Pseudolite System for Reusable Launchers and Lunar Navigation

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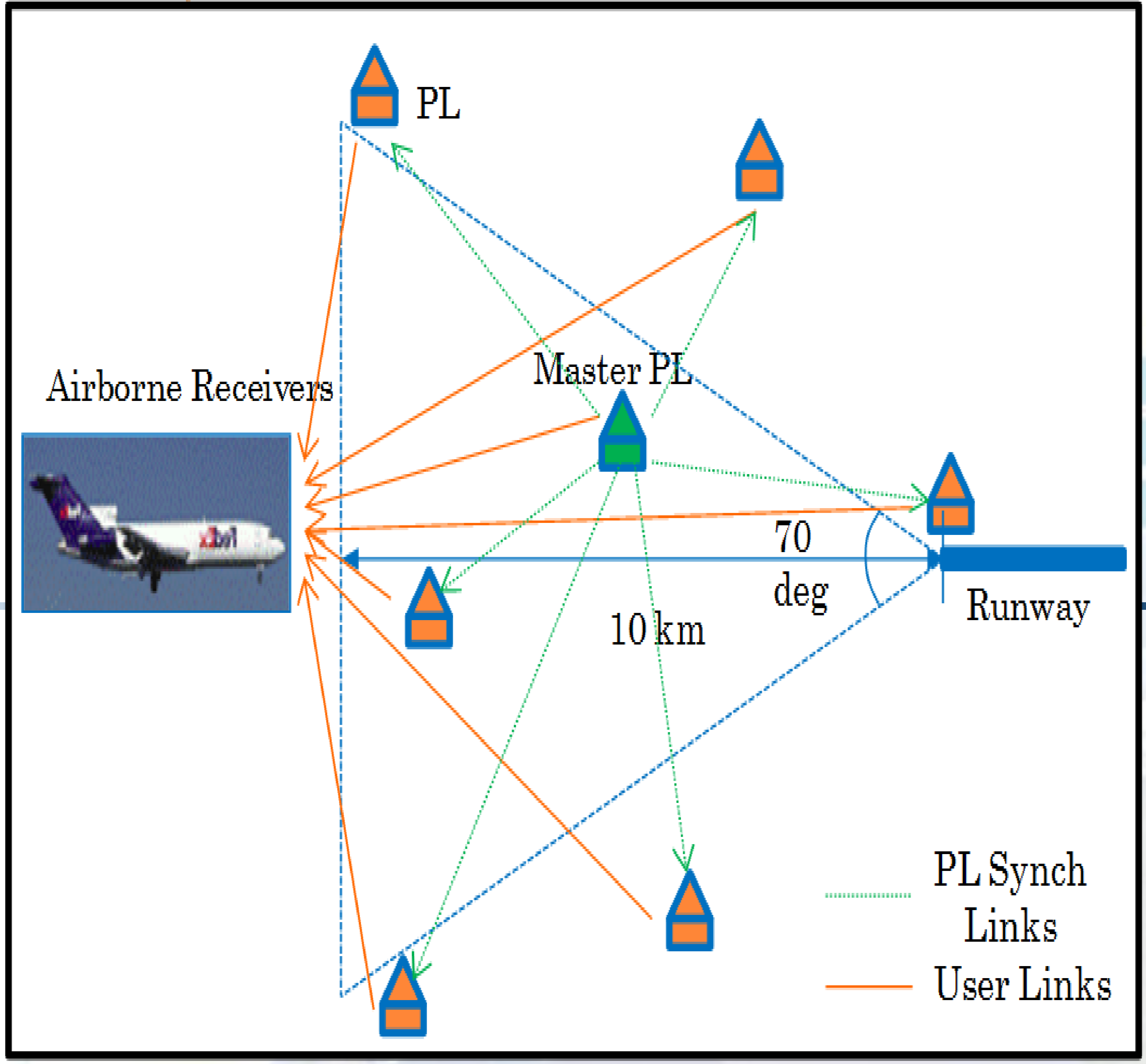
Pseudolite System for RLV LEX & Orbital Re-Entry (ORE)

- RLV-Technology Demonstrator (RLV-TD) is one of the most challenging endeavours of ISRO’s Reusable Launch Vehicle program.
- Standalone Pseudolite based Navigation System was developed by SAC ISRO as a key technology for RLV.
- Pseudolite System provided lateral guidance to RLV during the Landing Phase in LEX-01 mission.
- An upgraded version of Pseudolite System combined with GPS & NavIC is being developed for RLV ORE & landing of civilian aircrafts.

Standalone Pseudolite System for RLV-LEX & ORE: Salient Features



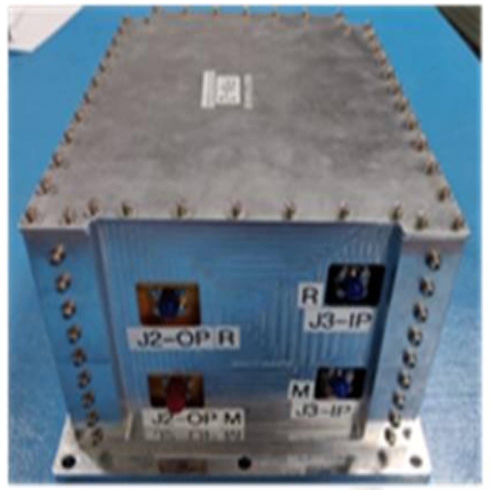
Pseudolite System Concept

- Standalone navigation system, independent of satellite systems.
- Low cost pseudolite transceivers, No use of atomic clocks.
- Passive ranging system.
- Self Synchronized system in Master Slave mode.
- S band ISM license free spectrum.
- Frequency: 2414.28 MHz

- 10 Pseudolite (PL) Transceiver stations are deployed for RLV landing.
- 5 PL transceivers on each side of the runway.
- RLV-LEX Position Accuracy Requirement: 4 m (3 sigma) across the track.

Pseudolite Sub-Systems


User Receiver


LNA & Filter Integrated package


Pseudolite Pole System

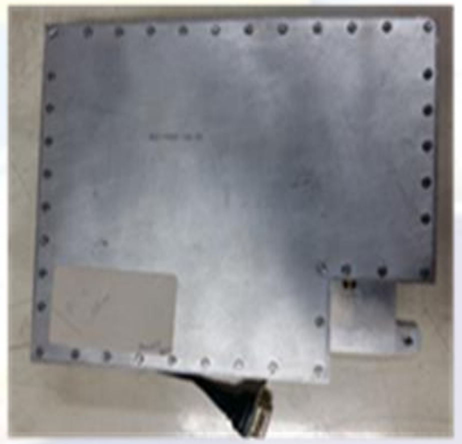

Receive Antenna


Power Module


Power Combiner


PL Tx Antenna


PL Rx Antenna


PL Transmitter


PL Simulator

Pseudolite User Receiver :

- 10 channel Acquisition & Tracking in Pulsed-CDMA mode
- Non-iterative Closed Form User Position Algorithm

Pseudolite Receiver for Time Synchronization:

- Two Channel RF Front end Design with Acquisition & tracking

Tx-Rx Antenna, PL Transmitter

- Quadrifiller Helix Tx, Patch Rx & User Rx
- Tx Power: Up-to 1 Watt

Applications:

- Precise Landing of Aircraft at Indian Airports
- RLV-LEX & Orbital Re-Entry (ORE) Mission

Position Accuracy during Helicopter Trials before RLV LEX-01

1. Static, Multicopter and Helicopter Trials were carried out using Pseudolite System before the LEX-01 mission.
2. In the helicopter trial, 10 Pseudolite Stations were used.
3. HDOP and Accuracy during landing phase was within specified limit.

HDOP Range & Across the Track Error during Landing Phase

Service Volume	HDOP Range	Position Error (m) (3σ)
SV 3m	0.78-1.14	3.97

Pseudolite System Performance in RLV LEX-01

ISRO has successfully demonstrated precise landing of RLV LEX-01 on 2nd April 2023

Standalone Pseudolite System developed by SAC ISRO provided lateral Guidance to RLV during the Landing Phase

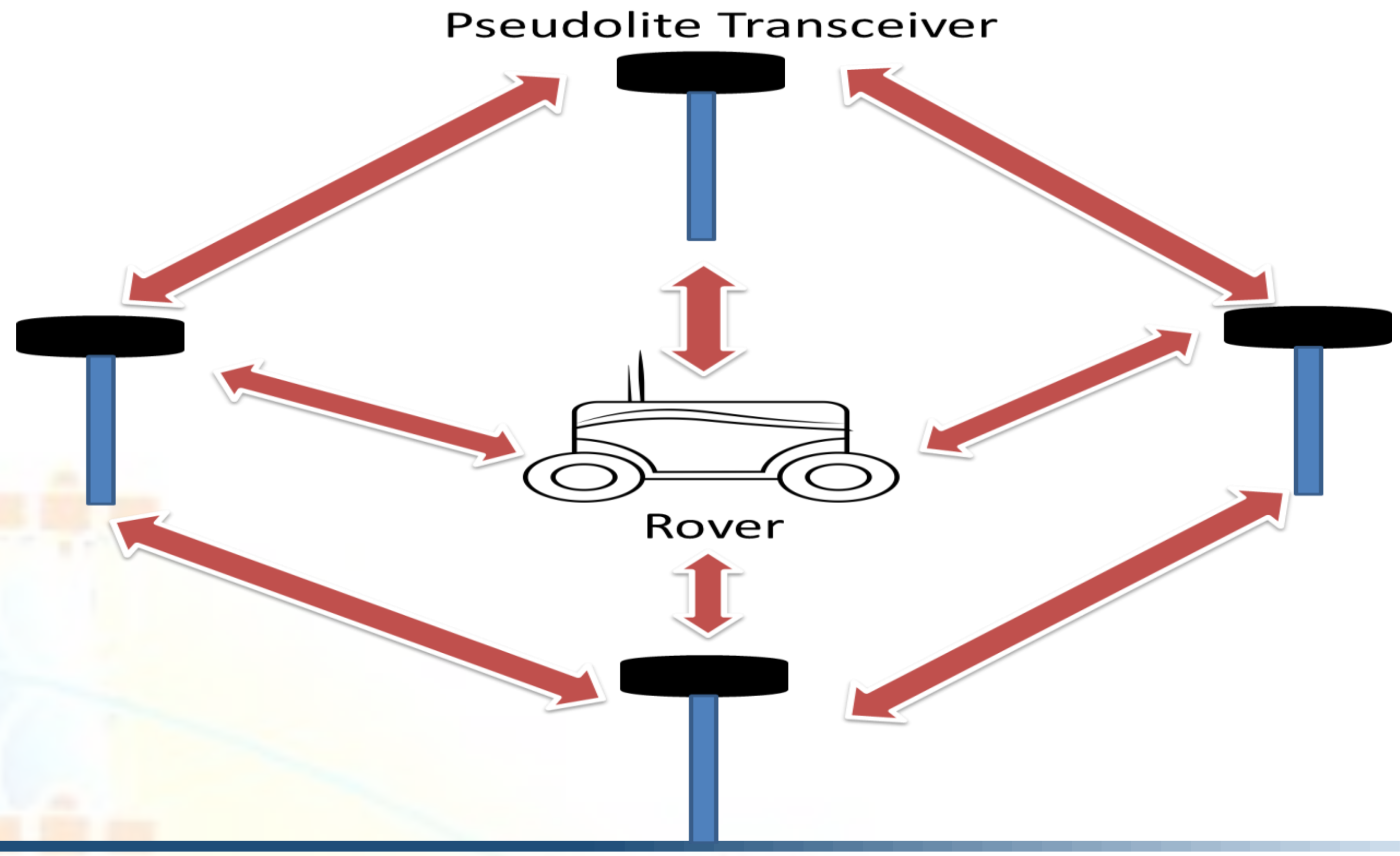
All 10 Pseudolite stations were used in service volume with specified HDOP & 100% availability

13 cm across the track accuracy achieved at touch down

Pseudolite System for Lunar Navigation

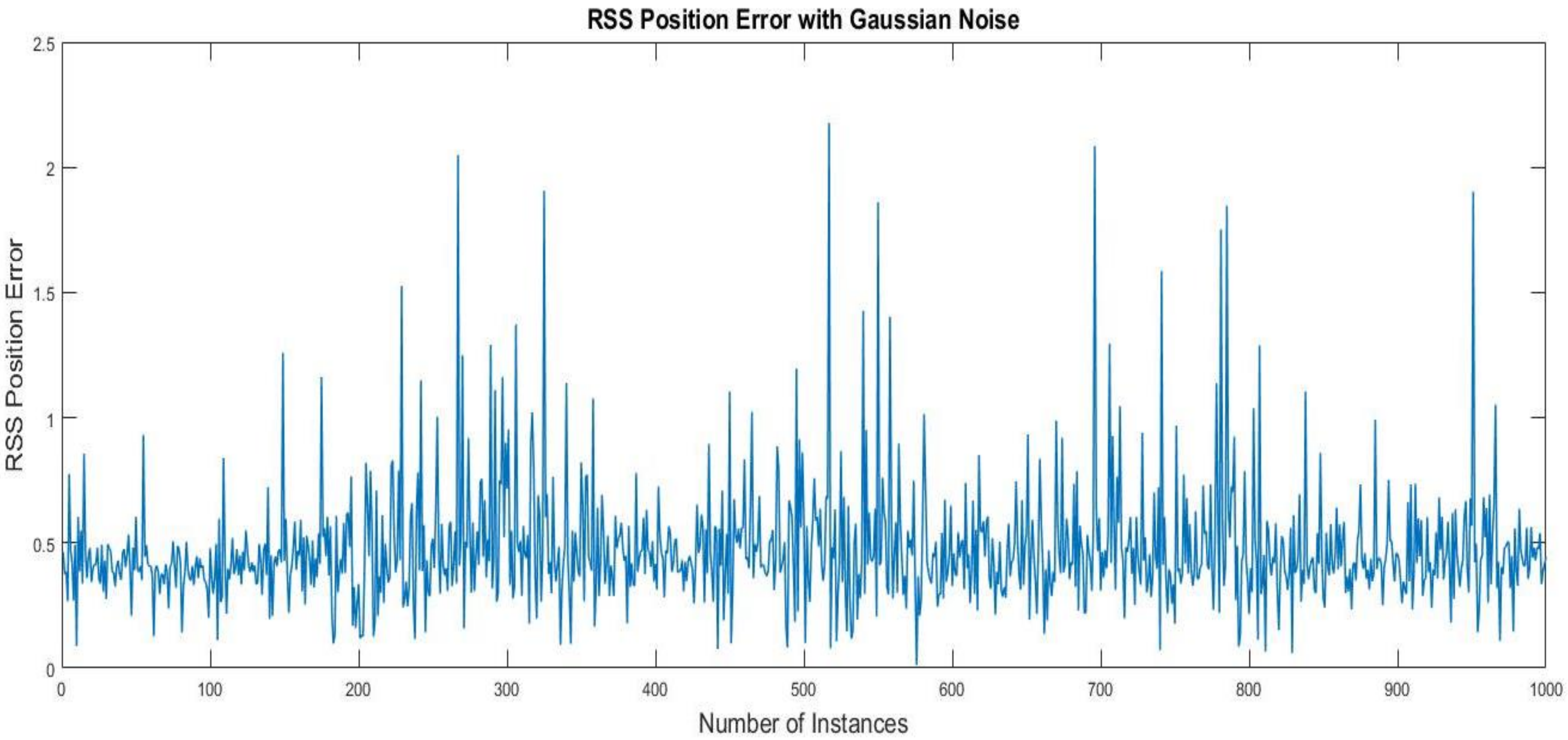
- In the absence of any Lunar navigation system, navigation using Ground Based Pseudolite transceivers is one of the possible options.
- Pseudolite relative Self-Positioning using Bi-directional Ranging is used due to non-availability of absolute locations of Pseudolite transceivers.

$$\nabla\Delta\phi_{i,j}^{i,j} = 2\left|\left|p^i - p^j\right|\right| + \nabla\Delta N_{i,j}^{i,j} + \nabla\Delta b_{i,j}^{i,j} + \nabla\Delta v_{i,j}^{i,j}$$



- Rover positioning is done in association with AI path planning using simulated data .

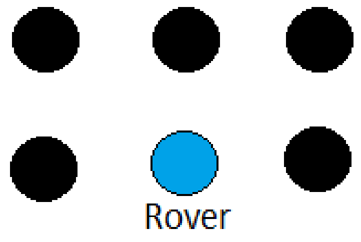
Lunar Rover Positioning Simulation Results



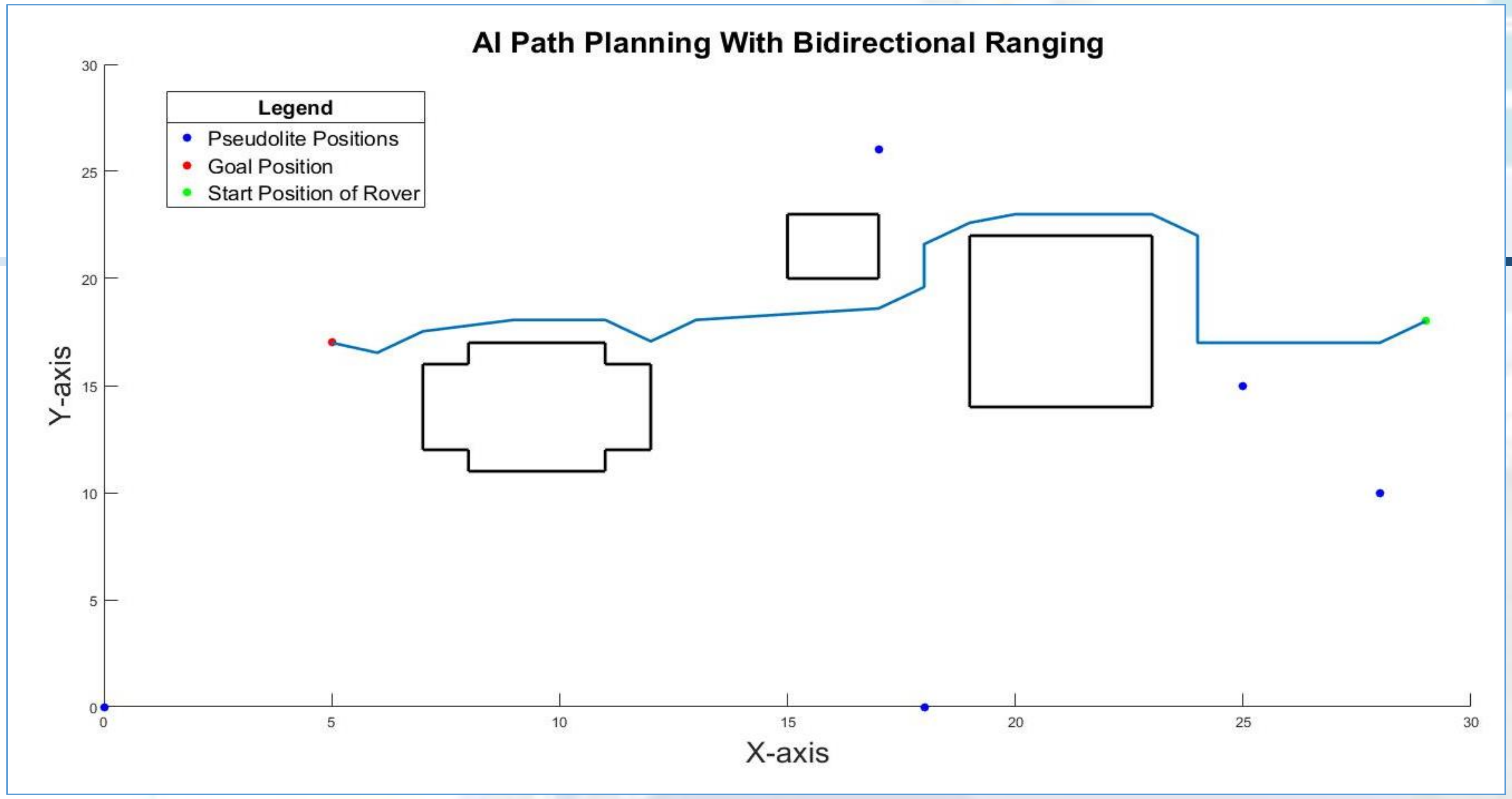
- Rover positioning using bidirectional ranging was done after introducing Gaussian Noise in the data
- RMS position error of 0.49 m is achieved.

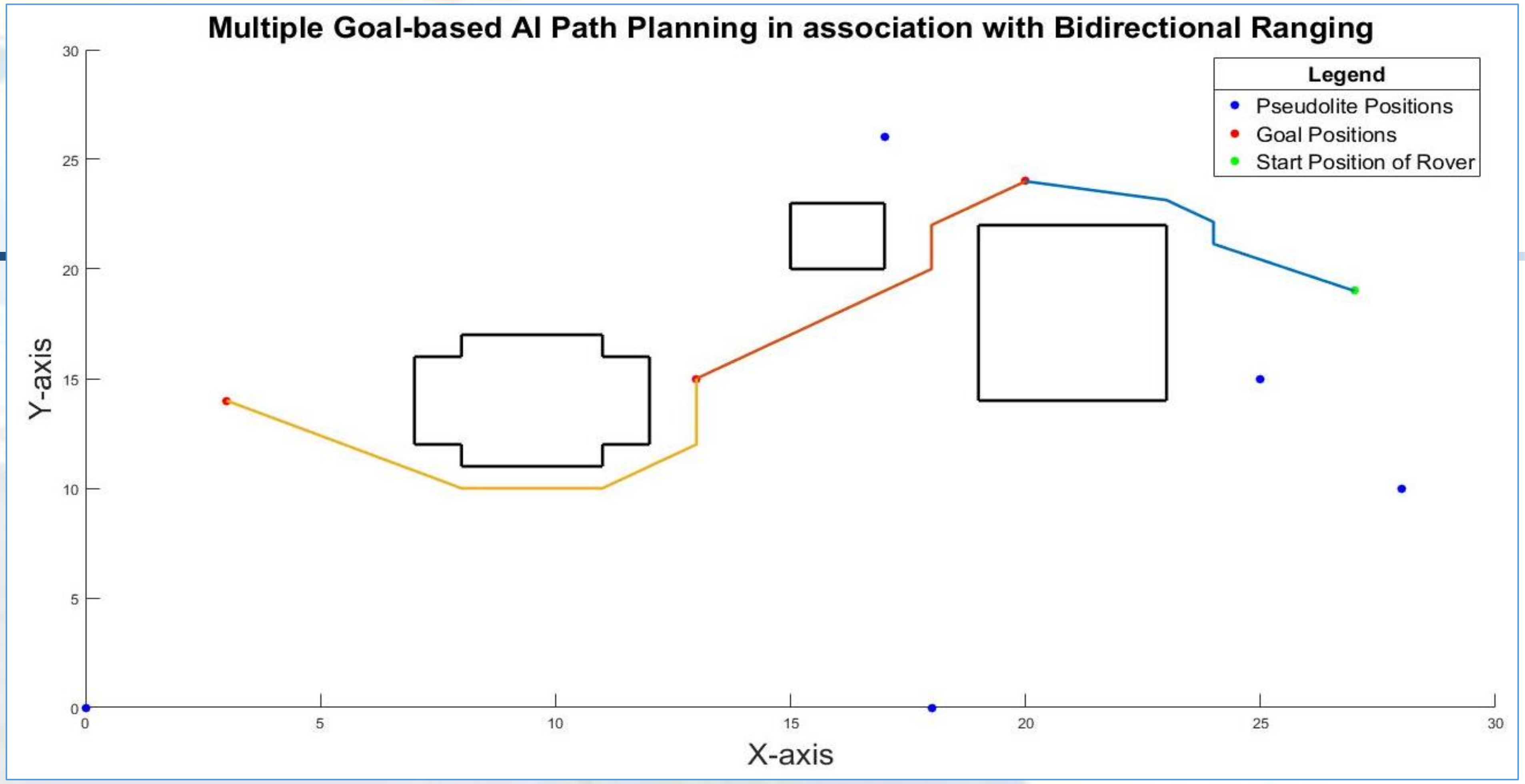
AI Based Rover path planning with Bidirectional Ranging: Single & Multiple Goals

- AI based path planning is an improved version of traditional path planning algorithm in combination with bi-directional ranging.
- Straight line motion and boundary to follow modules are implemented and will work based on the direction of the goal from the current position of the rover.
- The AI Path planning module has predefined percept sequences in the form of a 2D array was not accessible to the rover.
- Rover had access to only the immediate 8 neighbouring cells at its current position.



8 neighbors of Rover's Current Position

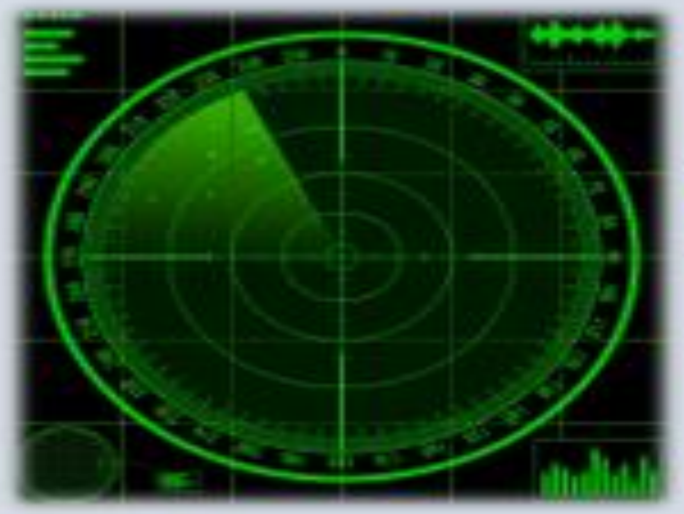


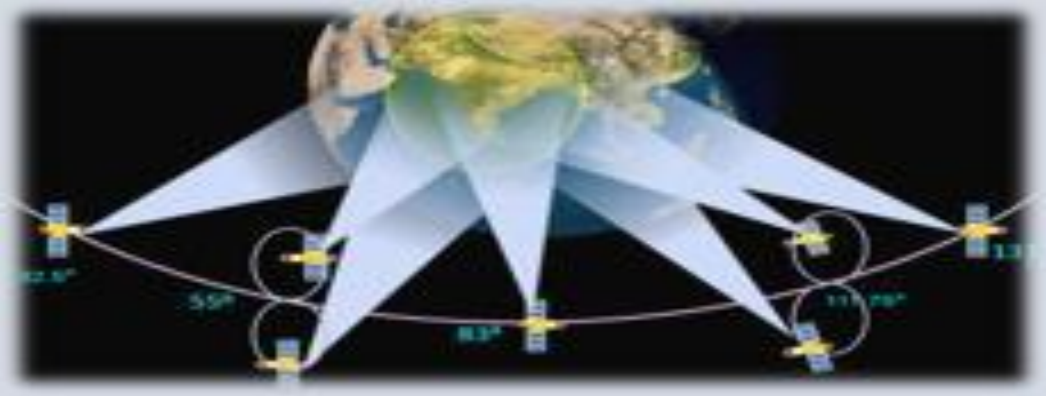


Conclusion

- India has developed Pseudolite Based Navigation System for providing lateral guidance to RLV for precise landing.
- RLV Landing Experiment (LEX-01) was done successfully on 2nd April 2023 with cm level accuracy.
- A Pseudolite Based frame work for future interplanetary/Lunar missions is also worked out.
- The AI-based path planning was implemented in association with bidirectional ranging to achieve cm level position accuracy.

- In future, we aim at developing prototype hardware to make the rover to follow the AI-based path planning.






Thank You