

LunaNet Perspectives – How the International Standards Community Can Help

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11-13 February, 2025

ICG-IOAG Cislunar PNT Workshop

Session 3

Vienna, Austria

- **LunaNet Interoperability Purpose**
- **The Requests**

LunaNet

Framework for Standardized Interoperable Services, umbrella under which many providers collectively work. Interoperability defined in a set of *specifications*.

Lunar Comm. Relay and Navigation System (LCRNS)

NASA's instantiation of LunaNet Lunar Relay Services— a LunaNet Service Provider (LNSP)

Currently scoped for Initial Operating Capability

Moonlight Lunar Communications and Navigation System (LCNS)

ESA's instantiation of Lunar Relay Services

Lunar Navigation Satellite System (LNSS)

Japan's instantiation of Lunar Relay Services

Ground Stations for Lunar Missions

e.g. NASA's Lunar Exploration Ground Segment

Others

e.g. other orbiting systems, surface comm and/or PNT systems (future), ground systems, users

Lunar Reference

A canonically defined set of components for consistent, accurate, and safe navigation.

Interoperability defined in Applicable Document 5 (AD5).

- ❑ While LunaNet aims to define the interoperable parameters associated with the reference systems and time system, it is not the purview of LunaNet to define terms or standards in these foundational areas.
- ❑ LunaNet looks to the international standards community(ies) to sanction agreed-upon definitions and approaches.
 - Please note, the dates identified herein are recommended dates for LunaNet.

➤ Asks of the International Time Standards Community:

1. Document the relevant lexicon/definition of terms. ASAP 2025.
2. Establish, sanction (agree upon), and document a mathematical representation of Lunar Reference Time (LRT) with respect to UTC. ASAP 2025.
 - i. Include influences on the potential need for a “Coordinated” contribution.
 - ii. Document the definition of LCRS and **TCL**, in concert with IAU resolution. June 2025.
 - iii. Ensure the document reflects the mathematical formula for (TCL-TT). June 2025.
 - iv. Define radius, shape model, gravity, and lunar geoid for application to navigation, with **lunar geoid applicability to Lunar Reference Time**, in coordination with other organizations such as IAG, IAU. June 2025.
 - v. Incorporate modes/methods for realizing LRT. Sept 2025.
3. Define an epoch for LRT (wrt UTC/TAI). June 2025.
 - i. IAU Resolution: “the reading of TCL be 1977 January 1, 0h 0m 32.184s exactly when the reading of TCB be 1977 January 1, 0h 0m 32.184s at the center of the Moon ”

➤ Continued:

4. What resolution for traceability is needed in identifying the LTC – UTC relationship
 - i. Is there a recommended method to represent these offsets for distribution? March 2025.
 - ii. How do we operationally translate between the identified offset and colloquial terms such as “day”, “month”, “year”, etc. c2028.
5. Identify the Δt offsets across the maximum/minimum gravitational potential at the Moon. April 2025.
6. For a set of Use Cases, identify the time scale(s) to apply. September 2025.
7. Current thinking is that no Time Zones will be needed at the Moon; confirm if this is the correct operational approach. December 2025.
 - i. What about at Mars, will Time Zones be needed?
8. How should the link between LRT and UTC be assured? c2026.
9. Generalized rules of thumb or applicable algorithms to relate the periodicity of a TWSTT contact period, the level of resolution achieved by each TWSTT contact period, and the signal structure (frequency band, code or frame rate) needed to achieve that outcome. Dec 2025.
10. What organization will be responsible for *establishing* the lunar time; who will *monitor* the realization(s)? c2026.

Ref. Systems

- Asks of the Reference Systems (Celestial/Inertial and Body-Fixed) International Standards Communities:
 1. Complete documenting the definition of the Lunar Celestial Reference System (LCRS) and Time Coordinate Lunar (TCL). POC: IAU, per adopted Resolution II. June 2025.
 2. Complete the lexicon to define terms relevant to celestial body reference and time systems. POC: IAU? September 2025.
 3. Define and recommend a lunar body-fixed frame for navigation for near term application (prior to an international lunar reference frame). POC: IAG. March 2025.
 - a. Include an assessment of the impact of using the different realizations available today.
 4. Define lunar radius, reference shape (e.g. ellipsoid), and lunar geoid for application to lunar-focused navigation. POC: ? June 2025.
 5. Identify the operational application of Lunar Orientation Parameters. POC: IAG? June 2025.
 6. Identify the transformations between frames (combinations of inertial and body-fixed, Earth-Moon-Barycenter, e.g. LCRF to GCRF, Lunar PA to LCRF, etc). POC: ?? September 2025
 7. Develop a statement on a future international lunar reference system and international lunar reference frame. POC: IAG? December 2025.
 8. Identify needed sensors and systems, and their location on the Moon, to inform and realize the international lunar reference system and international lunar reference frame. POC: IAG?
 9. General: Consider development of an International Lunar Rotation and Reference Service analog to IERS.

- Definition of the reference systems and time models and recommended approaches are critical foundations to providing in-situ PNT.
- As established for Earth, the PNT community relies on the communities of international standards to define these foundational elements.
- The need is *urgent*:
 - NASA, ESA, and Japan instantiations of LunaNet systems are underway.
 - NASA intends to launch the first LunaNet Service Provider lunar relay within a year.
 - Artemis, CLPS, and other lunar missions will rely on the LunaNet PNT services.

Questions?

