Cislunar PNT Workshop

Korean Cislunar PNT

February 11, 2025

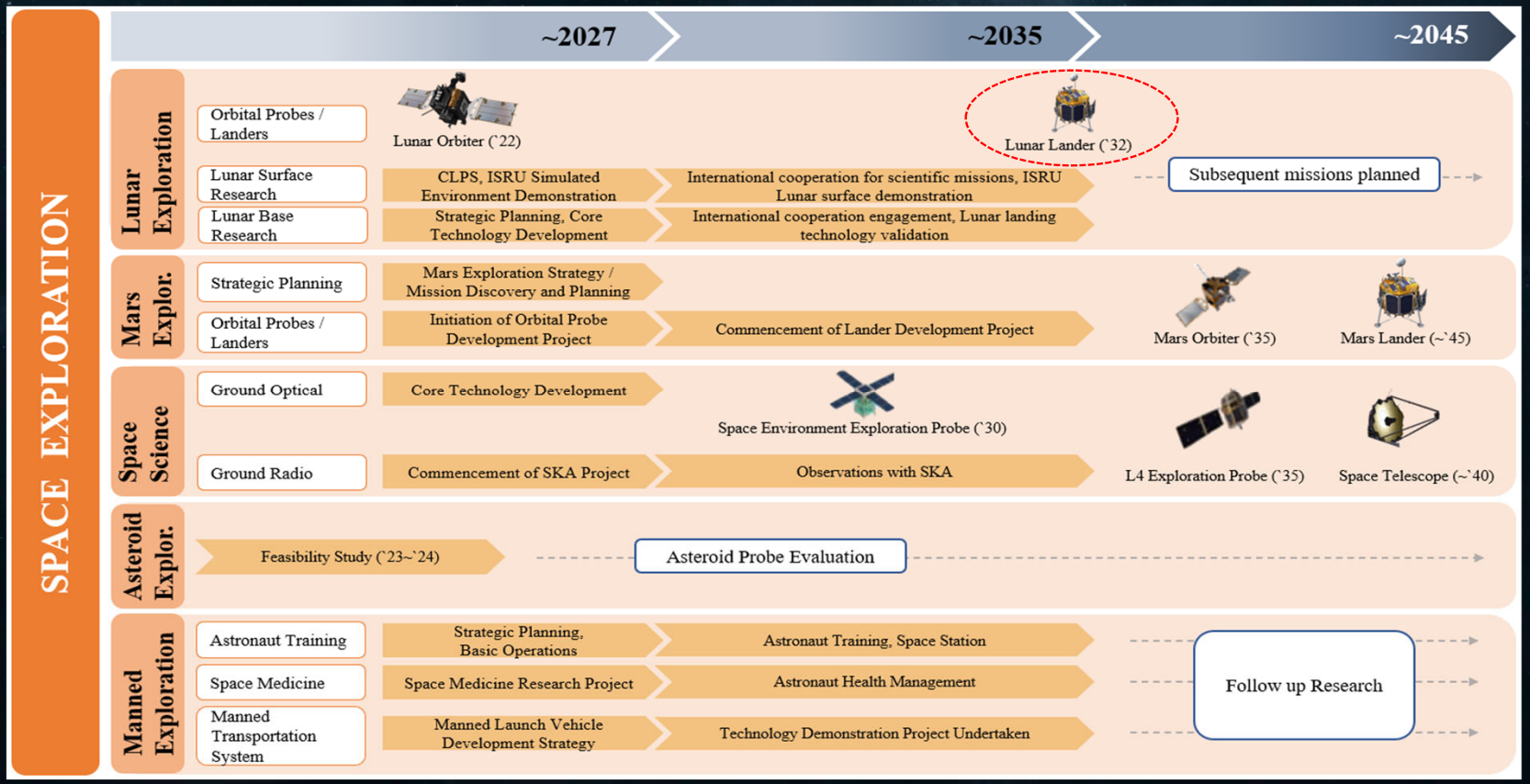
Korea Aerospace Research Institute

Dr. Jungmin Joo

01 Space Exploration Plan (Republic of Korea)

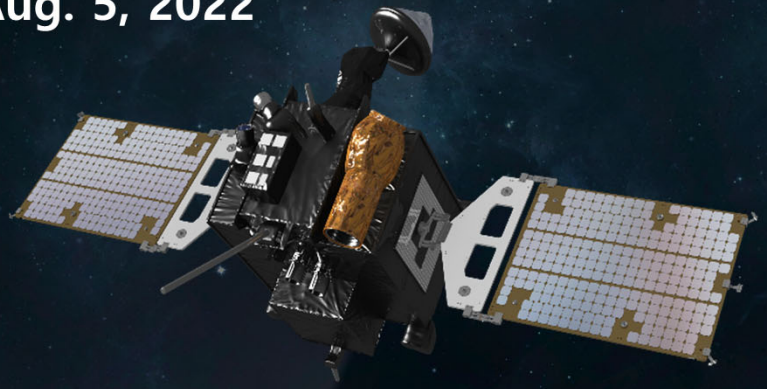
❖ 4th Basic plan for Space Development Promotion('22.12)

- Lunar & Mars Exploration, Space Science, Asteroid & Manned Exploration



02 Korea Pathfinder Lunar Orbiter (KPLO, Danuri)

❖ KPLO was lunched by Falcon 9 on Aug. 5, 2022



Earth Rise Image taken by LUTI

KPLO LEOP Team at KMOC (KPLO Mission Operation Center)

03 Korea Lunar Lander Development Project (Passed PFS)

Lunar Exploration Project (2nd Phase)

❖ PROJECT OVERVIEW

Objectives | Developing an independent a 1.8-ton lunar lander for scientific exploration.

Significance
- Enter the field of Lunar exploration
- Expand Korea's space exploration capabilities
- Secure lunar landing & exploration capabilities

Period	2024 to 2033 (10 years)
Budget	About 400 million (USD)

Project Initiation **2024**

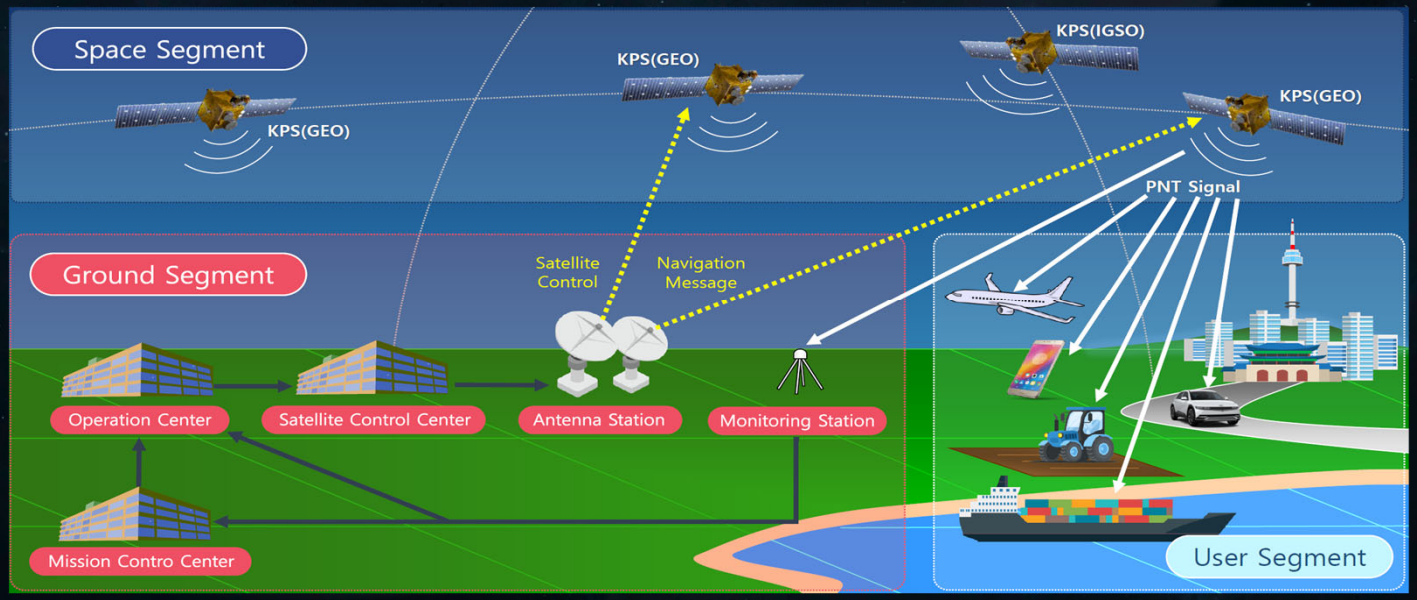
Lander Design Completion **2028**

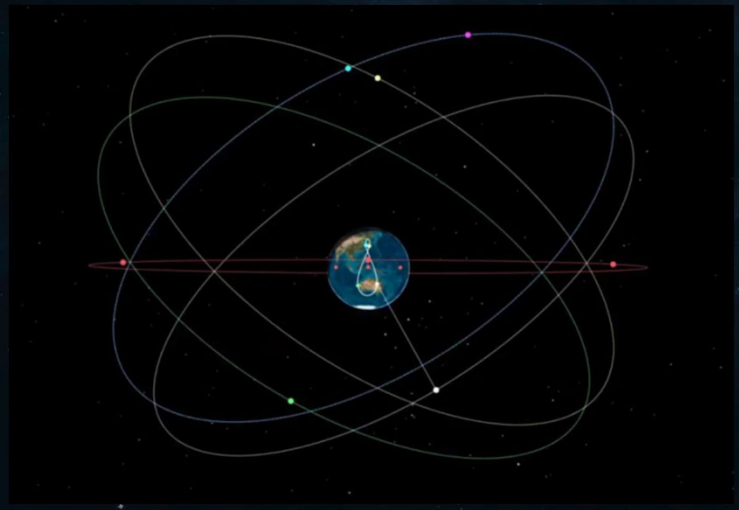
Launch & Verification of lunar landing **2031**
- Using the next generation launch vehicle (KSLV-III)

Lunar lander launch & Scientific exploration mission **2032**

04 Korean Positioning System(KPS)

Program	KPS R&D Program (including Space, Ground and User Segment)
Period	2022~2035 (14 years)
Governing	우주항공청 Korea AeroSpace Administration
R&D	KARI 한국항공우주연구원 Korea Aerospace Research Institute

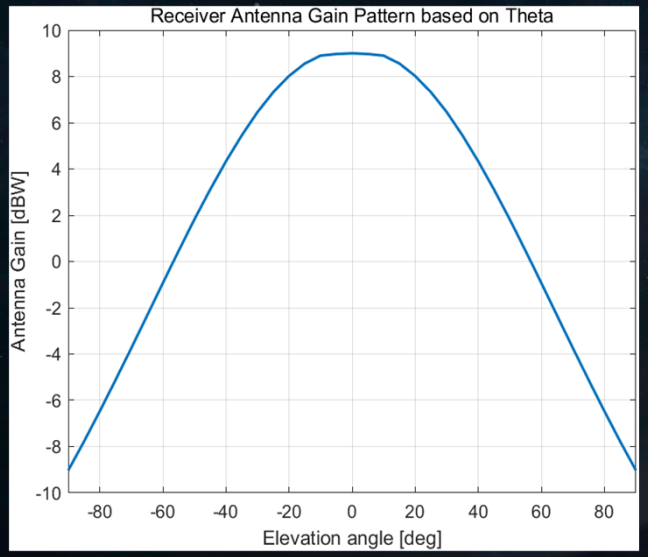




KPS Constellation

05 GNSS+KPS Cislunar Performance Analysis(1/4)

❖ Simulation for CisLunar PNT
- L1, L5 signals for all GNSS plus KPS
- Longitude point considering Earth's rotation
- 5 points in CisLunar
  · 7/20/33/45/58 RE

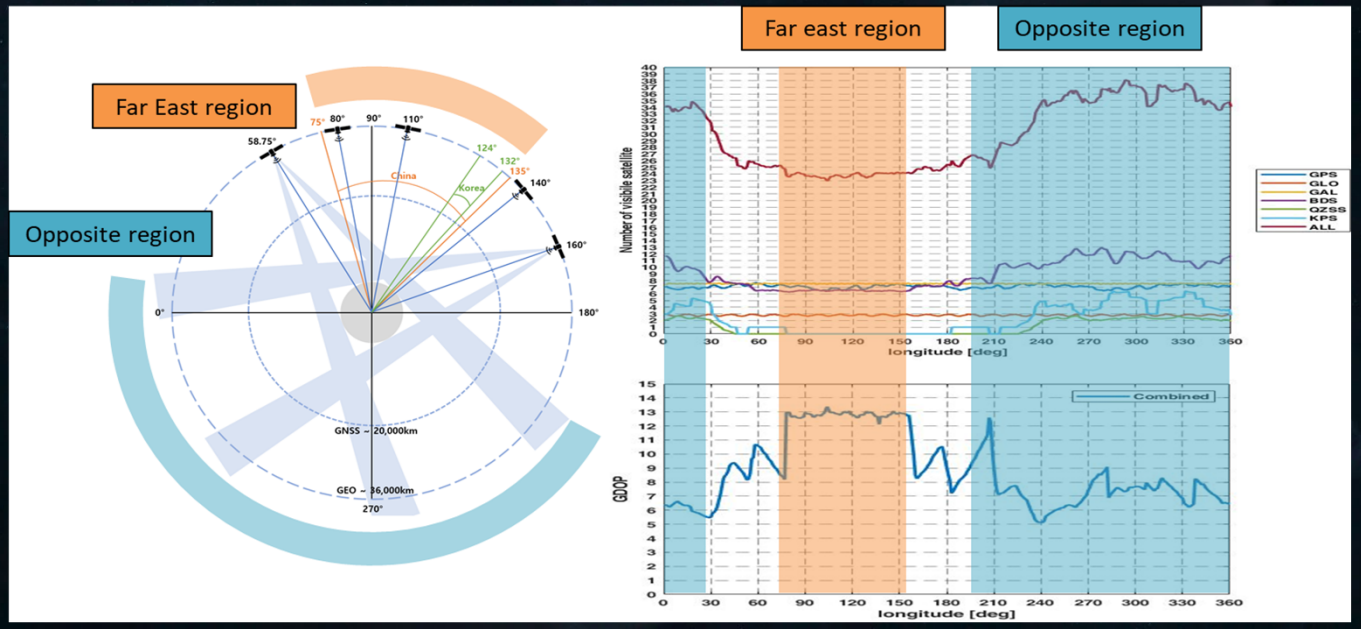


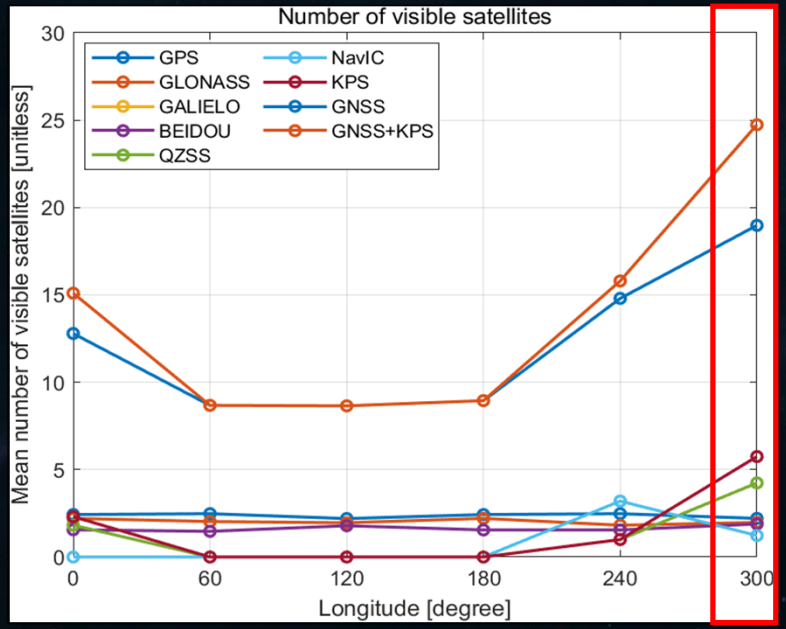
GNSS		Frequency	C/N_0 Threshold (dB-Hz)	Tx. Power (dBW)	Reference Off-boresight Angle (°)	Tx. Antenna Gain Pattern	Rx. Antenna Gain Pattern
GPS	L1	1575.42	20	14.3	23.5	Lockheed Martin	ICG Booklet Data
	L5	1176.45		16	26		
GALILEO	E1	1575.42		15	20.5	FOV Data	
	E5a	1176.45		17	23.5		
GLONASS	L1	1605.375		Same as GPS	26	Same as GPS	
	L3	1201			34		
BDS	B1C	1575.42		Same as GPS	25	Same as GPS	
	B2a	1191.795			28		
QZSS	L1	1575.42		15	22	QZSS Data	
	L5	1176.45		17	24		
NavIC	L5	1176.45		Same as GPS	16	Same as GPS	
KPS	L1	1575.42		16.7	20	KPS Data	
	L5	1176.45		17.3	20		

05 GNSS+KPS Cislunar Performance Analysis(2/4)

❖ Simulation for CisLunar PNT

- Different longitude points in opposite region
  - · Considering Earth's rotation
  - · Better visibility due to GEO and IGSO satellites (BDS, QZSS, KPS)



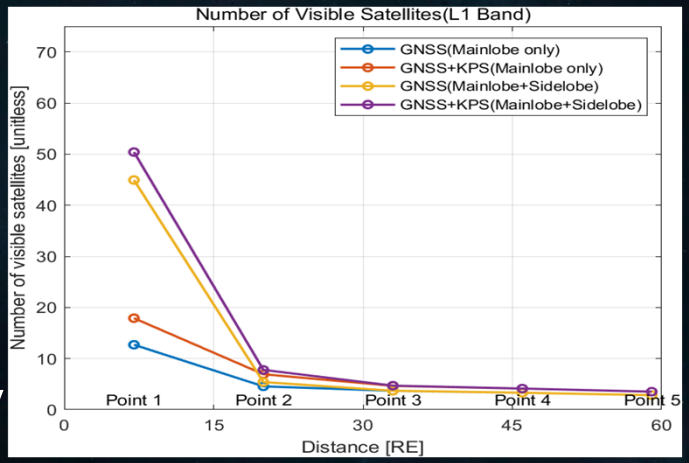


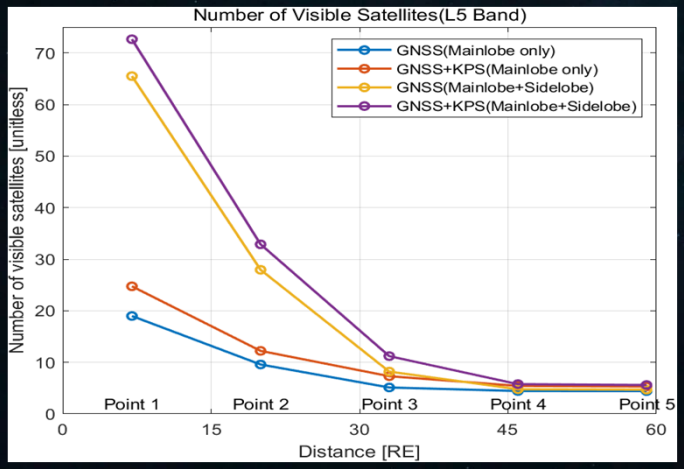
05 GNSS+KPS Cislunar Performance Analysis(3/4)

❖ Simulation Results of Visible Satellites

- L5 compared to L1
  - 45.81% higher satellite visibility
- Additional use of KPS vs. GNSS-only
  - 23.71% higher satellite visibility
- Additional considering of side lobe signals vs. Mainlobe-only
  - Higher satellite visibility up to point 3 (33RE)

Frequency	Constellation	Sidelobe	P1(7RE)	P2(20RE)	P3(33RE)	P4(45RE)	P5(58RE)
L1	GNSS	Include	44.93	5.40	3.7	3.31	2.84
		Not include	12.70	4.56	3.69	3.31	2.84
	GNSS+KPS	Include	50.4	7.78	4.7	4.13	3.52
		Not include	17.9	6.93	4.66	4.13	3.52
L5	GNSS	Include	65.49	27.94	8.2	4.78	4.7
		Not include	18.98	9.58	5.12	4.44	4.42
	GNSS+KPS	Include	72.64	37.88	11.2	5.77	5.60
		Not include	24.74	12.22	7.31	5.43	5.31



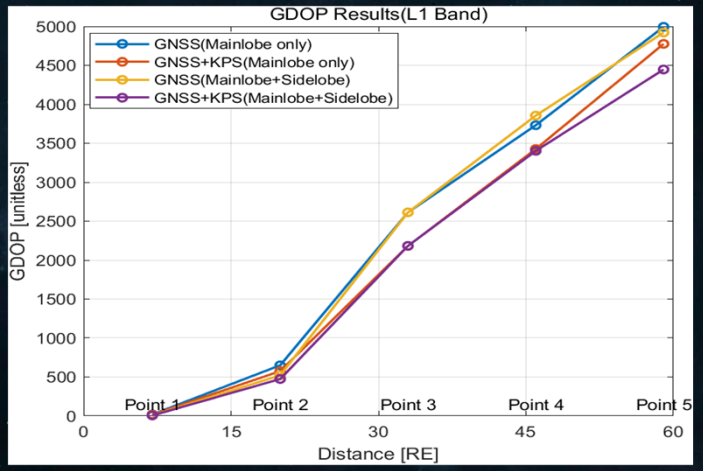


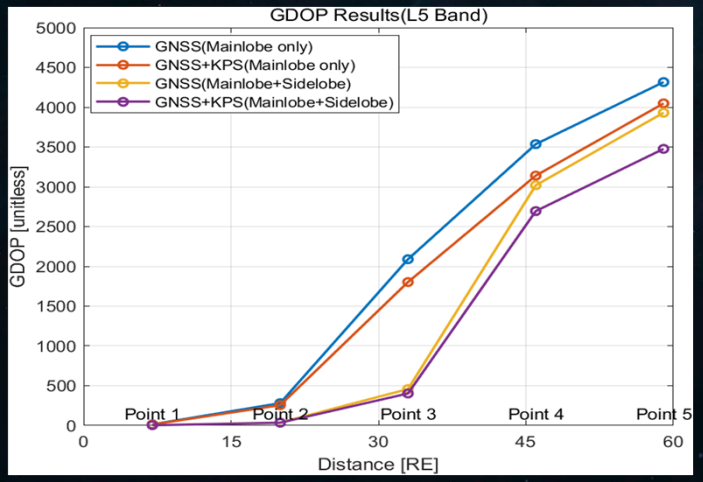
05 GNSS+KPS Cislunar Performance Analysis(4/4)

❖ Simulation Results of Position Accuracy

- The longer distance, the higher GDOP
  - Low satellite visibility
  - Narrow satellite distribution
- To decrease GDOP
  - Consider KPS signals
  - Consider 1st side lobe signals in simulations

Frequency	Constellation	Sidelobe	P1(7RE)	P2(20RE)	P3(33RE)	P4(45RE)	P5(58RE)
L1	GNSS	Include	6.4	521.3	2612.7	3854.9	4921.3
		Not include	19.5	650.1	2613.0	3731.5	4994.3
	GNSS+KPS	Include	6.2	473.7	2183.4	3402.3	4446.9
		Not include	17.4	574.9	2181.8	3426.1	4775.2
L5	GNSS	Include	3.8	36.7	457.98	3018.9	3930.9
		Not include	14.8	281.2	2089.4	3535.8	4315.4
	GNSS+KPS	Include	3.7	35.2	402.37	2694.1	3476.4
		Not include	13.4	255.3	1802.5	3140.3	4047.7

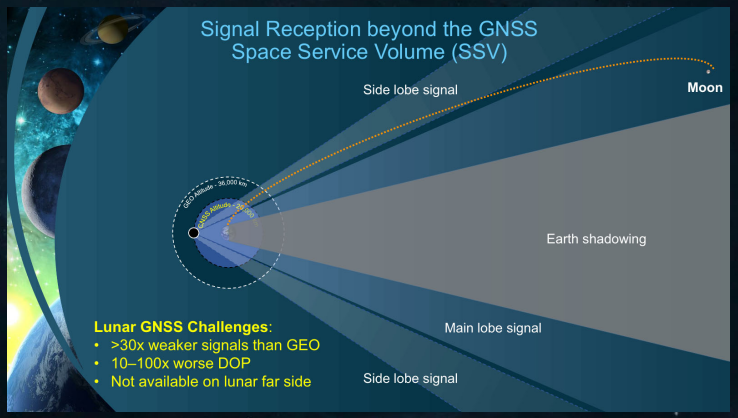




06 KPS Signals for Lunar PNT

❖ KPS Architecture & Signals for Lunar PNT
- L1, L2, L5, L6 signals
- Ant. Input Power (TBC)
- 8 satellites (IGSO, GEO)

Signals	Ant. Input Power (dB)
L1C	16.72
L2C	13.20
L5	17.30
L6	13.34

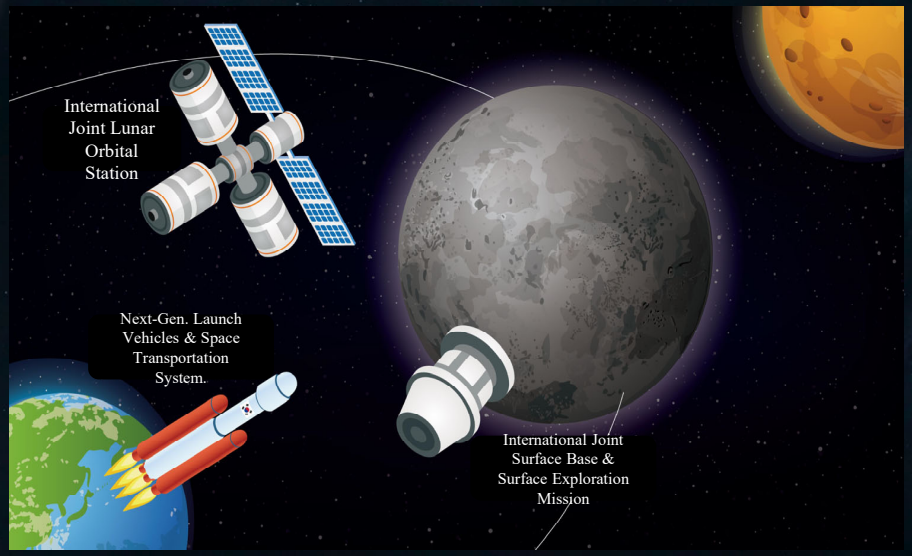


❖ Minimum Rx. Power (TBC) on Moon
- Edge-of-Coverage(EOC) angle : 9.4 deg
- 20 deg. Off-axis angle
  · Narrower than MEO
- Cut-Off(CO) angle : 22.4 deg.

Signals	Rx. Power@EOC (dBW)	Rx. Power@20 deg (dBW)	Rx. Power@CO (dBW)
L1C	-173.68	-195.78	-205.70
L2C	-175.10	-197.20	-207.12
L5	-170.60	-192.70	-202.62
L6	-175.26	-197.36	-207.28

07 Korean Lunar PNT

- Space Exploration, including the Moon & Mars, is a crucial mission for the sustainable prosperity and peace of humanity.
- Republic of Korea has long term space exploration plans, lunar exploration, and aims to secure independent capabilities while strengthening global space development cooperation.
  - Lunar landing(`32) & Mars landing(`45)
  - Participation in the Artemis program
- Lunar PNT system is a core element of lunar exploration and a cornerstone for Mars exploration.
- KASA is currently conducting preliminary research on the Korean Lunar Positioning System(LPS) and looks forward to collaborating with international partners in its development.



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