18th International Conference on Space Operations, Montreal, Canada, 26 - 30 May 2025.

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SpaceOps-2025, ID # 45

Universal Timekeeping in Space Shifting Beyond Earth-Centric References

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Abstract

Establishing a timekeeping solution for the Moon marks a pivotal moment for humanity. In general, timekeeping across space presents unique challenges, as current theories focus on Earth-based observers rather than accommodating multiple observers spread across space and time. Due to spacetime effects, time dilations complicate clock synchronization for distant observers. The US government (White House) presented a goal for time on the Moon to ensure traceability, accuracy, resilience, and scalability for space-timekeeping. Current proposals for Moon time fall short, relying on an unscalable geo-centric approach aimed at accommodating relativity and achieving real-time synchronization using a grid of clocks synchronized to a single point on Earth. Vartis Space offers a simplified solution with only two clocks, one on Earth and the other on the Moon. This is made possible by revolutionizing the tools for modeling space and time.

The approach combined an in-depth study of ancient timekeeping systems with modern advancements in the theory of relationalism as well as established principles in set theory, computer theory, dimensional analytics, and signal processing. These emerging tools pave the way to achieve current goals for Coordinated Lunar Time and introduces the first step towards a universal calendar system that begins by linking Earth's Coordinated Universal Time with Coordinated Lunar Time. The tools are also proposed to incrementally achieve similar results across wider spans of space, enabling precise synchronization processes for independent multi-celestial clocks throughout the galaxy.

Keywords: Moon Time, Moon18, Luniterranean, relationalism, relativity.

Nomenclature

D_n = Dihedral symmetry group (n)
bx = Radix (base-x) group
Tun = Mesoamerican division of a duration into 360 parts (18[20])
in = base unit ratio for Moon18 time
Metz = proposed standardized based unit ratio of *in* within a local frame of reference
D = duration; relational based absolute point-time period, measurable by local frame of reference
W = count of a duration, either sample or frame periods
k = ordered part of a whole duration that has been divided and subdivided
N = total number of ordered parts of a whole divisional and subdivisional operation
c = constant for the speed of light in a vacuum
Δt = period of time as measured between two spacetime coordinates from a local frame of reference

1. Introduction

As humanity prepares to return to the Moon, a critical question emerges: What time is it on the Moon? Unlike Earth, the Moon's weaker gravity causes time to pass about 56 microseconds faster per day, a small difference that can lead to major navigation errors. To address this, scientists are working on a Coordinated Lunar Time (LTC) to synchronize international missions. While current proposals appear to meet immediate needs, they come with high costs and fall short in part on components of scalability, traceability, resiliency, and accuracy—issues that will only grow as we expand deeper into space.

As humanity advances in philosophy, mathematics, technology, and cooperation for a new era of space exploration, the establishment of celestial time standards has become a critical imperative. Traditional Earth-centric (geo-centric) time standards, such as Coordinated Universal Time (UTC), are insufficient for the unique environments and local frames on the Moon, Mars, and beyond, where variations in gravity and orbital mechanics cause time as we currently

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define it to pass differently. Recognizing this challenge, the White House Office of Science and Technology Policy (OSTP) released a policy in April 2024 directing NASA to develop a Coordinated Lunar Time (LTC) standard by the end of 2026. Additionally, a resolution for at the XXXIInd International Astronomical Union General Assembly also recommended a lunar reference time scale and other time scales are pursued in collaborative agreement among the relevant international organizations. These initiatives aim to ensure accurate navigation, communication, and interoperability for future lunar missions and serves as a foundational step toward broader celestial time standardization.

The National Cislunar Science & Technology Strategy underscores the importance of international collaboration in establishing these standards, highlighting the role of organizations like the Bureau International des Poids et Mesures (BIPM) in coordinating global metrology efforts. As missions extend to asteroids, moons, Mars, and other celestial bodies, creating harmonized time *n*-body time units and calendars becomes essential for seamless coordination and the advancement of a sustainable space economy.

Vartis Space delivers practical, theory-backed solutions using advanced relationalism—termed rishta (*rt) relationalism*.[1-4] The platform enables local time systems for celestial bodies like moons, planets, even stars, while coordinating time points across inter-celestial space. It supports a unified calendar framework that integrates with local time. This novel approach could reach a zero-temporal reference point, expand global standards, and open new frontiers in quantum research.

1.1 Current state of proposals

The goal of establishing celestial time standards is to define, develop, and implement distinct reference times for each planetary body and its surrounding space environment. These standards are intended to ensure traceability to Coordinated Universal Time (UTC), provide the accuracy necessary for precision navigation and scientific measurements, maintain resilience in the face of potential communication loss with Earth, and offer scalability to support future missions across increasingly distant and diverse regions.

The challenge of timekeeping across vast interplanetary distances is a significant hurdle in space exploration using existing approaches. Traditional Earth-centric time systems for missions spanning multiple celestial bodies have to manage with the complexities. Two featured approaches have been proposed which include:

1. *Establishing n-body celestial local time and continuously synchronizing them*: The goal is to create independent time systems for each celestial body, tailored to their motion, and continuously synchronize them using satellite relays to ensure scalable, coherent timekeeping across space missions.
2. *Creating a relay of satellite constellations across the solar system to expand Earth's local frame and UTC across the inner solar system*: Aims to link specific points in time to a location on Earth by deploying a network of satellites.

Current solutions focus on interplanetary communications, continuous real-time synchronization, and timing using relativity and satellite relays. Relying solely on relativistic models struggles with varying gravity, orbits, and time dilation—issues that worsen with distance from Earth. Vartis Space offers a new approach: separating time from space and using relationalism, synergistic with relativity, to redefine how we measure and coordinate durations independent of space.

1.2 Vartis Space Solution for Multi-Celestial Timekeeping

Byron Byer's Deep Thinking reminds us that real breakthroughs come from bold shifts—not only continuous learning. Vartis Space takes that leap, redefining durations as a relational construct, not just a measurement. Grounded in math, group theory, philosophy, and synergistic with relativity, this system decouples time from space to enable scalable, coherent, and universal timekeeping across celestial bodies. It meets global needs, anticipated to reduce costs, and becomes independent of radio-wave based systems for communication systems.

The limits of time modeling are not just technical—they are conceptual. Unlike abstract, space-bound systems, Vartis offers a relational model rooted in natural geometry and ordered structure. Grasping it requires a shift in thinking: seeing time not as motion through space, but as a geometric, proportional phenomenon. This perspective offers an alternative to traditional relativity-based models, potentially enhancing the synchronization and accuracy of timekeeping across different local celestial environments.

Vartis Space offers a third option addresses the limitations of existing proposals by combining the precision of atomic time standards with the natural cycles of celestial bodies.[1] This integration allows for a timekeeping system that is both accurate and relevant to the unique temporal dynamics of different planetary environments. This innovative approach aims to enhance coordination and interoperability for future space missions, ensuring that timekeeping remains consistent and reliable across various celestial local frames.

Introducing a new philosophy of time opening three immediate proposals for the Moon time challenge.

1. Moon18; Independent Lunar Coordinated Time (LTC)
2. Formula; Uniting relativity with relationalism for timekeeping
3. Luniterranean calendar; Moon's lunation cycle with an Earth day

1.3 Philosophies on time

Physics examines how the universe behaves when abstract and continuous time cannot equal zero, while rt relationalism emphasizes applied relationships that exist in a state of now and durations between present state of now and past states of now can be quantified from independent frames of reference using spacetime coordinates. As a conceptual foundation, philosophy precedes mathematics and physics, making it essential to explore key philosophical distinctions (as shown in Table 1).[5]

Table 1. Brief comparison between philosophies of time

Aristotelian philosophy (Eurocentric)	Pioneering Relational (Pre-Greek) philosophy (Based on ancient China, Egypt, India, Sumerian, etc.)
Abstract infinitely divisible (mathematical) time	Indivisible (zero-time) points, divisible applied time intervals, and indivisible atomic units
First principle is change. Aristotle's paradox about an indivisible present 'now' in an infinitely divisible continuous time.	First principle is here and now. No paradox with a state of now [$t = 0$] defined by the collapse of quantum particle to a base state.
Time is infinitely divisible. Unaligned with Plank limits. Continuous or discrete (debated in quantum physics).	Time is divisible and temporal points are indivisible. Divisibility aligned with Planck limits. Both continuous & discrete.
Quantum time (fixed, absolute, external) Backdrop for quantum state evolution. Relativistic time (dynamic, spacetime curvature) Local time that varies for different observers. Acts 'weird' in extreme environments (black holes).	Relational time (fixed, absolute, internal to point) Backdrop for relational stop-frame state changes when measured/observed here and now. Does not act 'weird' in extreme environments
($t \neq 0$) Continuous time	($t \neq 0$) 'Continuous' time, bound by temporal points, divisible to 'atomic' Planck time. [$t = 0$] Point of zero-dimensional time

From Aristotle's model of continuous time and motion, grounded in sensory observation to Newton's absolute time and space, all the way to today's foundations of modern physics, these approaches have relied on continuous, divisible time. Before this philosophy, ancient philosophies described by pre-Greek Egypt, Vedic readings, Chinese Mohist canon, and other Greek philosophers such as Zeno, Parmenides, Leucippus, and Democritus supported an alternative consideration for time. Unlike Aristotle's work and subsequent evaluations of Aristotle's work by Simplicius, works from philosophers that were contrarian to Aristotle were largely destroyed and lost to the public, remembered primarily through ridicule and paradoxical statements taken from the interpretations of the widely distributed works of Aristotle and Plato.

Today, both relativity and quantum mechanics struggle to reconcile this model, especially as quantum limits like Planck time suggest time may not be infinitely divisible. Rt relationalism opens new possibilities by proposing a fundamentally discrete, present state of now that focuses a novel modelled structure of dimensional and applied time. Consider if you will that relativity operates using infinitesimals, with the present being an abstract mathematical limit, or a state of "not-now," while relationalism defines relationships purely using static states of "now."

2. Material and methods

2.1 Moon18: A Unified Approach to Timekeeping: Merging Ratio Units with Standardizations

A powerful yet overlooked structure for organizing n-body time units was revealed by study of ancient systems using dihedral symmetry groups combined with radix-based subdivisions (base-x systems). This enables ways to geometrically model *n*-body time using applied group symmetry, including arrangement of time units within geometric spaces. The result is a unified and elegant framework—ideal for advanced watch face designs spanning short (second like) to long durations (centuries like), expanding timekeeping expressions with geometric display capabilities (expression 1).

$$W\|D_n|\langle bx_1\rangle\langle bx_2\rangle\langle bx_3\rangle\langle bx_z\rangle \cdot \langle 10_1\rangle\langle 10_z\rangle \tag{1}$$

Where the dot is a positional delimiter between radix subdivisions and a decimal system. Where z represents a natural number of an expanding group order placement. Example shows a duration for Earth's rotational count with a defined subcomponent. Here is an example of using an expression to represent counts and parts of a whole rotation, D_{24}, rotation symmetry (see expressions 2, 3).

$$Days\|24|\langle 60\rangle\langle 60\rangle \cdot \langle 10\rangle\langle 10\rangle \tag{2}$$

$$3\|10|\langle 22\rangle\langle 45\rangle \cdot \langle 3\rangle\langle 4\rangle = 3\text{ days; } 10\text{ hours, } 22\text{ minutes, } 45.34\text{ seconds} \tag{3}$$

Time units come in two types: ratio units and standard units. Ratio units divide a full cycle into consistent parts with geometric symmetry and order, though their durations may vary between cycles. Standard units, like the second are currently defined by ^{133}Cs atomic transitions, remain constant but lack natural geometric structure. Today's standardized second originated from dividing one solar Earth day into 86 400 equal parts—24 'hours', 60 'minutes' per hour, 60 'seconds' per minute—reflecting an ordered rotational symmetry. To maintain 86 400 standardized units in a time interval in one Earth day with a slowing rotation, leap seconds are periodically required given Earth's slowing rotation.

Standardized time units are vital for modern computing and science, but they fall short in complex, multi-body celestial systems. By combining them with cyclic ratio units—divisions of whole durations—we gain a more adaptable framework for timekeeping across varying cosmic distances and local frames. Atomic clocks used today to define standards offer precise measurements, yet their frequency breaks down across different frames due to relativistic and environmental effects.

The solution includes uniting a universal ratio-based system with local frame standardized units, enabling consistent, scalable timekeeping throughout the cosmos when durations are measured using relativity within a frame. Vartis Space proposes a Moon18-based timekeeping system inspired by Mesoamerican timekeeping structures.[1, 6] The proposed Moon18 time units is a division of a whole duration, in this application the lunation cycle period our Moon's orbit.

Unlike the Earth-based day, which divides one full rotation into 24 hours—as adopted in systems like Mars24—this approach introduces a framework where planets may adopt a 24-part division, while moons follow an 18-part structure. Drawing inspiration from Mesoamerican calendar systems and their temporal groupings (see expression 4):

$$Lunation\ counts\|18|\langle 20\rangle\langle 20\rangle \cdot \langle 10\rangle\langle 10\rangle \tag{4}$$

Each ordered 7200 units proposed as an *in* (a smaller subdivision than 360 *k'in*) **(Fig. 1)**.

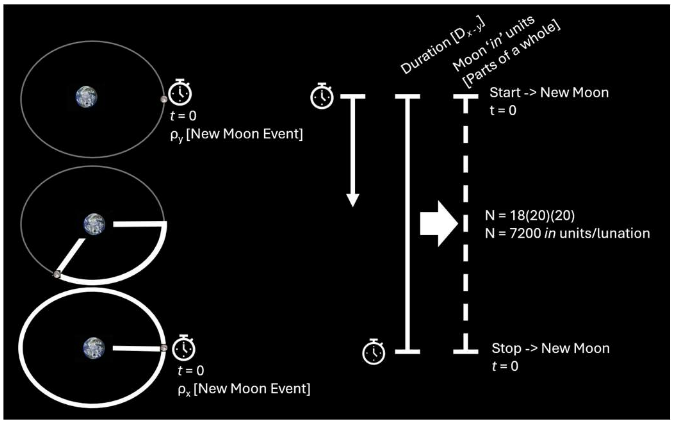

Fig. 1: Moon's lunation duration divided and subdivided into 7200 ratio units for local frame standardization.

Vartis proposes using one '*in*' as the base ratio unit for a lunation duration, applicable for unique standardization in each independent local frames, such as Earth's UTC, the Moon LTC, or spacecraft. We propose once standardized within a frame, perhaps using local atomic clocks, that the standardize unit be named the *Metz*, in honour of Meztli,

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the Mesoamerican Moon goddess. As orbital periods vary over time, intercalary adjustments are necessary to keep standardized units aligned with ratio-based units. This temporal discrepancy between standard units and ratio units is exceptionally useful for other purposes beyond the scope of this application.

To provide some historical context, colonial friars authored chronicles of Mesoamerican timekeeping systems in the image of the Gregorian calendar, interpreting the '*Tun'* cycle as 360 days + 5 (365-day Haab calendar), mirroring the 1582 Pope Gregorian XIII reform. In contrast, we utilize the *'Tun'* structure to model a lunation cycle using the New Moon as a natural reset point. Importantly the methodology provides a naturally occurring reference for Moon time, a recurring event to synchronize an anchor point of time across frames.

For *n*-body unit systems, Vartis Space proposes a universal timekeeping framework using object-oriented ratio units (divisions of full cycles of a duration using absolute point-time) combined with frame-dependent definitions for standardizing the units. The divisional and subdivisional structure of ratio units supports advanced geometric modeling and group theory, enabling the creation of *n*-body clocks and a co-existing network of durations that can be harmonized in geometric modelling as well as calendar systems—clock-like devices that share the same object-oriented ratio units but tick at rates unique to their respective frame of reference.

2.2 Frame Equivalence Duration Formula

The approach uses a Frame Equivalence Duration Formula [1] (see equation 5) to define a universal duration between two absolute time points. Each local frame converts this duration into its own standardized time using existing technologies and relativistic adjustments:

$$D_{[x-y]} = c\Delta t \tag{5}$$

where $\Delta t = t(x) - t(y)$, calculated as a Lorentz-invariant metric; y represents the starting-point signal, and x represents the terminal end-point signal.

Key features of formula:

1. Equates frame-dependent time measures for a universal duration.
2. Maintains parts of whole for timekeeping device, equated from different frames of reference.
3. Discrete synchronization between local frames (accuracy limited by relativity)

Vartis Space's methodology [7] uses advancements in technology and *n*-body deployments to enable each celestial body to maintain an independent timekeeping system. Temporal point synchronizations let clocks realign in different frames, supporting new ways to improve timekeeping. Today's accuracy depends on current tech and relativity, but there's room to advance further. While tracking exoplanet rotations is challenging, orbital periods can be estimated. Longitudinal data archives will help increase accuracy of interplanetary calendars, linking Earth with exoplanets and synchronizing celestial systems across space and local frames.

This proposal introduces a method that defines an absolute point-time duration from a local frame of reference using relativistic frameworks. This allows celestial bodies to maintain independent timekeeping systems while synchronizing their clocks across different frames **(Fig. 2)**. Relativistic calculations ensure accuracy and scalability, with potential for future advancements. Longitudinal data archives will help create interplanetary calendars, linking Earth with exoplanets and enabling synchronization of celestial systems independent of spatial distance.

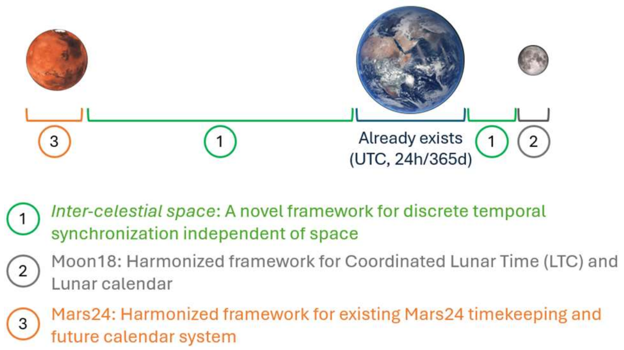

Fig. 2. Local spaces (Moon18, Mars24, and Earth24) synchronized independent of inter-celestial space. *(Images credit: NASA)*

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2.3 Luniterranean calendar

Julian-style calendar methodologies, including the modern Gregorian calendar introduced in 1582 by Pope Gregory XIII, are not suited for building a universal calendar system. However, by combining pre-Greek and non-European timekeeping methods (Egypt, Hindu, Sumerian, etc.) with modern advancements makes a universal calendar system possible. A universal calendar would be a network of overlapping relational durations based on celestial cycles. By using recorded data—like the cycles of Earth and the Moon—a calendar system of durations can be created and shown through geometric patterns, clock faces.

The Luniterranean calendar is based on lunar cycles, with each moonth representing one lunation (New Moon to New Moon). A standard Luniterranean year has 13 moonths, with 384 days. This is not aligned to seasonal cycles but there can be more than one calendar system depending on what cycles are being harmonized. To maintain long-term alignment with Earth's axial rotation, a leap year with 385 days occurs every 10 years, and a skip year with 383 days to resynchronize the lunar (*Tun*) and civil (*Haab*) calendars using a paired function equation estimated to be about 400 luniterranean years, luniterranean quadricentennial year (5200 lunations ≅ 153 638 days). Accuracy requires longitudinal prospective record keeping for confirmation.

The Luniterranean calendar's 383-day skip-year intercalation timing parallels colonial-era friar interpretations of the Mesoamerican Calendar Round, which was understood to repeat every 52 years. Friars considered comments of 52 being in relation to the hypothesized '260-day Tzolk'in' cycle and the hypothesized '365-day Haab' year, with 52 serving as the least common multiple for both (18 980 days). In both the Catholic and these modern hypotheses, a Calendar Round marks the end of one cycle and start of another.

Using a novel harmonization of Mesoamerican timekeeping units and structure (expression 5 template with expression 6 shown in **Fig. 3**), Vartis Space designs a watch face that displays time from small unit durations to a quadricentennial luniterranean year—synchronized to real celestial events like the New Moon—measured within a local frame of reference **(Fig. 3)**. The design was inspired by the Aztec calendar stone design, whereby Moon18 ratio units harmonize with the Luniterranean calendar system, offering a refined structure that departs from colonial-era interpretations and Catholic definitions of indigenous calendrical methods following the loss of indigenous source documents.

$$\langle bx'_z\rangle\langle bx'_2\rangle\langle bx'_1\rangle\|D_n|\langle bx_1\rangle\langle bx_2\rangle\langle bx_3\rangle\langle bx_z\rangle \tag{5}$$
$$\langle 20'\rangle\langle 20'\rangle\langle 13'\rangle\|18|\langle 20\rangle\langle 20\rangle \tag{6}$$

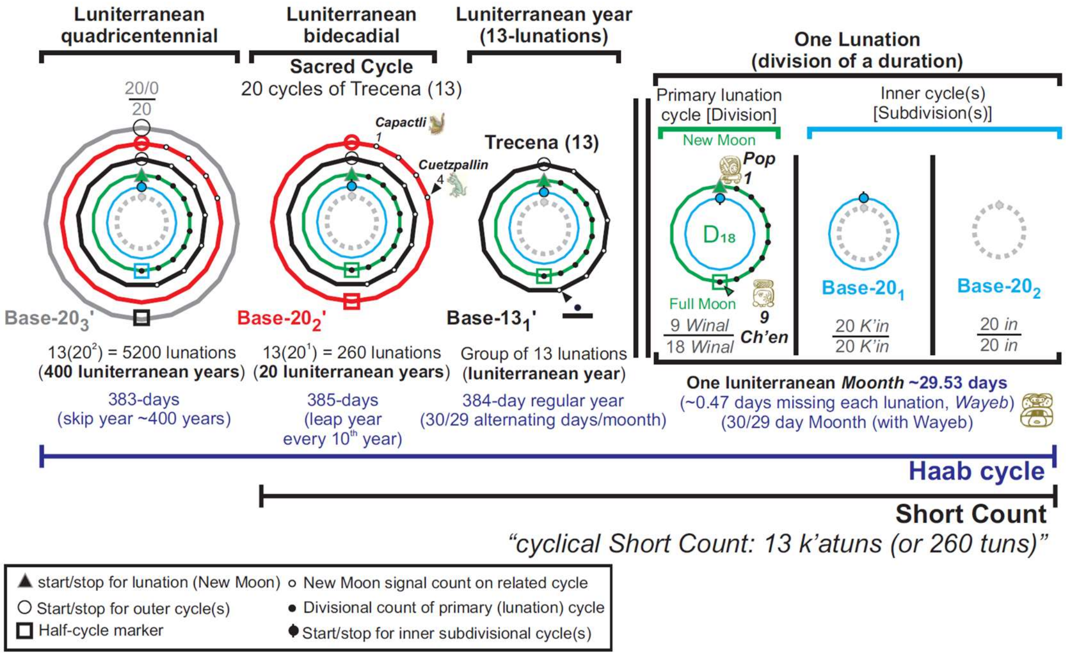

Fig. 3. Luniterranean clock design with Moon18 ratio units: echoing Mesoamerican chronometric systems. Concentric rings show base ratio units (right) to large durations (left). Similarities to Calendar Round, Tzolk'in, Short Count, Trecena, Tun, Sacred Cycle, Haab, and Wayeb shown. Watch (far left) shows frame period of 4 luniterranean years, 6 moonths, on an observed Full Moon.

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3. Conclusions

Universal timekeeping for the cosmos is not just about extending Earth-centric concepts like the modern Gregorian calendar, atomic defined Earth seconds, Earth's coordinated local time, or atomic clock systems to other planets. It's about forging a universal framework that transcends geo-centricity, embracing diverse approaches to time that better reflect the independent but unified physical universe with cyclic events—unlocking new frontiers in deep space exploration.

What time is it on the Moon? Vartis Space offers a bold answer: decouple time from space by adopting a new philosophy rooted in relationalism, working in synergy with relativistic principles. This leads to three proposals for the Moon Time Challenge: Moon18, an independent Lunar Coordinated Time (LTC); Formula, uniting relativity with relationalism for practical timekeeping; and the Luniterranean Calendar, combining the Moon's lunation cycle with the familiar Earth day for long term coordination. Vartis Space offers a fresh foundation for time beyond Earth leading to a theoretically accurate, scalable, traceable, and resilient timekeeping system for *n*-body possibilities.

Vartis Space's methodological approach pushes the frontier of timekeeping proposed to be limited only by the precision of today's relativistic and astrophysical tools, opening new directions for future technological advancements. This is an open invitation to the global community: to explore, validate, and consider the capabilities of this proposal for the international challenge. The path forward involves deeper conceptual exploration and the development of local frame unit standards—establishing the foundation for a truly universal system capable of dimensionally quantifying and geometrically modeling dynamic systems within local frames of reference.

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