

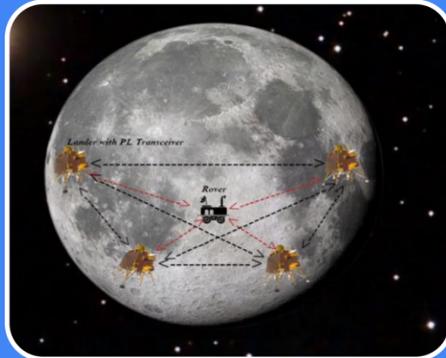


Indian Lunar PNT System Development

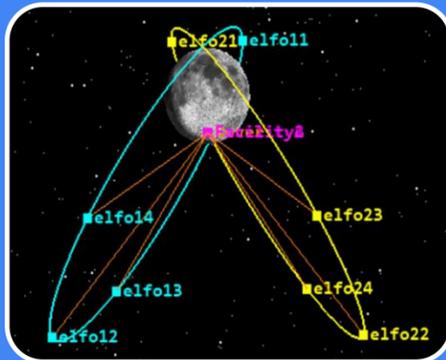
Dr. Ashish K Shukla
Scientist & Head, Advanced Navigation & Science
Applications Division
SAC-ISRO, India

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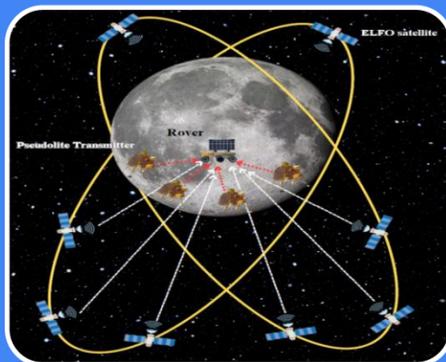




Phase I: Pseudolite based Navigation System



Phase II: Satellite Based Navigation System



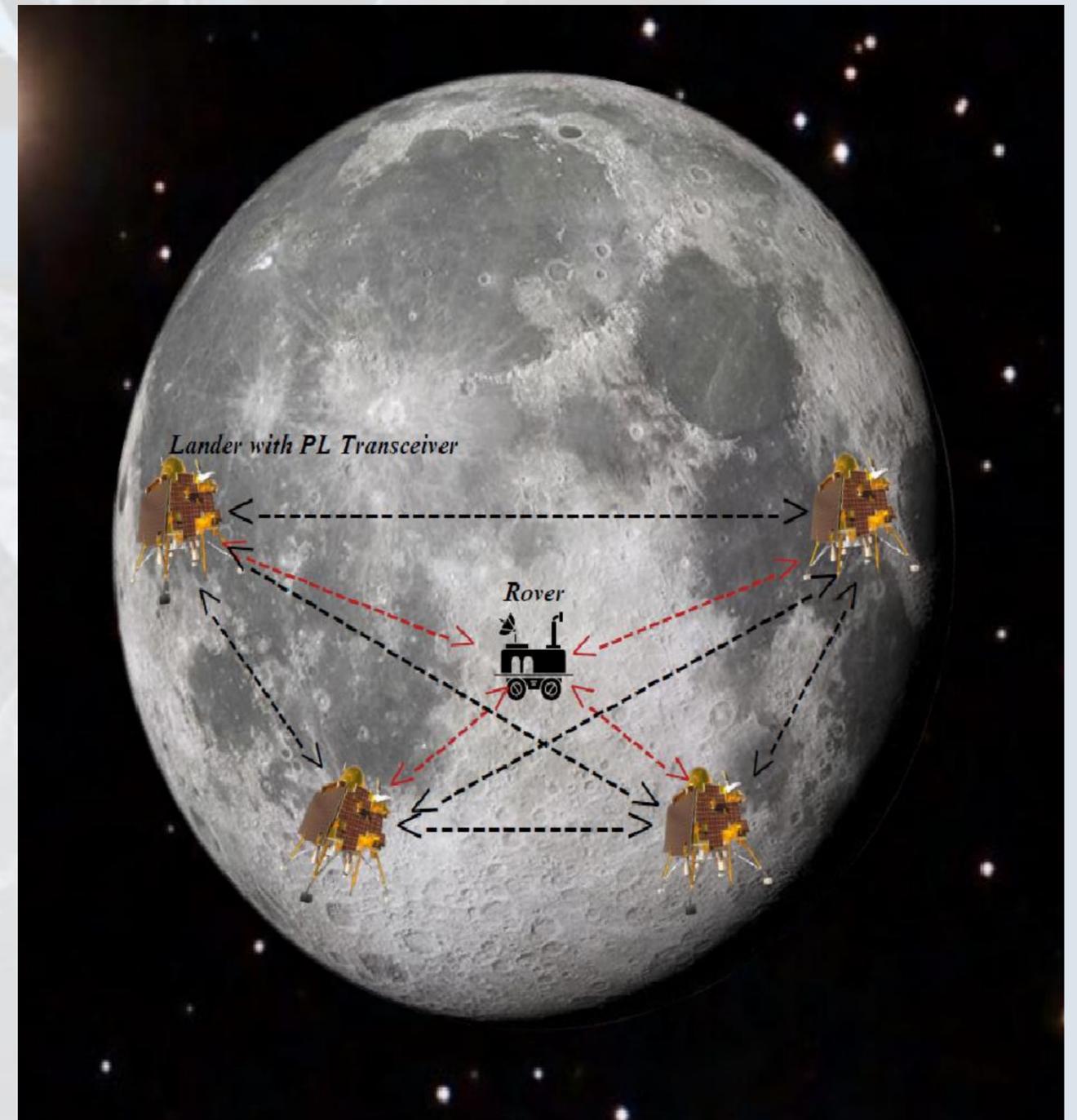
Phase III: Hybrid Satellite & Pseudolite Navigation System

Phase I-Pseudolite System for Lunar PNT

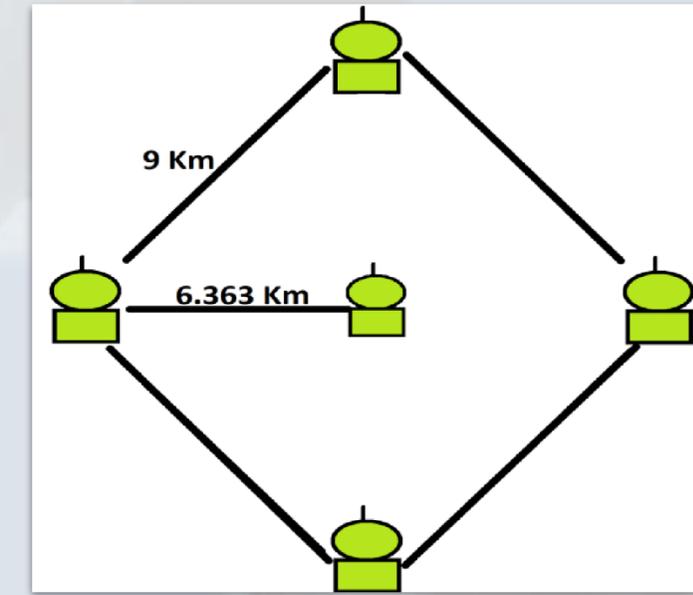
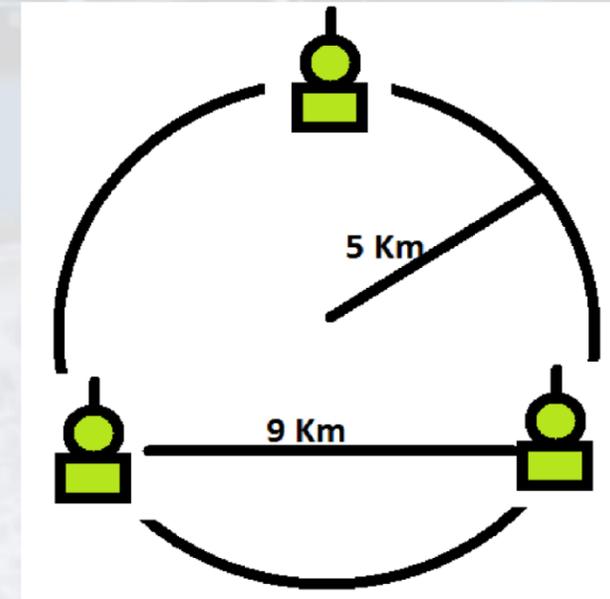
- Pseudolite System for the Lunar PNT has been proposed by India in order to deploy pseudolite transceivers as a new radio navigation sensor in its future lunar landers.
- In the absence of any radio navigation system on the Moon, pseudolite system is one of the most feasible options for the lunar PNT.
- India may provide pseudolite transceivers to other space agencies as part of their future lunar landers to form a pseudolite network.
- A Common framework for Pseudolite Transceiver Network & system specifications is being defined for an interoperable & compatible system for Lunar PNT.

Local Area Navigation System

- Autonomous & Independent
 - Self-calibrated
 - Self-synchronized
-
- Bi-directional Ranging
 - AI-Based path Planning for the Rover
 - Positioning in Relative & Absolute Reference Frames

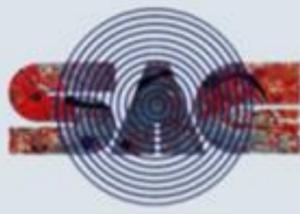


- Configuration with 3/4/5 pseudolite transceivers has been proposed.
- Coverage area with different radii depending on the number of pseudolite transceivers was worked out.



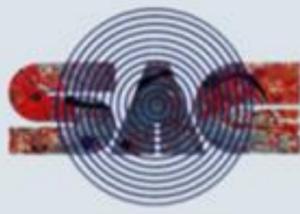
Number of Pseudolites	Maximum distance of rover from pseudolite (Km)	Service Area (km^2)
3	10	78.53
5	11.2	100.48

Pseudolite Navigation Signal Parameters



Frequency Band	S-Band	2414.28/2491.005 /2492.028 MHz
Transmission Mode	Pulse-CDMA	
PRN Code	Gold Code	IZ ₄ Code
Modulation	BPSK	
Ranging	Bi-directional	
Range	10 Km	LoS

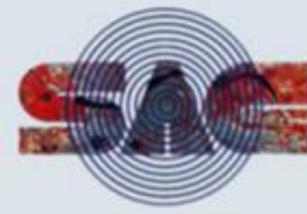
Lunar Pseudolite System Position Error Budget



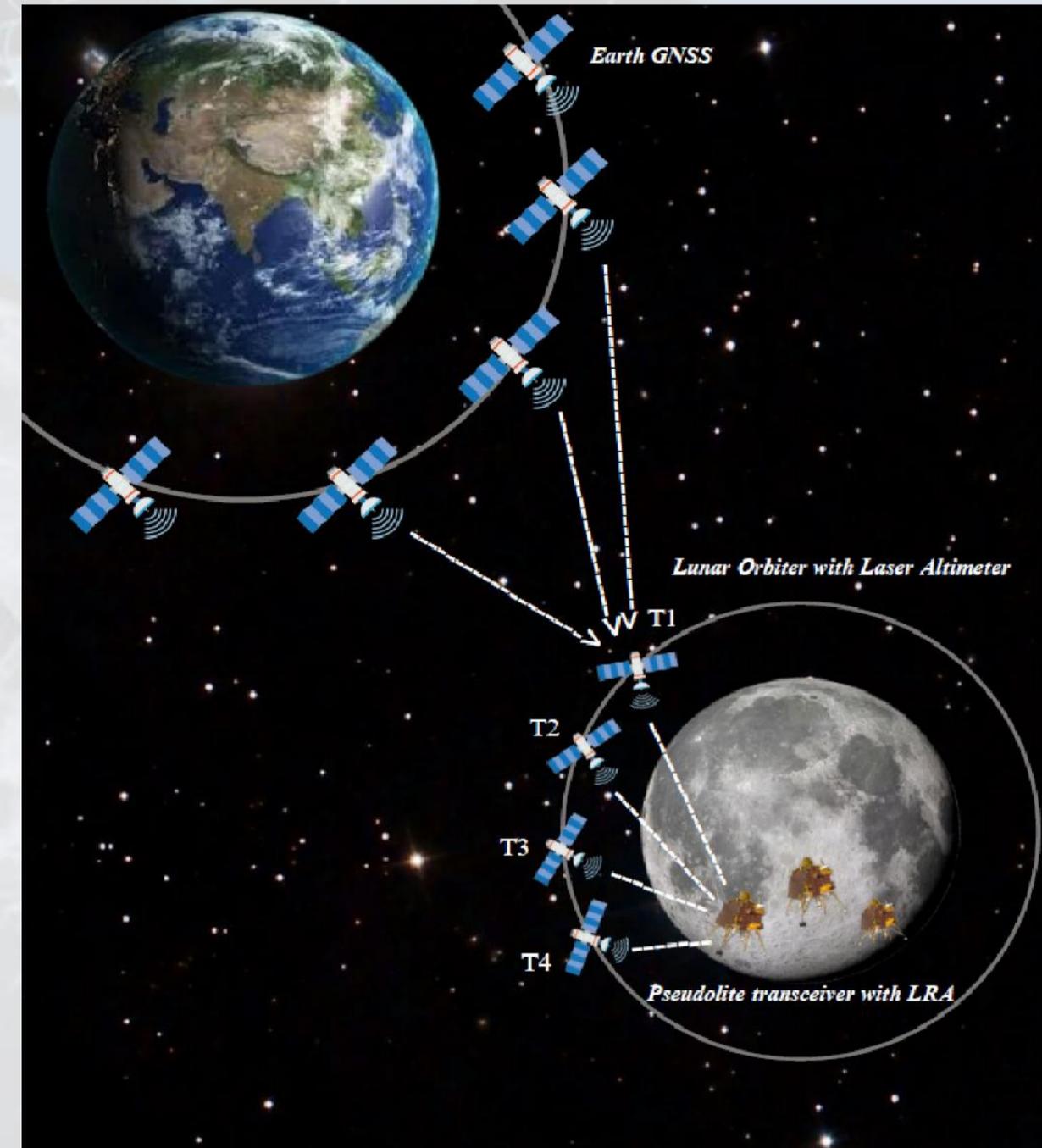
Component	Value
PL co-ordinates Error	0.01 m
Synchronization Error	0.03 m
Multipath Error	0.5 m
Rx Noise	0.3 m
UERE	0.34
HDOP	3.0
Horizontal Accuracy	1.02 m

Instrument	Details	Remarks
Pseudolite Transceiver	On-board Lunar Lander	PL Signal Transmitter
Laser Altimeter (LA)	On-board Lunar Orbiter	For ranging
Laser Retro-Reflector Array (LRA)	On-board Lunar Lander	For Ranging
Earth-GNSS Receiver	On-board Lunar Orbiter	For orbit determination
Pseudolite User Receiver	PL User Segment	Rover

Pseudolite Transceiver absolute Location Determination using LRA Concept



- Location determination of Pseudolite Transceiver to be determined using Laser Retro-Reflector Array (LRA) on lunar lander & LA on-board Lunar Orbiter.
- Lunar orbiter with a Laser Altimeter/LIDAR will communicate with LRA on the lander to generate range measurements.
- Location of Lunar Orbiter to be determined using Earth GNSS signals received by GNSS receiver on the orbiter.
- Using 3-4 such range measurements from different locations, accurate position of the pseudolite transceiver can be estimated.
- NASA-ASI joint LuGRE receiver has shown the capability to receive Earth GNSS signals in Lunar orbits & surface which strengthens this methodology.

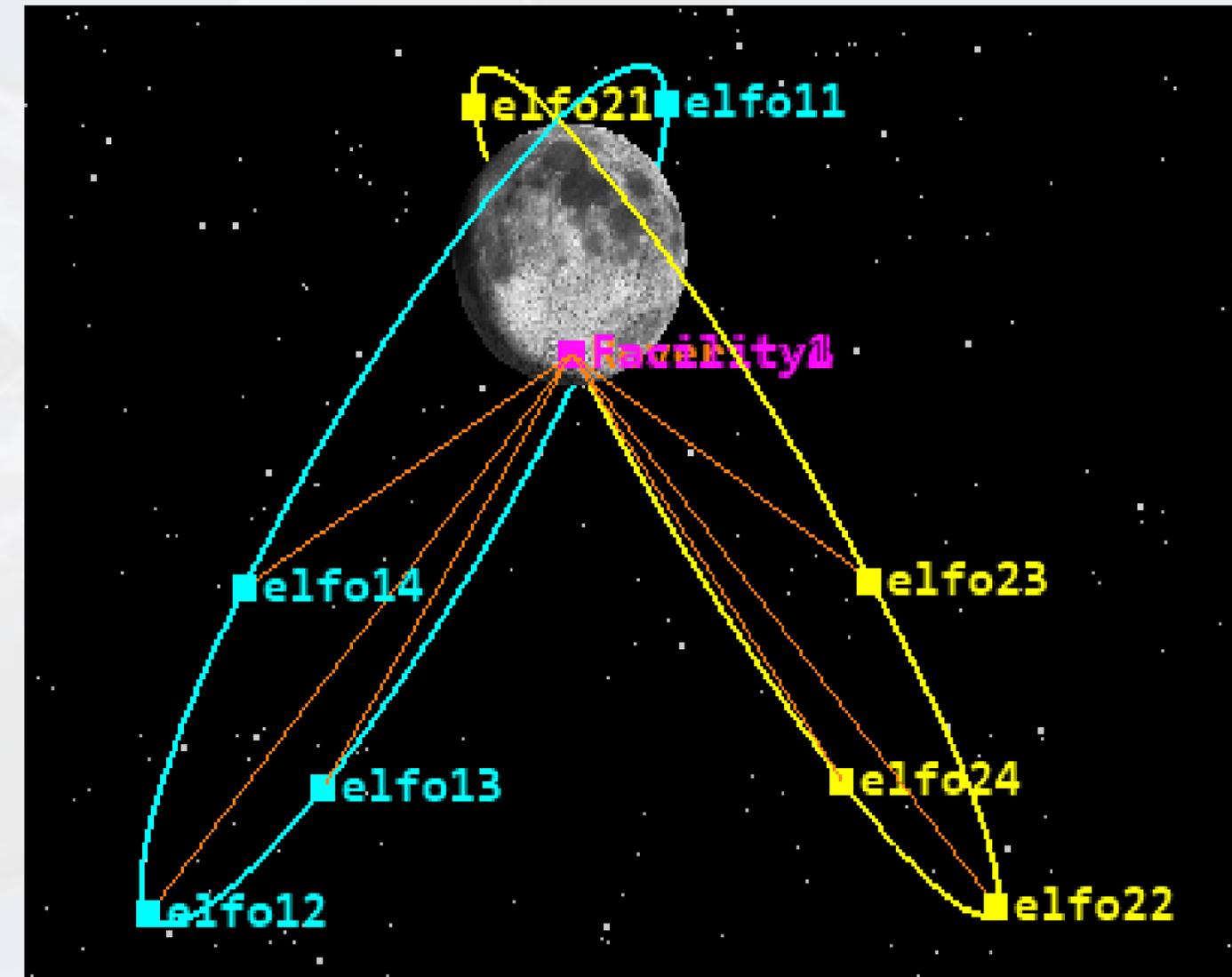


Phase II-Satellite Based Lunar Navigation System

Lunar Orbit Types

Orbit	Orbital Period	Altitude	Advantage
Elliptical Lunar Frozen Orbit (ELFO)	14-24 Hrs	100-10,000 km	Very Good stability & surface coverage, better Earth visibility
Low Lunar Orbit (LLO)	2 Hrs	30-200 Km	Low stability, Very good surface coverage, Intermittent visibility from Earth
Near Rectilinear Halo Orbit (NRHO)	6-8 days	2000-76,000 km	Very high stability, limited surface coverage, Very good Earth visibility

- Elliptical Lunar Frozen Orbit (ELFO) constellation is simulated in STK with 8 navigation satellites in 2 orbital planes, each having 4 satellites.
- Simulation is done around “Shiv-Shakti” Chandrayaan-3 landing point and necessary data is generated.
- Chosen ELFO constellation provides around 76 % visibility around the selected user location.

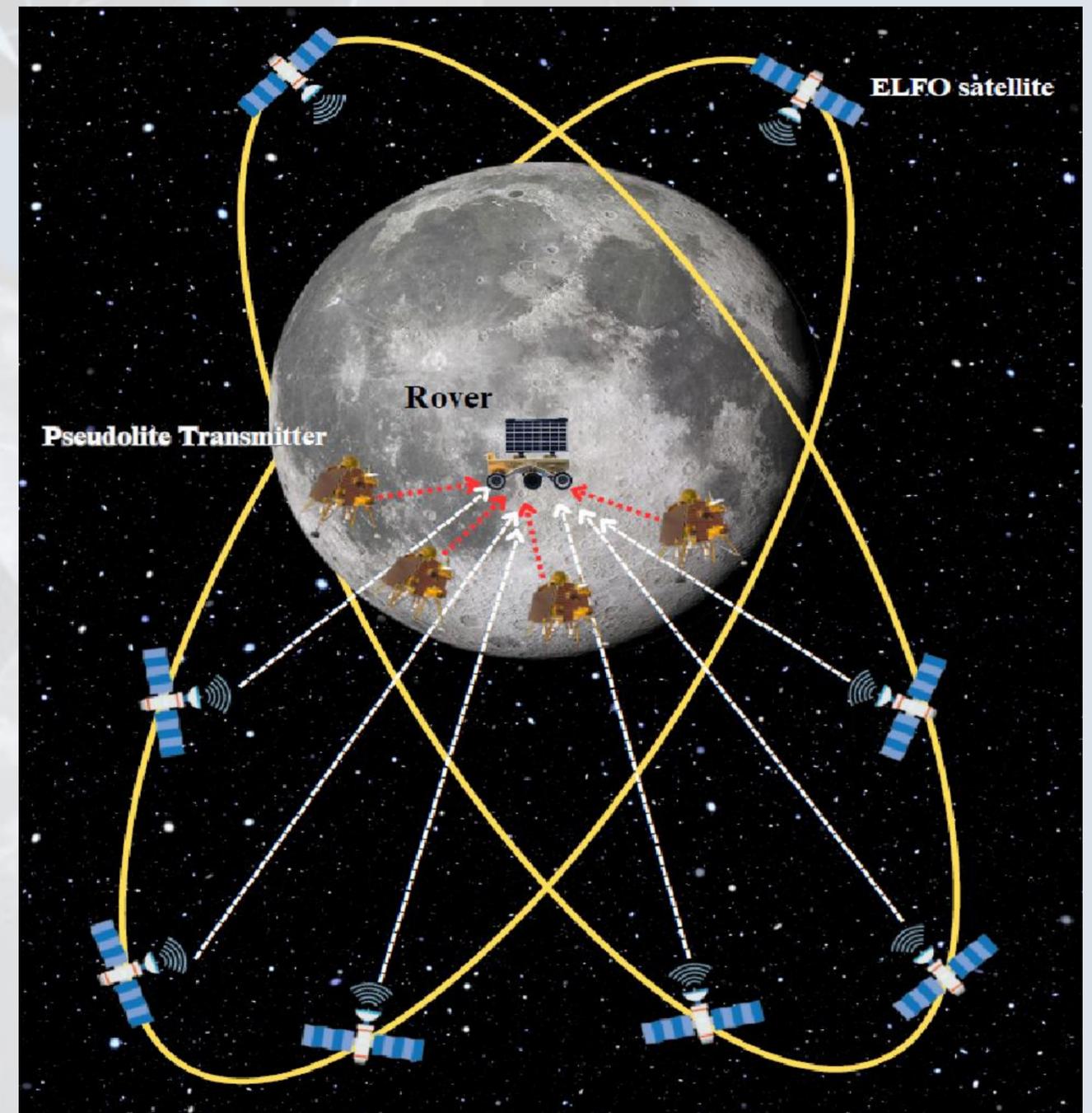


ELFO Constellation

Elements of Space Segment

Frequency	S-Band	2483.5-2500 MHz
Satellite Platform	SmallSat	
Satellite Orbit	ELFO	Stable orbit Preferred for Satellite Navigation & Communication
No of Orbital Planes	02	
No of Satellites	08	
Lunar Orbit Determination	ISL	RF/Optical link
Orbit Determination & Time Synchronization (ODTS)	Using Earth GNSS Receiver on-board Lunar Nav Sat	RAFS/Space Grade CSAC/DSAC

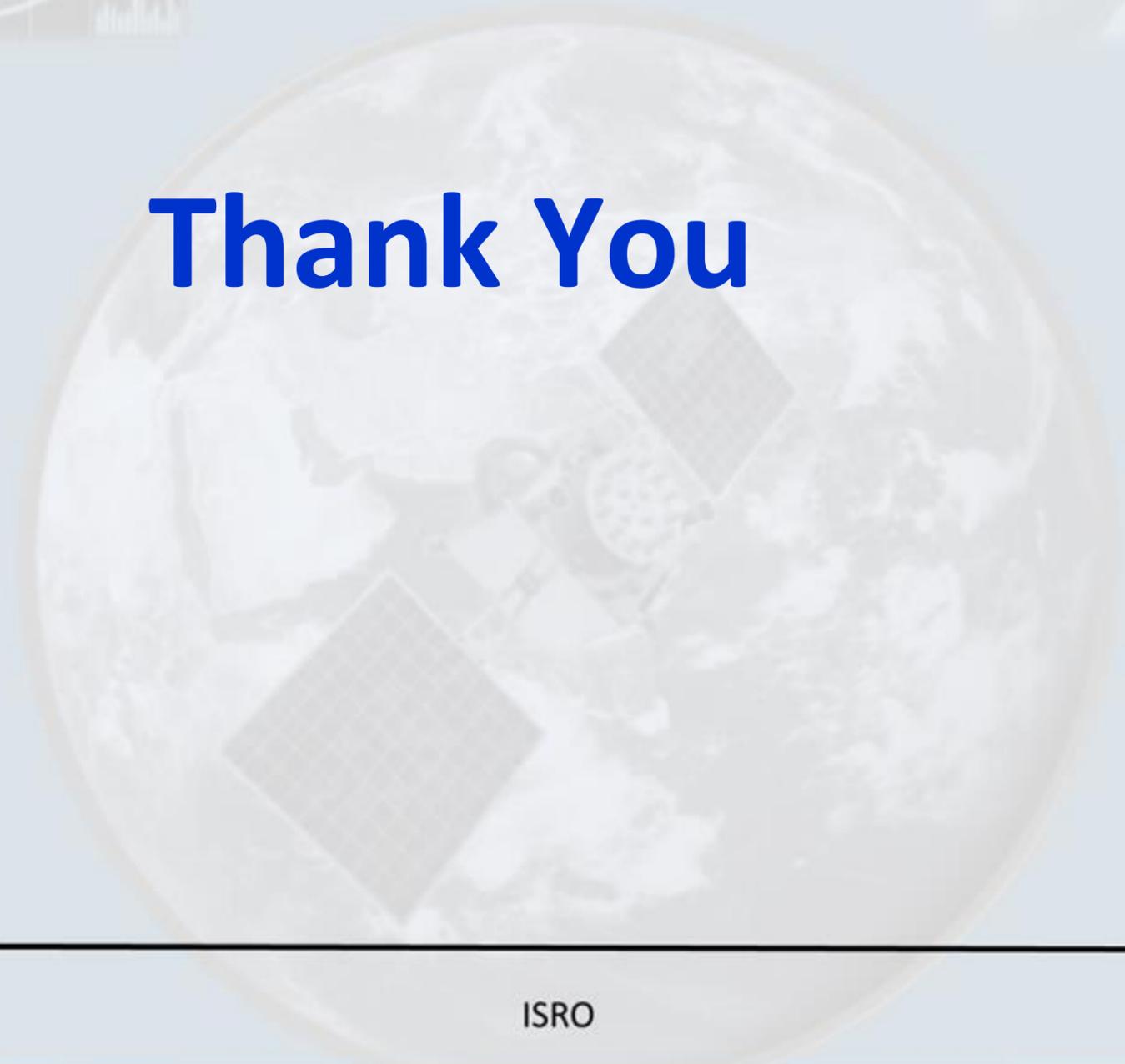
- A hybrid Satellite & Pseudolite based lunar navigation system for future lunar missions would provide more accurate position solution.
- This system is proposed to have 8 satellite in ELFO orbit and a network of Pseudolite Transmitters on lunar surface.
- When the satellite based navigation systems are combined with the Ground Based Navigation system, vertical & 3D position accuracy improves significantly.
- This improvement is due to improved geometry & hence better PDOP.



Component	Value
Sat + PL Orbit Error	2.5 m
Sat + PL Clock Error	2.0 m
Multipath Error	0.5 m
Rx Noise	0.3 m
UERE	3.28 m
PDOP	0.91
3D Position Accuracy	3.02 m

Summary

- India Plans to develop Pseudolite & Satellite based systems for Lunar PNT.
- System configuration along with Ground & Space segment requirements are being worked out.
- Better position accuracy can be achieved using hybrid Pseudolite & Satellite based system.



Thank You