Pseudolite System for Lunar PNT

ICG Intersessional Meeting

Vienna, 25 June 2024

Dr. Ashish K Shukla

SAC- ISRO, INDIA

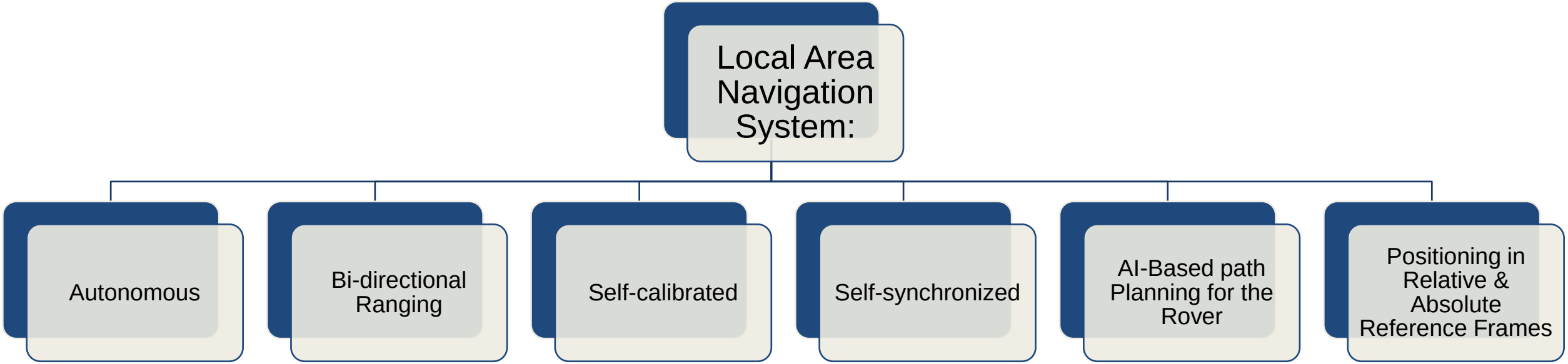
Goal & Major Objectives

- ***Navigation sensor for Lunar PNT should be designed for:***
  - ❖ Autonomous operation capability
  - ❖ Durability & adaptability to challenging environment
- ***Design & architecture of Pseudolite transceivers constellation & exploration of existing systems for aiding***
- ***Define Common Standard for the Lunar Pseudolite Transceiver Network***

Role of WP-4 Lunar PNT Group

- Under ICG WP-4 on Lunar PNT, advanced Pseudolite System has been proposed & being discussed for the future Lunar PNT.
- New ideas, sensors & deployment strategies to be discussed & developed.
- ISRO-INDIA is considering to develop pseudolite transceiver as a new radio navigation sensor in its future lunar landers.
- All the Space agencies under WP-4 should come together to develop similar pseudolite sensor in their lunar landers as well.
- A Common standard for Pseudolite Transceiver Network & system specifications are to be defined for the Lunar PNT

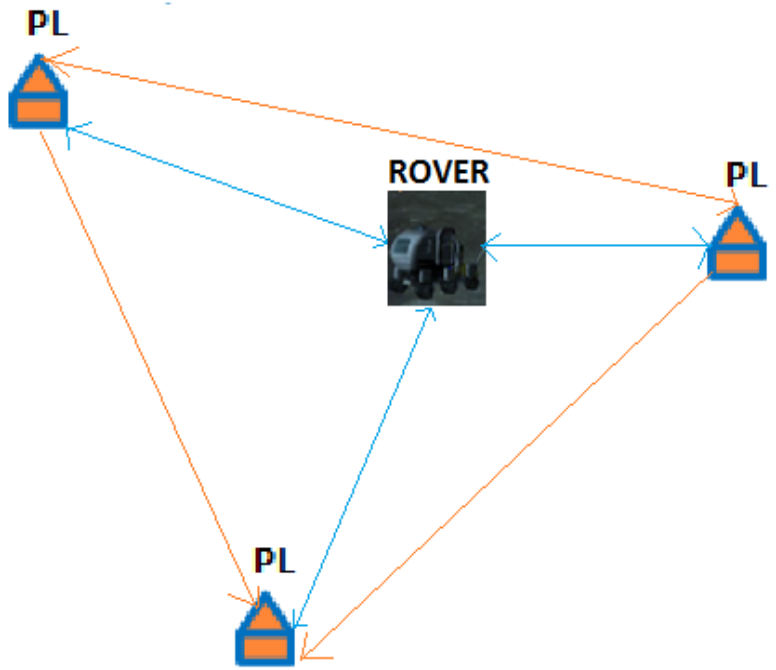
Salient Features of Pseudolite System for Lunar PNT



Autonomous Pseudolite System for Lunar Navigation

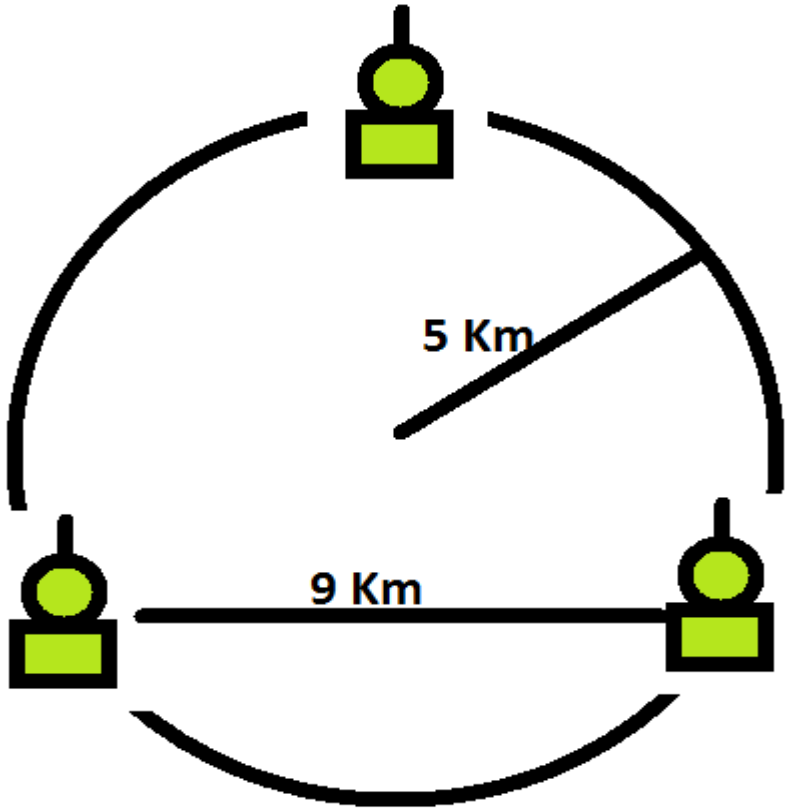
Relative Reference Frame

- In the absence of any Lunar navigation system, standalone Pseudolite System is one of the possible options.
- Pseudolite **relative Self-Positioning** using Bi-directional Ranging in case absolute locations of Pseudolite transceivers are not available.
- Autonomous system & independent of any satellite based system for Lunar PNT.



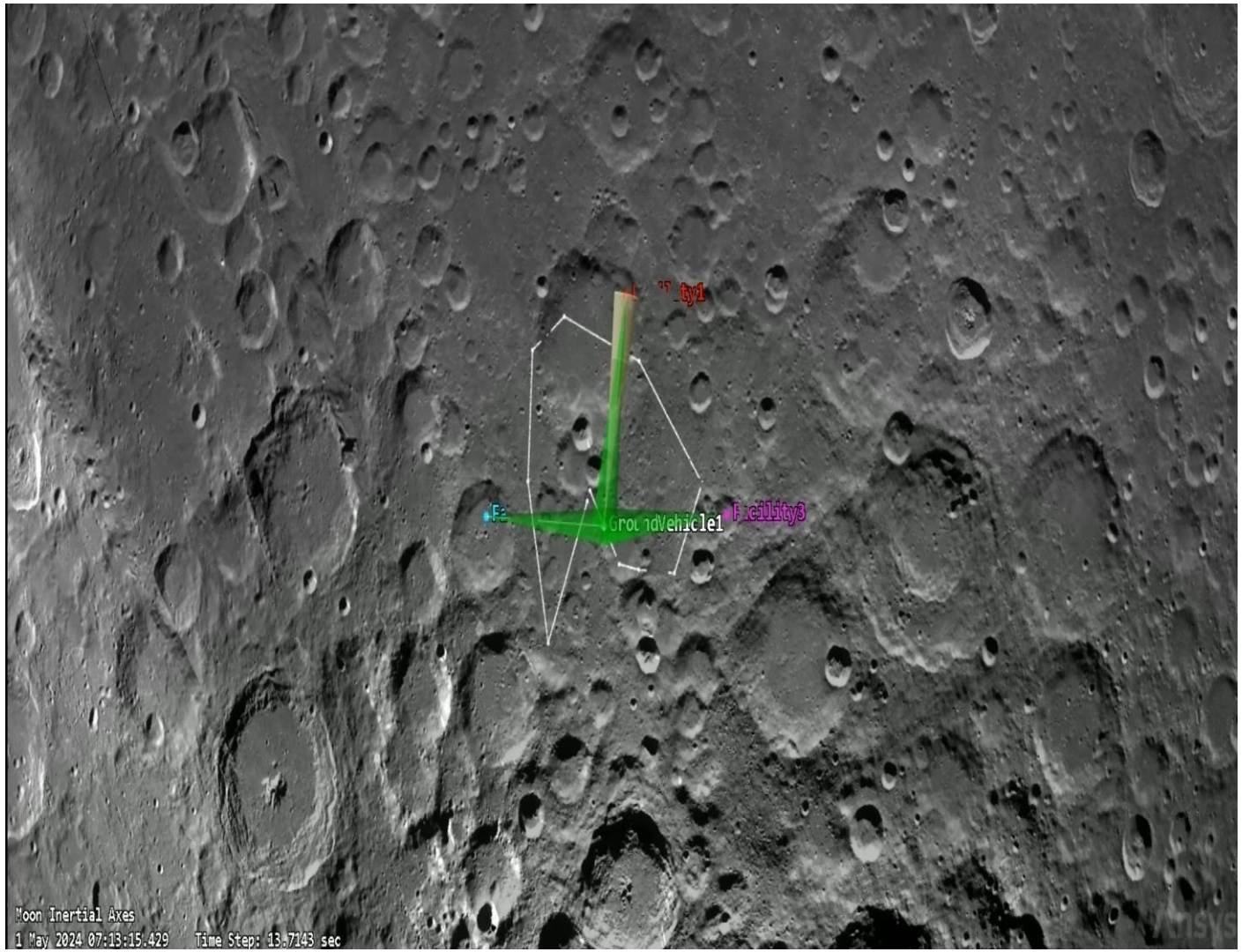
Configuration , Service Area & Targeted Accuracy

- A circular area with radius of 5 km is proposed to be the considered as the service area.
- Minimum 3 Pseudolite Transceivers are required for 2D position.
- Maximum distance (LoS) between Pseudolite Transceiver & Rover is 10 km.
- Distance between the Pseudolites is around 9 Km.



2D Position Accuracy (m)	Service Area
Sub- metre Level	10 Km LoS

STK Simulation with Three PL Transceivers



- Simulations are done in STK with three Pseudolite Transceivers.
- Rover moving in pre-defined path within the service volume.
- Visibility, position accuracy & optimum configuration is to be worked out.

Proposed Navigation Signal Parameters

Frequency Band	S-Band (designated Band for Lunar Navigation)	**2414.28 MHz or 2424.5MHz**
Transmit Power	1 Watt	Pulse-mode
PRN Code	Gold Code	1023 Chips
Code Rate	10.23 Mcps	
Modulation	BPSK-R	
Ranging	Bi-directional	

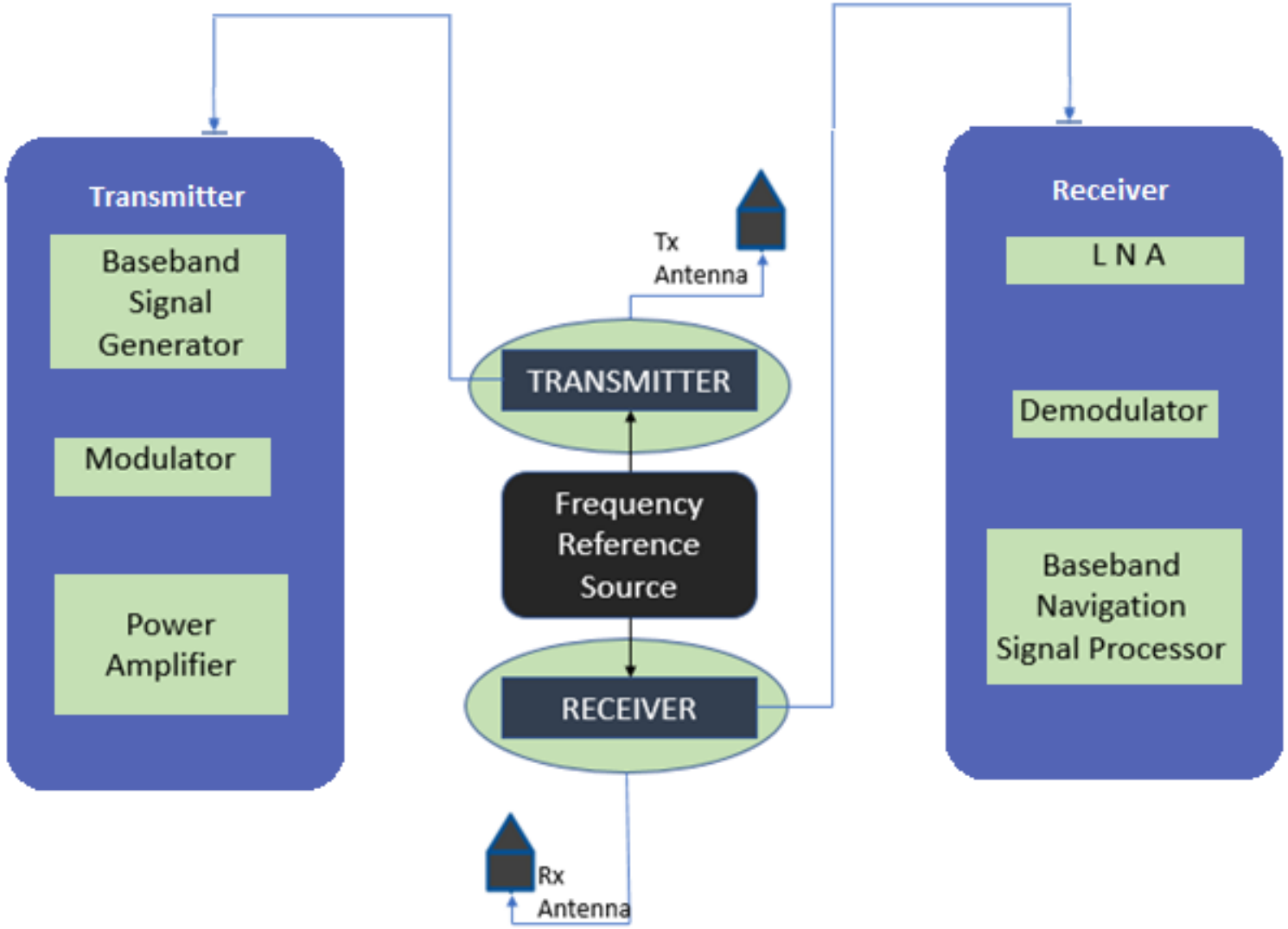
Pseudolite to Rover Navigation Link

- In the proposed service area, the maximum range between any PL and rover will be 10 kms LoS.
- Both the transceiver antennas are considered as omni directional.
- RF transmit Power should be according to the S-band regulations of lunar spectrum providers.

Inter Pseudolite Link

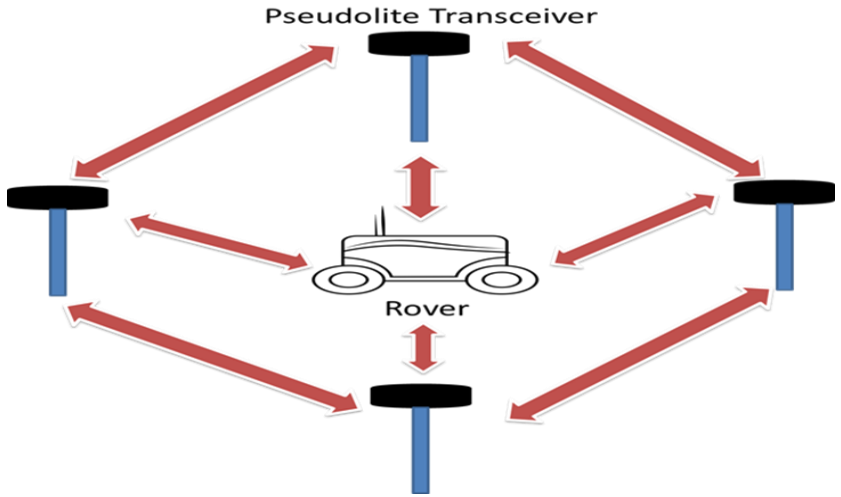
- For typical Pseudolite system with 3-PL transceivers, the maximum distance between one Pseudolite to another Pseudolite is 9 km.
- Both the transceiver antennas are considered as Omni directional.
- RF transmit Power will be according to the lunar spectrum regulations.

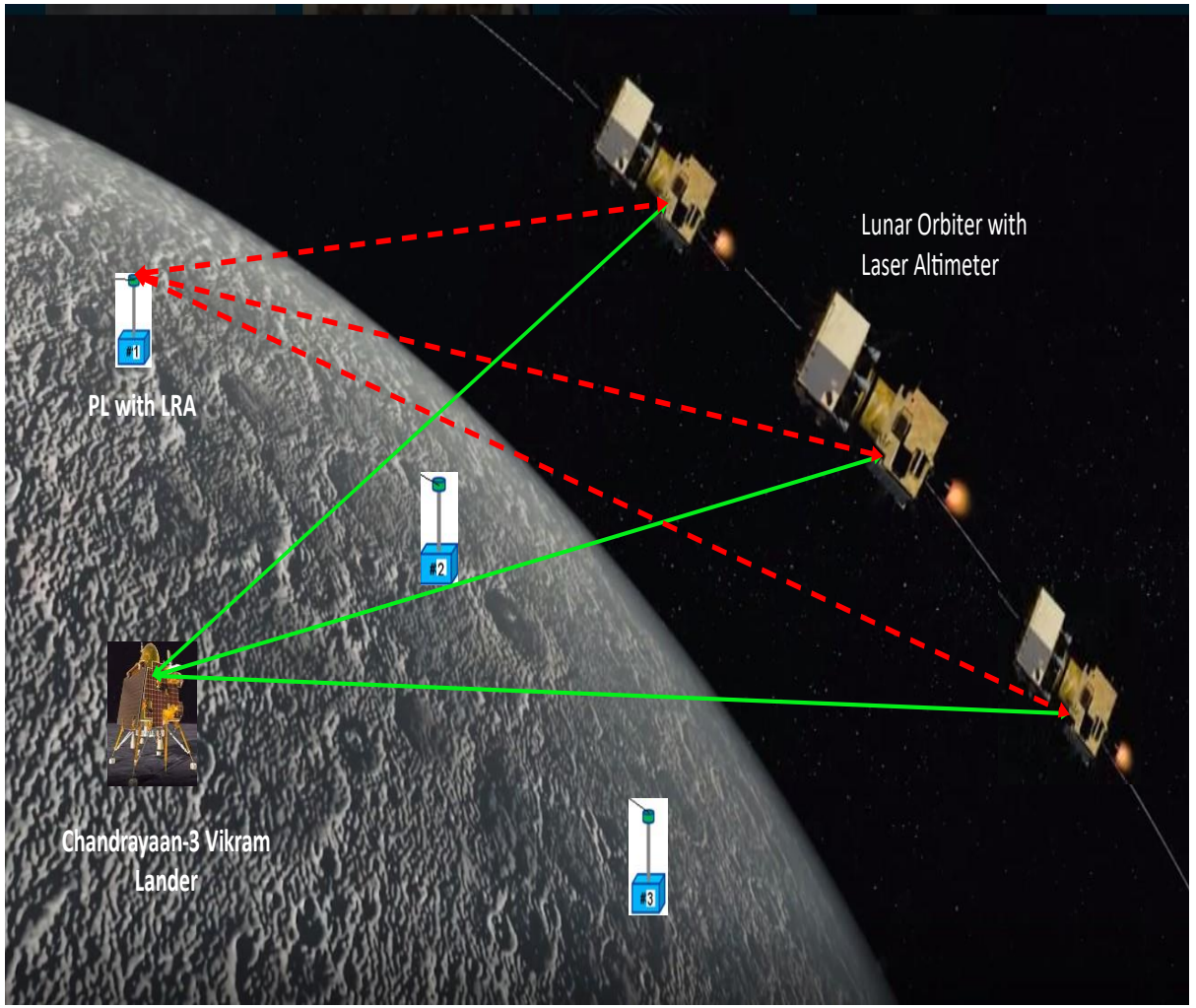
Pseudolite Transceiver Architecture



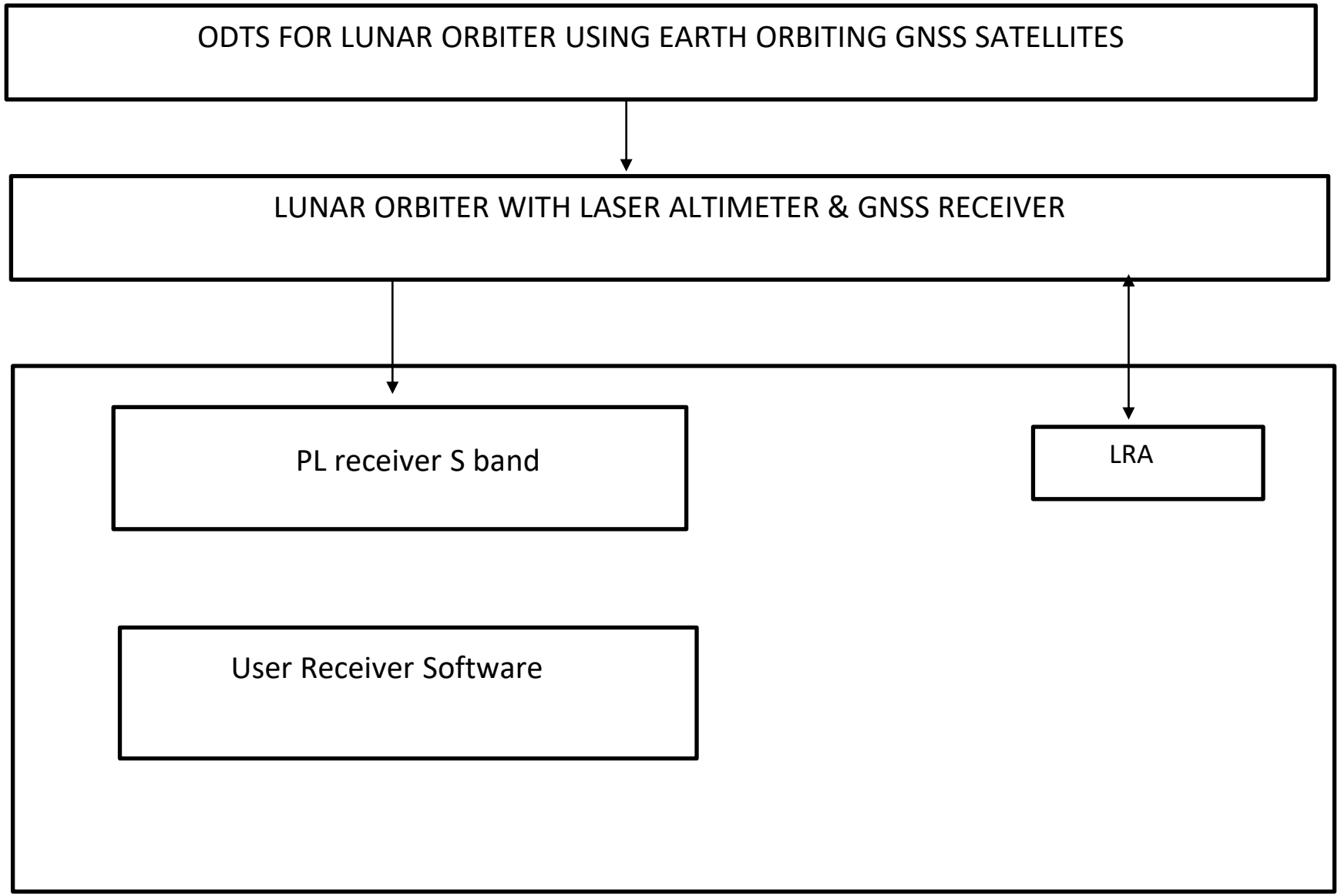
Absolute Positioning using Pseudolite System with LRA, orbiter & GNSS satellites

- Location determination of Pseudolite transceivers can be done with Laser Retro-Reflector Array (LRA) on-board lunar lander.
- A small LRA (shown as placed on Chandrayaan-3 lander) on the Moon can be detected by an orbiting Laser Altimeter on-board lunar orbiter.
- Once Pseudolite transceiver locations are determined in lunar reference frame, absolute positioning of rover can be done using bidirectional ranging.





Absolute Location Determination of Pseudolite Transceiver



Summary

- Autonomous & Satellite based Pseudolite navigation system is proposed for the Lunar PNT.
- Pseudolite network configuration & architecture with minimum number of Pseudolites has been worked out.
- Major Navigation signal parameters are proposed for the pseudolite system.
- Methodology for pseudolite transceiver positioning in relative & absolute reference frames are worked out.
- Simulations are carried out in STK to assess the coverage, visibility & accuracy.
- A common standard has to be worked out for the interoperable Pseudolite System for Lunar PNT.

Thank You