**SYSTEM ENGINEERING AREA**

**Time Management Working Group Charter**

**April 2019**

**DRAFT**

**Approved:**

**Erika Sanchez\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

### BoF Chair Date

### Peter Shames\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Area Director Date

### Leadership

Proposed chair: TBD

Proposed deputy chair: TBD

### Scope of activity

The Time Management Working Group will concentrate on creating and maintaining standards relating to time transfer, time correlation, and time synchronization in space operations contexts. The activities will be coordinated under the Systems Engineering Area (SEA).

### Rationale for activity

Space agencies need to manage time on their spacecraft for the effective execution of maneuvers, coordination of scientific observations, ranging, docking or other robotic collaboration, and for scheduling of communications links or other activities. CCSDS member agencies see value in standardizing parameters and protocols for accomplishing time correlation and synchronization, so that agencies can offer cross support for their timing needs. The biggest motivation for doing this work in CCSDS is to enable a move from mission or agency approaches to internationally interoperable standardized approaches.

### Goals

Standards shall be developed to promote common understanding of time correlation and synchronization approaches and to facilitate cross support of time management operations among space operations assets. The Working Group has the following goals:

1. Collect and analyze the technical literature, and codify it into specific time correlation and synchronization methods that can be analyzed and compared, in preparation for developing CCSDS Green, Blue, and Magenta Books. As part of this, the requirements for time correlation and synchronization for emerging mission domains/enterprises will be determined and reviewed with other CCSDS stakeholders.
2. Produce a Green Book describing suitable operational domains, applications, and methods used for time correlateion and synchronization. Applications include maneuvers, coordination of scientific observations, ranging, docking or other robotic collaboration, and scheduling of communications links or other activities. The book will describe methods for time correlation and synchronization, including those for near Earth, cislunar, and deep space regimes. The book will separately address application domains in which a Global Navigation Satellite Service (GNSS) is or is not available. A multitude of time transfer, correlation, and synchronization methods will be described, including those involving ranging methods (telemetry ranging, PN ranging, and GMSK+PN ranging), one way data delay coupled with trajectory data, two-way range signaling similar to that used by the Tracking and Data Relay Satellite System (TDRSS)), the use of local aera time zones (e.g., rovers and orbiters around Mars), and methods using or not using explicit time code format representations in the signaling. The Green Book will also discuss the roles of clocks, frequency standards, and topics such as X-Ray Pulsars as frequency sources for timekeeping. Error sources will be identified, including limitations in orbit knowledge, calibration, and time tags.
3. Produce a Blue Book describing protocols for time correlation and for time synchronization. The Blue Book will define the signaling of time correlation data (signaling containing time code formats) or time-bearing signals (telemetry/PN/GMSK+PN ranging) needed to accomplish time correlation. It will define protocols for time synchronization that are suitable for use in traditional single space link deployments as well as in Solar System Internet (SSI) deployments using DTN or IP protocols.
4. Produce a Magenta Book that defines recommended procedures for using these normative approaches, in space and on the ground, to produce the desired outcomes for cross supported mission and multi-mission time management.

### Survey of similar standards efforts undertaken in other bodies and elsewhere in CCSDS

CCSDS has developed standards for Time Code Formats (CCSDS 301.0-B-4), Pseudo-Noise (PN) Ranging Systems (CCSDS 414.1-B-2), GMSK+PN Ranging, and telemetry ranging (in CCSDS 401.0-B-28), PN ranging using CDMA from a Relay Satellite (CCSDS 415.1-B-1), Earth Receive Time (ERT) time stamps delivered by Space Link Extension (SLE) return frame services (CCSDS 911.1-B-4, CCSDS 911.2-B-3). Each of these standards relates to the representation of or exchange of time, or the measurement of elapsed time useful in determining the range between a reference point on the ground and a reference point on a spacecraft.

A series of IETF RFCs (RFCs 778, 781, 956, 958, 1059, 1305, 5905, 7822) describes the Network Time Protocol (NTP) and its extensions, for time synchronization over the Internet. NTP is one of the oldest Internet protocols in current use. There is not yet a corresponding set of time synchronization standards for the Delay Tolerant Network (DTN) suite.

There are time and position services from GPS/GNSS that are in wide use for near Earth and that have a usable service volume that may extend to cis-Lunar distances. There is an European Cooperation for Space Standardization (ECSS) clock correlation standard that is used in Europe, and there are other agency and mission clock correrlation approaches, some of which are well documented.

NIST maintains an atomic clock standard, and has established standard definitions for much of the terminology involved. BIPM also maintains an atomic clock standard and uses the same standard definitions. There are a few terrestrial deployments of synchronized clocks that may be used for timekeeping on Earth, but, aside from GNSS systems, no such “fabric” deployed in space.

These various standards and standard definitions will be utilized where they are suitable in formulating a time transfer and time correlation protocol, and time synchronization standards.

### Patent licensing applicability for future standards

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|  | The current WG participants know of no limitations at this stage on usage of the planned technologies as far as patent restrictions or licensing requirements are concerned. Certain GPS localization technologies may be patented and require a license. |

### Technical risk mitigation strategy

No technical risks have been identified by the BOF at this stage.

There are several systems that already support parts of the desired features in specific environments. The Space Network (SN) has deployed transponders that successfully use PN ranging since 1985. GPS and other GNSS systems, for Earth surface and near Earth uses, provide highly accurate time and position information that is globally used.

JPL has been testing telemetry ranging and PN ranging and the next generation Transponder has accepted the requirement to time tag their Clock in association with a specified bit in the PN. Bepi-Columbo is currently building a transponder that performs regenerated ranging using the PN but they have no requirement to use the PN correlation to time tag the PN with the transponder clock.

The WG will review and evaluate existing approaches to determine where, and if, they are applicable in the space operations domain.

The WG will define a consistent set of terms that align with best current practices, see annex for definitions of the terms used in this Charter.

### Management risk mitigation strategy

Schedule relies upon the support of multiple CCSDS Agencies and on the allocation of adequate Agency resources to the WG.

This work involves coordination between the Systems Engineering Area (SEA) and the Space Link Services (SLS) and Space Internetworking Services (SIS) areas which develop specific link and internetworking protcols used in time exchange. This will be particularly important for IP and DTN “wide area” deployment in the Solar System Internet. Coordination will also be required between this WG and the Mission Operations and Information Management (MOIMS) SM&C & Nav WGs for requirements and as stakeholders when they work on MO Time Services and Nav data exchange standards. Coordination will also be required between this WG and the Spacecraft Onboard Information Services (SOIS) App WG when they work on electronic data sheets for onboard clocks to provide time access services for MO Time Services and for other applications.

A risk management approach will be used to formulate a risk management plan and identify risks other than schedule and resources.

### Schedule

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| **Date** | **Milestone** |
| May 2019 (Spring meeting) | BoF conclusion to AD and WG charter submitted to SE Area  |
| 1st July 2019  | WG Charter Adopted by CESG and CMC |
| 1st July 2019 | Green Book organization prepared and work delegated |
| 15 September 2019 | First Draft of the Green Book before the fall meeting 2019 (ambitious) |
| October 2019 |  First Draft Deadline for comments  |
| August 2020 | Second draft of the Green Book (before the fall meeting of 2020) |
| November 2020 | Final Green Book after the fall meeting 2020 (18 months) |
| September 2019 | White Books on standard approaches for time correlation and synchronization protocols based for various operational environments. (Blue Book track) |
| November 2020 | Final standard White Book submitted to AD for further processing |
| September 2021 | White Book on recommended practices for deployments using these normative approaches, in space and on the ground. (Magenta Book track) |
| September 2021 | Blue Book prototyped |
| March 2022 | Blue Book published |
| November 2022 | Final recommended practice White Book submitted to AD for further processing |
| March 2023 | Magenta Book published |
| June 2023  | WG disbands |

**Annex – Definition of terms**

* **Clock** - a device that generates periodic, accurately spaced signals for timekeeping applications. A clock consists of at least three parts: an oscillator, a device that counts the oscillations and converts them to units of time interval (such as seconds, minutes, hours, and days), and a means of displaying or recording the results. [3]
* **Coordinated Universal Time** (UTC) - The international atomic time scale that serves as the basis for timekeeping for most of the world. UTC is a 24-hour timekeeping system. The hours, minutes, and seconds expressed by UTC represent the time-of-day at the Earth's prime meridian (0° longitude) located near Greenwich, England. [3]
* **Global Navigation Satellite Systems** (GNSS) - A satellite system that can be used to locate a user’s receiver anywhere in the world.  The Global Positioning System (GPS) was the first global navigation satellite system (GNSS), but has been followed by the three other systems, BeiDou, Balileo, and GLONASS. [3]
* **International Atomic Time** (TAI) - A time scale maintained internally by the BIPM, but seldom used by the general public. TAI realizes the SI second as closely as possible, and runs at the same frequency as Coordinated Universal Time (UTC). However, TAI differs from UTC by an integral number of seconds. This difference is related to leap seconds, and increases whenever a leap second occurs. [3]
* **Time** – The designation of an instant on a selected time scale, used in the sense of time of day; or the interval between two events or the duration of an event, used in the sense of time interval. [3]
* **Time correlation** - the determination of the variance and time offset of two continuous timescales provided by two different clock-ensembles. This procedure may require the knowledge of clock parameters (stability, drift,...) and also propagation delay of the time transfer.
* **Time interval** - The elapsed time between two events. In time and frequency metrology, time interval is usually measured in small fractions of a second, such as milliseconds, microseconds, or nanoseconds. [3]
* **Time scale** - An agreed upon system for keeping time. All time scales use a frequency source to define the length of the second, which is the standard unit of time interval. Seconds are then counted to measure longer units of time interval, such as minutes, hours, and days. Modern time scales such as UTC define the second based on an atomic property of the cesium atom, and thus standard seconds are produced by cesium oscillators. Earlier time scales (including earlier versions of Universal Time) were based on astronomical observations that measured the frequency of the Earth's rotation. [3]
* **Time synchronization** - the process of setting a clock-ensemble to the same time.
* **Time transfer** - A measurement technique used to send a reference time or frequency from a source to a remote location. Time transfer involves the transmission of an on-time marker or a time code. The most common time transfer techniques are one-way, common-view, and two-way time transfer. [3]
* **Time unit** – the reference time unit is a second, which is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. [1], [2].

[1] The International System of Units (SI), NIST Special Publication 330.

[2] <https://www.bipm.org/en/bipm-services/timescales/tai.html>

[3] NIST Time and Frequency Services, <https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z/time-and-frequency-z-z-index>