Joint Navigation Conference 2025,
Plenary Session

Navigating the Cosmos

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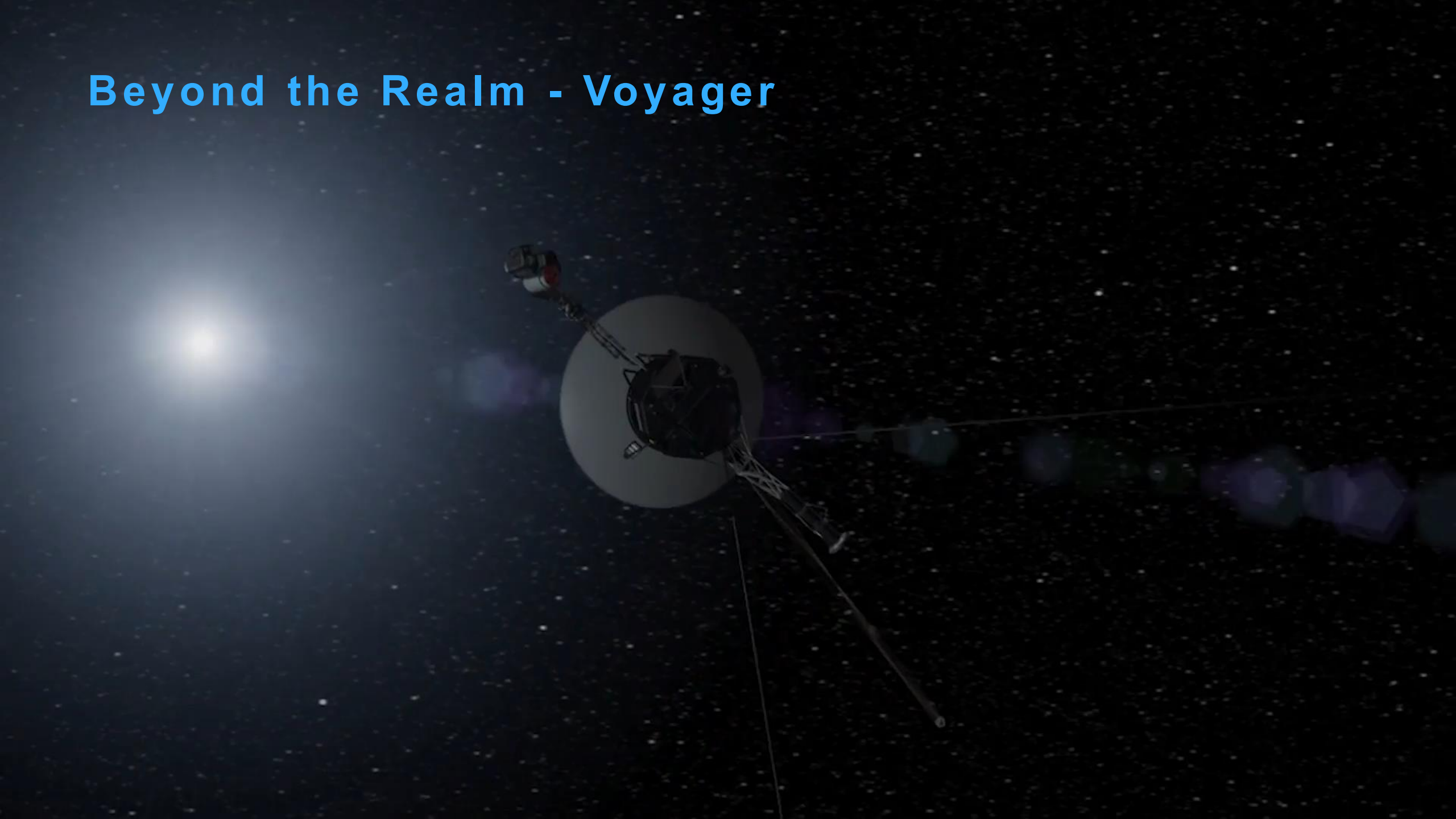
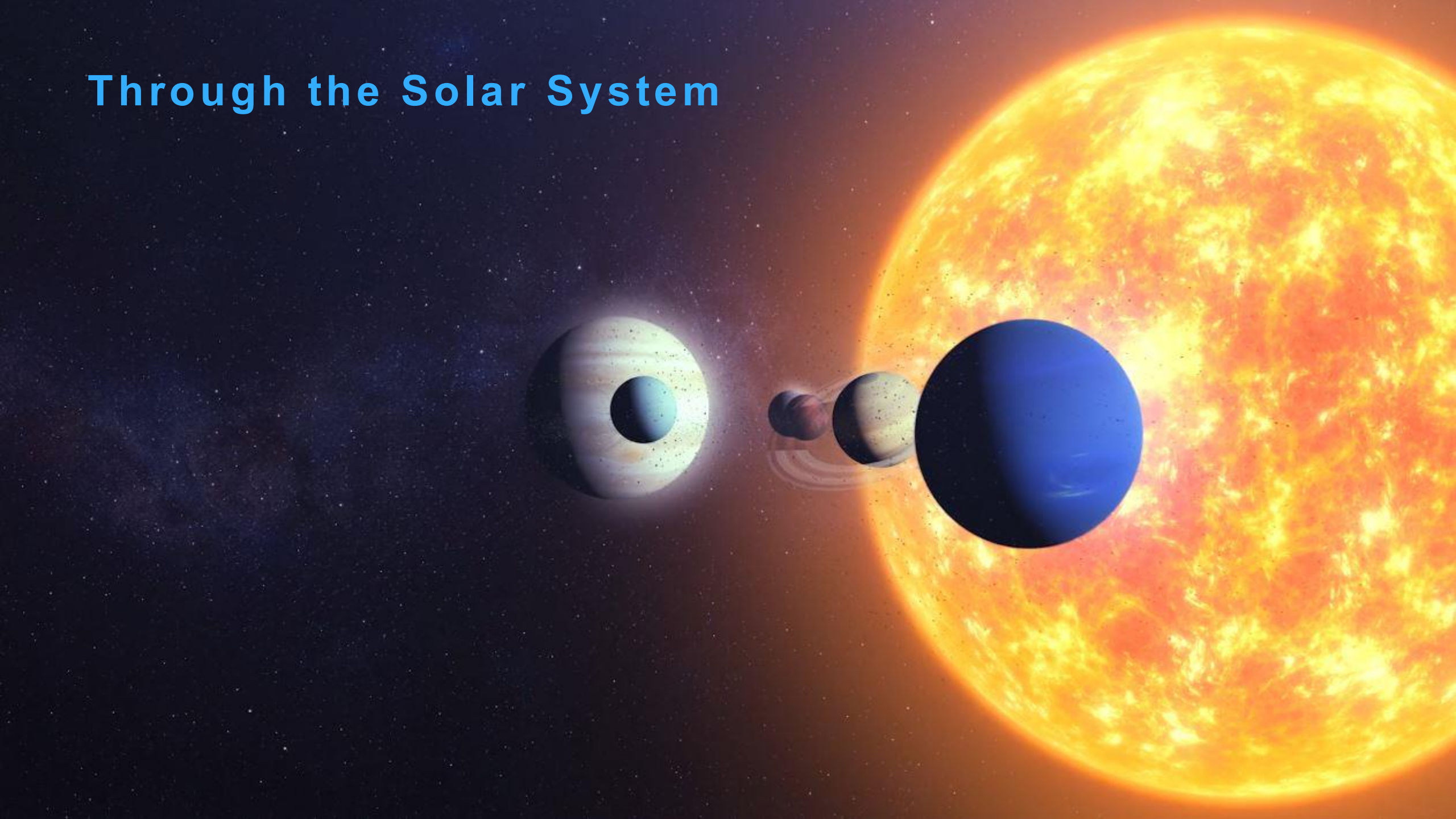
Beyond the Realm - Voyager



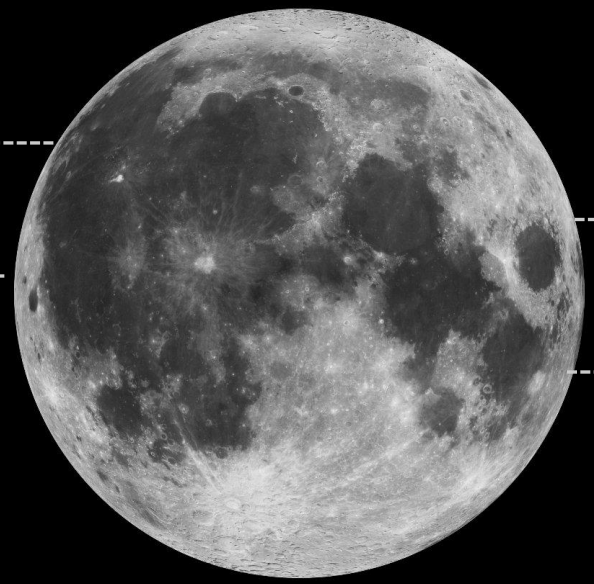
Through the Solar System



GPS: Transforming Life on Earth

Bringing PNT to the Moon, Together

We are forming the broadest space coalition in history: a whole-of-government approach to cislunar space, strengthened by international and commercial partners.



Lunar Communications and Navigation

LuGRE
Lunar GNSS Receiver Experiment

Lunar mGNSS
Lunar Multi-GNSS Receiver

KaSTLE
Ka-Steerable Terminal for Lunar Environments

LSP
Lunar Surface Propagation

Lunar 3GPP
Lunar Third Generation Partnership Project

LunaNet

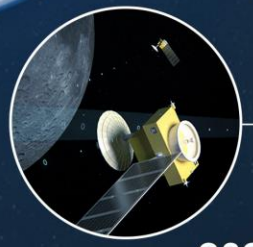
Lunar Coordinated Time

LEGS
Lunar Exploration Ground Sites

DAEP
Deep Space Network Aperture Enhancement Program

AutoNGC
Autonomous Navigation, Guidance, & Control

LCRNS
Lunar Communications Relay & Navigation Systems



O2O
Orion Artemis II Optical Communications System

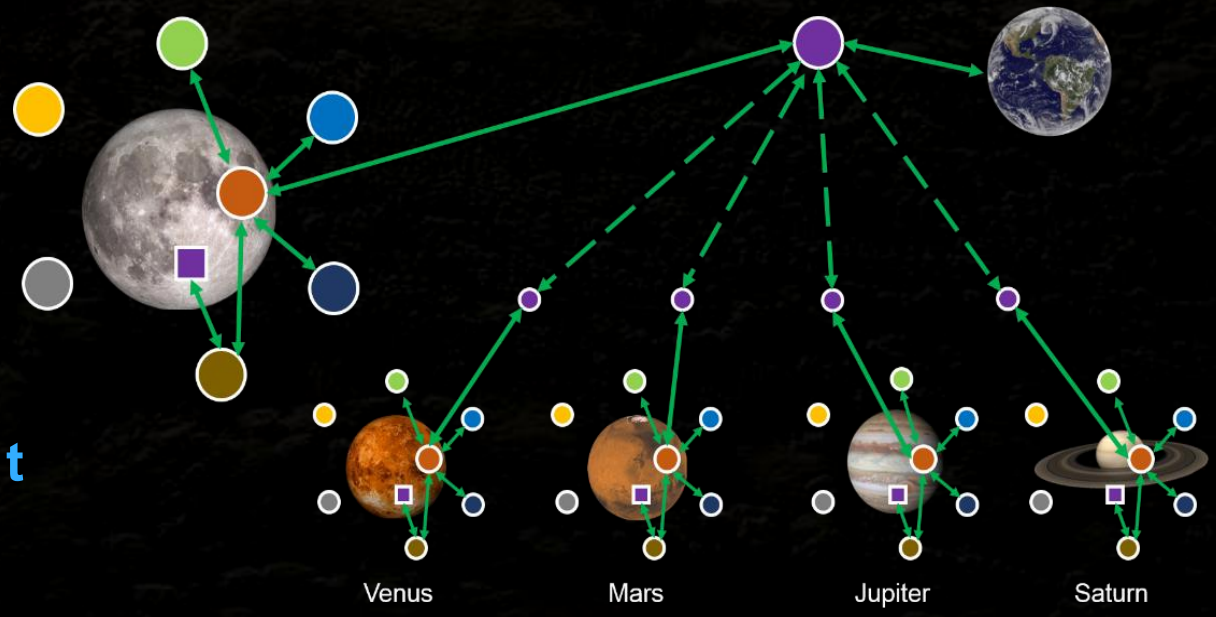
LunaNet

A lunar communications and navigation network

- Framework of mutually agreed-upon standards
- International & commercial engagement

Scalable ***Extensible*** ***Interoperable***

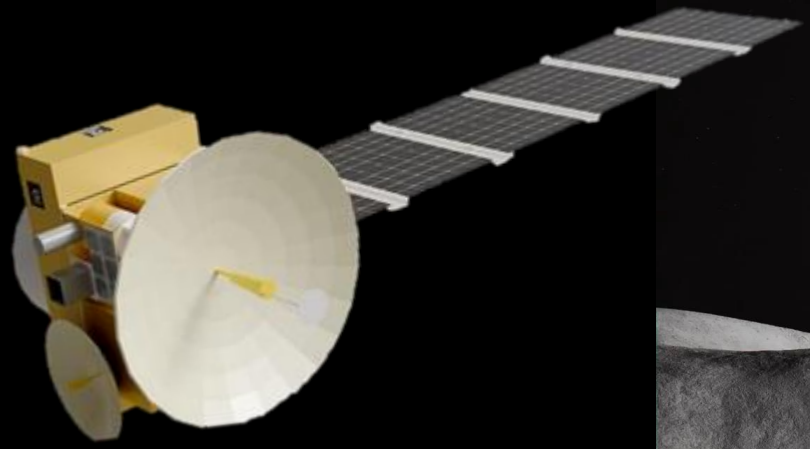
LunaNet

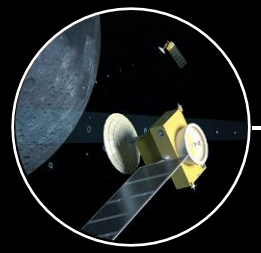


Lunar Relay

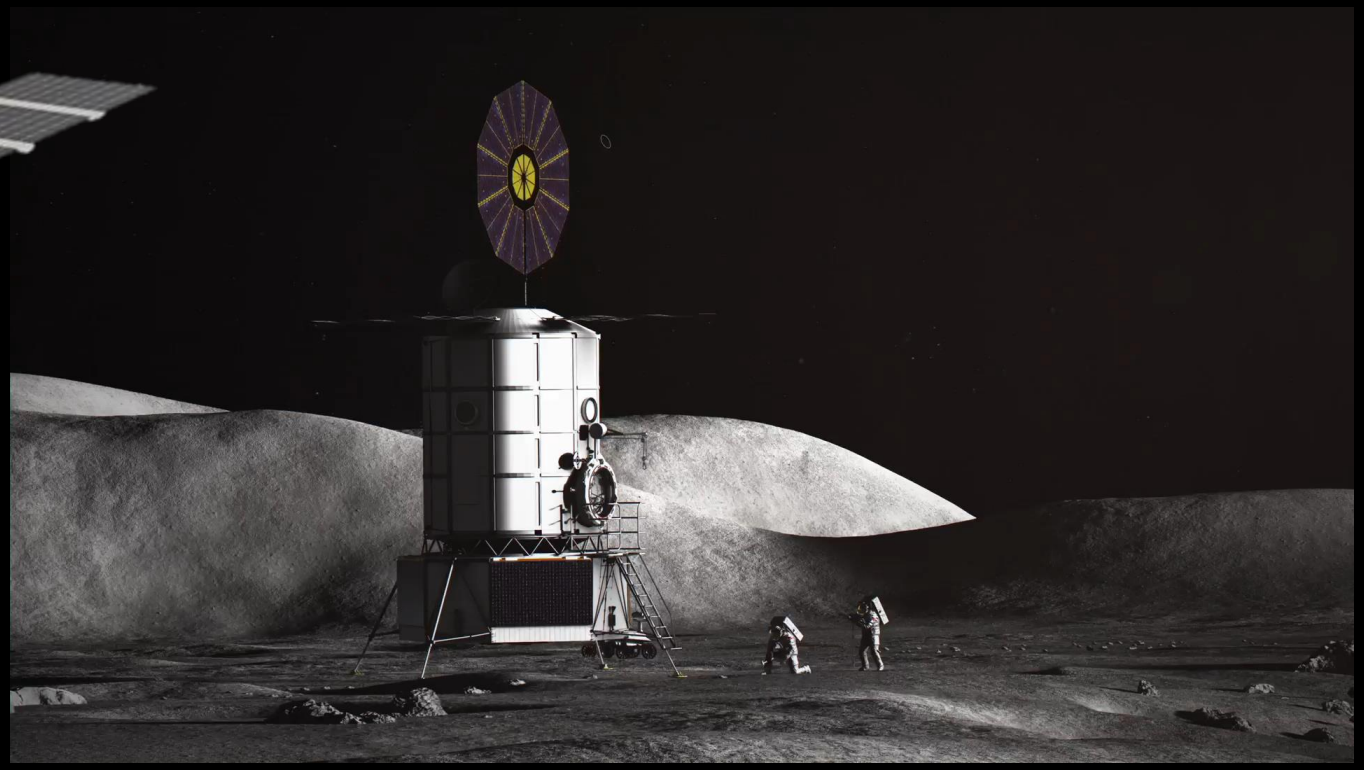
NASA selected Intuitive Machines to develop the agency's lunar relay system.

- Verifying and validating commercial lunar relay services
- Includes onboard PNT system





LCRNS



Lunar Time

NASA is collaborating with international organizations, other government agencies, and industry to develop Coordinated Lunar Time (LTC).

Enhances:

- mission coordination,
- data synchronization,
- astronaut and asset safety,
- overall mission success.

Lunar Coordinated Time

National Cislunar Science and Technology Strategy

Interagency Working Group

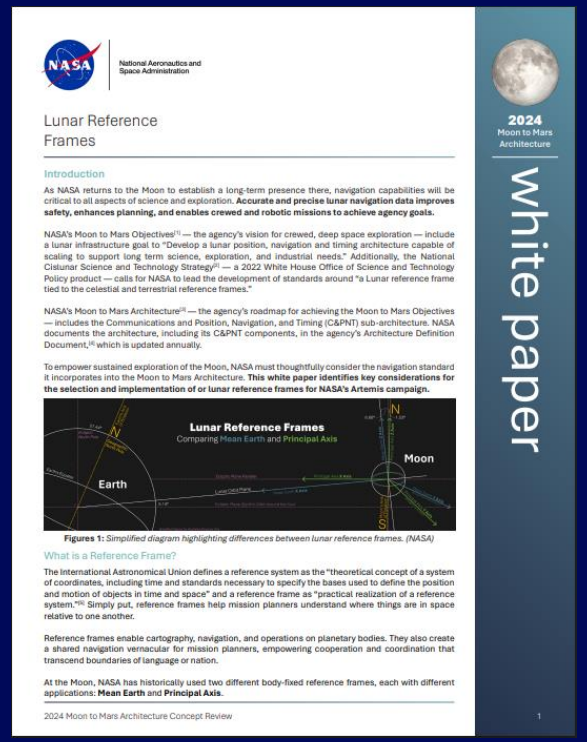
Resulted in:

Revision of the Communications & PNT architecture for Moon to Mars efforts.

Resulted in:

Internal NASA collaboration to develop an agencywide position on lunar reference systems.

Lunar Reference Frames



National Aeronautics and Space Administration

Lunar Reference Frames

Introduction

As NASA returns to the Moon to establish a long-term presence there, navigation capabilities will be critical to all aspects of science and exploration. **Accurate and precise lunar navigation data improves safety, enhances planning, and enables crewed and robotic missions to achieve agency goals.**

NASA's Moon to Mars Objectives[1] — the agency's vision for crewed, deep space exploration — include a lunar infrastructure goal to "Develop a lunar position, navigation and timing architecture capable of scaling to support long term science, exploration, and industrial needs." Additionally, the National Cislunar Science and Technology Strategy[2] — a 2022 White House Office of Science and Technology Policy product — calls for NASA to lead the development of standards around "a Lunar reference frame tied to the celestial and terrestrial reference frames."

NASA's Moon to Mars Architecture[3] — the agency's roadmap for achieving the Moon to Mars Objectives — includes the Communications and Position, Navigation, and Timing (C&PNT) sub-architecture. NASA documents the architecture, including its C&PNT components, in the agency's Architecture Definition Document,[4] which is updated annually.

To empower sustained exploration of the Moon, NASA must thoughtfully consider the navigation standard it incorporates into the Moon to Mars Architecture. **This white paper identifies key considerations for the selection and implementation of or lunar reference frames for NASA's Artemis campaign.**

Figures 1: *Simplified diagram highlighting differences between lunar reference frames. (NASA)*

What is a Reference Frame?

The International Astronomical Union defines a reference system as the "theoretical concept of a system of coordinates, including time and standards necessary to specify the bases used to define the position and motion of objects in time and space" and a reference frame as "practical realization of a reference system."[5][6] Simply put, reference frames help mission planners understand where things are in space relative to one another.

Reference frames enable cartography, navigation, and operations on planetary bodies. They also create a shared navigation vernacular for mission planners, empowering cooperation and coordination that transcend boundaries of language or nation.

At the Moon, NASA has historically used two different body-fixed reference frames, each with different applications: **Mean Earth** and **Principal Axis**.

2024 Moon to Mars Architecture Concept Review

2024 Moon to Mars Architecture

white paper

GNSS at the Moon

Extending Earth-based Global Navigation Satellite System (GNSS) signals beyond Earth.

- Complementary PNT technique
  - Lunar GNSS Receiver Experiment (LUGRE)
  - Multi-GNSS Receiver (mGNSS)

LuGRE

mGNSS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