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U.S. Leadership in Lunar Spectrum Policy

BY Shayna Gersten

Over the next decade, NASA and many commercial and international entities plan to send missions to the Moon. All of these missions will use spectrum to communicate with Earth. However, the international regulatory frameworks overseeing radio spectrum beyond Earth's orbits (such as "lunar spectrum") are underdeveloped, creating the potential for interference and disruptions to communications with missions on and in orbit around the Moon. Currently, the United States and International Telecommunication Union (ITU) are considering specific frameworks for coordinating and regulating lunar spectrum use. Despite a lack of frameworks, as of January 12, 2024, the ITU has already received over 50 filings for lunar missions from 9 different countries.[1]

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[1] Oliver Hawkins and Peggy Hollinger, "The race to claim the Moon's airwaves", Financial Times, 1/13/25, https://www.ft.com/content/4de3dce6-f94e-4b1b-b4a0-380386b5836c

Notably, 2024 was the first year that filings from commercial operators outnumbered government space agencies. The U.S.-proposed framework emphasizes international cooperation and coordination in the development and operation of lunar communications in a shared spectrum environment.[2]

Q1: How and why are communications to and from the Moon currently regulated?

A1: In the United States, spectrum -- including spectrum used for communicating between the Earth and Moon, as well as in lunar orbit and on the Moon's surface -- is regulated by the Federal Communications Commission (FCC), and the National Telecommunications and Information Administration (NTIA). The FCC manages spectrum allocation and licensing for commercial and non-federal entities, while the NTIA oversees spectrum for federal purposes like defense, public safety, and scientific research. While the FCC and NTIA regulate spectrum for entities under U.S. jurisdiction, frameworks for lunar uses are underdeveloped at both domestic and international levels. Since the FCC lacks comprehensive lunar spectrum regulations, the FCC uses its authority to issue experimental research licenses for commercial lunar spectrum use. These temporary licenses are limited in scope and duration, creating uncertainty for commercial operators planning long-term cislunar deployments. Recent lunar missions, such as Intuitive Machines' IM-2 mission, have operated under short-term experimental licenses. As a result of this regulatory gap, companies seeking long-term deployments have been left in limbo until robust lunar spectrum guidelines are finalized.[3] For example, Lockheed Martin's subsidiary, Crescent Space, has attempted to file for a 15-year FCC license for its Parsec lunar communications system.[45] Additionally, Lockheed has applied for a blanket license to deploy 230 lunar stations for communications and data storage, though industry pushback exists against blanket applications that bypass individual frequency approvals.[67] Due to the regulatory void, Lockheed has requested FCC waivers and urged the agency to grant licenses with conditional future compliance once lunar guidelines are established. Whether these requests will be approved before international standards are set remains uncertain.

Among other responsibilities, the ITU facilitates international coordination and global regulations on radio spectrum and satellite orbits, including spectrum use beyond Earth's orbits, including cislunar space and on the Moon. The ITU Radio Regulations (RR), updated every three to four years at the World Radiocommunication Conference (WRC), are legally binding rules for the ITU's 193 members. The last WRC in 2023 invited ITU Radiocommunication (ITU-R) Working Party 7B to conduct studies to determine future spectrum allocations for lunar space.[8] These studies will focus on developing rules for using spectrum in support of scientific and technical research activities on the lunar surface and for spacecraft in lunar orbit.[9] While the current focus is limited to missions dedicated to scientific or technical research purposes, this is a critical

[2] James Schier, Catherine Sham, Dennis Lee, Kedar Abhyankar, Karen Clothier, "International Coordination and Cooperation on Lunar Spectrum", NASA, 10/2024, https://ntrs.nasa.gov/api/citations/20240011047/downloads/2024_Ka-Band_LunaNet_Spectrum.pdf

[3] Intuitive Machines Homepage, https://www.intuitivemachines.com/

[4] Crescent Space Homepage, https://crescentspace.com/

[5] https://fcc.report/IBFS/SAT-LOA-20220218-00020

[6] https://licensing.fcc.gov/myibfs/download.do?attachment_key=23036041

[7] https://licensing.fcc.gov/myibfs/download.do?attachment_key=22718429

[8] Cathy Sham, Dennis Lee, Karen Clothier, Kedar Abhyankar, International Spectrum Regulatory Recognition of Lunar and Cislunar Activities, NASA, https://arc.aiaa.org/doi/10.2514/6.2024-4856

[9] Resolution 680 (WRC-23) Studies on frequency-related matters, including possible new or modified space research service (space-to-space) allocations, for future development of communications on the lunar surface and between lunar orbit and the lunar surface, ITU, https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A0000100015PDFE.pdf

first step in creating a comprehensive lunar framework. Currently, lunar operations that are granted temporary experimental licenses are not entitled to protections from interference by other operations and must cease transmissions if they disrupt other operators.[10] Without explicit ITU allocations for lunar frequency bands, lunar space missions can still operate and be filed under ITU Radio Regulation Article 4.4 which states that one, "shall cause no harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with provisions of the RR."[11] Securing ITU lunar spectrum allocations and thereby ensuring international regulatory protections is crucial as the increase in lunar missions heightens the risk of interference.

Internationally binding Radio Regulations designate which portions of the frequency bands are allocated for specific purposes, ensuring efficient and interference-free communication. Delineating portions of the spectrum band for distinct operational uses such as lunar emergency beacons, lunar surface communications, or lunar surface-to-orbiter links to name a few is critical for establishing a reliable and deconflicted lunar communications environment.

The results from the ITU study will guide the first phase of shared lunar spectrum regulations, which will be addressed in 2027 at WRC-27.[12] Technical studies will occur in 2025, regulatory conditions will be developed in 2026, and in 2027 the new regulations and allocations will be signed in the ITU. Once the ITU finalizes spectrum allocations for lunar space, domestic frequency agencies, like the FCC, can confidently finalize and issue long-term spectrum licenses on and around the Moon, backed by international regulatory protections, frequency designations, and acknowledgments.

Q2: How are lunar communications coordinated internationally?

A2: Today, there are several international fora in which countries try to coordinate on lunar spectrum such as the Space Frequency Coordination Group (SFCG), the Interagency Operations Advisory Group (IOAG), and the Consultative Committee for Space Data Systems (CCSDS). Among these, the SFCG has a leading role in advancing internationally developed shared lunar spectrum resolutions. This international technical body, comprising 32 member agencies, including major space agencies such as NASA, the European Space Agency (ESA), Russia's ROSCOSMOS, and the China National Space Administration (CNSA), operates with the ITU as an observer. Unlike the ITU, the SFCG was not established by treaty and is an informal forum, allowing space actors to reach nonbinding agreements on specific frequencies and technical issues.

In 2006, the SFCG established the Lunar Martian Spectrum Group (LMSG), which is chaired by a NASA representative who also leads the ITU-R subgroup in charge of testing lunar spectrum.[13] The LMSG is the main sub-group within the SFCG working on addressing both lunar and martian spectrum challenges, including developing and maintaining spectrum plans, addressing mission-specific requirements, and facilitating collaboration among space agencies. Since the ITU can only update its internationally binding Radio Regulations every three to four years, forums like the SFCG provide supplementary venues where space

[10] James Schier, Catherine Sham, Dennis Lee, Kedar Abhyankar, Karen Clothier, "International Coordination and Cooperation on Lunar Spectrum", NASA, 10/2024, https://ntrs.nasa.gov/api/citations/20240011047/downloads/2024_Ka-Band_LunaNet_Spectrum.pdf

[11] ITU RRs: https://www.unoosa.org/pdf/icg/2015/presentations/43.pdf

[12] Cathy Sham, Dennis Lee, Karen Clothier, Kedar Abhyankar, International Spectrum Regulatory Recognition of Lunar and Cislunar Activities, NASA, https://arc.aiaa.org/doi/10.2514/6.2024-4856

[13] Lunar Spectrum Considerations, ICG-17 Plenary, NASA, Cathy Sham, 2023, https://www.unoosa.org/documents/pdf/icg/2023/ICG-17/icg17.02.08.pdf

actors can hold international discussions and forge agreements at a pace more commensurate with advancements in space technology and mission timelines.

Q3: What actions is NASA taking?

A3: NASA has developed a Lunar Spectrum Management Portal (LSMP) which acts as a voluntary international coordination point for planning lunar missions.[14] Originally created as an internal coordinating tool, the Space Frequency Coordination Group (SFCG) is now recommending its usage for lunar spectrum filing for all commercial and governmental space actors.[15] Previously, no pre-coordination process existed for commercial users unless they partnered with NASA, another U.S. government agency, or an international civil space agency. With the increase of commercial operators, the LSMP can provide a valuable coordination role between commercial and government users, ensuring a safer and more organized operating environment by offering tools for effective spectrum management like recommended frequency selection, interference analysis, and technical pre-coordination processes.[16]

Additionally, LunaNet, now being co-developed by NASA, ESA, and the Japan Aerospace Exploration Agency (JAXA), is an innovative approach to lunar communications standards in a shared spectrum environment. LunaNet operates as a 'network of networks', managed and co-developed by multiple organizations to deliver interoperable Communications, Position, Navigation, and Timing (CPNT) services to any user in the lunar region. Due to LunaNet's emphasis on interoperability, any company or organization can deploy a satellite or communication device in the lunar region and seamlessly integrate as a node within the network, thereby accelerating the network's rapid expansion.[17] This framework is based on internationally agreed upon standards, protocols, frequency bands, and interface requirements, with shared spectrum usage as a founding principle.[18] It is expected that LunaNet will be expanded across the solar system as an interplanetary network.[19] LunaNet's current spectrum plan comprises X and Ka bands for Earth-Moon satellite communications, with possible optical links, and S and Ka bands for communications around the Moon as shown in Figure 1.[20] The distance between the Moon and Earth should ensure that S-band interference does not occur between lunar and terrestrial Earth use. Additionally, tests are scheduled to assess the establishment of a 3GPP type network on the lunar surface. The 3rd Generation Partnership Project (3GPP) develops global standards for mobile communications, including 4G, 5G, LTE, and other networking standards currently under development. Replicating frequency band designations that align with those already used in

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[14] About the Lunar Spectrum Manager, NASA, https://www.nasalsmp.org/SitePages/About-the-Lunar-Spectrum-Manager.aspx

[15] Resolution A40-1: Assistance in the Assignment of Frequencies to Missions in the Lunar Vicinity, SFCG, 2024, https://www.sfcgonline.org/Resolutions/RES%20SFCG%20A40-1%20(Assistance%20in%20the%20Assignment%20of%20Frequencies%20to%20missions%20in%20the%20Lunar%20Reg).pdf

[16] Cathy Sham, Lunar Spectrum Considerations, 2024, https://www.unoosa.org/documents/pdf/icg/2023/ICG-17/icg17.02.08.pdf

[17] James Schiera , Coralí Rouraa , Phillip Paulsenb, Karl Vadenb, Jennifer Rockb, Charles Sheeheb, Angela Peurac , Marc Seibertc , Erica Weird, Deeper Dive into Interoperability and Its Implications for LunaNet Communications and Navigation Services, NASA, June 28, 2024, https://ntrs.nasa.gov/api/citations/20240007403/downloads/Interoperability%20for%20LunaNet%20Services.pdf

[18] Catherine G. Manning, LunaNet Interoperability Specification, Feb. 08, 2024, NASA, https://www.nasa.gov/directorates/somd/space-communications-navigation-program/lunanet-interoperability-specification/

[19] James Schier, Catherine Sham, Dennis Lee, Kedar Abhyankar, Karen Clothier, "International Coordination and Cooperation on Lunar Spectrum", NASA, 10/2024, https://ntrs.nasa.gov/api/citations/20240011047/downloads/2024_Ka-Band_LunaNet_Spectrum.pdf

[20] James Schier, Cathay Sham, Karen Clothier, Dennis Lee, Kedar Abhyankar, International Coordination and Cooperation On LunaNet Spectrum Deck, NASA, 2024, https://ntrs.nasa.gov/api/citations/20240011969/downloads/International%20Coordination%20on%20LunaNet%20Spectrum.pdf

Earth networks allows operators to leverage existing, proven technology that can be easily space-hardened, reducing development costs for lunar deployment. Nokia and Intuitive Machines, for example, attempted to deploy the first lunar 4G/LTE cellular network in February 2025, but the mission encountered landing complications and Nokia only had 25 minutes of network connection to run tests before losing all power.[21][22][23] The IOAG, an international forum focused on interagency space communication standards and strategies to ensure interoperability among space agencies, is developing governance structures for LunaNet through its Committee to Study LunaNet Governance.[24] However, at a Lunar PNT meeting jointly held in February 2025 with the International Committee on Global Navigation Satellite Systems (ICG), a body within the United Nations Office of Outer Space Affairs (UNOOSA), the IOAG stated that establishing an official governance structure will take time.[25] One idea proposed was creating a new Secretariat position under UNOOSA in charge of LunaNet/Lunar Governance.[26] In the near term, NASA, ESA, and JAXA will form the Coordinated LunaNet Administration Partners for self-administering critical topics in CPNT and developing non-binding standards amongst space agencies and commercial actors.[27] These standards are intended to be co-developed and defined with input from the global scientific community and commercial industry under the auspices of international organizations.[28] The IOAG and the Consultative Committee for Space Data Systems (CCSDS), both chaired by NASA representatives, have adopted LunaNet's founding SFCG-recommended frequencies as the optimal choice for lunar spectrum.[29] CCSDS is a multi-national forum that develops communications and data systems standards for spaceflight, ensuring interoperability among international space agencies and commercial operators. CCSDS essentially 'implements' the operational space communication requirements stemming from the IOAG.[30]

However, it remains to be seen whether China, who is planning a number of significant lunar missions, will abide by LunaNet standards. Despite this uncertainty, Beijing emphasized its desire for interoperability in a working group session on Lunar Position Navigation and Timing (PNT) back in June 2024 and again in February 2025. Notably, Beijing initially agreed with the United States on spectrum bands for use around the Moon and between the Earth and Moon; however, there are concerns that Beijing's recent lunar deployments could contradict this agreement, and that they may seek to reverse the decision within the SFCG, possibly testing their influence as a space superpower. Furthermore, at the ICG-IOAG Lunar PNT meeting in February 2025, multiple Chinese representatives mentioned utilizing

[21] Nokia and Intuitive Machines deliver first cellular network to the Moon; achieve some key mission objectives, 2025, https://www.nokia.com/about-us/news/releases/2025/03/10/nokia-and-intuitive-machines-deliver-first-cellular-network-to-the-moon-achieve-some-key-mission-objectives/

[22] Nokia's Cellular Network Ready for Moon as Intuitive Machines Complates Final Lunar Lander Installation, 2025, https://www.intuitivemachines.com/post/nokia-s-cellular-network-ready-for-moon-as-intuitive-machines-completes-final-lunar-lander-installat

[23] Cathy Sham, Dennis Lee, Karen Clothier, Kedar Abhyankar, International Spectrum Regulatory Recognition of Lunar and Cislunar Activities, NASA, https://arc.aiaa.org/doi/10.2514/6.2024-4856

[24] Committee to Study LunaNet Governance, IOAG, 2023, https://www.ioag.org/Public%20Documents/Committee%20to%20Study%20LunaNet%20Governance%20ToR.pdf

[25] Committee to Study LunaNet Governance, IOAG, 2023, https://www.ioag.org/Public%20Documents/Committee%20to%20Study%20LunaNet%20Governance%20ToR.pdf

[26] https://www.ioag.org/SitePages/Joint-ICG-IOAG-Multilateral-Cislunar-PNT-Workshop.aspx

[27] https://www.ioag.org/_layouts/15/WopiFrame.aspx?sourcedoc=%7B4BB19E35-E276-4A6F-B0D8-54C9265EA1D9%7D&file=01%20LunaNet%20for%20ICG-IOAG%20CisLun%20PNT%2011-13Feb2025v4.pdf&action=default

[28] https://www.ioag.org/_layouts/15/WopiFrame.aspx?sourcedoc=%7B838B241A-29D6-49F6-9D66-5604FF99D0A6%7D&file=03%20LunaNet%20Perspectives,%20Frame,%20Suzuna%20OKAMOTO%20(JAXA)_A.pdf&action=default

[29] CCSDS Blue Book of Recommended Standards Table 3-1: Recommended Frequency Bands for Communications in the Lunar Region, 2024, https://public.ccsds.org/Pubs/883x0b2.pdf

[30] https://www.ioag.org/_layouts/15/WopiFrame.aspx?sourcedoc=%7BCBBE47E8-08DA-480E-B0E1-0365245CB8C2%7D&file=06%20CCSDS-LunarPNT-13-02-25.pdf&action=default

both S-band and L-band for Lunar PNT.[31] Both the U.S. and the SFCG stated that S-band is the optimal choice for lunar PNT and not L-band which could cause harmful interference to radio astronomy observations in the Shielded Zone of the Moon (SZM), which are protected by ITU Radio Regulations. Although, in multiple presentations, Chinese representatives emphasized the desire for interoperable lunar PNT systems through standardization at national and international levels. Furthermore, when presenting on S-band PNT frequencies, Chinese representatives displayed the same S-band frequency listed by LunaNet's PNT Augmented Forward System (AFS), 2483.5 - 2500 MHz. Despite Beijing's statement to also study L-band as a PNT backup, CCSDS stated that they will be studying LunaNet's AFS as a potential standard for lunar PNT, further strengthening NASA's push for international LunaNet adoption.

NASA is also embedding compliance mandates in its commercial contracts for lunar missions. Contractors for the Lunar Communication Relay and Navigation System (LCRNS) must adhere to LunaNet standards, ensuring alignment with NASA's vision.[32] Companies like Intuitive Machines and Lockheed Martin's subsidiary Crescent Space are already agreeing to adopt these standards.[33]

Q3: What are the chances NASA's plans will be adopted internationally?

A2: NASA's strategic use of contractual mandates and active role in international fora positions it to influence the establishment of global standards for lunar communications. Both ESA and JAXA have committed to abide by LunaNet for future lunar missions and mandate compliance for their commercial contractors, which will further strengthen this foundation.[34] ESA's Moonlight program, a European and Canadian industry consortium encouraging commercial development and control of lunar SATCOM, will be fully LunaNet compliant.[35] Moonlight will deploy five satellites in-orbit around the Moon, four for navigation and one for communication, targeting the lunar south pole. After the initial Lunar Pathfinder satellite mission, ESA has committed to requiring LunaNet compliance in future contract proposals, ensuring that their commercial partners adhere to the same lunar spectrum usage standards.[36] [37]Similarly, JAXA's Lunar Navigation Satellite System (LNSS) is designed to abide by LunaNet's frequency ranges.[38] LNSS will consist of eight relay orbiters providing GPS for the lunar south pole, with the first deployment scheduled to be built by the Japanese company Arkedge Space. The combination of NASA's, ESA's, and JAXA's planned lunar SATCOM deployments, built with LunaNet principles, should create a robust foundation for lunar communications infrastructure. Future space actors, both commercial and governmental, should be influenced to adopt LunaNet

[31]https://www.ioag.org/_layouts/15/WopiFrame.aspx?sourcedoc=%7BA47F26D6-C27D-460E-B025-E64D615DBEA4%7D&file=01%20IOAG-ICG%20on%20Lunar%20PNT-Feb2025-SFCG.pdf&action=default

[32] LCRNS Lunar Relay Services Requirements, NASA, 2023, https://sam.gov/api/prod/opps/v3/opportunities/resources/files/384128cc09134971b29c51d6b1256fb7/download?&status=archived&token=

[33] LM/Crescent Lunar-Cislunar Services Overview, Lockheed Martin, June 2023, https://licensing.fcc.gov/myibfs/download.do?attachment_key=23036041

[34] Cheryl Graming NASA, Juan Crenshaw NASA, Floor Melman ESA, Richard Swinden ESA, Masaya Murata JAXA, LunaNet: Interoperability for Lunar PNT, 2024, UNOOSA ICG, June 2024, https://www.unoosa.org/documents/pdf/icg/2024/WG-B_Lunar_PNT_Jun24/LunarPNT_Jun24_01_01.pdf

[35]ESAs Moonlight Programme: Pioneering for Lunar Exploration, ESA, 2024, https://www.esa.int/Applications/Connectivity_and_Secure_Communications/ESA_s_Moonlight_programme_Pioneering_the_path_for_lunar_exploration

[36] US-ESA MOU Lunar Pathfinder, https://www.state.gov/wp-content/uploads/2023/10/22-615-European-Space-Agency-Space-Lunar-Pathfinder-6.15.2022-TIMS-63201.pdf

[37] Joint Concept of Operations for Cooperative Lunar Relay and Navigation, ESA-NASA, 2022, https://www.nasa.gov/wp-content/uploads/2023/04/joint_con_ops_document_dec_14_2022_final_draft.pdf

[38] Lunar Navigation Satellite System (LNSS) and Its Demonstration Mission, JAXA, 2022, https://www.unoosa.org/documents/pdf/icg/2022/ICG16/WG-B/ICG16_WG-B_03.pdf

principles, recognizing it as the most cost-efficient option since the foundational infrastructure will have been established. All three systems have a planned interoperability test demonstration scheduled for 2029 to prove to the industry the robustness of the LunaNet concept. NASA’s shared lunar spectrum vision is also being adopted by international organizations, with the IOAG establishing a Committee to Study LunaNet Governance and the Consultative Committee for Space Data Systems (CCSDS) recommending LunaNet’s founding SFCG frequencies in their Blue Book of Recommended Standards. CCSDS also created an annual LunaNet Developers Forum and a Lunar Interoperability Forum.[39][40] Additionally, the SFCG recommends NASA’s LSMP as an international coordination point prior to filing for lunar spectrum and there are multiple frequency overlaps between LunaNet frequencies and those currently undergoing testing by the ITU as shown in Table 1.[41] Furthermore, NASA continues to provide technical support for ITU lunar spectrum studies, with the results directly influencing WRC-27 regulatory decisions, which will serve as the foundation for the FCC's eventual lunar framework.

The Moon will be the proving ground for all future space exploration, and the rules established during this next phase in space development will create a framework for human exploration across the entire solar system. It is imperative that a robust framework is set up based on internationally developed shared spectrum usage to ensure the success of all future space endeavors. ›

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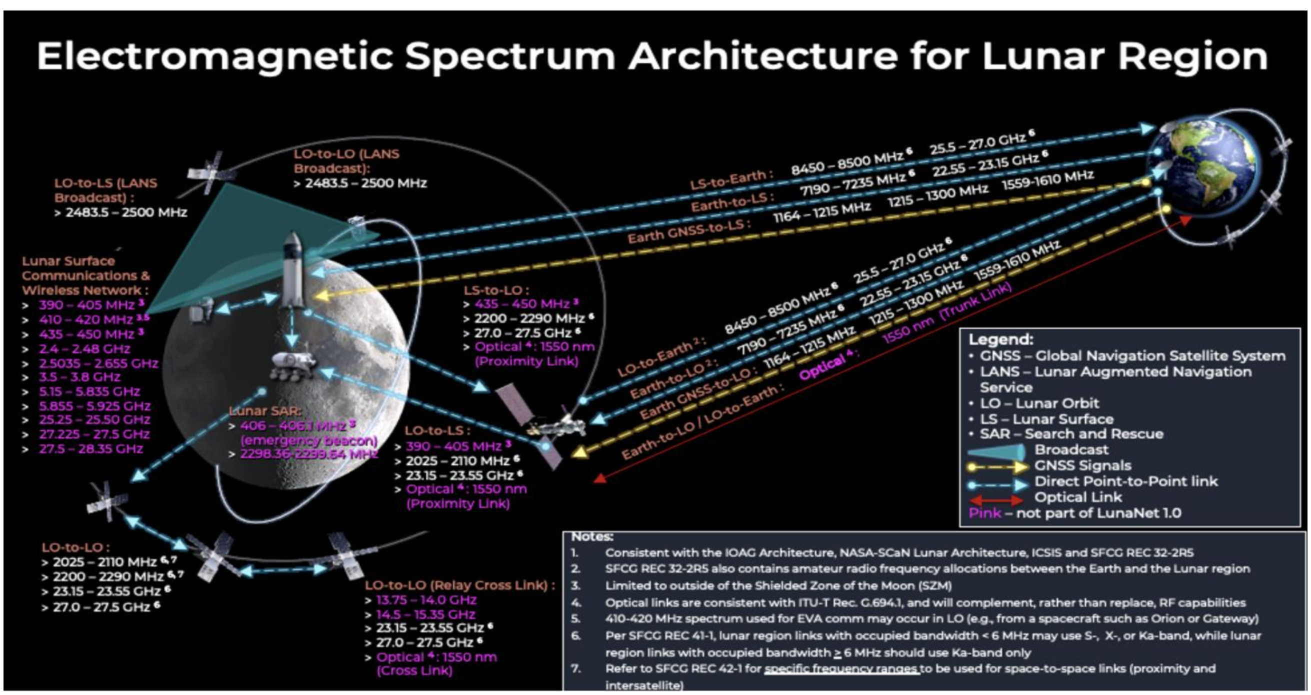
Figure 1: Electromagnetic Spectrum Architecture for Lunar Region
(Source: LunaNet Interoperability Specification Version 5, 2025, https://www.nasa.gov/wp-content/uploads/2025/02/lunanet-interoperability-specification-v5-baseline.pdf?emrc=606f9)



[39] CCSDS LunaNet Developers Forum, https://public.ccsds.org/meetings/2023Fall/DevForum.aspx
[40] CCSDS Lunar Interoperability Forum, https://public.ccsds.org/LunarForum.aspx
[41] Resolution A40-1: Assistance in the Assignment of Frequencies to Missions in the Lunar Vicinity, SFCG, 2024, https://www.sfcgonline.org/Resolutions/RES%20SFCG%20A40-1%20(Assistance%20in%20the%20Assignment%20of%20Frequencies%20to%20missions%20in%20the%20Lunar%20Reg).pdf

Table 1: Lunar Spectrum Frequencies

(Sources: (1) Lunar Spectrum Management Portal Recommended Frequency Bands, https://www.nasalsmp.org/SitePages/Recommended-Frequency-Bands.aspx, and (2) International Coordination and Cooperation on LunaNet Spectrum, NASA, 2024, https://ntrs.nasa.gov/api/citations/20240011047/downloads/2024_Ka-Band_LunaNet_Spectrum.pd)

Broad Lunar Spectrum Categories	SFCG Lunar Frequencies	Band	Selected for ITU Lunar Testing	LunaNet Frequencies
Earth to Lunar Orbit	2025-2110 MHz 7190-7235 MHz 22.55-23.15 GHz 40.0-40.5 GHz	S C K Ka	 7190-7235 MHz	2025 – 2110 MHz 7190 – 7235 MHz 22.55 – 23.15 GHz
Lunar Orbit to Earth	2200-2290 MHz 8450-8500 MHz 25.5-27.0 GHz 37-38 GHz	S X Ka Ka	 8450-8500 MHz	2200 – 2290 MHz 8450 – 8500 MHz 25.5 – 27.0 GHz
Earth to Lunar Surface	2025-2110 MHz 7190-7235 MHz 22.55-23.15 GHz	S C K	 7190-7235 MHz	2025 – 2110 MHz 7190 – 7235 MHz 22.55 – 23.15 GHz
Lunar Surface to Earth	2200-2290 MHz 8450-8500 MHz 25.5-27.0 GHz	S X Ka	 8450-8500 MHz	2200 – 2290 MHz 8450 – 8500 MHz 25.5 – 27.0 GHz
Lunar Orbit to Lunar Surface	390-405 MHz 2025-2110 MHz 23.15-23.55 GHz	UHF S K	390-406.1 MHz	406 – 406.1 MHz (emergency beacon) 2025 – 2110 MHz 23.15 – 23.55 GHz
Lunar Surface to Lunar Orbit	435-450 MHz 2200-2290 MHz 27.0-27.5 GHz	UHF S Ka	440-450 MHz	435 – 450 MHz 2200 – 2290 MHz 27.0 – 27.5 GHz
Lunar Orbit to Lunar Orbit	2025-2110 MHz 2200-2290 MHz 23.15-23.55 GHz 27.0-27.5 GHz	S S K Ka		2025 – 2110 MHz 2200 – 2290 MHz 23.15 – 23.55 GHz 27.0 – 27.5 GHz
Lunar Surface Wireless Network	390-405 MHz 410-420 MHz 435-450 MHz 2.400-2.480 GHz 2.5035-2.655 GHz 3.5-3.8 GHz 5.15-5.835 GHz 5.855-5.925 GHz 25.25-25.5 GHz 27.225-27.5 GHz 27.5-28.35 GHz	UHF UHF UHF S S S C C Ka Ka Ka	390-406.1 MHz 420-430 MHz 440-450 MHz 2 400-2 690 MHz 2 400-2 690 MHz 3 500-3 800 MHz 5 150-5 570 MHz 5 775-5 925 MHz 25.25-28.35 GHz 25.25-28.35 GHz 25.25-28.35 GHz	406 – 406.1 MHz (emergency beacon) 410 – 420 MHz 435 – 450 MHz 2.4 – 2.48 GHz 2.503 – 2.655 GHz 3.5 – 3.8 GHz 5.15 – 5.835 GHz 5.855 – 5.925 GHz 25.25 – 25.50 GHz 27.225 – 27.5 GHz 27.5 – 28.35 GHz
Lunar Relay to Lunar Relay Cross Link	13.75-14 GHz 14.5-15.35 GHz 23.15-23.55 GHz 27.0-27.5 GHz 37-38 GHz 40-40.5 GHz	Ku Ku K Ka Ka Ka		13.75 – 14.0 GHz 14.5 – 15.35 GHz 23.15 – 23.55 GHz 27.0 – 27.5 GHz
Amateur Radio Operations, Earth-to-Lunar Orbit	144-146 MHz 435-438 MHz 2.4-2.45 GHz 5.65-5.67 GHz	VHF UHF S C		
Amateur Radio Operations, Lunar Orbit-to-Earth	144-146 MHz 435-438 MHz 10.45-10.5 GHz	VHF UHF X		
Lunar PNT (LunaNet AFS for Navigation)	2483.5-2500 MHz	S		2483.5 – 2500 MHz
Earth GNSS to Lunar Surface		L L L		1164 – 1215 MHz 1215 – 1300 MHz 1559 – 1610 MHz
Optical Links				Optical: 1550 nm (Proximity Link) Optical: 1550 nm (Cross Link) Optical: 1550 nm (Trunk Link)

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Notes

LunaNet and Lunar Communications:

1) Lunar Spectrum Overview and World Radio Conference Update, NASA 2024, https://www.unoosa.org/documents/pdf/icg/2024/WG-B_Lunar_PNT_Jun24/LunarPNT_Jun24_02_01.pdf?utm_source=chatgpt.com
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