National Aeronautics and Space Administration

NASA Space Communications and Navigation: Presentation to the Workshop on Synchronization and Timing Systems

Insights for Position, Navigation and Timing (PNT) at the Moon

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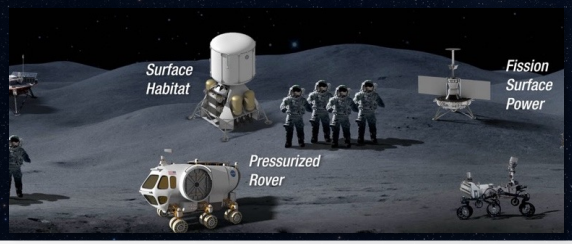
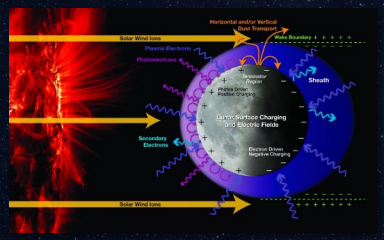
Space Communication and Navigation (SCaN) Capability Development Cislunar Strategist

Lunar PNT Challenges

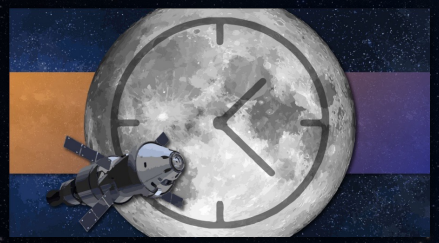
Orienteering Accuracy



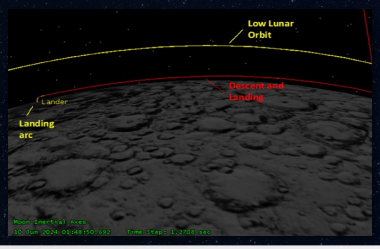
Power / Mass / Volume – Constrain what users can carry for nav



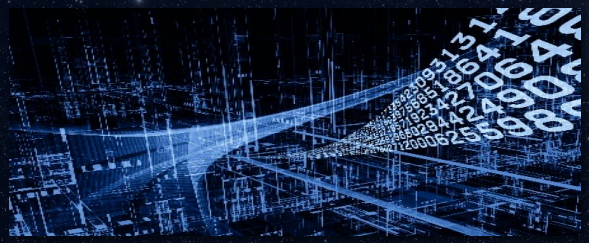
Surface Environment



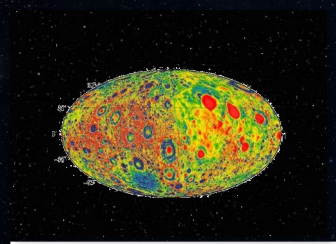
Reference Time



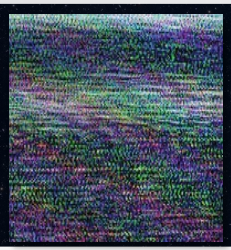
Dynamic Conditions – descent/ascent trajectories



Data/Sensor Fusion

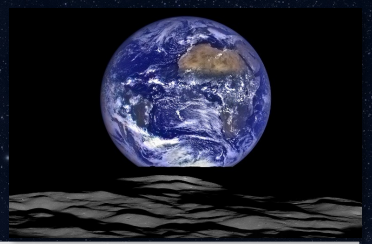


Reference Geodetics & Celestial Relationship



Interference

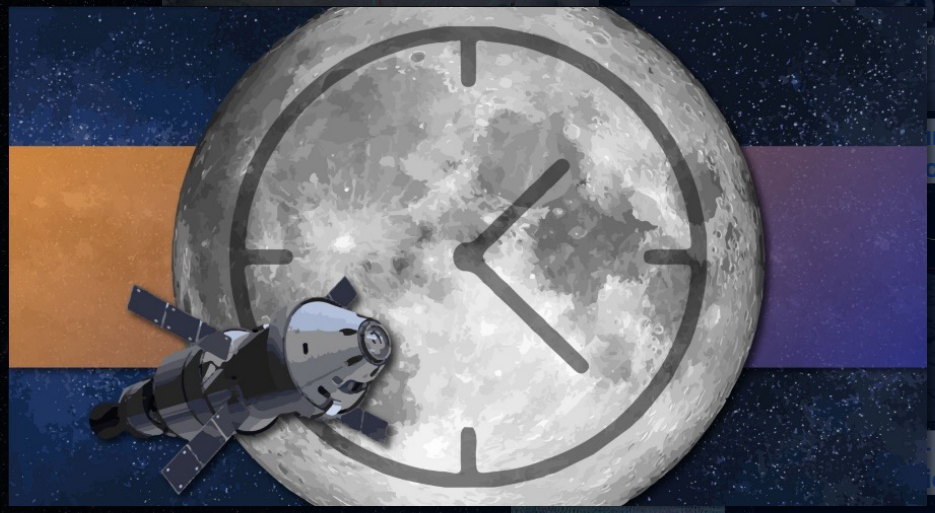
Stark Lighting – difficult for traditional cameras

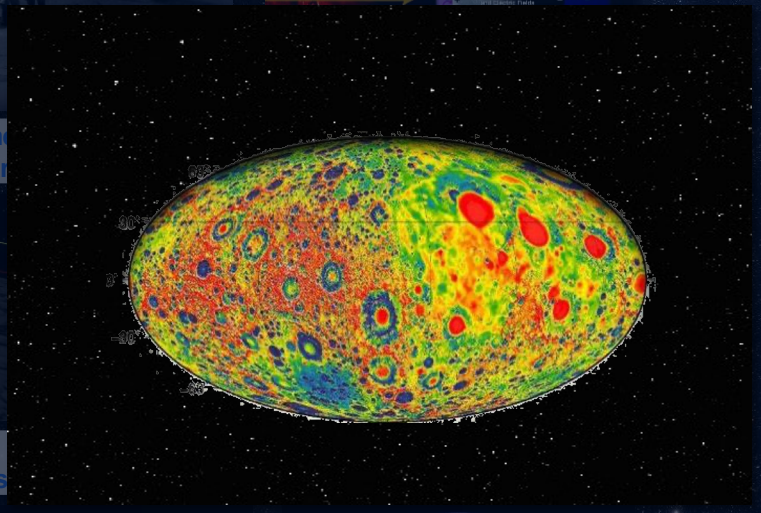


Earth Occultation – limits Earth-based tracking

Fault tolerant autonomous systems providing PNT knowledge + situational awareness will be needed.

Lunar PNT Challenges





Reference Time

Reference Geodetics & Celestial Relationship

Interference	Stark Lighting – difficult for traditional cameras	Earth Occultation – limits Earth-based tracking

Fault tolerant autonomous systems providing PNT knowledge + situational awareness will be needed.

STARK LIGHTING CONDITIONS ENCOUNTERED ON THE MOON

Image: Johnson Space Center Virtual Reality Simulation

User Drivers

Global, safe navigation

Operating in highly dynamic environments (e.g., descent, ascent)

Situational awareness

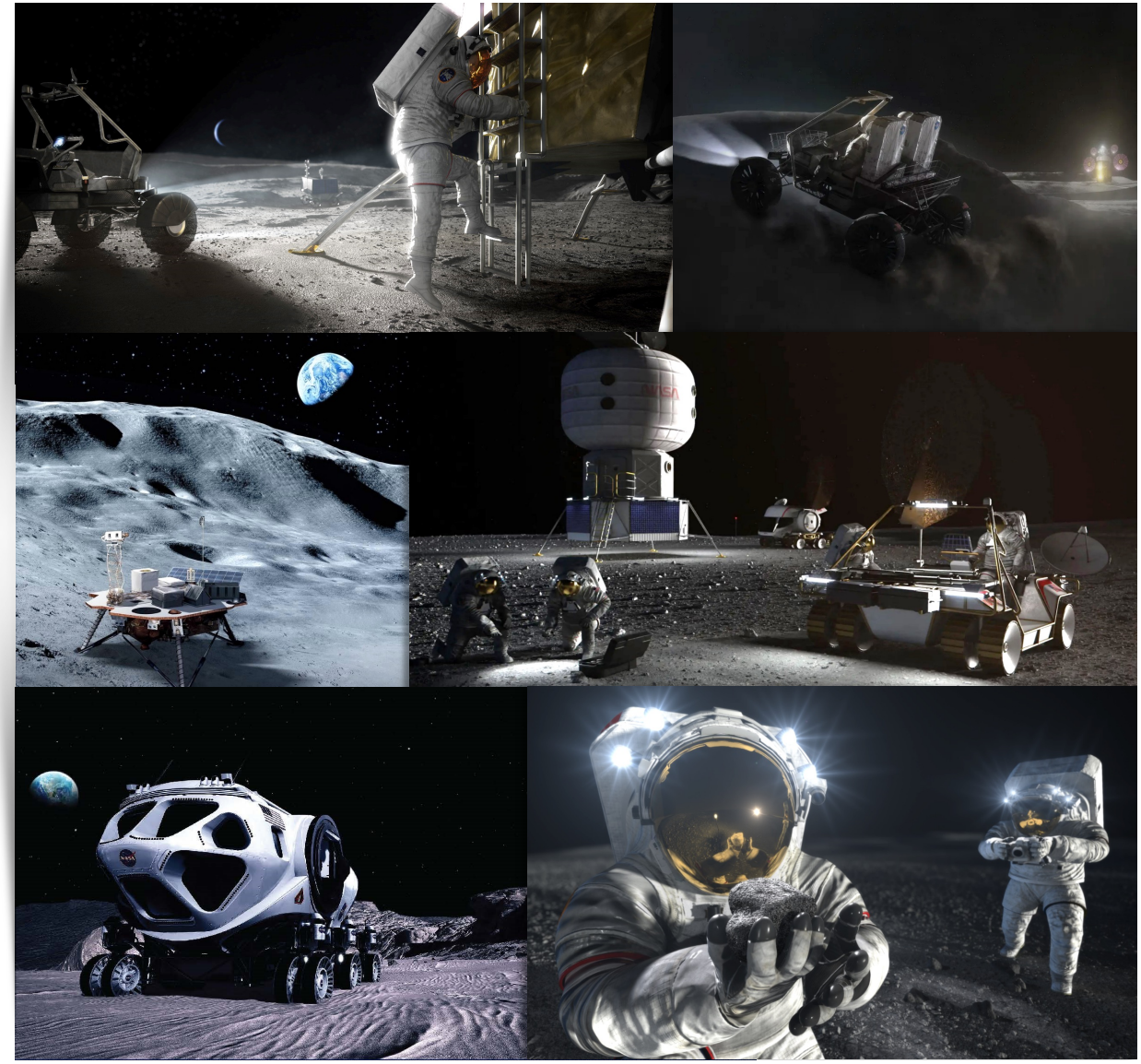
Efficient operations due to EVA time constraints and multiple mission objectives

- Limited survivability resources
- Apollo-type navigation (orienteering) requires stop-time
- Contingency walk-back scenarios

Telerobotic operations, e.g., LTV surface prep for crew

Real time localization on a map

Accurate science



INSIGHTS FOR PNT AT THE MOON

LunaNet

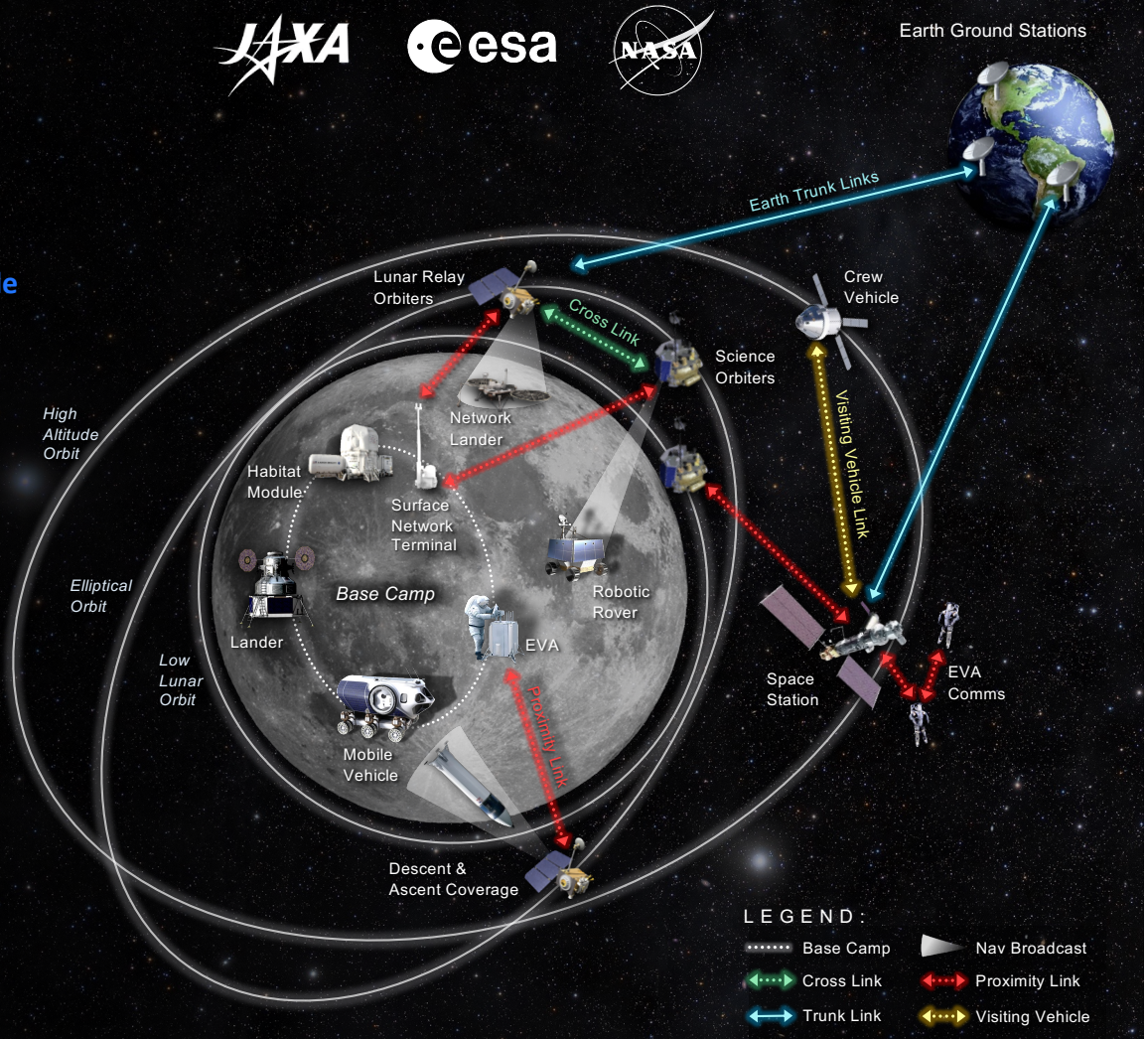
LunaNet is a set of cooperating networks providing interoperable communications and position, navigation, and timing (PNT) services for users in transit to, around, and on the Moon.

Based on the framework of mutually agreed-upon standards, protocols, frequency bands, and interface requirements that enable interoperability.

Allows many lunar mission users to engage the services of diverse commercial and government service providers in an open and evolvable architecture.

- Service-Oriented
- Scalable
- Open
- Resilient
- Secure
- Extensible

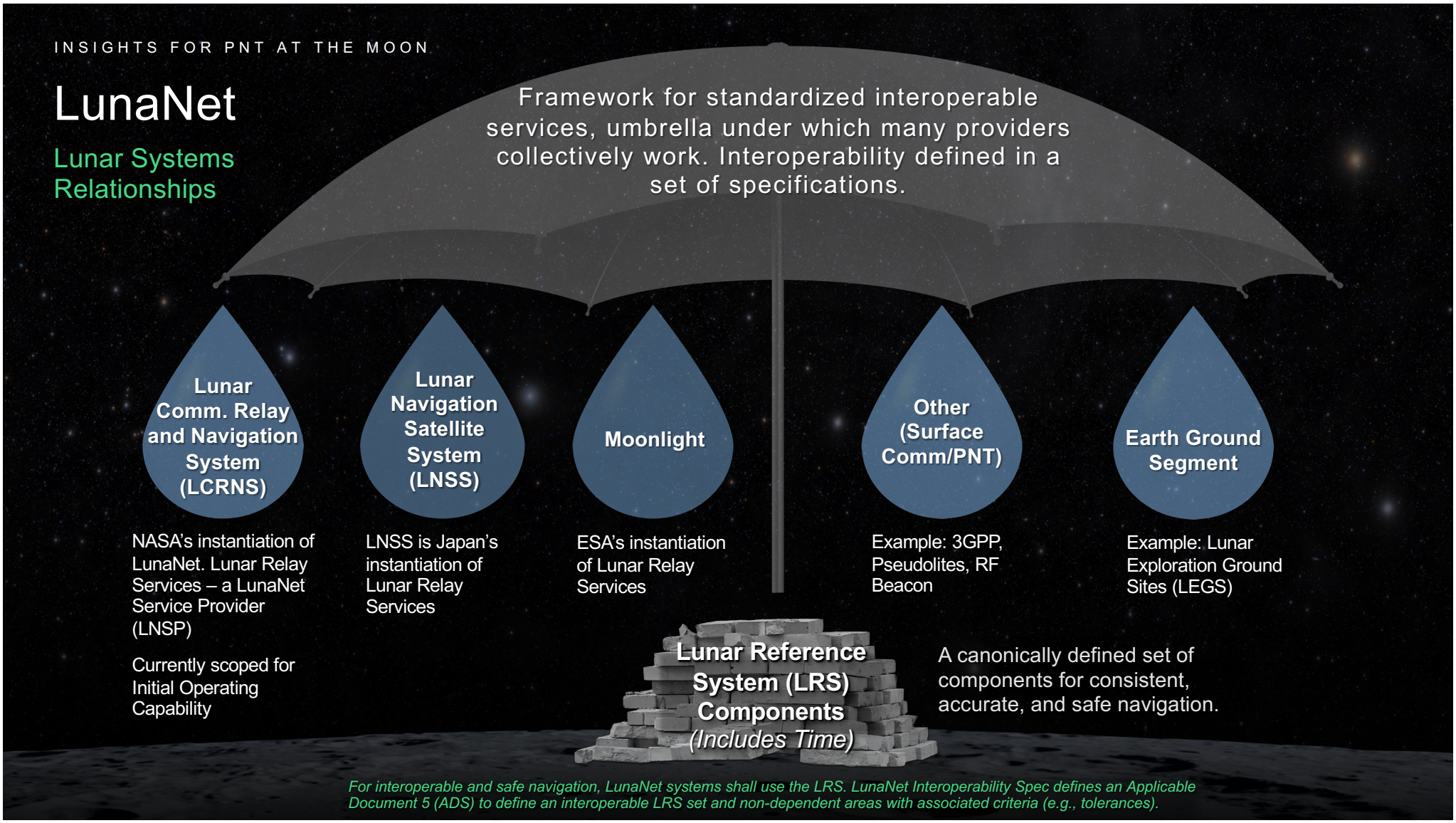
LunaNet consists of Earth Ground Stations (for Direct with Earth links), lunar orbital relays (lunar proximity and Earth trunk links), and surface assets.



INSIGHTS FOR PNT AT THE MOON

LunaNet

Lunar Systems Relationships

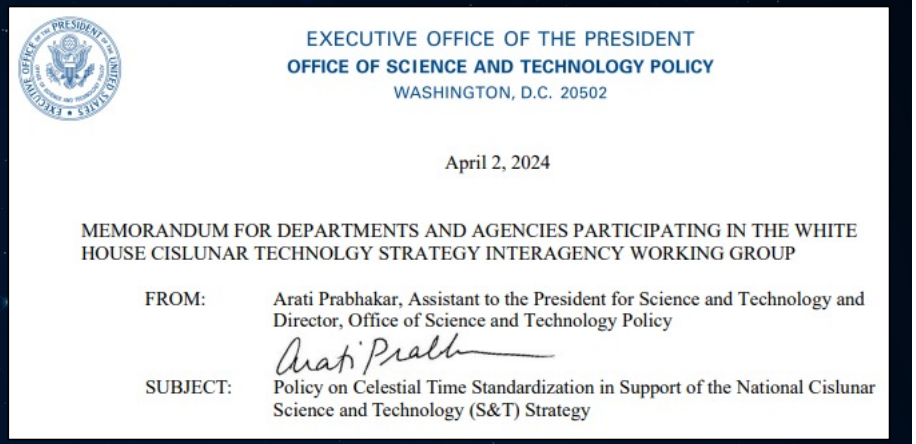


OSTP Policy Guidance for Lunar Time Development

"Coordinated Lunar Time (LTC) will act as the established standard to enable Cislunar operations and maintain traceability to UTC."

"NASA, in coordination with the Departments of Commerce, Defense, State, and Transportation, will study, define, and implement a Coordinated Lunar Time (LTC) to support the gradual establishment of lunar infrastructure."

- NASA, with support from parenting departments and agencies, will establish the approach to LTC as the international standard through existing standards bodies
- NASA considered LTC as part of its annual Moon-to-Mars Architecture Concept Review cycle in 2024
- NASA will provide a finalized strategy to the Executive Office of the President to implement lunar timing standardization no later than December 31, 2026.



EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

April 2, 2024

MEMORANDUM FOR DEPARTMENTS AND AGENCIES PARTICIPATING IN THE WHITE HOUSE CISLUNAR TECHNOLGY STRATEGY INTERAGENCY WORKING GROUP

FROM: Arati Prabhakar, Assistant to the President for Science and Technology and Director, Office of Science and Technology Policy

SUBJECT: Policy on Celestial Time Standardization in Support of the National Cislunar Science and Technology (S&T) Strategy

Click link to view Celestial Time Standardization Policy

International Standards Organizations: Current Status

International Astronomical Union (IAU) Commission A3, Fundamental Standards

- Developing a lexicon for standardizing terms.
- IAU General Assembly in August 2024, ACCEPTED two relevant Resolutions:
  - Recommendation to define a Lunar Celestial Reference System (LCRS) and a Lunar Coordinate Time (TCL)
  - Recommendation to establish Coordination Lunar Time by international agreement.

IAU WG Cartographic Coordinates and Rotational Elements (CCCRE)

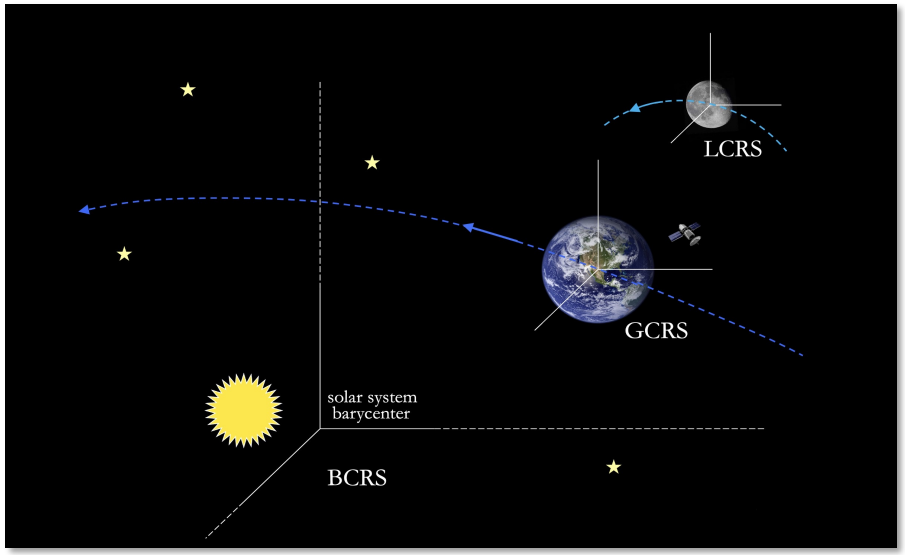
- Expecting continuation on lunar cartographic and rotational elements focus on Mean Earth Rotating frame.

International Association of Geodesy (IAG) established WG 1.1.3

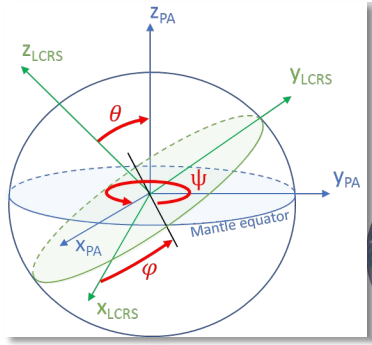
- Address the connection between Celestial, Earth, and Lunar Reference Frames [and time] for the future missions in coordination with the IAG, IAU, and IERS, [and BIPM] and formulate recommendations regarding the definition, realization, and dissemination of Lunar Reference Systems, across agencies and user communities.

Bureau International des Poids et Mesures (BIPM)

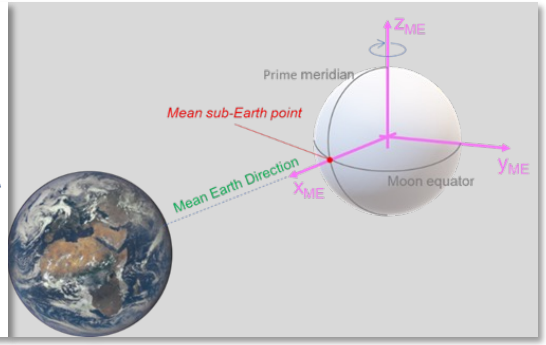
- Consultative Committee on Time and Frequency Moon Time Task Group in place; Plan for recommendation on lunar time, Sept 2025; Vote Oct 2026.



Principal Axis

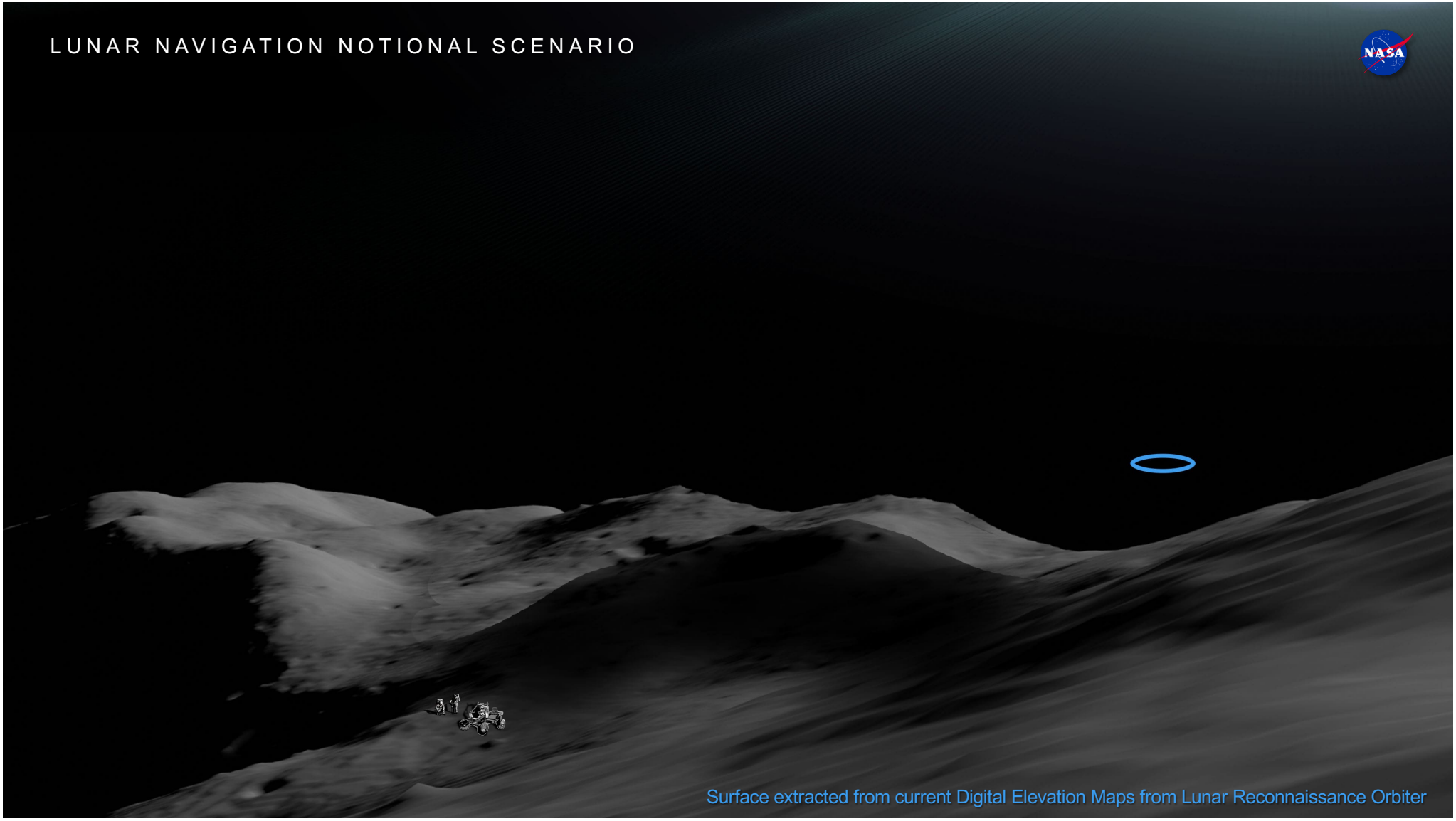


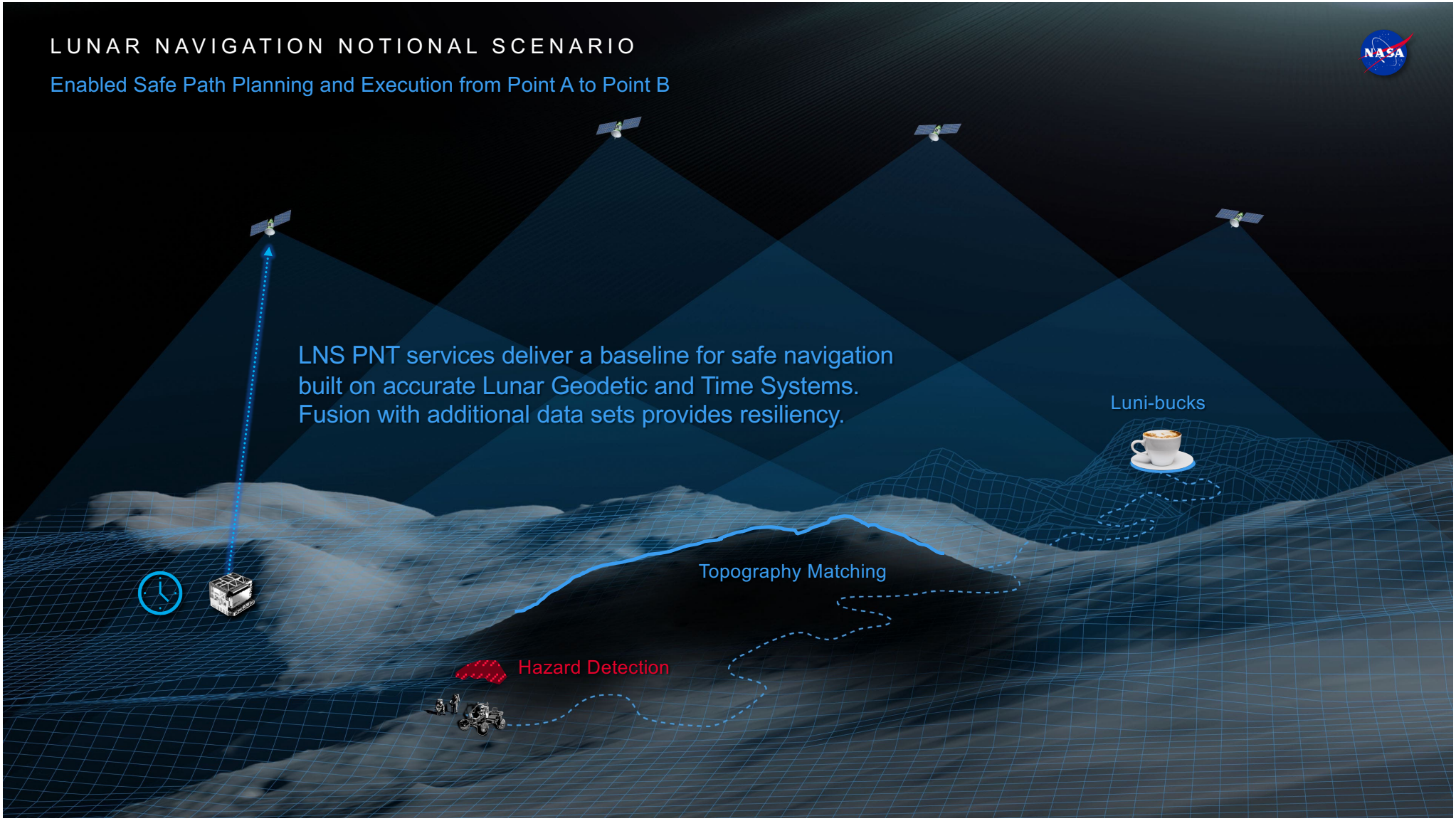
Mean Earth



PNT Services rely on definition, adoption, and maintenance of common lunar geodetic and time systems, and transforms to other frames and UTC.

LUNAR NAVIGATION NOTIONAL SCENARIO




LUNAR NAVIGATION NOTIONAL SCENARIO
Enabled Safe Path Planning and Execution from Point A to Point B
NASA
LNS PNT services deliver a baseline for safe navigation
built on accurate Lunar Geodetic and Time Systems.
Fusion with additional data sets provides resiliency.
Luni-bucks
Topography Matching
Hazard Detection

INSIGHTS FOR PNT AT THE MOON

Lunar South Pole: 2040 Vision

The Moon will serve as a proving ground for the transformational communications and navigation technologies needed for a sustained presence on the Moon, Mars, and beyond. Knowledge of Time is foundational to a lunar economy.