

Name

Mr. JAMES HIGGINS



Presentation
Title

Lunar Spectrum Activities - An Overview

Abstract

The last few years have seen a sharp increase in lunar activities, including NASA's upcoming Artemis missions, and plans from other space agencies and commercial entities. All these activities require spectrum, both for spacecraft and for Moon surface activities.

Bio data

Higgins supports NASA in its spectrum management programs both domestically (in the USA) and internationally (at the ITU) in his role at ASRC Federal ADS. He previously worked for the US Federal Communications Commission for 37 years in satellite and terrestrial monitoring, interference investigations, radio inspections and special development projects. He is a graduate of the University of Massachusetts - Lowell with a Bachelor of Science in Electrical Engineering.



Overview of Lunar Spectrum Activities

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Spectrum Management Engineer
ASRC Agile Decision Sciences
(NASA Space Communications and Navigation Support)

25th International Space
Radio Monitoring Meeting

NASA Lunar Spectrum Team

3 September 2024

25th ISRMM – Doha, Qatar



Outline

F u n F a c t s a b o u t t h e M o o n

E n t i t i e s a c t i v e a r o u n d t h e M o o n

L u n a r S p e c t r u m M a n a g e r

(L S M) O v e r v i e w

L u n a r S p e c t r u m A r c h i t e c t u r e

a n d I n t e r f e r e n c e C o n s i d e r a t i o n s

I T U a n d S p a c e F r e q u e n c y C o o r d i n a t i o n

G r o u p (S F C G) a c t i v i t i e s

R e l e v a n t D o c u m e n t a t i o n

a n d R e c o m m e n d a t i o n s

Artemis Accords

Fun Facts about the Moon

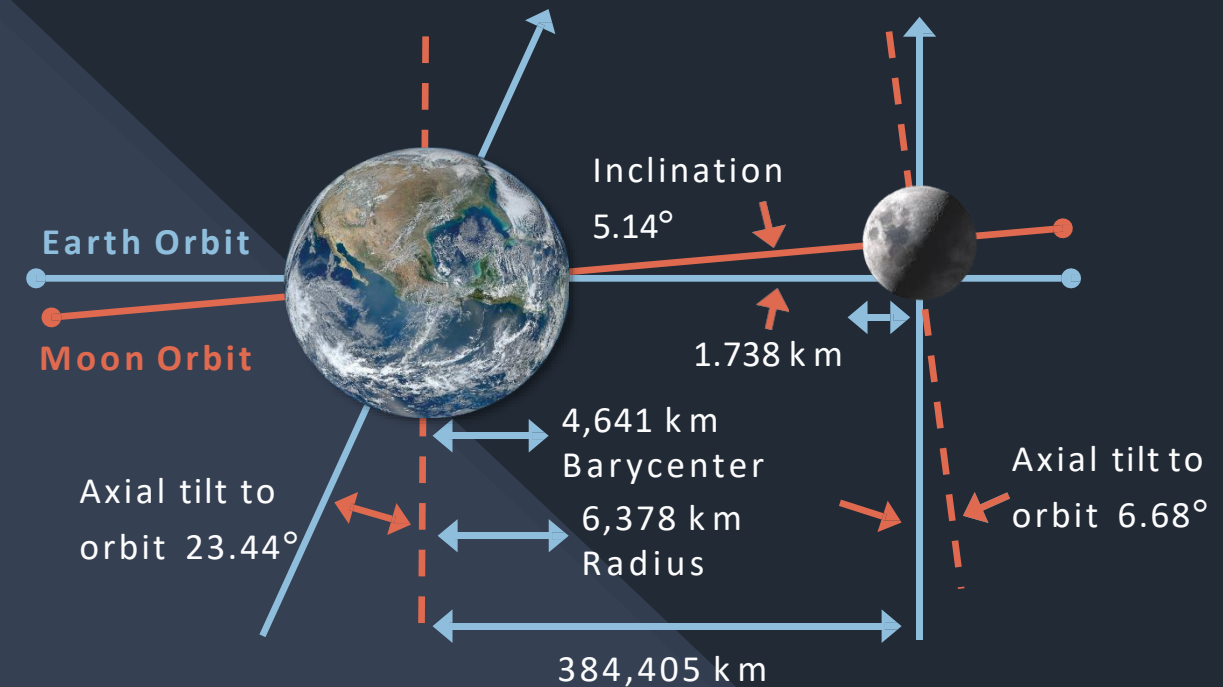
The distance between Moon and Earth varies between ~363,000 km and ~406,000 km

- Still within the 2 million km distance from Earth that marks the beginning of the deep space regime as defined by the ITU!

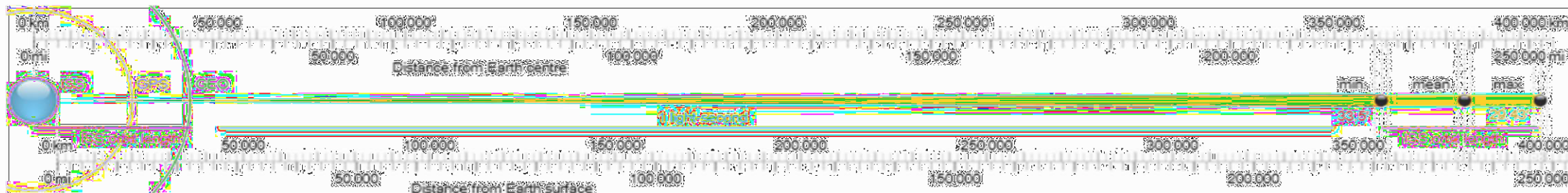
The Moon is rotating at the same rate that it revolves around Earth (called synchronous rotation), so the same hemisphere faces Earth all the time*

**Pink Floyd's "Dark Side of the Moon" is a bit of a misnomer, but "The Far Side of the Moon" probably didn't sound as enigmatic!*

The Moon's inclination in relation to the Earth's equator varies between 18.3° and 28.6° over an 18.6-year cycle

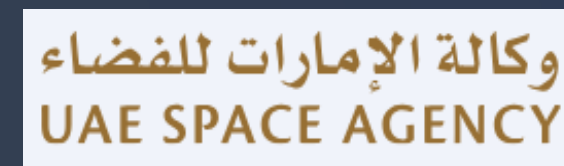


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Some Organizations recently involved in Lunar Activities



National
Spectrum
Regulators



Why do we need a Lunar Spectrum Manager?

- More National Space Agencies have accomplished or have planned Lunar space activities in recent years
- More commercial entities are getting involved in Lunar activities
- Coordination among all these new users across the globe is a “must” to ensure compatibility and avoid interference
- The ITU and the Space Frequency Coordination Group (SFCG) play key roles in Lunar Spectrum Management

NASA has offered, in the SFCG, to assist both SFCG Member **and** non-Member Agencies, at their request, with frequency assignments and related matters for lunar mission activities. (See Resolution SFCG A40-1)

Lunar Spectrum Coordination

Previously Launched Lunar Systems



International Spectrum Regulations for Lunar Uses

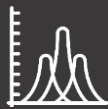
The ITU is the primary specialized agency of the United Nations Organization for managing the international use of radio frequency bands in order to avoid harmful interference between radiocommunications users, both Earth and space.



Role of a Lunar Spectrum Manager (LSM)



Provide **information** on available spectrum and applicable spectrum use **policies** and **constraints** pertinent to lunar region missions



Perform **frequency selection** (if requested) and **sharing analyses** to support coordination



Leverage knowledge of current and future spectrum usage to enable **early technical coordination** and develop viable mitigation approaches while **minimizing impacts** to involved lunar missions (U.S. missions, foreign space agencies, commercial missions)



Track **status** of lunar activities and **prioritize** spectrum pre-coordination actions based on launch timeframe, lunar project maturity, etc.



Provide post-launch **interference resolution assistance** when requested



*Serves as the
Central Focal Point
to facilitate a
comprehensive and
efficient spectrum pre-
coordination between lunar
and near-Earth missions
among all users of
spectrum around the Moon*

As Lunar region activities evolve...

NASA's Lunar & Human Spaceflight Spectrum Manager (Cathy Sham):

Serves as the **Central Focal Point** to facilitate comprehensive and efficient spectrum pre-coordination between lunar and near-Earth missions for U.S. & Other International Civil Space Agencies through participation in the US Domestic and International groups.

Provides **information** on available spectrum and applicable spectrum use **policies** and **constraints** pertinent to lunar region missions

Provides **frequency selection** (if requested) and **sharing analyses** to support coordination and develops viable mitigation approaches while **minimizing impacts** to involved lunar missions (U.S. missions, foreign space agencies, commercial missions)

Leverages knowledge of current and future spectrum usage to enable **early technical coordination**

Cathy Sham also Chairs the Lunar Martian Spectrum Group (LMSG) in the SFCG

NASA Lunar Spectrum Manager (LSM) Role & Responsibilities



NASA, Department of Defense (**DoD**), and Department of Commerce (**DoC**) (**NDD**) Working Group supports pre-coordination across US space programs

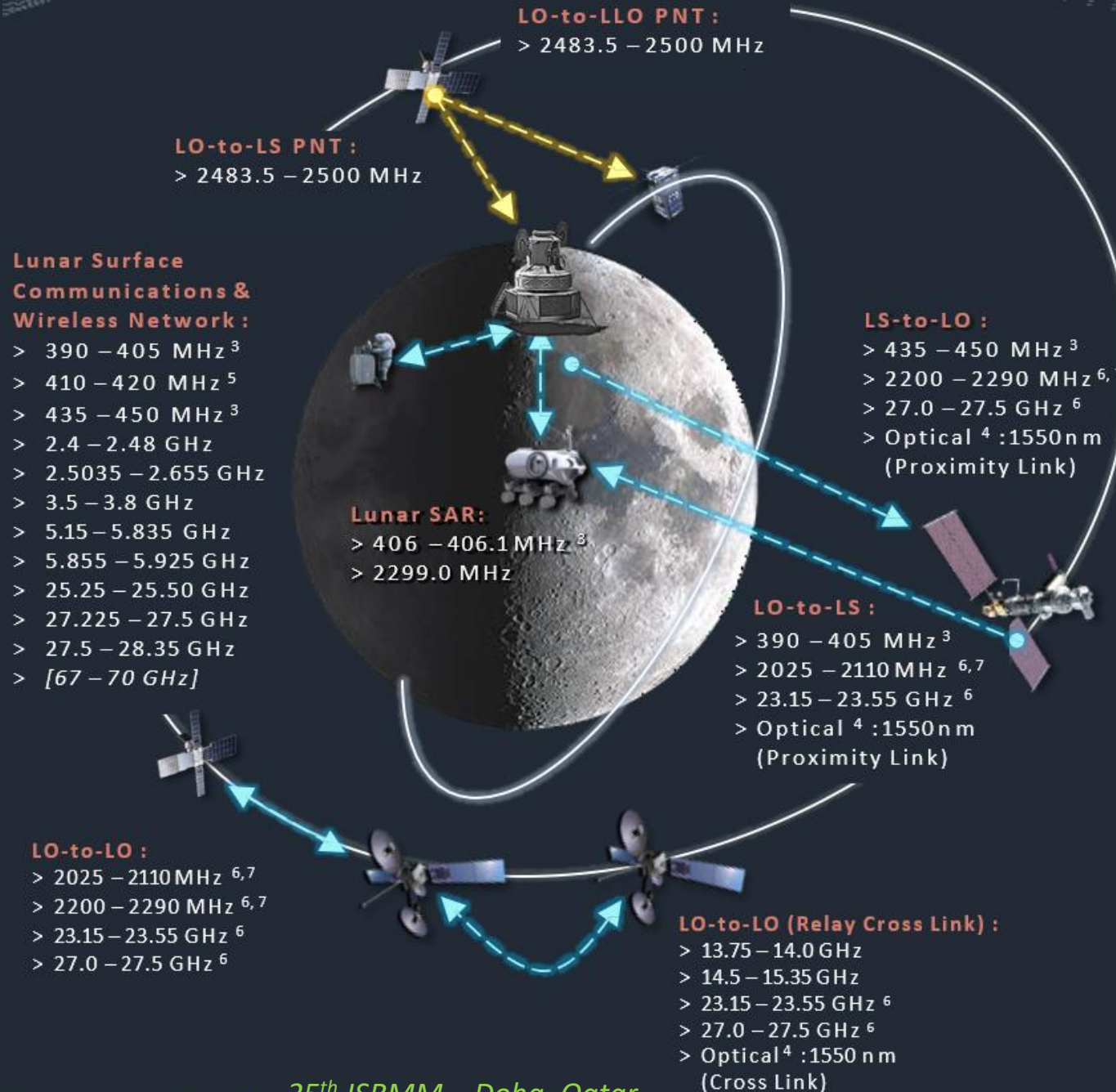
NTIA IRAC SPS Working Group: reviews certification requests for federal Lunar Missions & US commercial missions via FCC liaison

International Telecommunications Union (**ITU**) Working Party 7B-Space Radiocommunications Applications

Space Frequency Coordination Group (**SFCG**) Lunar Martian Spectrum Group (**LMSG**)

Lunar Vicinity Electromagnetic Spectrum Architecture

Radio Frequency¹ and Optical⁴



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

Active remote sensing frequencies are identified in SFCG REC 29-2

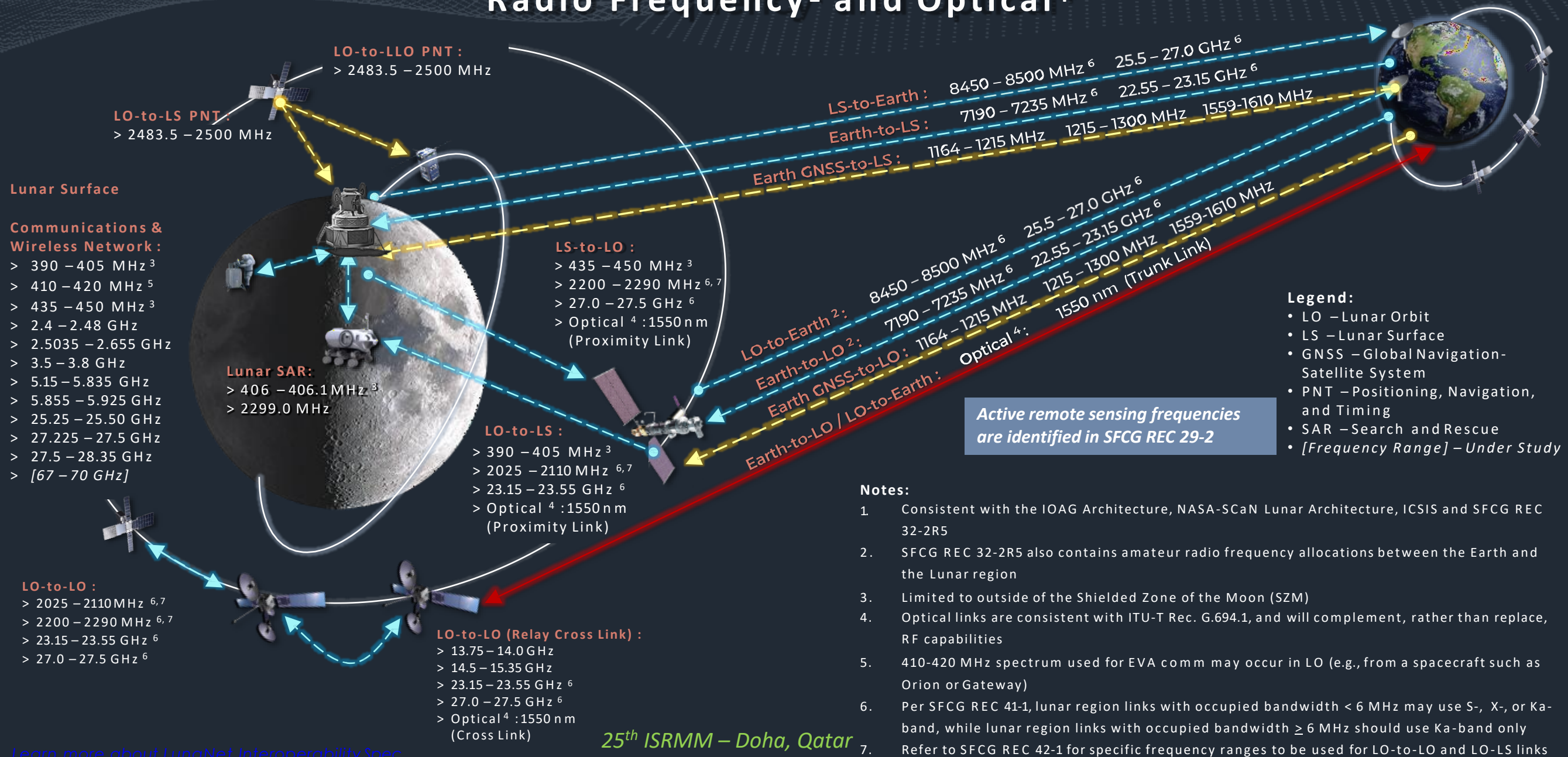
[Learn more about LunaNet Interoperability Spec](#)

Legend:

- LO – Lunar Orbit
- LS – Lunar Surface
- GNSS – Global Navigation-Satellite System
- PNT – Positioning, Navigation, and Timing
- SAR – Search and Rescue
- [Frequency Range] – Under further SFCG member agencies investigation

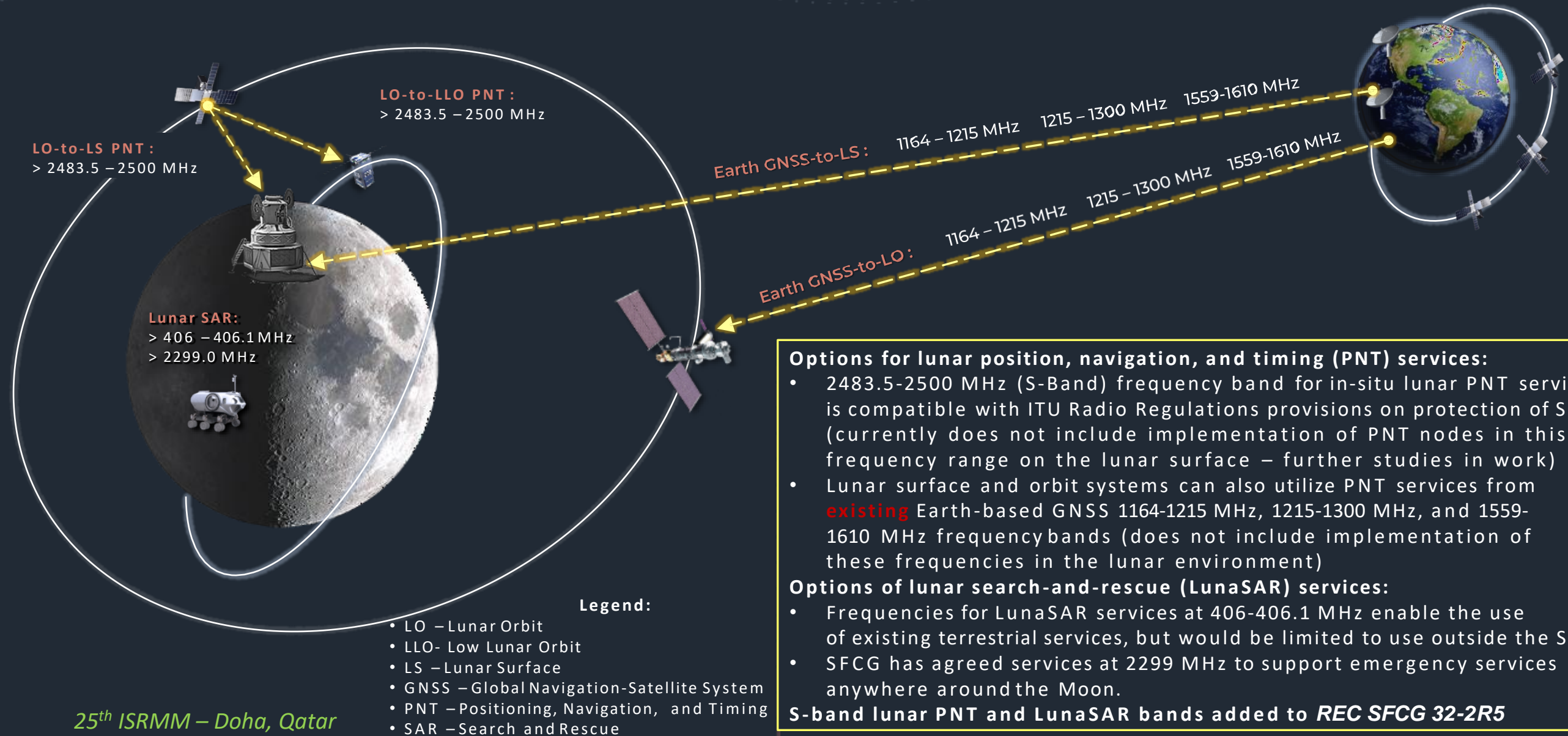
Lunar Exploration Electromagnetic Spectrum Architecture

Radio Frequency¹ and Optical⁴



Lunar Electromagnetic Spectrum Architecture

Considerations for Lunar PNT & SAR Services





Interference Considerations for Lunar/Cislunar Spectrum Use

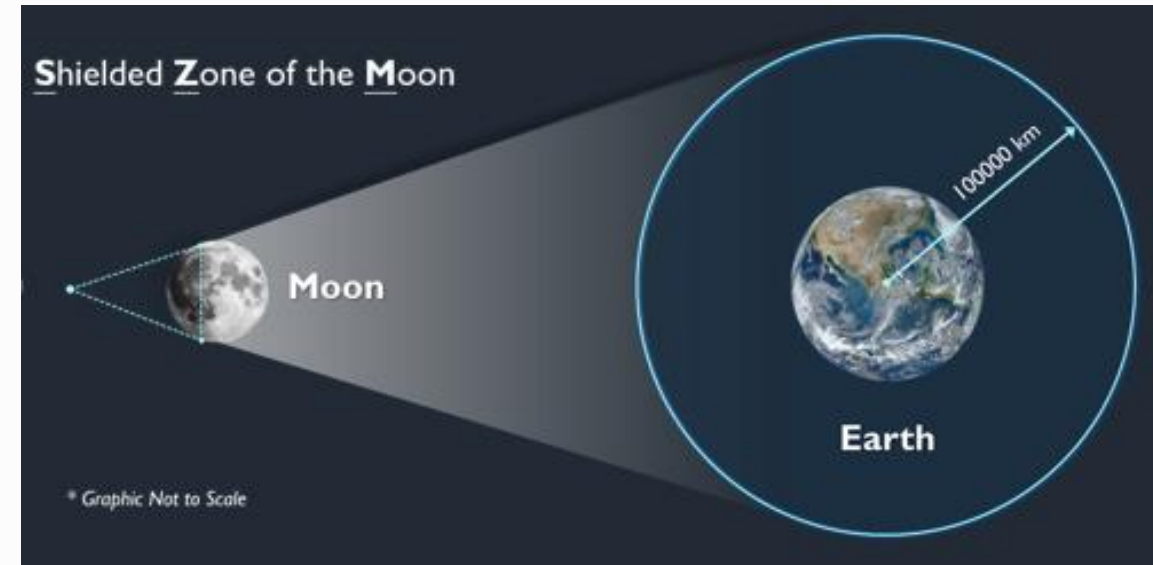
Interference issues on the Moon:

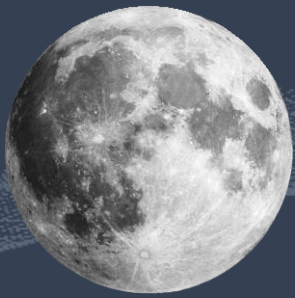
- are equivalent to those on Earth
- in band interference (if systems not coordinated)
- adjacent band interference from nearby systems
- protection of RAS in Shielded Zone of the Moon (SZM)

The goal of the Lunar spectrum management

coordination process for frequency, power, and related parameters is to avoid interference around the Moon and from Moon activities to Earth systems.

For interference associated with Earth-Moon links, the considerations are mostly related to Earth spectrum activities





WRC-27 Agenda Item on Lunar/Cislunar Spectrum Use

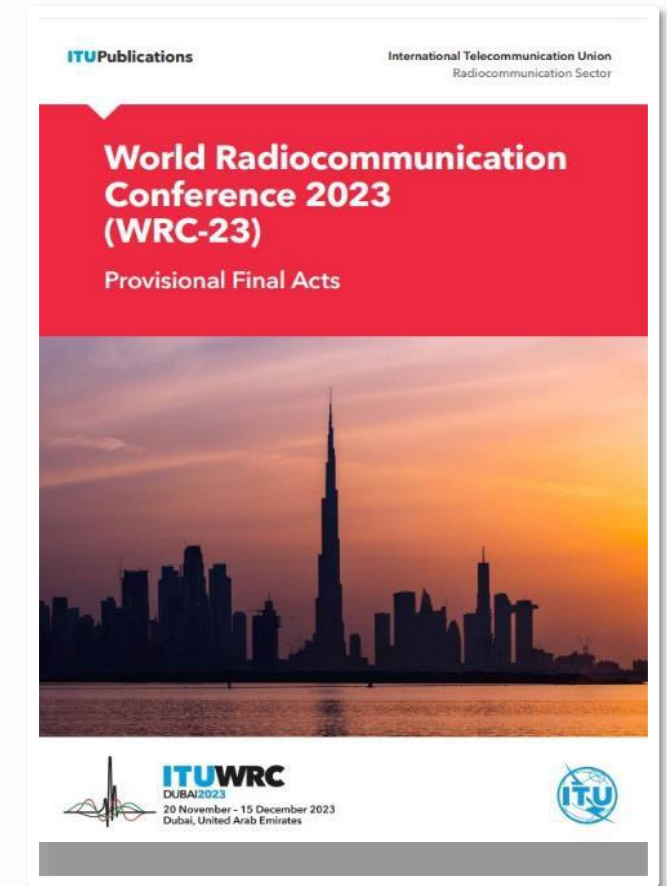
As agreed at World Radio Conference 2023
(WRC-23) which concluded on 15 December 2023

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 and between lunar orbit and the lunar surface, in accordance with Resolution 680 (WRC-23)

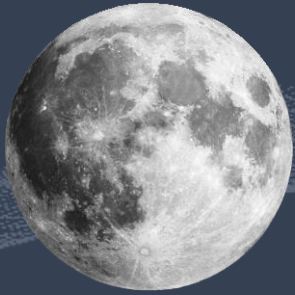
Studies will be led by International Telecommunications Union (ITU) Working Party 7B in frequency ranges specified by Resolution 680 (WRC-23)

- Technical and operational characteristics for lunar space research service systems are under development in WP 7B (update in just-concluded March 2024)
- Preliminary sharing studies anticipated to begin through contributions to the September 2024 WP 7B meeting, per agreed work plan (7B/35 [Annex 1](#))



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

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

<https://www.sfcgonline.org/Resources/default.aspx/>

**Space Frequency
Coordination Group**



Resolution SFCG A40-1

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

The SFCG

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.

**Space Frequency
Coordination Group**



Recommendation SFCG 32-2R5

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

THE SFCG

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)

**Space Frequency
Coordination Group**



Resolution SFCG 23-5 R1

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

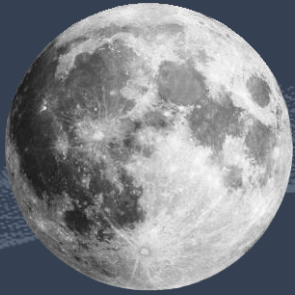
The SFCG,

CONSIDERING

a) that the Shielded Zone of the Moon (SZM) provides a unique radio

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

<https://www.sfcgonline.org/Resources/default.aspx/>

**Space Frequency
Coordination Group**



Recommendation SFCG 41-1

**EFFICIENT SPECTRUM UTILIZATION FOR SPACE RESEARCH
SYSTEMS IN THE LUNAR REGION**

The SFCG,

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 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

**Space Frequency
Coordination Group**



Provisional Recommendation SFCG 42-1

**FREQUENCY CHANNEL PLAN FOR IN-SITU LUNAR DATA RELAY
SATELLITES**

The SFCG,

CONSIDERING

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

**Space Frequency
Coordination Group**



Recommendation SFCG 29-2

**FREQUENCY ASSIGNMENT GUIDELINES FOR ACTIVE REMOTE
SENSING IN THE LUNAR REGION**

The SFCG,

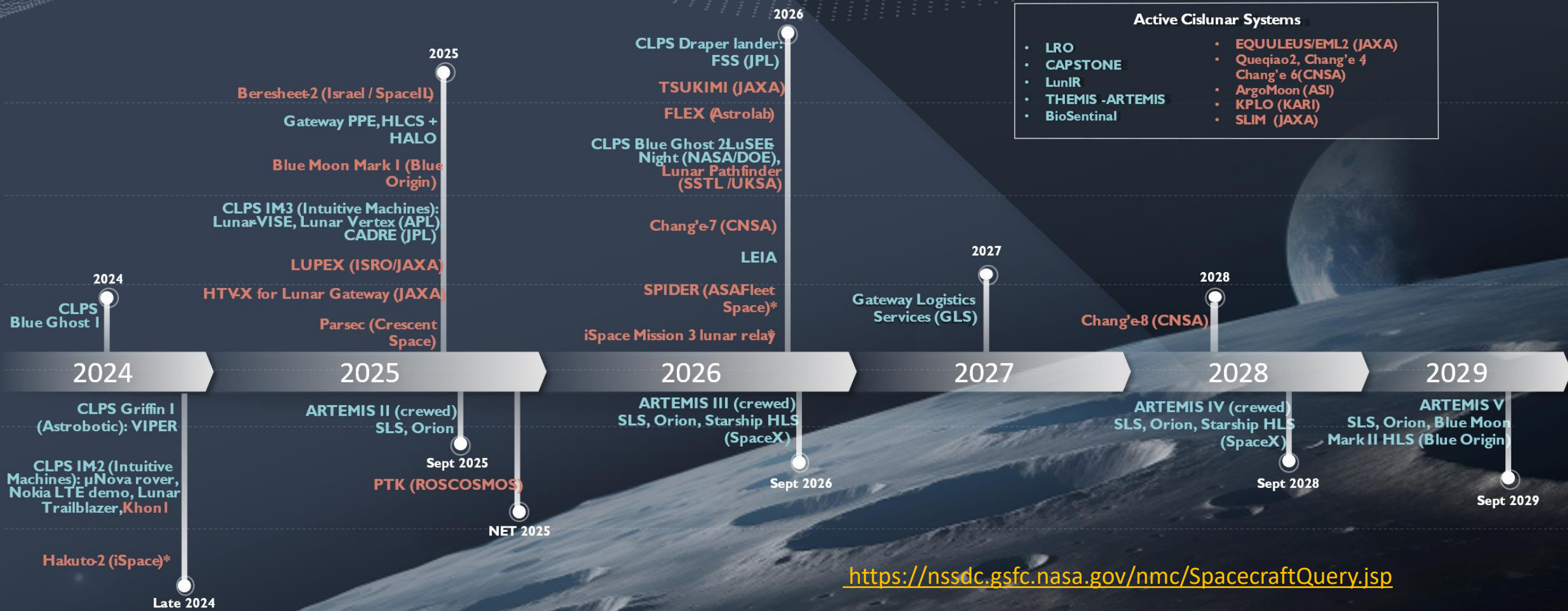
CONSIDERING

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.

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Lunar Mission Landscape*



<https://nssdc.gsfc.nasa.gov/nmc/SpacecraftQuery.jsp>

<https://www.eoportal.org/satellite-missions?Mission+type=Non-EO>

■ NASA and NASA-Partner Lunar Activities (including CLPS missions) ■ Other Lunar Activities (e.g. International Space Agencies, Commercial Ventures)

* Lunar missions known only to NASA Lunar Spectrum from popular media as of June 2024; may not receive mission technical data for frequency pre-coordination on all missions shown

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Summary

Effective Collaboration

- Collaboration among stakeholders to define a Lunar Spectrum Architecture
- Balancing the needs of Lunar surface, Lunar orbit, Radio Astronomy in SZM and Earth-orbiting activities

The Way Forward

- Planning for in-situ Lunar Communications requirements
- Identifying appropriate spectrum for in-situ Lunar PNT and Lunar search and rescue (SAR) services

Sharing and compatibility studies by stakeholders in SFCG, ITU-R and other Fora

Cooperation in Space Activities – The Artemis Accords

The Artemis Accords are a set of statements that set out common principles, guidelines, and best practices that apply to the safe exploration of the moon and eventually beyond as humanity extends the duration of space missions and its reach to Mars



ARTEMIS ACCORDS



<https://www.state.gov/artemis-accords/>

<https://www.nasa.gov/artemis-accords/>

United for Peaceful Exploration of Deep Space



Acknowledgements

Thanks to the NASA Lunar Spectrum Team and Cathy Sham, NASA and SFCG Lunar & Human Spaceflight Spectrum Manager, who provided materials for this Presentation

QUESTIONS

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Thank You!

James Higgins

Spectrum Management Engineer

ASRC Federal Agile Decision Sciences

(NASA Space Communications and Navigation Support)

www.nasa.gov/scan