National Aeronautics and Space Administration

Lunar Spectrum Overview and World Radio Conference Update

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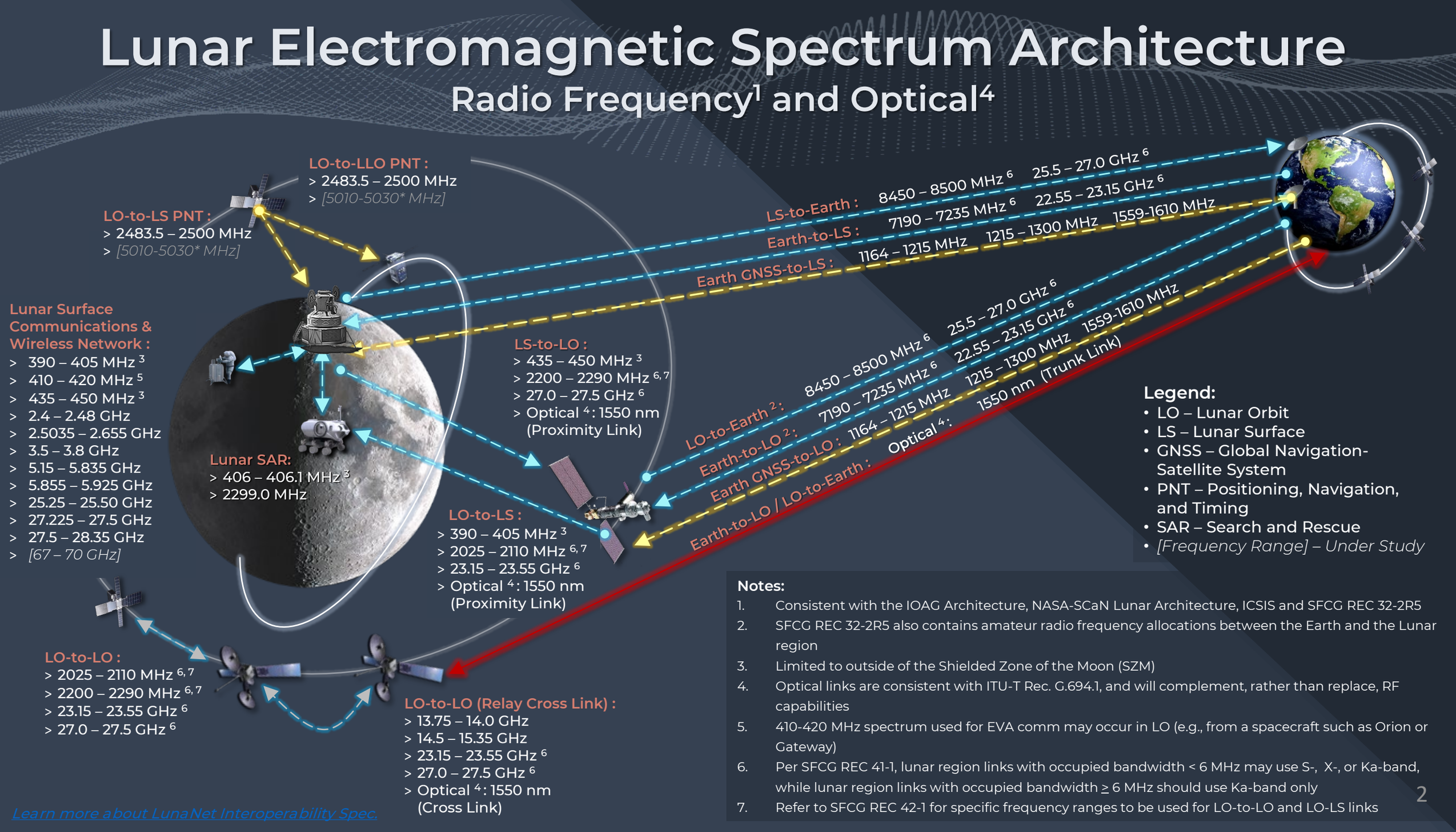
Joint Working Group Session(WG B, D & S)

ICG Intersessional Meeting

25 – 26 June 2024

Lunar Electromagnetic Spectrum Architecture

Radio Frequency[1] and Optical[4]



Legend:

- LO – Lunar Orbit
- LS – Lunar Surface
- GNSS – Global Navigation-Satellite System
- PNT – Positioning, Navigation, and Timing
- SAR – Search and Rescue
- *[Frequency Range] – Under Study*

Notes:

1. Consistent with the IOAG Architecture, NASA-SCaN Lunar Architecture, ICSIS and SFCG REC 32-2R5
2. SFCG REC 32-2R5 also contains amateur radio frequency allocations between the Earth and the Lunar region
3. Limited to outside of the Shielded Zone of the Moon (SZM)
4. Optical links are consistent with ITU-T Rec. G.694.1, and will complement, rather than replace, RF capabilities
5. 410-420 MHz spectrum used for EVA comm may occur in LO (e.g., from a spacecraft such as Orion or Gateway)
6. Per SFCG REC 41-1, lunar region links with occupied bandwidth < 6 MHz may use S-, X-, or Ka-band, while lunar region links with occupied bandwidth ≥ 6 MHz should use Ka-band only
7. Refer to SFCG REC 42-1 for specific frequency ranges to be used for LO-to-LO and LO-LS links

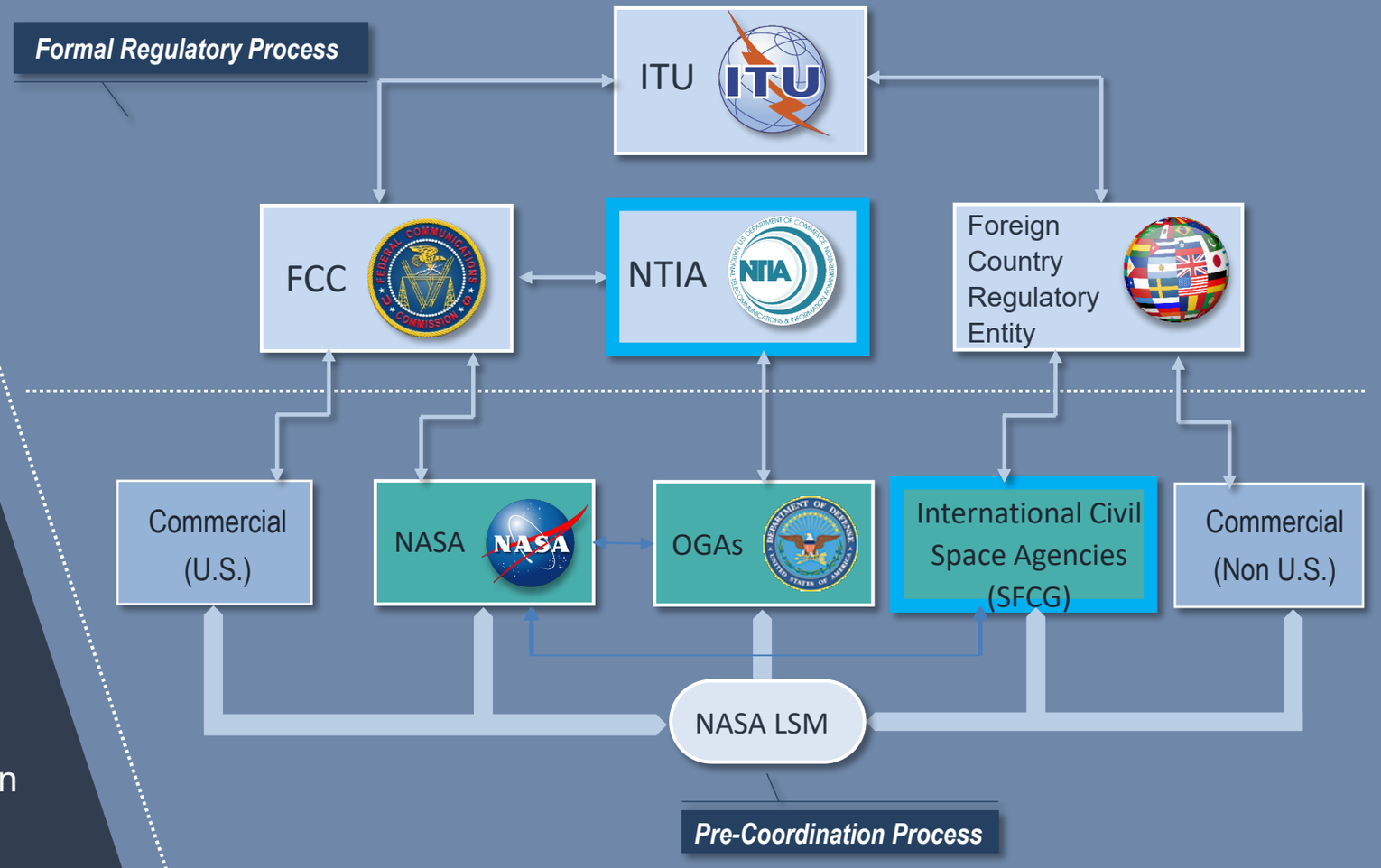
Learn more about LunaNet Interoperability Spec.

NASA Lunar Mission Pre-Coordination Process

Pre-Coordination promotes maximum compatibility and mission success by facilitating technical analysis and pre-coordination between lunar-region missions.

The International Space Station RF coordination process established in 2000 has served the international partners well and is used as a model for lunar coordination.

- **Lunar Working Group,** chaired by NASA, to assist NTIA IRAC Subcommittees in assessing lunar region spectrum-dependent systems proposals during spectrum certification, ITU filing initiation, and frequency assignment processes.
- **SFCG Administrative Resolution A40-1,** encourages lunar mission planners at member agencies and within their perspective administrations to initiate technical pre-coordination during the initial formulation phase or as early as possible during the planning phase.

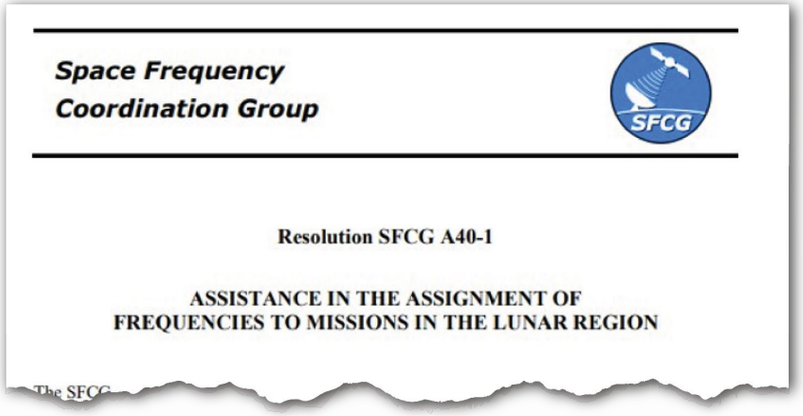


Space Frequency Coordination Group (SFCG) Overview

- **A forum for member civil space agencies to collaborate and develop solutions in a flexible environment for efficient and effective spectrum sharing for missions of mutual interests that operate in frequency bands allocated to space science services.**
  - Conduct **technical studies** to enable scientific missions and its applications in the following **space services**:
    - Space research
    - Space Operations
    - Earth Exploration Satellite
    - Meteorological Satellite
    - Inter-satellite
  - Feeder links and data relay satellites operated in connection with above services, and with space-based radio astronomy (including radio astronomy)

- SFCG member space agencies work with relevant partners within their countries' space communities to achieve mutual goals in space.

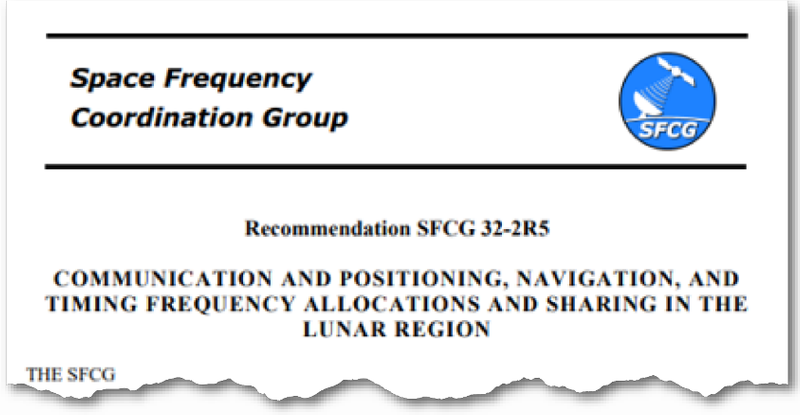
Recent SFCG Outputs of Interest (1 of 2) (Lunar/Martian Spectrum Group (LMSG))


Space Frequency Coordination Group

Resolution SFCG A40-1

ASSISTANCE IN THE ASSIGNMENT OF FREQUENCIES TO MISSIONS IN THE LUNAR REGION

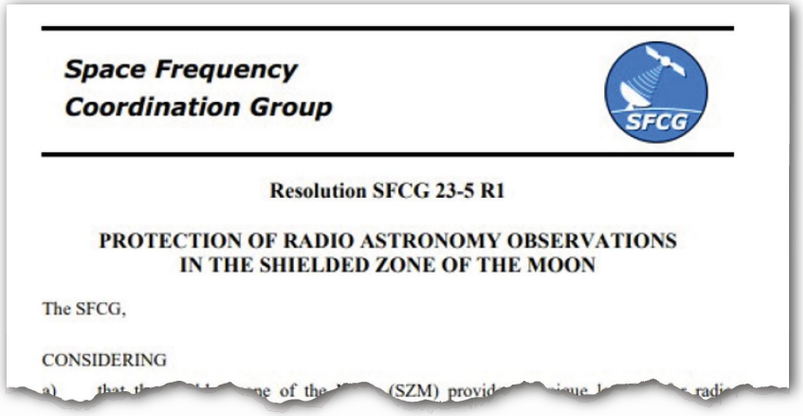
The SFCG


Space Frequency Coordination Group

Recommendation SFCG 32-2R5

COMMUNICATION AND POSITIONING, NAVIGATION, AND TIMING FREQUENCY ALLOCATIONS AND SHARING IN THE LUNAR REGION

THE SFCG


Space Frequency Coordination Group

Resolution SFCG 23-5 R1

PROTECTION OF RADIO ASTRONOMY OBSERVATIONS IN THE SHIELDED ZONE OF THE MOON

The SFCG,

CONSIDERING

SFCG RES A 40-1,"Assistance in the Assignment of Frequencies to Missions in the Lunar Region":

- Process to provide assistance with the selection of frequency assignments to SFCG Member Agencies and non-SFCG organizations for lunar missions.

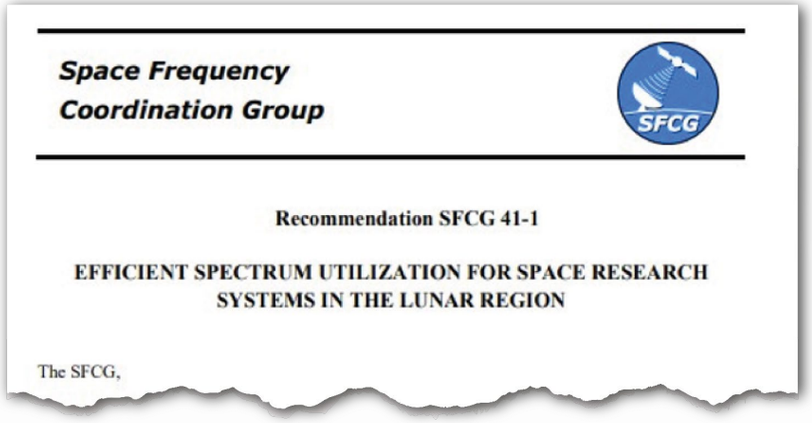
SFCG REC 32-2R5, "Communications and Positioning, Navigation, and Timing Frequency Allocations and Sharing in the Lunar Region":

- Regularly updated to reflect ongoing assessments considering recommended frequencies for lunar vicinity applications.
- Addresses various services including communications (between Earth and lunar vicinity and local lunar links), PNT, and lunar search-and-rescue (LunaSAR)

SFCG RES 23-5,"Protection of Radio Astronomy Observations in the Shielded Zone on the Moon":

- SFCG members will limit uses of active systems in the SZM as described by ITU RR Article 22, Nos. 22.22 through 22.25.
- SFCG members will coordinate the envisioned uses of active systems in the SZM with the Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF) through the SFCG.

Recent SFCG Outputs of Interest (2 of 2) (Lunar/Martian Spectrum Group (LMSG))

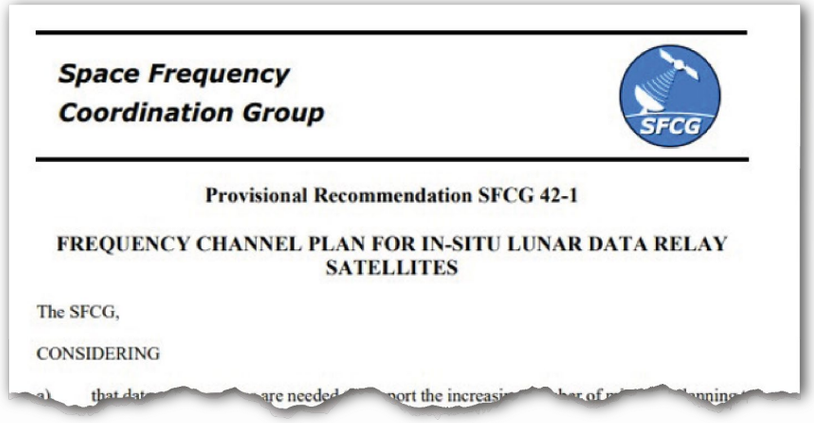


Space Frequency Coordination Group

Recommendation SFCG 41-1

EFFICIENT SPECTRUM UTILIZATION FOR SPACE RESEARCH SYSTEMS IN THE LUNAR REGION

The SFCG,



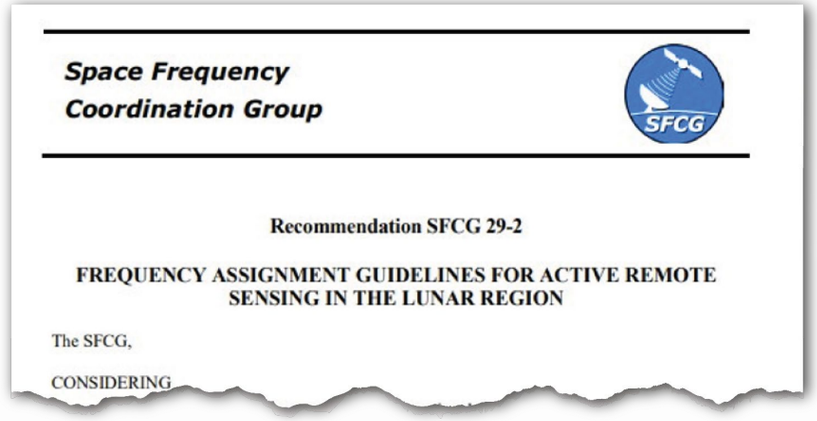
Space Frequency Coordination Group

Provisional Recommendation SFCG 42-1

FREQUENCY CHANNEL PLAN FOR IN-SITU LUNAR DATA RELAY SATELLITES

The SFCG,

CONSIDERING



Space Frequency Coordination Group

Recommendation SFCG 29-2

FREQUENCY ASSIGNMENT GUIDELINES FOR ACTIVE REMOTE SENSING IN THE LUNAR REGION

The SFCG,

CONSIDERING

SFCG REC 41-1, "Efficient Spectrum Utilization for Space Research Systems in the Lunar Region":

- *Technical conditions for Earth-to-space and space-to-Earth links, as well as in-situ lunar links (space-to-space) and relay links*

SFCG REC 42-1, "Frequency Channel Plan for In-situ Lunar Data Relay Satellites":

- Support interoperability by defining dedicated frequencies in S-band for single access and multiple access services, and also S-band Prox-1 channels
- Definition of Ka-band channels for in-situ lunar relay services is under study

SFCG REC 29-2, "Frequency Assignment Guidelines for Active Remote Sensing in the Lunar Region":

- Current in-force recommendation includes science-focused frequencies for lunar exploration.
- Work in progress to evaluate existing & proposed active remote sensing frequencies including compatibility with passive missions, including radio astronomy observations in the SZM.

SFCG Prov. REC 43-1, "PROTECTION OF IN-SITU LUNAR REGION POSITIONING, NAVIGATION, AND TIMING (PNT) SERVICES IN THE 2 483.5 – 2 500 HZ FREQUENCY BAND FROM UNWANTED EMISSIONS FROM LUNAR SURFACE COMMUNICATIONS SYSTEMS"

- Recommends emitter and receiver design considerations to protect in-situ S-band links

WRC-27 Agenda Item on Lunar / Cis-lunar Spectrum Use

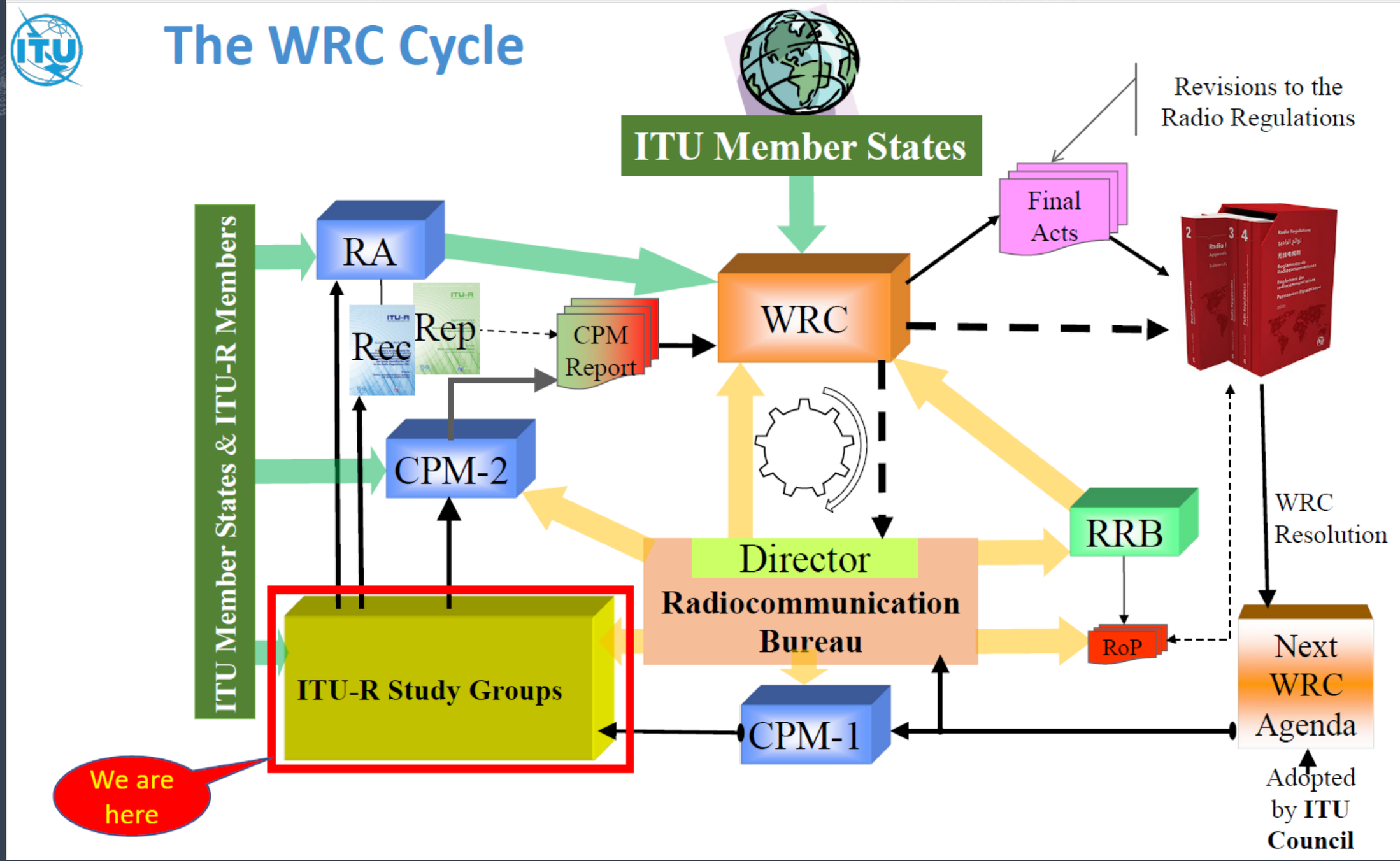
As agreed at World Radio Conference 2023 (WRC-23) which concluded on 15 December 2023

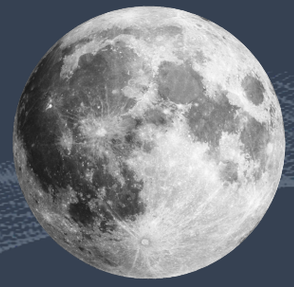
WRC-27 Agenda Item 1.15: to consider studies on frequency-related matters, including possible new or modified space research service (space-to-space) allocations, for future development of communications on the lunar surface and between lunar orbit and the lunar surface, in accordance with **Resolution 680** (WRC-23)

Studies will be led by International Telecommunications Union (ITU) Working Party 7B in several frequency ranges, including 2 400-2 690 MHz which encompasses the 2 483.5-2 500 MHz for messaging to subscribers including Positioning, Navigation, and Timing (PNT) data.

https://www.itu.int/wrc-23/

The WRC Cycle





Work Plan* for WRC-27 Agenda item 1.15 (2024 – 2025)

2024	
1st WP 7B meeting (18-22 March 2024)	– Send liaison statements (LS) to WPs 1B, 3J, 4A, 4C, 5A, 5B, 5C, 5D, 7A, 7C and 7D, requesting propagation models and characteristics of the existing primary services in frequency ranges in Resolution 680 (WRC-23) – Continue development of WD towards a preliminary draft new Report (PDNRpt) ITU-R SA.[LUNAR.SRS STATIONS CHAR] on the Concept of operations and technical and operational characteristics of systems for Lunar operations – Develop a work plan for WRC-27 AI 1.15.
2nd WP 7B meeting (16-27 September 2024)	– Finalize/Continue development of concept of operations, technical and operational characteristics in the PDN Report ITU-R SA.[LUNAR.SRS STATIONS CHAR] – Develop first version of working document towards PDN Report ITU-R SA.[LUNAR_1.15_STUDIES] on sharing and compatibility studies related to systems in the SRS per Res. 680 (WRC-23) resolves 1, 2 and 4, based on input contributions – Analyze and respond to LS from contributing groups and develop reply LS as necessary – Review and update the work plan as necessary.

2025	
3rd WP 7B meeting (March/April 2025)	– Finalize collection of propagation models and technical characteristics from contributing groups and update WD towards PDN Report ITU-R SA.[LUNAR_1.15_STUDIES] (Annex [TBD] of Chair's Report Doc. 7B/[TBD]), based on input contributions – Finalize PDN Report ITU-R SA.[LUNAR.SRS STATIONS CHAR] and submit to Study Group (SG) 7 for consideration – Send LS to contributing groups as necessary – Initiate development of draft CPM text for WRC-27 AI 1.15 based on input contributions associated with the studies referred to in resolves to invite the ITU-R to complete in time for the 2027 world radiocommunication conference 1 to 5 – Initiate studies referred to in Resolution 680 (WRC-23) invites the ITU-R 1 and 2 – Review and update work plan as necessary.
4th WP 7B meeting ([TBD 2025])	– Update PDN Report ITU-R SA.[LUNAR_1.15_STUDIES], based on input contributions – Update draft CPM text for WRC-27 AI 1.15 based on input contributions – Send LS to contributing groups as necessary – Continue work on studies referred to in Resolution 680 (WRC-23) invites the ITU-R 1 and 2 – Review and update work plan as necessary.

**work plan will be reviewed at every WP meeting and updated as appropriate.*

Lunar Spectrum Planning & Coordination: Opportunities and Challenges

The Moon offers unique scientific value to radio astronomers; we must balance opportunities to explore it with **the need to protect and preserve it.**

Aim to define a frequency architecture with mutually agreed-upon standards to be applied by users and service providers in a cooperative network supporting missions on and around the Moon and **respect the provisions of ITU RR Article 22.22-22.25 and protect the Shielded Zone of the Moon.**

Space Frequency Coordination Group (SFCG) Resolution A40-1 actively encourages member civil space agencies and commercial entities to proactively cooperate with its national space agencies, voluntarily engage with the NASA Lunar Spectrum Manager (LSM) regarding planned lunar missions, and to leverage the assistance of the LSM with frequency selection, interference analysis., and technical precoordination process.

NASA's experience with programs such as International Space Station have demonstrated the criticality of a centralized focal point in the lunar region for advanced spectrum planning and facilitating pre-coordination.

Key Takeaways

Protecting the Shielded Zone of the Moon

- Directing missions to respect the provisions of ITU RR Article 22.22-22.25, including not transmitting in the SZM except for services authorized in Article 22

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Transmission Limits

- Directing missions to only transmit when in view of their receiving station
- Defining sharing and compatibility criteria to protect performance integrity and provide maximum operational flexibility

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Lunar Spectrum Architecture

- The Lunar Spectrum Architecture (e.g. LunaNet and similar efforts) is being defined with protection of the SZM in mind, following ITU RR & SFCG Recommendations