on penalties, governance can attract voluntary participation.

Enhance Data Transparency and Sharing

A recurring theme was the need for publicly accessible and trusted repositories of orbital and spectrum-use data. Such systems should include real-time positional updates, collision-avoidance notifications, and standardized reporting formats. Increased transparency would build trust among operators and provide the evidence base needed for enforcement, research, and policymaking.

11.3 Summary

The Munch and Muse session explored how the space sector could evolve over the next decade, using scenario planning to map a range of plausible futures. The discussion underscored that the coming 10–15 years will be shaped by a mix of political, economic, technological, and governance forces that will determine whether space remains an open, sustainable commons or shifts toward fragmentation and exclusion.

Participants identified five foundational parameters that will drive the trajectory of the space industry:

- *Regulatory maturity:* The speed and effectiveness of building enforceable, globally recognized rules for orbital conduct and debris management.
- *Market dynamics:* How power is distributed between governments, major corporations, and emerging space nations.
- *Public vs. private incentives:* The balance between profit-driven ventures and non-commercial missions that serve public interest science.
- *Technological uncertainty:* Whether new capabilities like optical communications and autonomous navigation reduce risk or accelerate congestion.
- *Political will and governance structures:* The ability to create institutions with real authority beyond Earth's surface.

Four plausible futures emerged:

- *Regulated Commons:* Strong multilateral agreements, predictable norms, equitable access, and active sustainability measures.
- *Commercial Wild West:* Market dominance by a few powerful actors, weak oversight, worsening congestion and interference.
- *Cold War 2.0:* Rival geopolitical blocs shape separate governance regimes, with military priorities overshadowing cooperation.
- *Ethical Renaissance:* Slower, deliberate growth guided by ecological ethics, cultural respect, and long-term stewardship.

Four key priorities for action stood out:

- *Build minimum viable governance now:* Establish enforceable baseline rules for debris mitigation, collision avoidance, and orbital transparency.

- *Institutionalize scenario planning:* Use structured foresight to prepare for multiple futures instead of reacting to crises.
- *Engage the public:* Raise awareness of the stakes for science, culture, the environment, and everyday services.
- *Align incentives for good behavior:* Reward compliance with sustainability measures through licensing benefits, insurance discounts, or shared infrastructure access.

The central takeaway: The next decade is a pivotal window. Decisions made now on governance, technology deployment, and market structure will set the long-term tone for space activity — whether cooperative, sustainable, and inclusive, or fractured, contested, and unstable.

12 Conclusions & Recommendations

During this conference, panelists and keynote speakers from industry, government, and academia came together to discuss how rules, markets, and engineering can merge to keep pace with an exponentially growing space economy and an overcrowded sky. Today's policy choices will set the standard for responsible behavior in space for decades. The consensus is that orbital space is now essential infrastructure, but not an endless frontier. Suppose minimum-viable, evidence-based norms grounded in shared data, predictable licensing, market incentives for safety, and respect for science, culture, and public services are set today. In that case, innovation can align with accountability, and good habits can be carried from LEO to the Moon and beyond.

The recommendations below represent regulatory and operational actions necessary to encourage "order" and equitable innovation without sacrificing accountability or sustainability.

I. **Build a shared, trustworthy operations management scheme for space objects and spectrum allocation.**

II. **Reliable and timely data are crucial for true safety and accountability in space.**

A unified validated SSA catalog that combines radar, optical, and laser-ranging tracks would provide operators with a clear view of objects in space, locations, and ownership. Including covariance (confidence bounds) helps operators assess maneuver margins accurately. Timely, authenticated ephemeris updates ensure everyone works from the same data. This framework can then model orbital carrying capacity, altitude "lanes," right of way rules, and interference metrics.

III. **Ensure licensing is parametric, predictable, and efficient.**

IV. **Innovation slows when licensing relies on late-stage conditions that change from one case to another.**

Increasing predictability can reduce costs, improve compliance, and accelerate public-interest deployments. This can be achieved by publishing technology-neutral performance budgets that address key areas such as collision risk, brightness, emissions, ephemeris quality, and end-of-life timelines. Such measures enable engineers to design once and ensure compliance globally, eliminating months of guesswork and rework.

V. **To power a circular space economy, reward safety solutions with financial incentives, price harms, and clarify legal gaps.**

VI. **Encourage responsible behavior by pricing harms and linking rewards to measurable performance, so cleanup in orbit becomes standard, investment-friendly, and safe.**

A weight-indexed "Orbital Superfund" fee compensating certified removers per kilogram turns debris removal into a marketable service, making the safest option the most affordable. Operators can document safety practices and performance (maneuver responsiveness, accurate and timely ephemerides, clean emissions) to earn better rates from insurers and lenders, while insurers reinforce good design with premium discounts for design-for-disassembly, standardized refueling ports, low-interference transmissions, and credible end-of-life plans. However, incentives alone cannot enable large-scale cleanup with ambiguous ownership and liability laws. To fix this, define when a silent satellite is legally "abandoned" after a set number of verified periods of inactivity, establish pre-approval salvage registries, and specify exactly when liability shifts at capture or servicing. With prices aligned with safety habits and legal rights clarified, "debris-to-delta-V" and other ISAM business models become financeable, accelerating controlled deorbit, extending satellite life, and enabling in-space reuse.

VII. **Consider science, culture, and public services as top design priorities.**

VIII. **Foundational public goods like science, culture, and public services should be treated as primary design priorities because failure costs are broad, hidden, and often irreversible.**

Ignoring these needs can cause harm such as degraded weather forecasts, weakened disaster response, lost cultural heritage, and slowed scientific discovery, which are hard to fix later. Markets tend to undervalue these impacts, so proactive measures prevent systemic risks. With this frame in mind, passive sensing deserves protected bands because even slight stray emissions skew models and increase life and property risks. Similarly, astronomy needs enforceable brightness limits and schedule-aware boresight avoidance so research continues without interrupting service. Life-cycle environmental reviews can catch reentry byproducts and other cross-domain effects before they escalate. Lastly, co-designing with Indigenous and rural communities builds legitimacy and preserves cultural significance as connectivity expands.

IX. **Launch minimum-viable governance now and apply it to space operations on the Moon and beyond.**

X. **Setting shared standards in LEO now creates the templates that will keep future space operations in lunar and cislunar orbit and beyond safe, fair, and scalable.**

Without a LEO playbook, rules become inconsistent, risks increase, and problems inevitably spread to new orbits. Reciprocal standards for transparency, collision avoidance, disposal, and interference mitigation establish enforceable expectations across borders and business models, providing operators and investors with predictable guardrails. The same LEO standards will then translate into lunar and cislunar missions with predictable frequency, pointing, and timing templates, better propagation models, shared navigation and relay hubs, and carefully deployed optical links. Thus, it creates an order where sovereignty tools are not yet in existence. By proving these norms from LEO, missions avoid first-mover lock-in, preserve open access, and replace uncertainty with interoperable practices.

XI. **Institutionalize foresight and public legitimacy.**

XII. **Testing policy changes through scenario analysis is crucial because space governance operates in a highly uncertain environment where geopolitics, markets, and technology change faster than any rulebook.**

By rehearsing policy decisions against clear archetypes, policymakers can identify potential failures, weigh key trade-offs, and determine the most effective rules' boundaries and triggers. These exercises lead to tangible adjustments, such as which metrics to monitor, which contingencies to pre-approve, and which standards are likely to be maintained across different futures without costly rewrites. Then publishing these results and underlying data can help policymakers build credibility, reduce policy fluctuations, and enable external experts to replicate or challenge analyses. Finally, a public dashboard that links "quieter, safer skies" to real-world outcomes, like improved hurricane tracking, wildfire communication, and culture access, helps align political will with long-term stewardship, ensuring rules endure beyond a single launch cycle.

13 Participants

Adam Cassady – Principal Deputy Assistant Secretary and Deputy Administrator, NTIA

Angel Abbud-Madrid – Director, Space Resources Program, Colorado School of Mines

Anna Gomez – FCC Commissioner

Ashley VanderLey – Astronomer, American Astronomical Society

Brad Bernthal – Executive Director & Entrepreneurship Initiative Director, Silicon Flatirons

Carolyn Kahn – Distinguished Chief Spectrum Economist, The MITRE Corporation

Chris Anderson – Theory Division Chief, NTIA/ITS

Daniel Baker – Director, Colorado Space Policy Center

David Goldman – Vice President, Satellite Policy at SpaceX

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Rob Frieden – Academy and Emeritus Professor, Penn State University

Scott Palo – Professor, University of Colorado Boulder

Suraj Jog – Senior Research Scientist, Microsoft

Thomas Dombrowsky – Vice President, Engineering and Technology Policy, T-Mobile

Zack Donohew – Assistant Teaching Professor, University of Colorado Boulder

14 Acronyms

AAS	American Astronomical Society
ASAT	Anti-satellite
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
CBRS	Citizen's Broadband Radio System
DOC	Department of Commerce
DOD	Department of Defense
EPFC	Equivalent Power Flux Density
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GEO	Geostationary Earth Orbit
GPS	Global Positioning System
GSO	Geostationary Orbit
GHz	Gigahertz
IMO	International Maritime Organization
ISS	International Space Station
ITS	Institute for Telecommunication Sciences
ITU	International Telecommunications Union
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MHz	Megahertz
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NGSO	Non-Geostationary Earth Orbit
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NTIA	National Telecommunications and Information Administration
OSC	Office of Space Commerce
OST	Outer Space Treaty
RF	Radio Frequency
SFCG	Space Frequency Coordination Group
SSA	Space Situational Awareness
UNCLOS	United Nations Convention on the Law of the Sea
UNOOSA	United Nations Office for Outer Space Affairs
WRC	World Radio Conference

15 About Silicon Flatirons Center

15.1 Mission

Silicon Flatirons' mission is to elevate the debate surrounding technology policy issues; support and enable entrepreneurship in the technology community; and inspire, prepare, and place students in these important areas. Learn more at siliconflatirons.org/about-us/.

15.2 Spectrum Policy Initiative

Spectrum policy dictates how, where, and when wireless services can be delivered to devices—and it has deep ramifications for the economy, scientific development, national security, personal enjoyment, and more. Since 2005, Silicon Flatirons has explored the intersection of policy and engineering in the heavily regulated and rapidly changing wireless services industry.

Silicon Flatirons convenes stakeholders and provides law and engineering students with a foundational understanding of spectrum policy. The Spectrum Policy Initiative engages a wide range of wireless industry professionals, radio engineering professionals, and spectrum policymakers from Colorado, Washington, D.C., and across the country.

Learn more about the Spectrum Policy Initiative and other Silicon Flatirons Initiatives at siliconflatirons.org/initiatives/.

15.3 Our Team

For more information about center leadership, faculty, staff, fellows, and advisory board, visit siliconflatirons.org/about-us/our-team/.

15.4 Our Supporters

Silicon Flatirons exists thanks to the generosity of our supporters and the strength of our community. We rely on their contributions to advance our mission to catalyze policymaking and innovation and to develop the next generation of tech lawyers, policy experts, and entrepreneurs. For more information on current official Silicon Flatirons Supporters, visit siliconflatirons.org/about-us/supporters/.

15.5 Publications

We promote thought leadership and intellectually honest discourse not only in our events, but in publications from our team, our roundtables, and scholars presenting at our conferences. See more at siliconflatirons.org/publications/.