

Connecting the Next Waypoint

Advanced Navigation and Communication for Cislunar Exploration

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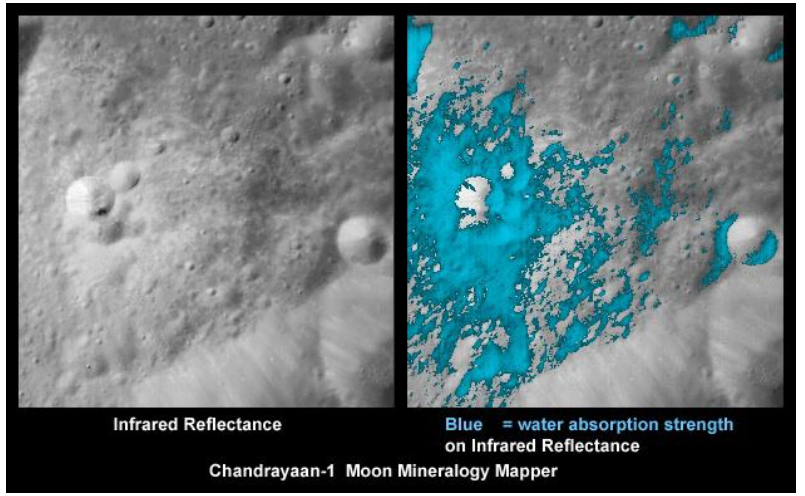
Connecting the Next Waypoint

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- International context
- Communication architectures
- Navigation solutions
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Brief history of lunar exploration

- Space Race (1959-1976)
  - Driven by USA-USSR prestige
- From hiatus to new discovery (1976-2013)
  - Discovery of polar water ice
- Polycentric return to the Moon (2013-now)
  - New players and long-term (human) presence



Reasons for return



NEW SPACE RACE

CHINA, INDIA AND COMMERCIAL PLAYERS



RESOURCE EXTRACTION

MINING OF WATER AND OTHER KEY RESOURCES



LUNAR SCIENCE

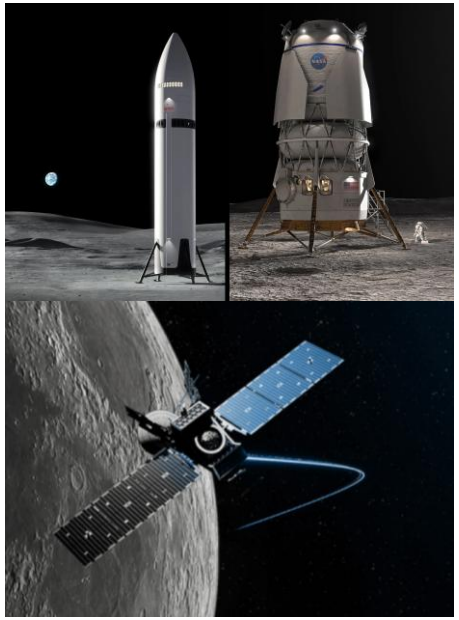
UNDERSTANDING EARTH FORMATION



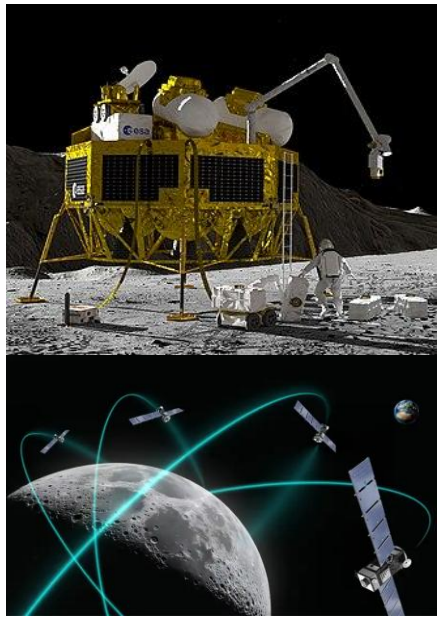
PROVING GROUND

PREPARING FOR INTERPLANETARY EXPLORATION

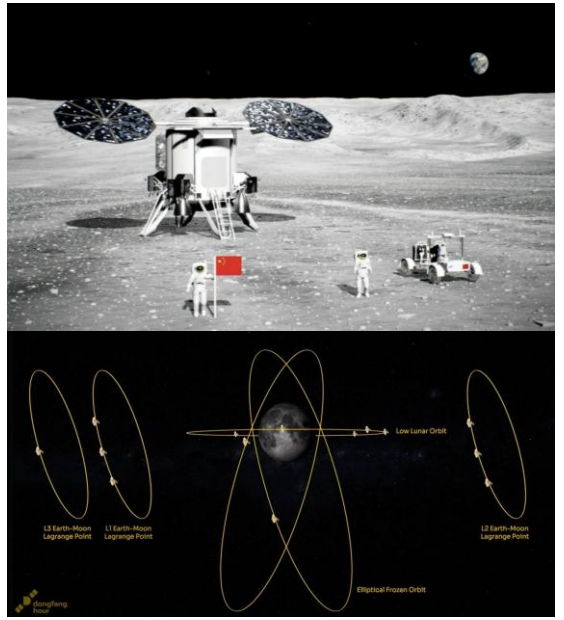
Polycentric exploration



Artemis and Altus



Argonaut and Moonlight



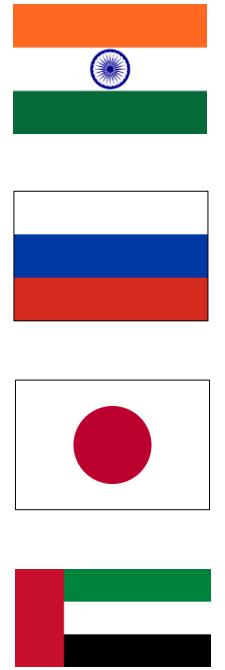
Lanyue and Queqiao

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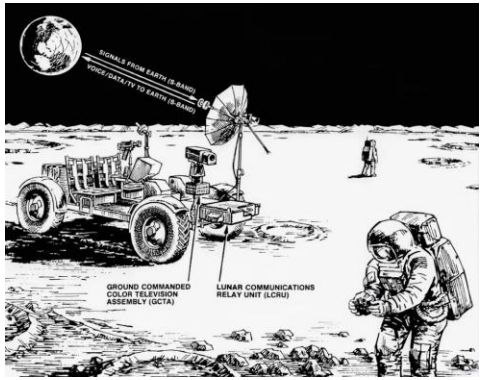
Communication challenges

- Line-of-sight difficult in craters and on far side (59% out of view from Earth)
- Continuous link needed for human missions (1.3 s delay)
- Coordination needed between different countries

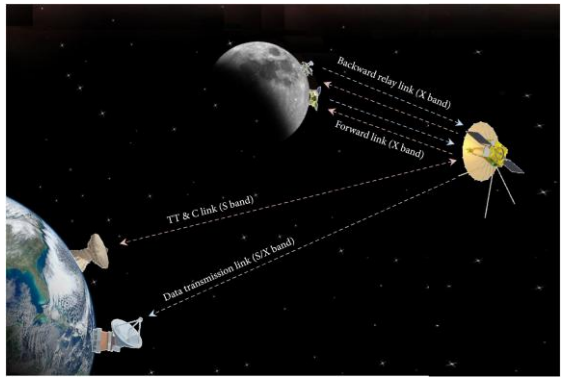


Radio-frequency communication

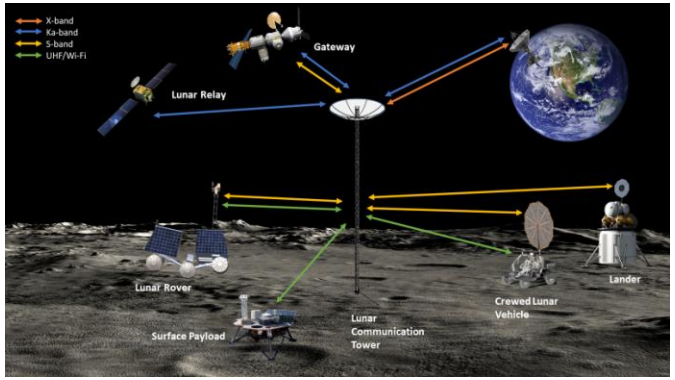
- Need for terrestrial deep space antenna coverage
- Link congestion for large number of missions
- Evolving architecture based on well-proven technology



Direct link



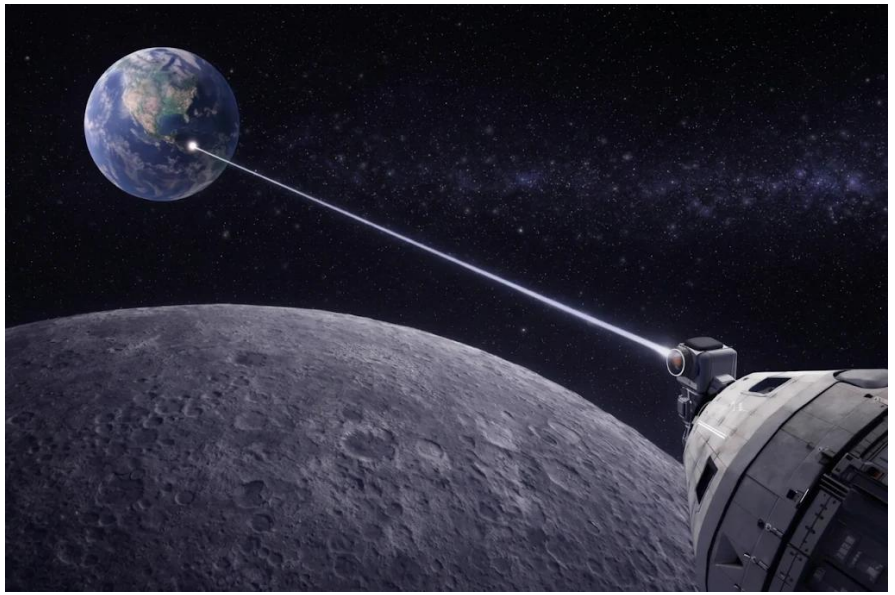
Relay satellite



Surface network

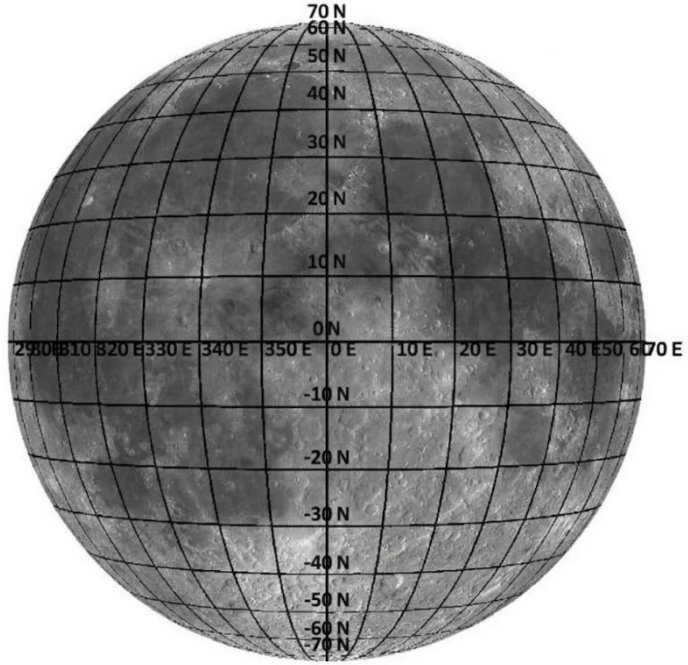
Laser communication

- Novel technique with greater bandwidth (622 Mbit/s demonstrated)
- Sensitive to atmospheric disturbance and lunar dust
- Great application for intersatellite communication links



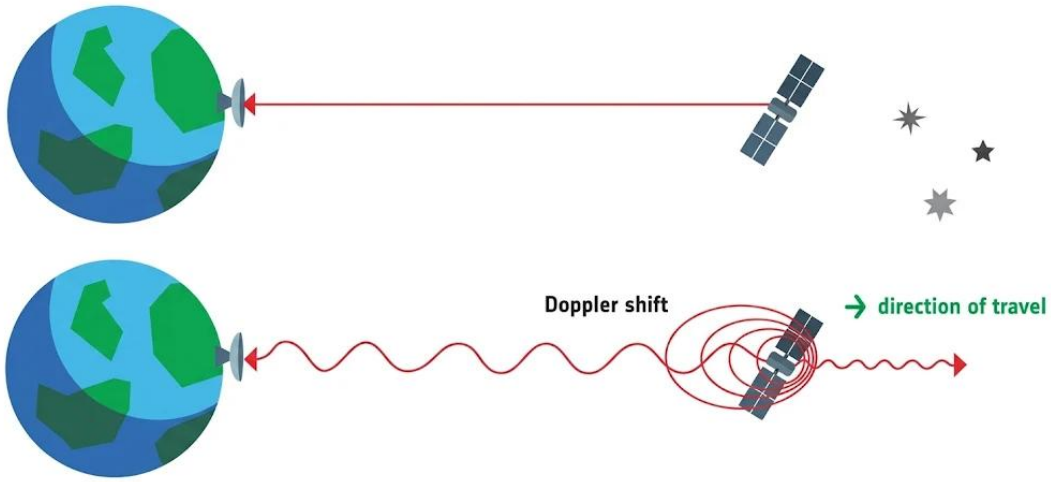
Navigation challenges

- High-accuracy positioning requirements
  - Proximity to other craft and lunar terrain
- Disrupted line-of-sight from Earth
- Connecting Earth and Moon reference frames
  - Lunar time is 56 μs/day faster



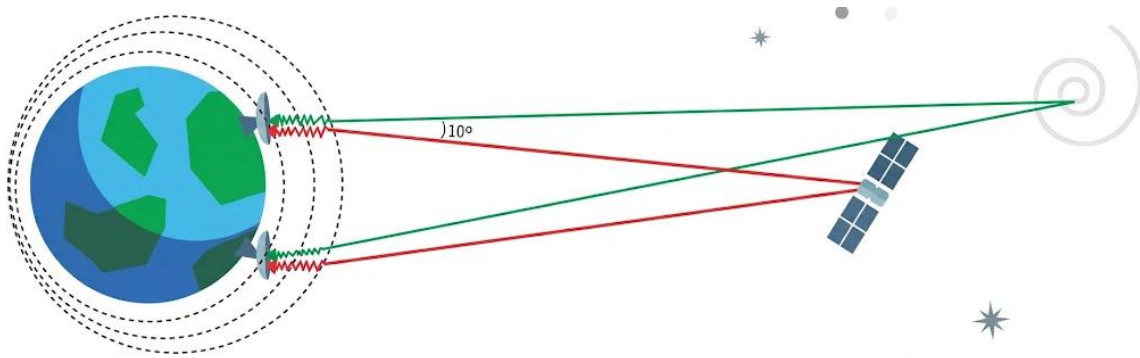
Classical spacecraft ranging

- Time delay on signal determines distance (up to 1 m accuracy)
- Doppler shift provides relative velocity (up to 0.1 mm/s accuracy)
- Limited in angular information



Very Long Baseline Interferometry

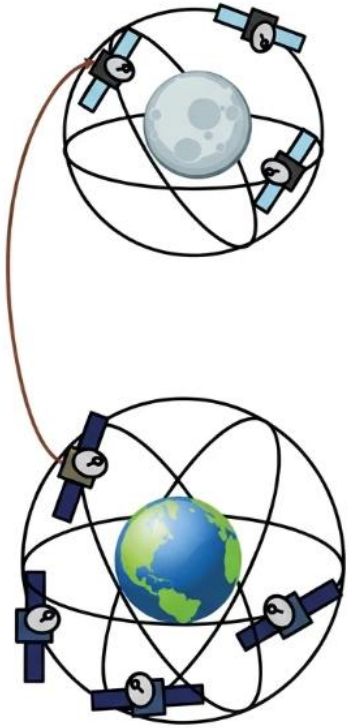
- Propagation delay to two distant ground stations
- Comparison to quasar aids in calibration
- Very accurate angular positioning (up to 1 m accuracy)



GNSS-like signals

- First acquisition of GPS and Galileo signals at the lunar surface (2025)
- Positional accuracy is poor
- Moonlight constellation: 4 navigation and 1 communication





Antwerp Space in navigation

- Galileo navigation test receivers
- LARA payload for ExoMars lander
- Genesis payload integration and calibration (Earth frame up to 1 mm)
- Wideband VLBI transmitter for terrestrial and lunar applications



Antwerp Space in communication

- Communication subsystems
- Satellite modems and relays
- Deep Space Transponder (ranging up to 30 cm)
  Transmit, receive and ranging



Backbone for a permanent lunar presence

- Staying on the Moon requires infrastructure, not just landers
- Communication and navigation are moving from Earth to lunar orbit: relays, laser links and a GPS-like constellation
- Join Antwerp Space and other Belgian space companies in pushing these developments forward

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Join us!



Questions?

Thank you for your attention