Recommended Reading List for Challenges in Sustaining Space as a Resource Conference

Hosted at the University of Colorado Law School June 24–25, 2025

Shorter reading list:

Aaron Boley et al., "The National and International Landscape Concerning Dark and Quiet Skies," International Astronomical Union, Center for the Protection of Dark & Quiet Sky (2024), https://zenodo.org/records/14579453/files/DQS_WP2.pdf.

- This IAU report examines the environmental, light-pollution, and spectrum laws of more than 70 nations, illustrates how the ITU's radio-spectrum playbook could also reduce orbital light pollution, and advocates for an "Earth-Space sustainability" agenda that integrates spectrum sharing, debris mitigation, and light pollution controls into clearer national laws and international treaty obligations. Readers will discover the concrete legal levers already available and understand why winning the modern spectrum battle relies on treating the night sky as a shared environmental resource, rather than merely an engineering issue.
- Essential pages:
 - **Pages 3-4 executive summary**: One-page overview of why orbital light and spectrum pollution threaten space sustainability and what policy levels exist to act.
 - **Pages 14-15:** Frames the open legal questions, "Is astronomy 'exploration' under the OST?", "Can the ITU police light pollution?"
 - Pages 21-22: Bullet list of actionable next steps.

Mohammad Alzenad, Ahmed Alkhateeb & Syed A. Jafar, "Emerging NGSO Constellations: Spectral Coexistence with GSO Satellite Communication Systems," *arXiv preprint* (Apr. 2024), <u>https://arxiv.org/pdf/2404.12651</u>.

- This IEEE Communications Magazine article provides readers with a practical post-WRC-23 playbook for integrating mega-LEO constellations and long-lived GEO satellites into the same Ku/Ka spectrum. It demystifies four leading solutions: keep-out angles, power throttling, dish-tilt, and AI-driven beamforming. In a single scorecard graphic, it illustrates how each option balances interference risk against customer capacity. Start here if you want to speak the engineers' language about how to make NGSOs and GSOs coexist.
- Essential pages:
 - **Pages 2-3:** Authors unpack the *new* WRC-23 rules to help readers understand *why* the GSO-NGSO clash is suddenly urgent and what questions regulators must still answer.
 - **Pages 4-5:** A single graphic with side-by-side arrows compares the four leading mitigation strategies and their performance metrics.

Sara Dalledonne et al., "Space Spectrum Management: Foundations for an Informed Policy Discussion towards WRC-23 and Beyond," *European Space Policy Institute Policy Report* (Oct. 2023), <u>https://www.espi.or.at/wp-content/uploads/2023/10/ESPI-Space-Spectrum-Policy-Report-1-1.pdf</u>.

- This ESPI policy primer explains why orbital radio frequencies are running out, how the ITU's rules operate, and highlights the six major disputes influencing the road to more effective and efficient management with the congested space and spectrum environment: over-filing, fair access for new entrants, spectrum sharing across services, improved real-time monitoring, stricter EPFD limits for mega-constellations, and expanded space sustainability responsibilities. Read it if you want the plain-language playbook on what regulators must address before mega-LEOs and 6G flood the airwaves.
- Essential pages:
 - **Pages 2-3**: This executive summary spells out *why* orbital spectrum is tightening, the ITU ground rules at stake for WRC-23/27, and the report's headline warning: without stronger licensing and enforcement, mega-LEOs and 6G will overwhelm today's allocation system.
 - **Pages 29-30**: Discusses the heart of the equity argument regarding how to reconcile first-come-first-served rules with fair access for emerging and developing space-faring countries.

Extended Reading List:

Connor Haffey, "Bridging the U.S. Regulatory Gap: Why the FCC Should Authorize Novel Commercial Space Activities," 77 Fed. Comm. L.J. 1 (Nov. 2024), <u>http://www.fclj.org/wp-</u>content/uploads/2024/11/77.1.1_Bridging-the-US-Regulatory-Gap.pdf

- This law review article offers a concrete blueprint for addressing the question of "Who governs what in outer space?" Its legal analysis of the U.S. "mission-authorization gap" illustrates how consolidating mission authorization within the FCC would pair regulatory certainty with spectrum stewardship. This single-agency approach, Haffey argues, would reduce red tape, align spectrum and safety decisions, and fulfill the Outer Space Treaty's Article VI supervision duties without creating new bureaucracy.
- Essential pages:
 - **Pages 1-3**: Frames the regulatory gap, stakes for U.S. operators, and treaty compliance.
 - **Pages 20-24**: Outlines the statutory, technical, and political case for allowing the FCC to run mission authorization.

Connor Hagan et al., "Silicon Flatirons Roundtable Outcomes Report: Space Sustainability," *Silicon Flatirons Center* (Nov. 27, 2024), <u>https://siliconflatirons.org/wp-content/uploads/2024/11/Outcomes-Report_2024-06-</u>28 Roundtable Space-Sustainability.pdf.

- This is the outcomes report from the 2024 Space Sustainability Conference, which captures where the dialogue left off last year. It highlights four persistent problem areas (RF "loud skies," resource management, licensing for novel tech, and enforcement) and outlines a to-do list that this year's panels are designed to advance. The main takeaway is that space is already a congested, shared commons and that more innovative governance (real-time SSA, clearer agency roles, incentives-aligned standards, and economic valuation of science) is urgent if we are to avoid "poisoning the public well."
- Essential pages:
 - Pages 5-6: Key findings and recommendations of all panels
 - Pages 17-18: Key findings and recommendations of session 1
 - **Pages 27-8:** Key findings and recommendations of session 2
 - Pages 39-40: Key findings and recommendations of session 3
 - Pages 47-48: Key findings and recommendations of session 4

**Federal Communications Commission, "Promoting the Development of Positioning, Navigation, and Timing Technologies and Solutions, Notice of Inquiry – WT Docket No. 25-110," *FCC Fact Sheet* (Mar. 6, 2025), https://docs.fcc.gov/public/attachments/DOC-410031A1.pdf.

- This Notice of Inquiry (NOI) is the FCC's latest statement on how to utilize scarce spectrum to create a resilient "system-of-systems" backup to GPS. It asks industry, agencies, and researchers which satellite constellations, TV broadcast signals, terrestrial beacons, or public-private testbeds could share spectrum to deliver more robust, tamper-proof positioning, navigation, and timing, and what new rules or band assignments the FCC should adopt to make that a reality. Readers will gain insight into the questions regulators are posing before they rewrite the spectrum playbook that underpins every sustainability debate.
- Essential pages:
 - Page 1: A one-page synopsis, or "fact sheet," outlining what the NOI requests and why.
 - **Pages 9-12**: (Under the "discussion" section.) Outlines the "system-of-systems" goal, surveys space and ground-based options, and poses the spectrum questions the FCC needs answered.

**This is a reference/link to the pre-meeting draft of this NOI. The final version adopted by the FCC is "Promoting the Development of Positioning, Navigation, and Timing Technologies and Solutions," Notice of Inquiry, WT Docket No. 25-110, FCC 25-20 (Mar. 28, 2025), https://docs.fcc.gov/public/attachments/FCC-25-20A1.pdf.

Ling Zhang et al., "Spectrum Sharing in the Sky and Space: A Survey," *MDPI* (Dec. 29, 2022), <u>https://pmc.ncbi.nlm.nih.gov/articles/PMC9824622/pdf/sensors-23-00342.pdf</u>.

• This open-access survey provides attendees with a map that illustrates how satellites, High Altitude Platforms (HAPs), Unmanned Aerial Vehicles (UAVs), and 6G ground systems can share limited bands

while addressing technical challenges in dynamic sensing, interference budgeting, and governance of shared databases. It offers non-engineers a foundational understanding of policy trade-offs in spectrum sharing schemes (authorized vs. unlicensed, centralized vs. distributed, interweave/underlay/overlay), summarizes best-practice tactics supported by recent studies, and identifies the three main concerns of space and spectrum policy experts.

- Essential pages:
 - **Pages 12-13:** Figure 7 and Table 6 provide a visual cheat sheet of the interweave, underlay, and overlay model.
 - **Pages 26-27:** Provides a list of unresolved issues, offering questions that attendees can expect the panelists to discuss further.

Timothy M. Farrar & J. Armand Musey, "Spectrum for Emerging Direct-to-Device Satellite Operators," *Summit Ridge Group White Paper* (Jan. 2025), <u>https://summitridgegroup.com/wp-content/uploads/D2D-White-Paper-SRG-TMF-Final.pdf</u>.

- This 2025 TMF white paper explains today's "spectrum traffic jam" for satellite-to-smartphone (direct-todevice or D2D) services. It shows why ordinary phone antennas spread signals too widely to share existing mobile-satellite service (MSS) bands, maps every current D2D partnership and spectrum play, and makes a convincing case that leasing underused 2GHz MSS spectrum from its current license holders is the only practical, scalable path to global coverage.
- Essential pages:
 - **Pages 3-4**: Executive summary.
 - **Pages 15-18**: Provides a plain English explanation of why CBRS-style priority sharing fails when millions of phones point omni-antennas skyward.
 - **Pages 24-27:** Makes the case that contiguous, lightly used 2 GHz MSS spectrum offers the cleanest runway for mass-market D2D broadband.