NASA/US Perspective on Lunar Timing Needs & Constraints

Cheryl Gramling
NASA HQ
Space Communications and Navigation

Juan Crenshaw
NASA GSFC

11 February, 2026

ICG Cislunar PNT Workshop

Vienna, Austria

Objectives

Review the perspective of NASA on a reference time scale suitable for navigation around/on celestial bodies.

Identify requests and open questions for the timing community.

US Approach for Lunar Reference Time Scale

NASA leads a Working Group with membership from across the US (government, industry, academia) with the objective to study, define, and establish an approach for lunar time that provides:

1. Traceability to Coordinated Universal Time (UTC);
2. Accuracy sufficient to support precision navigation and science;
3. Resilience to loss of contact with Earth;
4. Scalability to space environments beyond the Earth-Moon system.

NASA engages with the international standards community through the US National Metrology Institutes (NIST and USNO) and scientists, engineers, and operators involved in terrestrial and space-borne time systems for knowledge and maintenance.

The US, including NASA, favors a practical approach that can fully realize a lunar time scale that represents the primary operating environment (the surface), maintains the SI second in a relevant frame, and enables reuse of techniques and principles of terrestrial GNSS.

NASA Perspective for LunaNet and Lunar Time Scale

Philosophies employed in developing LunaNet Interoperability Specification:

1. Keep the system as easy as possible for the users to lower the barrier to entry, especially outside traditional space agencies;
2. Mitigate the user burden in terms of size, mass, power, and applicability;
3. Reuse as many of the terrestrial GNSS techniques and principles as possible.

A lunar time scale referenced to the equipotential surface:

- ❑ Allows us to leverage Concepts for Operations from Earth/GNSS and address aspects of interoperability between GNSS and lunar PNT systems;
- ❑ Maintains the SI second consistent with the SI meter in that frame applicable to the surface users;
- ❑ Lowers the barrier to entry for the user community to encourage a lunar economy;
- ❑ Supports differential corrections from the surface;
- ❑ Can readily be informed by in-situ realization to fully validate the model.

Acknowledge that TCL may be more easily scalable to other bodies.

- ❑ However, clocks reside on the body surface to realize a time scale. ➔ Still need to define the constant $L_{<X>}$ to translate from center of mass to surface (analog to L_G on Earth).
- ❑ International Association of Geodesy Working Group 1.1.3 effort underway to define the lunar geoid.

Open Questions for the Timing Community

1. Provide a lexicon of terminology we should all adhere to.
2. Provide the equation that represents the translation from lunar time ($TL^{\%}$) to UTC (or TT).*
3. Provide the equation that represents the translation from lunar time to TCB.*
4. Provide recommendations for how we should operationally translate between the identified different time scale and colloquial terms such as “day”, “month”, “year”, etc. (consider applicability to other bodies besides the Moon)
5. Identify recommended method(s) to represent the $TL^{\%}$-UTC offsets in a Message for distribution via PNT broadcast services. What is the recommended resolution on the traceability between the Earth and Moon time scales?
6. Identify any generalized rules of thumb or applicable algorithms to relate the periodicity of a TWTT (Earth ←→ Moon) contact period, the level of resolution achieved by each TWTT contact period, and holdover between TWTT contacts.
7. Can a roadmap be developed to arrive at the following:
   i. In the future, what is the recommendation for the organization that will be responsible for coalescing inputs for *establishing* the lunar time reference (akin to BIPM’s role for UTC for Earth); what entity(ies) will *monitor* the realization(s)?
   ii. In the *future*, when there are [accurate] clocks in multiple places across the Moon, what are recommended approaches for ensembling these multiple clocks to inform a reference lunar time? Are there methods to enable performing the ensembling function on Earth with data sent from the Moon?
   iii. For the *future*, consider how a “consolidated” reference time at other bodies will be handled in the future.

% -- TL is generically used to represent a lunar time scale

* -- May just be application of negative sign(s), but want to be certain of the equation. Using “TL” as a general term for the lunar time scale.

Summary of US/NASA Views on Lunar Time Scale

NASA's position is informed by and in concert with subject matter experts across the US Government, industry, and academia.

The US, led by NASA, favors a practical approach that can fully realize a lunar time scale that represents the primary operating environment (the surface), maintains the SI second in a relevant frame, enables reuse of techniques and principles of terrestrial GNSS, aligns with a body-centered/body-fixed reference system, and lowers the barrier to entry for users of PNT systems.

A lunar time scale referenced to the equipotential surface meets the criteria to enable accurate real time radionavigation.

Included a list of requests for the timing community to consider.

Frame and Time Scale Alignment for Navigation

Maintaining the SI second (hence the meter) is of primary importance for in-situ real time operations for navigation and timing.

Alignment of a time scale for navigation with the body-centered body-fixed reference system/frame facilitates accounting for the time-dependent longitude drift due to rotation of the body and librations.

The body-centered body-fixed (BCBF) frame defines position based on the rotation and librations of the body;
Time on the equipotential surface of that body provides precise and consistent time knowledge allowing us to account for the longitudinal drift when transforming from inertial to to BCBF frame through the orientation parameters.