MISB Motion Imagery Standards Board	MISB ST 0603.3
STANDARD	
Common Time Reference for Digital Motion Imagery Using Coordinated Universal Time (UTC)	**29 October 2015**

1 Scope

An absolute, reliable, common time reference is essential in timestamping Motion Imagery and metadata collected in operations. Such a common reference affords knowledge of precise event occurrences and facilitates photogrammetric analysis, interoperability and exploitation of Motion Imagery products.

This standard specifies Coordinated Universal Time (UTC) as the deterministic common time reference for correlating Motion Imagery (Class 0 Motion Imagery, Class 1 Motion Imagery, and Class 2 Motion Imagery) to metadata. Two timestamps are defined in this document: the Precision Time Stamp, which is mandatory in Motion Imagery and in many MISB metadata sets, and the Commercial Time Stamp, which is optional but useful in commercial editing/processing environments.

2 References

[1] MISB, MISP-2016.1: Motion Imagery Handbook, MISB, 2015.

[2] ISO 8601:2004 Data Elements and Interchange Formats – Information interchange – Representation of Dates and Times, 2004.

[3] IEEE Std 1003.1 – 2008 Standard for Information Technology – Portable Operating System Interface (POSIX®).

[4] SMPTE ST 12-1:2014 Television, Time and Control Data, 2014.

[5] Assistant Secretary of Defense for Command, Control, Communications and Intelligence Global Positioning Standard Positioning Service Performance Standard 4th Ed, Sept 2008.

[6] SMPTE RP 210v13:2012 Metadata Element Dictionary.

[7] MISB ST 0605.6 Encoding and Inserting Time Stamps and KLV Metadata in Class 0 Motion Imagery, Jun 2015.

[8] MISB ST 0604.3 Time Stamping Compressed Motion Imagery, Feb 2014.

[9] SMPTE EG 40:2012 Conversion of Time Values between SMPTE 12-1 Time Code, MPEG-2 PCR Time Base and Absolute Time, 2012.

3 Terms and Definitions

For additional information on time systems and definitions see the Motion Imagery Handbook [1].

All dates and times within ST 0603 use the ISO 8601 [2] standard formatting of:

CCYY-MM-DD**T**hh:mm:ss.sZ

Where CCYY is a four digit year; MM is the month number; DD is the day within the given month; **T** is a placeholder to signify a separation between the Date and Time; hh is the hour number ranging from 0 to 23; mm is the number of minutes in an hour; *ss.s* is the number of seconds along with fractions of a second which can be more than one digit; Z is a single letter that signifies the time zone of the time. In this document all times are in the Zulu, or Z, time zone. Zulu refers to the time at the prime meridian.

accuracy The statistical difference between a measured or computed value of a physical quantity and the standard or accepted value for that quantity. For measured values, the mean (average) of the data is used. For timestamping, accuracy is the average difference between each timestamp (the measured time) and the actual time of the event (reference time).

epoch An instant in time chosen as the origin of a particular era. The "epoch" serves as a reference point from which time is measured. Time measurement units are counted from the epoch so that the date and time of events can be specified unambiguously.

precision The ability of a measurement to be consistently reproduced. For measured values, the standard deviation of the data is used. For timestamping, precision is the variation of the difference between each timestamp (the measured time) and the actual time of the event (reference time). The standard deviation of the data is the metric normally used to measure this range.

resolution Smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

timestamp Generally, the current time an event is recorded.

4 Acronyms

GPS Global Positioning System
IRIG Inter-Range Instrumentation Group
SI International system of units
TAI International Atomic Time
UL Universal Label
UTC Coordinated Universal Time

5 Revision History

Revision	Date	Summary of Changes
0603.3	10/29/2015	• Revised definitions for accuracy and precision • Added definitions for epoch and timestamp • Modified Figure 1 • Deprecated REQs -01, -02 • Appendix A, B material moved to MI Handbook

6 Common Time Reference

Correlation of temporal events acquired from Motion Imagery sensors is critical for monitoring the nature of activities in the field of view as they change continuously over time. Post event analysis is enhanced with temporal synchronization across Motion Imagery streams and associated metadata. Adherence to a common time reference enables the frame-accurate synchronization of imagery and metadata from multiple sensors to assist temporal fusion for post-mission analysis.

Coordinated Universal Time (UTC) is a time scale based on the second (SI unit). The use of UTC as the common time reference for Motion Imagery and metadata enables frame-accurate temporal fusion of Motion Imagery streams from multiple sensors located worldwide. POSIX time [3] is a system for describing instants in time defined as the number of seconds that have elapsed since midnight January 1, 1970 (1970-01-01T00:00:00Z), not counting leap seconds. "Microseconds since 1970" provides for an increase in resolution over POSIX seconds to microseconds. SMPTE ST 12-1 [4] defines Time Code, which is a time system used in commercial products for measuring hours, minutes, seconds and frames in video for the editing and processing of content.

This standard defines an absolute timestamp – the Precision Time Stamp (based on "Microseconds since 1970"), and a relative timestamp – the Commercial Time Stamp (based on SMPTE 12-1) for Motion Imagery and metadata. Both the Precision Time Stamp and the Commercial Time Stamp are derived from (without including leap seconds) UTC (see Figure 1).

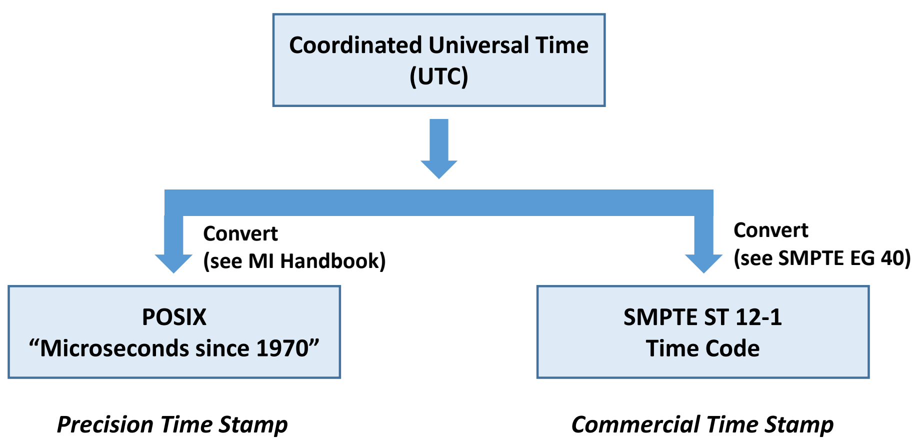

Figure 1: Precision Time Stamp and Commercial Time Stamp derived from UTC

6.1 GPS

GPS [5] provides position and time information enabling geo-location anywhere on or above the earth. The GPS system consists of a constellation of satellites orbiting the earth, where each satellite provides location and time information to GPS receivers.

Many GPS receivers output time information along with a one pulse per second (1PPS) synchronization signal. This time information may be in a variety of formats (UTC, GPS, etc.) and is usually accurate only to the second. The 1PPS synchronization signal enables sub-second finer gradations of time (i.e. microseconds) to be derived by phase locking a high frequency (e.g. 1 MHz) clock to the signal. Some GPS receivers output an Inter-Range Instrumentation Group (IRIG) Standard 200 time signal from which time to the second and time to the sub-second can be derived.

6.2 UTC from GPS

GPS time is not the same as UTC time; however, both are based on International Atomic Time (TAI). GPS was synchronized to UTC in 1980, and is kept in close synchronization with International Atomic Time (TAI is essentially UTC without leap seconds accounted). Because of rotation and adoption of changes in the duration of the TAI second, GPS time reference is no longer exactly the same as UTC time, differing by discrete time offsets known as “leap seconds”, which are updated periodically by U.S. and international standards bodies. UTC accounts for leap seconds and are added (or subtracted) to adjust for slowing of the Earth’s rotation as an effect of tidal and lunar effects. Since GPS went online there have been 17 leap seconds, which means GPS time is 17 seconds ahead (as of July 2015) of UTC. Most GPS time systems provide leap second information, thus ensuring that GPS time is converted correctly to UTC.

UTC, when derived from GPS time, maintains synchronization with the official time kept by the U.S. Naval Observatory’s Master Clock to within one millisecond. Since Motion Imagery sensors commonly operate from 2 to 60 frames per second (FPS) with a frame period of 500 to 17 milliseconds respectively, global synchronization of shutters and timing can be obtained to sub-frame accuracy. See the MI Handbook [1] for a method to convert GPS time to UTC.

Notes: (1) Absolute accuracy of the timestamp is beyond the purview of the MISB. (2) Timing requirements of mission components may be more stringent than that required by the MISP. When such requirements exist, MISP-conformant data should take advantage of them. In many cases, broadcast GPS time will meet and exceed the MISP requirement.

7 Timestamps – Types

The two different types of timestamps are discussed next.

7.1 Precision Time Stamp

The Precision Time Stamp is a 64-bit unsigned integer representing the number of microseconds since midnight January 1, 1970 (1970-01-01T00:00:00Z) without leap seconds, which is referred to as “Microseconds since 1970”. The Precision Time Stamp is similar to POSIX time, which shares the same epoch (starting point). Note: the rollover date is 584,942 years. The MI

Handbook references a method to convert a UTC date/time to "Microseconds since 1970" with leap seconds. The Precision Time Stamp needs to have the leap seconds removed.

The Precision Time Stamp can be specified to a resolution of 1 microsecond. Should sub-microsecond measurements be recorded, they are truncated to the nearest microsecond.

The Precision Time Stamp is foundational and in many cases mandatory across all MISB standards. The Universal Label (UL) for the Precision Time Stamp is 06.0E.2B.34.01.01.01.03.07.02.01.01.01.05.00.00 (CRC 64827) defined in the SMPTE RP 210 [6] KLV dictionary with a Data Element Name of "User defined Time Stamp – microseconds since 1970".

MISB ST 0605 [7] and MISB ST 0604 [8] describe how to format – and where to locate – the Precision Time Stamp in Class 0 Motion Imagery (uncompressed) and Class 1/Class 2 Motion Imagery (compressed), respectively. Older MISB documents specify a "Unix Time Stamp", but this designation is being replaced with "Precision Time Stamp". The following requirements apply to the Precision Time Stamp:

Requirement(s)	
ST 0603.2-03	The Precision Time Stamp shall be derived from Universal Coordinated Time (UTC) without leap seconds.
ST 0603.2-04	The Precision Time Stamp shall be a 64-bit unsigned integer representing "Microseconds since 1970" (1970-01-01T00:00:00Z).

Systems providing a Precision Time Stamp for Motion Imagery and metadata will have differing requirements for the accuracy and precision of the Precision Time Stamp. System Designers need to specify both the precision and the accuracy of the Precision Time Stamp, so that users of the data understand what can be expected in data analysis.

7.1.1 Time Stamp Status

The Time Stamp Status is a one-byte value providing additional information regarding the timing reference for the Precision Time Stamp. The Time Stamp Status, as defined in Table 1, is included along with the Precision Time Stamp in Class 0/1/2 Motion Imagery.

Table 1: Time Stamp Status

	Time Stamp Status (one byte value)	
bit 7	0 =	Locked to valid Precision Time Stamp reference (internal oscillator clock locked)
	1 =	Lock Unknown (internal oscillator clock not locked to Precision Time Stamp reference)
bit 6	0 =	Normal (time incremented normally since last message)
	1 =	Discontinuity (time has not incremented normally since last message)
bit 5	0 =	Forward (When Bit 6 = 1, indicates that the time jumped forward)
	1 =	Reverse (When Bit 6 = 1, indicates that the time jumped backwards)

bits 4-0	Reserved (‘11111’)

The Precision Time Stamp is often derived from a local time reference, which is either locked to a reference clock, or is operating as a systems-internal free running clock. Within the Time Stamp Status, bit 7 signals this condition. Bit 6 signals that time is either incrementing properly, or there is a discontinuity in the clock source; such as either a forward or reverse jump due to relocking the clock to its reference source, or other correction. Bit 5 signals a forward or backward increment in the time reference; for a system which assumes a monotonically increasing time value this information affords proper handling of such a discontinuity.

The Time Stamp Status is embedded in Motion Imagery along with the Precision Time Stamp. For example, in Class 0 Motion Imagery (uncompressed) MISB ST 0605 describes the format and location for inserting both the Precision Time Stamp and Time Stamp Status as a Time Stamp Pack, while MISB ST 0604 describes the format and location for insertion into Class 1 and Class 2 Motion Imagery (compressed). The Time Stamp Status may also be carried as an individual metadata element. The UL for the Time Stamp Status metadata element is 06.0E.2B.34.01.01.01.01.0E.01.01.03.10.00.00.00 (CRC 30903)

7.2 Commercial Time Stamp

The Precision Time Stamp is typically not recognized by commercial tools, such as a video editor. Time code was developed by the commercial broadcast industry for content manipulation, non-linear editing and other processing, and is the principle timing mechanism in those systems. One format for time code, which is defined by SMPTE ST 12-1 is HH:MM:SS:FF (hours:minutes:seconds:frames). The *resolution* of time code is one video (Motion Imagery) frame – typically measured in milliseconds. Time code can roll over; thus it is not unique. Although time code can be synchronized to an absolute time reference, it should be regarded as a relative time only.

In this standard and throughout MISB documents, time code is called the Commercial Time Stamp. The Commercial Time Stamp is optional in Motion Imagery (it is not specified in any MISB metadata set). However, its inclusion in the Motion Imagery may prove useful when using commercial products. If included in the Motion Imagery, the Commercial Time Stamp is derived from the same reference used to produce the Precision Time Stamp. SMTPE EG 40 [9] describes an algorithm for converting absolute time to SMPTE ST 12-1 time code. It should be noted that commercial tools may alter time code during editing; thus, there is no guarantee that a time code value, as initially inserted, will persist.

The limitations of the Commercial Time Stamp include:

- The resolution of the Commercial Time Stamp is a Motion Imagery frame.
- The Commercial Time Stamp is a relative timing signal.
- Non persistence. The Commercial Time Stamp may be modified in Motion Imagery processing.

As a result of its commercial heritage, there are formats and locations defined within Class 0 Motion Imagery (see MISB ST 0605), and within Class 1/Class 2 Motion Imagery (see

MISB ST 0604). When used, the requirements for the Commercial Time Stamp are as follows:

Requirement(s)	
ST 0603.2-05	The Commercial Time Stamp shall be derived from Universal Coordinated Time (UTC) without leap seconds.
ST 0603.2-06	The Commercial Time Stamp shall represent the identical time of the Precision Time Stamp within the resolution of the Commercial Time Stamp.
ST 0603.2-07	When a Commercial Time Stamp is used, it shall be represented in accordance with SMPTE ST 12-1 [4].

8 Deprecated Requirements

Requirement(s)	
ST 0603.2-01	Coordinated Universal Time (UTC) shall be the time reference source for deriving the timestamps defined in this Standard.
ST 0603.2-02	The US Global Positioning System (GPS) shall be the authoritative time reference source for UTC.