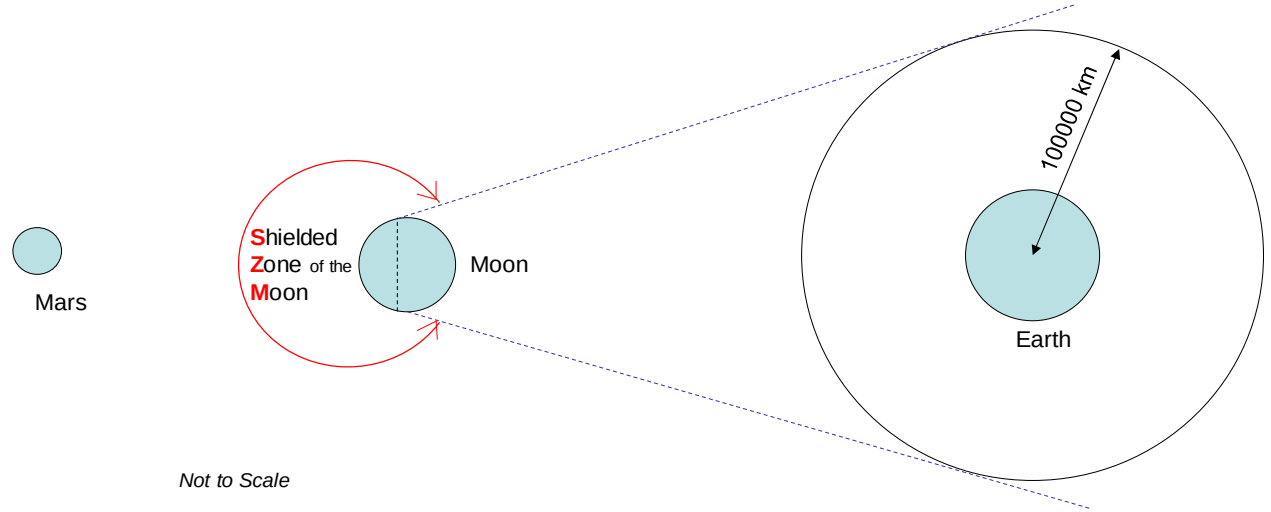
ITU REGULATORY ISSUE WITH GNSS L-BAND IN THE

SHIELDED ZONE OF THE MOON (SZM)



WAY FORWARD

cnes

ITU RADIO REGULATION (RR) IN THE SZM

RR : Article 22 – section V (+ REC 479-5) :

ITU RR is not compatible with deciding lunar frequency bands, **in particular between 300 MHz and 2 GHz**, without previous agreement of the Radio Astronomy (RA) community (IAU; IUCAF; ITU-WP7D and for regional levels: CRAF, CORF and RAFCAP).

REC 479-5 states: ***"the 300 MHz to 2 GHz range should be reserved for radio astronomy observations" : critical for RA in the SZM***

Due to the specific RR applicable in the SZM, a transmission which would be declared (even on a Non Interference Basis) without coordination with RA (under article 4.4 of ITU RR), in particular between 300 MHz and 2 GHz, would be not compatible with RR.

Section V of article 22 of the Radio Regulation has been set up by ITU also in order to avoid the SZM to be polluted before the arrival of the RA observatories.

LUNAR GNSS ORBITERS IN L-BAND ARE NOT COMPATIBLES WITH THE ITU RR & REC

It is necessary for lunar GNSS orbiters and beacons to use the lunar bands allocated by SFCG for local NAV (PNT).

One exemple of allowed SFCG bands is the S-band (2483.5-2500 MHz) already used by 3 GNSS systems within Earth, and planed to be used by several others GNSS's.

Other exemples also already allocated by SFCG for lunar NAV (PNT) are **2025-2110/2200-2290** MHz and **23.15-23.55/27.0-27.5 GHz** bands (Lunar Surface ←→ Lunar Orbit), and **2400-2480** MHz (Wireless).

The following bands are also possible in addition to 2.400-2.480 GHz for wireless lunar PNT: **2.5035-2.620 GHz** or **5.15-5.83 GHz**, or a part of the **63-70 GHz** when line of sight is guarantied.

Moreover, most of these bands are hosting mass market PNT technologies on Earth (*like the GNSS L-bands to avoid when transmitted from lunar orbit or surface*), which can be reused in the lunar environment without endangering Radio Astronomy.

GNSS SYSTEMS IN S AND L BANDS

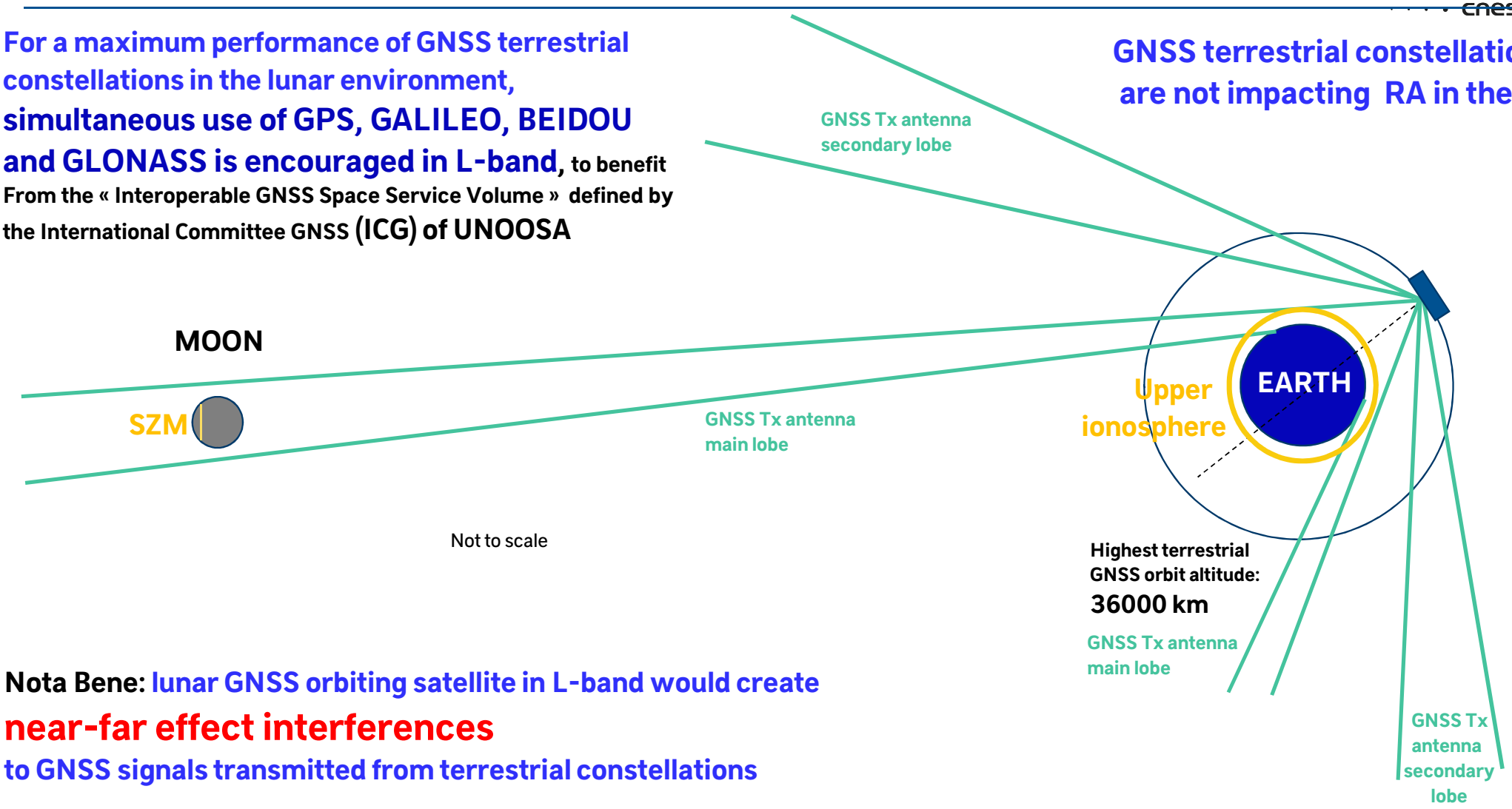
		L Band	S Band	Coverage	Date of Full Operational Capability
Galileo G1	EU	**Yes**	No	Worldwide	2022 (Initial services since 2016)
Galileo G2	EU	**Yes**	No (but G2G filings include S-band; experimentations ?)	Worldwide	2034
GPS	USA	**Yes**	No	Worldwide	1995
Glonass	Russia	**Yes**	No	Worldwide	1996
Beidou-1/2/3 RDSS	China	No	**Yes**	Worldwide excepted poles	2018
Beidou-3	China	**Yes**	**Yes**	Worldwide	2020
NAViC/IRNSS	India	**Yes**	**Yes**	Regional (India)	2018
NAViC Global	India	**Yes**	**Yes**	Worldwide	2030
QZSS	Japan	**Yes**	No	Regional (Japan)	2024
QZSS-2	Japan	**Yes**	TBD (S-band is an option)	Regional (Japan)	2030
Globalstar (with Echo-Ridge service and S-band pilots for measurements used in hybrid positioning)	USA	No	**Yes**	Quasi Worldwide (Globalstar declared iself COMs+GNSS system in 2018)	2021
KPS (Korean Positioning System)	South Korea	**Yes**	**Yes**	Regional (Korea)	2030
GNSSaS*	UAE	**Yes**	**Yes**	Regional (equatorial region)	2028
GEESAT* & CENTISPACE*	China	**Yes**	No	Worldwide	2028
Xona-Space*	USA	TBD	TBD	Worldwide	2028
European LEO PNT (TBC)*	Europe	**Yes (TBC)**	**Yes (TBC)**	Worldwide	2030

*** LEO GNSS: Very Usefull for quick enought « Position Velocity Time » initialisation, for Autonomous Cars, Taxi Drones, etc …**

CASE OF TERRESTRIAL GNSS L-BAND CONSTELLATIONS (2)

For a maximum performance of GNSS terrestrial constellations in the lunar environment, simultaneous use of GPS, GALILEO, BEIDOU and GLONASS is encouraged in L-band, to benefit From the « Interoperable GNSS Space Service Volume » defined by the International Committee GNSS (ICG) of UNOOSA

GNSS terrestrial constellations are not impacting RA in the SZM.



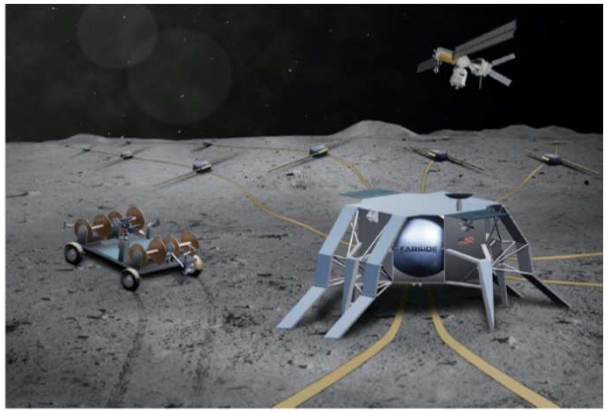
Nota Bene: lunar GNSS orbiting satellite in L-band would create

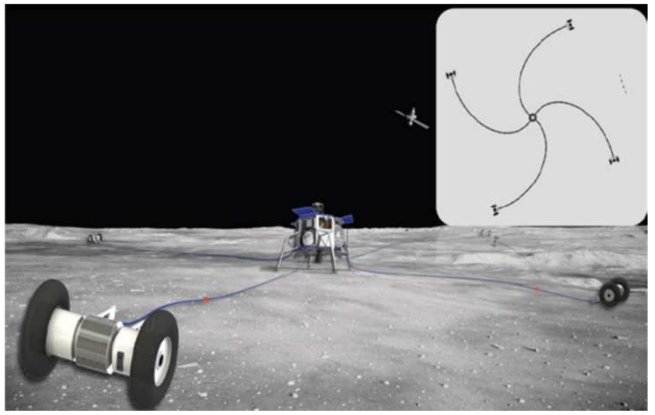
near-far effect interferences

to GNSS signals transmitted from terrestrial constellations

RA IN THE SZM HAS ALREADY STARTED

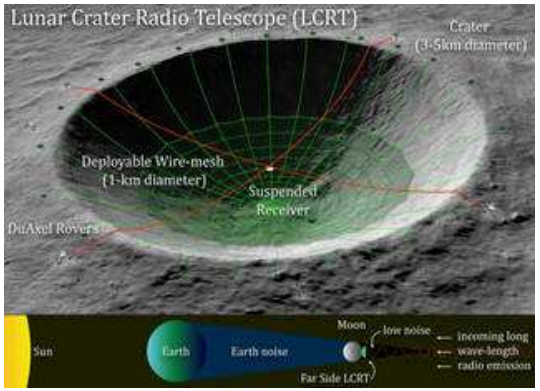
Many other Rain SZM projects coming soon

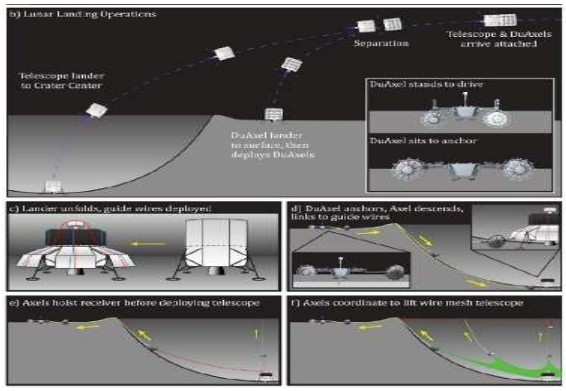




There is already an chinese-netherland satellite passing in the SZM, provided with a RA payload

Illustrations of a concept of radio telescope (FARSIDE) on the SZM, using array of antennas





Illustrations of conceptual radio telescopes within a crater on the Moon; concept studied under grant funding from NASA

CONCLUSIONS

ITU-RR and REC 479-5 show the need to not use in the SZM any frequency band between 300 MHz and 2 GHz.

Space agencies and commercial industry shall make sure the provisions of the RR are taken care of regarding the protection of RA in the SZM. It is of the outmost importance to apply the ITU-RR in the SZM and its REC 479-5, and SFCG REC 32-2R2.

These ITU RR and RA issues fully concern both public and/or commercial lunar projects.

It is also time to consider lunar orbital missions (with cubesats for instance) to both perform RA and Spectrum Monitoring in the critical 300 MHz- 2 GHz band *(and also the critical 0-100 MHz band)*, to detect interferences to RA.

Article 4.4 of ITU RR is not appropriate in the specific case of protection of RA in the SZM since there is no guarantee of no interference. However, some operators still believe it is possible to operate frequencies under RR n°4.4 in the SZM, and this is the reason why lunar spectrum monitoring missions are strongly encouraged.

Solutions being proposed today are in line with the SZM protection:

a) S-band is proposed today for lunar-GNSS-like signals

b) Protect also L-Band from lunar transmissions at this band (same objective that RA) to allow safely reception of GNSS signals providing from terrestrial constellations.

Finally, L-band GNSS signals coming from terrestrial constellations do not impact in any way the SZM radioastronomy needs and puts no threat.

BACK UP SLIDES

ADVANTAGES OF 2483.5-2500 MHz ON 2025-2110 MHz FOR LUNAR GNSS

- Allows to reuse international mass market COM and PNT techniques and technologies

- Contribute to avoid interferences of the 2025-2110 MHz band in the mid and long terms:

  - 2025-2110 MHz is allocated by SFCG for Lunar Orbit to Lunar Surface proximity links

  - UHF is also allocated by SFCG for Lunar Orbit ←→ Lunar Surface proximity links, but should be phased out in order to comply with RR in the SZM (and there is an adjacent RA band in UHF). Additional proximity links in 2025-2110 MHz could then replace UHF.

  - 2025-2110 MHz is also allocated by SFCG for Earth to Lunar Orbit links

  - 2025-2110 MHz is also allocated by SFCG for Earth to Lunar Surface links

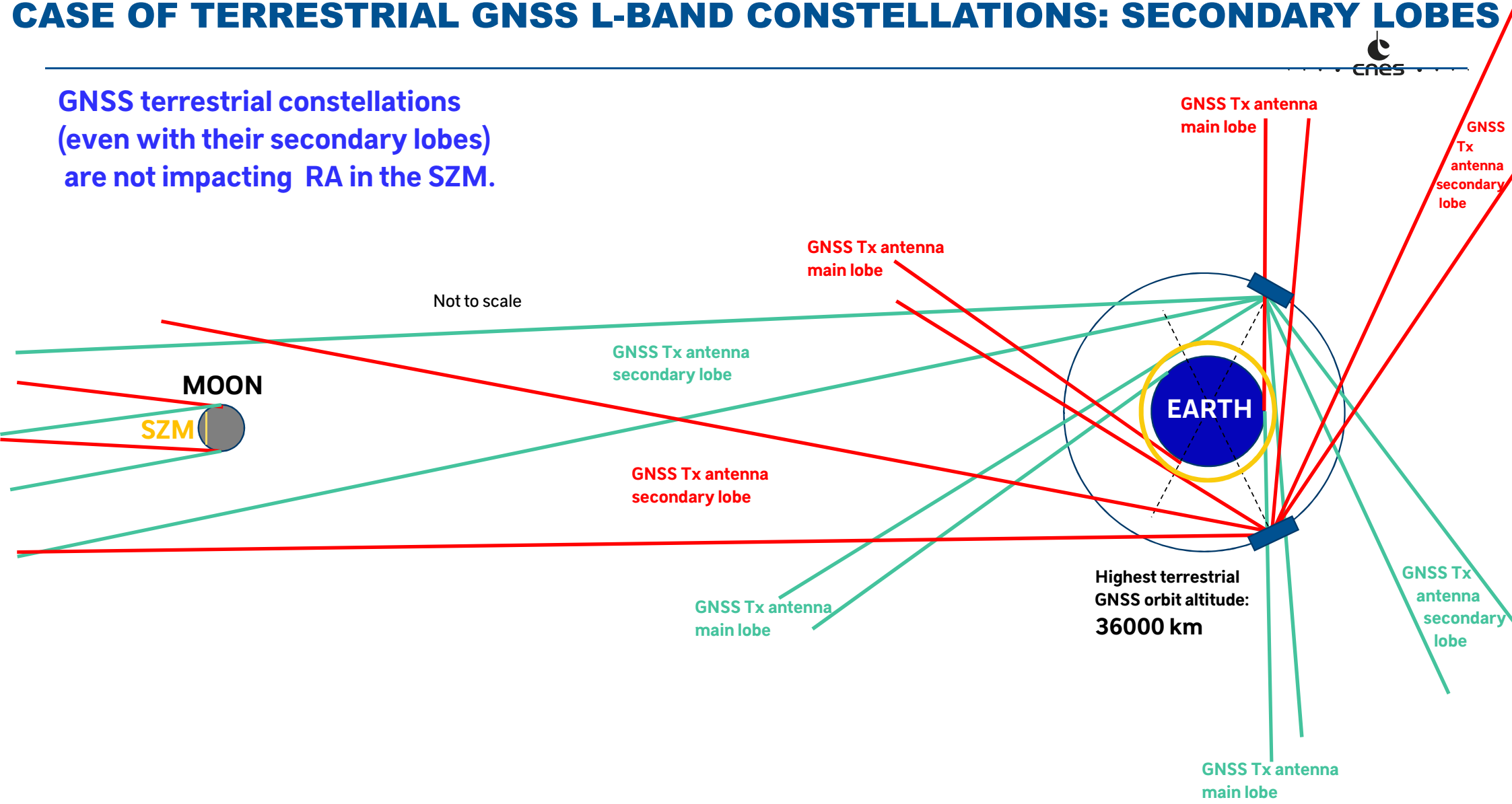
  - 2025-2110 MHz could be used for Lunar Orbit to Lunar Orbit as planed by several space agencies

  - 2025-2110 MHz could be used for Lunar Orbit to Lunar Low Orbit as planed by several space agencies

  - Use of a GNSS-like lunar CDMA PNT signal in 2025-2110 MHz would mobilize nearly 10% of this band already

CASE OF TERRESTRIAL GNSS L-BAND CONSTELLATIONS: SECONDARY LOBES

GNSS terrestrial constellations (even with their secondary lobes) are not impacting RA in the SZM.



RA IN THE SZM HAS ALREADY STARTED (MORE INFORMATIONS)

Some pathfinder Radio Astronomy instruments are already in operation in the SZM. They are part of China's **Chang'e-4 lander** on the moon's far side, as well as the **Queqia lunar orbiter** for a **RA mission in collaboration with the Netherland, passing regulary in the SZM for its operations**.

A next mission for far-side astronomy is **ROLSES (Radiowave Observations at the Lunar Surface of the photo Electron Sheath) to be launched end 2021** (lander licensed by NASA). ROLSES's task of characterizing the RFI generated by lunar soil is crucial for future work identifying other radio signals on the far side.

Another mission to characterize the RF interference on the moon, nammed **Lunar Surface Electromagnetics Experiment (LuSEE), should be launched in 2024 to land in the SZM**. The lander carrying LuSEE may also have **another payload: DAPPER (Dark Ages Polarimeter Pathfinder), a telescope for detecting 21-cm red shifted signals from the cosmic dark ages**. NASA has funded works on DAPPER.

The National Astronomical Observatories at the **Chinese Academy of Sciences has a tentative for a fleet of five to eight satellites** flying in formation to form a Radio Astronomy antenna array in lunar orbit.

To begin preparing for RA antenna array on the SZM Moon Surface, **Netherland and DLR are planning to test the deployment of radio antennas using robotic rovers**. Test are planed in 2021 on the flanks of Mount Etna in Sicily.

CNES also has in mind a Swarm of lunar cubesatellites, called NOIRE, benefiting from the SZM to perform RA.