MISB Motion Imagery Standards Board	MISB ST 0603.5
STANDARD	
MISP Time System and Timestamps	**5 October 2017**

1 Scope

An absolute, reliable time system is essential to precisely mark temporal events with timestamps for collected Motion Imagery and metadata. Such timestamps facilitate photogrammetric analysis, interoperability and exploitation of Motion Imagery products.

This standard specifies the MISP Time System, which is an absolute time scale from which timestamps are derived. Three types of timestamps are defined: 1) a Precision Time Stamp, which represents Absolute Time specified to microsecond resolution; 2) a Nano Precision Time Stamp, which represents Absolute Time specified to nanosecond resolution; and, 3) a Commercial Time Stamp, which represents a relative time consistent with time code used in the commercial broadcast industry, specified to video frame resolution. The Precision Time Stamp and the Nano Precision Time Stamp aide in correlating Motion Imagery with metadata.

This standard also specifies a Time Status byte, which is intended to provide additional information regarding the source used for timestamps.

2 References

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

[2] MISB MISP-2018.1: Motion Imagery Handbook, Oct 2017.

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

[4] MISB ST 0807.20 MISB KLV Metadata Registry, Oct 2017.

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

[6] 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

All dates and times within ST 0603 use the ISO 8601 [1] 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.

Epoch An instant in time chosen as the origin of an era. For example, the MISP Time System Epoch is 1970-01-01T00:00:00.0Z (i.e. midnight January 1, 1970). The Epoch serves as a reference point from which time is measured. Time is counted from the Epoch so that the date and time of events can be specified unambiguously.

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

Timestamp The current time an event is recorded. A timestamp is a value representing an instant in time.

4 Acronyms

GPS Global Positioning System
KLV Key Length Value
MISP Motion Imagery Standards Profile
SI International System (of units)
TAI International Atomic Time
UL Universal Label
UTC Coordinated Universal Time
Z Zulu

5 Revision History

Revision	Date	Summary of Changes
0603.5	10/05/2017	• Added Section 7 that discusses two representations for MISP Time System: Precision Time Stamp & Nano Precision Time Stamp • Editorial changes to Section 7.1 for Precision Time Stamp • Added Section 7.2, 7.2.1 & 7.2.2 for Nano Precision Time Stamp • Added requirement -09 • Editorial changes to Section 7.2.3 to implement a nomenclature change for Precision Time Stamp Status to Time Status; aligns with generic usage of timestamps for Absolute Time defined in ST 0603 • Corrected conversion algorithm in Section 7.3 Step 1 from 500 milliseconds to 500 nanoseconds

		• Removed floating point from conversion algorithm in Section 7.3; conversion now with integer arithmetic • Updated Table 1 to remove floating point arithmetic • Added reference MISB ST 0807

6 MISP Time System

The MISP Time System is a "Level 3[1]" time system exemplifying the following characteristics:

- Total Order of data
- Relative Differencing
- Absolute Time reference

The MISP Time System enables scientific and human analysis of Motion Imagery data in tasks such as exploitation, where knowing the timing relationships amongst related data is essential.

The MISP Time System is defined as follows:

- Epoch of 1970-01-01T00:00:00.0Z (starting point for time scale)
- Based on the SI Second (constant counting increment of time)
- Strictly monotonically increasing (no skips, no repeats in count)

The MISP Time System is locked (i.e. same clock-period and zero delay, see Motion Imagery Handbook [2]) with International Atomic Time (TAI); however, there is a fixed offset of 8.000082[2] seconds between the MISP Time System and TAI (i.e. MISP Time = TAI – 8.000082 seconds). The Global Positioning Satellite (GPS) system produces TAI with a fixed offset of 19 seconds (i.e. GPS Time = TAI - 19 seconds). GPS systems supply leap second corrections to compute UTC, or may supply UTC directly. UTC can be derived from the MISP Time System using its correct offset and inclusion of leap seconds.

Appendix A offers the rationale for introducing the MISP Time System as clarification to previous versions of this standard. The Motion Imagery Handbook [2] provides algorithms for converting between the MISP Time System and other time standards.

7 Representations of the MISP Time System

To be useful in Motion Imagery Systems, a representation of time as a discrete number is necessary. In Figure 1, two representations defined here are the Precision Time Stamp, which is specified to a resolution representing microseconds, and the Nano Precision Time Stamp, which is specified to a resolution representing nanoseconds. Both representations use the Epoch indicated above as their reference.

[1] See the Motion Imagery Handbook [2] for in-depth discussion and terminology

[2] Many systems may not need to account for the 82 microseconds; those with sensitive timing requirements may.

The decision to choose one representation over another depends on the application needs. It is **mandatory** that either a Precision Time Stamp or a Nano Precision Time Stamp be present in Motion Imagery and metadata. MISB standards indicate which representation is appropriate.

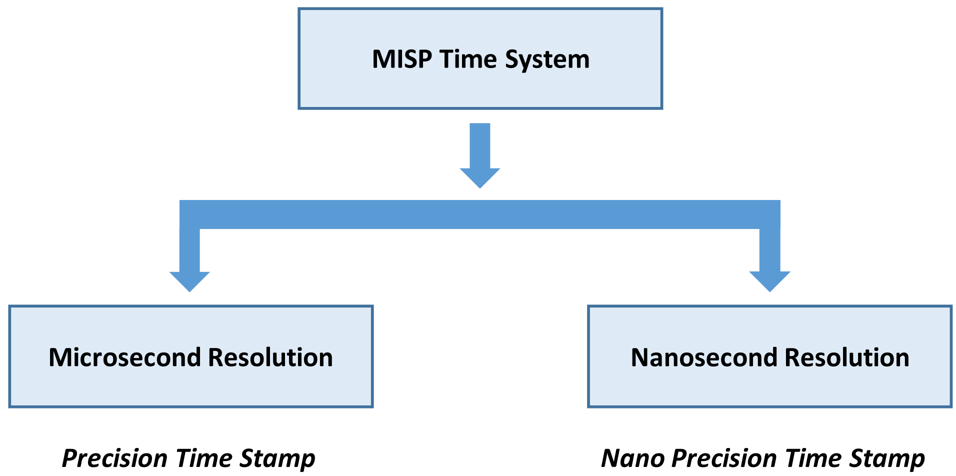

Figure 1: Representations of MISP Time System

7.1 Precision Time Stamp

The **Precision Time Stamp** represents a sampled and quantized time value of the MISP Time System specified to *microsecond* resolution. The Precision Time Stamp is defined to have the following properties:

1. Represented as a 64-bit unsigned integer (UINT64).
2. Specified to a resolution of 1 microsecond. Sub-microsecond measurements are truncated to the nearest microsecond.
3. Assigned the following KLV Universal Label (UL) in SMPTE RP210 [3][3]: 06.0E.2B.34.01.01.01.03.07.02.01.01.01.05.00.00 (CRC 64827)

Requirement	
ST 0603.4-08	The Precision Time Stamp shall represent a value of the MISP Time System truncated to the nearest microsecond.

Notes: (1) Accuracy of the Precision Time Stamp 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.

[3] The UL data element name is defined in SMPTE RP 210 as "User defined Time stamp - microseconds since 1970"

7.2 Nano Precision Time Stamp

The **Nano Precision Time Stamp** represents a sampled and quantized time value of the MISP Time System specified to *nanosecond* resolution. The Nano Precision Time Stamp is defined to have the following properties:

1. Represented as a 64-bit unsigned integer (uint64).
2. Specified to a resolution of 1 nanosecond. Sub-nanosecond measurements are truncated to the nearest nanosecond.
3. Assigned the following KLV Universal Label (UL) in MISB ST 0807 [4]: 06.0E.2B.34.01.01.01.01.0E.01.01.02.0A.08.00.00 (CRC 2123)

Requirement	
ST 0603.5-09	The Nano Precision Time Stamp shall represent a value of the MISP Time System truncated to the nearest nanosecond.

Notes: (1) Accuracy of the Nano Precision Time Stamp 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.

7.3 Conversions between Nano Precision Time Stamp and Precision Time Stamp

The Precision Time Stamp is a uint64 value specified to microsecond resolution. The Nano Precision Time Stamp is a uint64 value specified to nanosecond resolution. To convert a Nano Precision Time Stamp to a Precision Time Stamp, the following steps are performed (although conversion can be done in base 2, for illustration the operations are performed in base 10):

1) Add 500 nanoseconds to the Nano Precision Time Stamp (for rounding).
2) Divide the result by 1000 creating a microsecond value.

Precision Time Stamp = (Nano Precision Time Stamp + 500)/1000

Table 1 provides some examples. Note that this process can possibly result in two identical timestamps in microseconds when given two different timestamps in nanoseconds as shown in the last two entries of the table.

Table 1: Examples of Time Stamp Mapping

Nano Precision Time Stamp (nanoseconds)			Precision Time Stamp (microseconds)	
binary (64 bits)	*base 10*	*+500*	*÷ 1000*	*binary (64 bits)*
0x00007A2C	31276	31776	31	0x0000001F
0x009211DF	9572831	9573331	9573	0x00002565
0x00921118	9572632	9573132	9573	0x00002565

To convert a Precision Time Stamp to a Nano Precision Time Stamp, the Precision Time Stamp is multiplied by 1000 (base 10). This produces a value with three trailing zeros, which represents the fractional nanosecond portion.

Nano Precision Time Stamp = 1000 * Precision Time Stamp

Table 2 provides some examples. Note that converting from a Nano Precision Time Stamp to a Precision Time Stamp then back will occur a data loss. Converting from a Precision Time Stamp to a Nano Precision Time Stamp and back will not occur a data loss.

Table 2: Examples of Time Stamp Mapping

Precision Time Stamp (microseconds)		Nano Precision Time Stamp (nanoseconds)	
binary (64 bits)	*base 10*	*x 1000*	*binary (64 bits)*
0x0000001F	31	31000	0x00007918
0x00002565	9573	9573000	0x00921288

7.4 Time Status

Systems producing a timestamp representing Absolute Time for Motion Imagery and metadata will have differing requirements for the accuracy and precision of the timestamp. System designers need to specify both the precision and the accuracy of the timestamp, so that users of the data understand what can be expected in data analysis.

The purpose of the Time Status is twofold:

1. Provide information on the reference clock used to produce a timestamp, and
2. Provide a bit-efficient timestamp qualifier for use within Motion Imagery.

There are cases where a suitable reference for a timestamp is not available, or the synchronization to a reference may be temporarily lost. The Time Status provides end-user information regarding the reference for the timestamp in these instances.

The Time Status is a one-byte value with a UL assigned in MISB ST 0807 [4] and shown in Table 3. A timestamp representing Absolute Time is often derived from a local time clock, which is either synchronized (i.e. locked with zero offset) to a time reference, or a systems-internal clock. Bit 7 signals this condition.

Table 3: Time Status Byte

Time Status UL: 06.0E.2B.34.01.01.01.01.0E.01.01.03.10.00.00.00 (CRC 30903)	
bit 7	0 = Locked (internal clock locked to absolute time reference)
	1 = Lock Unknown (internal clock not locked to absolute time reference)
bit 6	0 = Normal (time incrementing forward in a linear fashion)
	1 = Discontinuity (time has not incremented forward in a linear fashion)
bit 5	0 = Forward (when bit 6 = 1, indicates time jumped forward)
	1 = Reverse (when bit 6 = 1, indicates time jumped backwards)
bits 4-0	Reserved (‘11111’)

Bit 6 signals time is incrementing forward in a linear fashion, or there is a discontinuity in the count, such as either a forward non-linear or reverse jump as a by-product of relocking the clock to a reference, or other correction. Bit 5 signals a forward non-linear increment or decrement in time; this information allows for handling such a discontinuity.

The Time Status is coded in Motion Imagery in conjunction with either the Precision Time Stamp, or the Nano Precision Time Stamp.

7.5 Commercial Time Stamp

The **Commercial Time Stamp** is equivalent to time code, developed by SMPTE (i.e. SMPTE ST 12-1 [5]), composed of numerical codes expressed as hours, minutes, seconds and frames. Time code is widely used in commercial products, specifically broadcast, to support content processing. The Commercial Time Stamp has the following attributes:

- Represented as HH.MM.SS.FF (hours, minutes, seconds and frames)
- Resolution is one video (Motion Imagery) frame. The Commercial Time Stamp has a finite, cyclical count; thus, its values over time may be non-unique.

Requirement	
ST 0603.2-07	When a Commercial Time Stamp is used, it shall be represented in accordance with SMPTE ST 12-1 [5].

A Commercial Time Stamp is **optional** in MISP Motion Imagery Systems. Because of its commercial heritage, the format and location for the Commercial Time Stamp within Motion Imagery are governed by commercial standards.

If included in the Motion Imagery, the Commercial Time Stamp is recommended to be derived from the MISP Time System. SMTPE EG 40 [6] provides guidance for converting between “absolute time” and time code. However, since the Commercial Time Stamp may be changed during editing/processing, there is no guarantee its initial value(s) will persist.

8 Deprecated Requirements

Requirement(s)	
ST 0603.2-01 (Deprecated)	Coordinated Universal Time (UTC) shall be the time reference source for deriving the time stamps defined in this Standard.
ST 0603.2-02 (Deprecated)	The US Global Positioning System (GPS) shall be the authoritative time reference source for UTC.
ST 0603.2-03 (Deprecated)	The Precision Time Stamp shall be derived from Universal Coordinated Time (UTC) without leap seconds.
ST 0603.2-04 (Deprecated)	The Precision Time Stamp shall be a 64-bit unsigned integer representing “Microseconds since 1970” (1970-01-01T00:00:00Z).
ST 0603.2-05 (Deprecated)	The Commercial Time Stamp shall be derived from Universal Coordinated Time (UTC) without leap seconds.
ST 0603.2-06 (Deprecated)	The Commercial Time Stamp shall represent the identical time of the Precision Time Stamp within the resolution of the Commercial Time Stamp.

9 Appendix A – Revision in MISB Guidance: Rationale – Informative

Prior to MISB ST 0603.3, MISB guidance for deriving a Precision Time Stamp was predicated on: Coordinated Universal Time (UTC) as a time standard "reference"; an Epoch of midnight January 1, 1970; and, a count of the number of microseconds since 1970 (the Epoch) consistent with the POSIX standard. This guidance had the following issues:

- Issue: Leap seconds in UTC and "microseconds since 1970" are inconsistent.

  Rationale: Practically, this introduced some confusion and inaccuracies in the guidance. The Precision Time Stamp is defined as a continuous count of microseconds since the Epoch; however, some implementations have used UTC as the time reference, which introduces leap seconds into the Precision Time Stamp. UTC is only used to define the MISP Time System Epoch, not continuous time for implementations. Using UTC introduces the maintenance of leap seconds, which requires correcting for a current date/time accumulation of leap seconds to the time of interest. Leap second corrections are listed within a table maintained by the National Institute of Standards and Technology (NIST). Thus, deriving a timestamp from a count of seconds since an Epoch is made more complicated than desired.

- Issue: Two methods are used for computing the offset between atomic time (International Atomic Time or TAI) and UTC depending on whether the offset is computed before or after 1972-01-01T00:00:00.0.

  Rationale: Before the Epoch for UTC (1972-01-01), fractional offsets were computed and the UTC second was not equivalent to an SI Second. After 1972-01-01T00:00:00, UTC accounts for whole second offsets (leap seconds) only, and the UTC second is the SI Second. This means that basing time on UTC, yet computing time from the earlier Epoch of 1970, has a fractional component. To date, the offset used by MISB is 8 seconds (typical in common use), but the offset is more accurately 8.000082. The difference between the two time values is 82 microseconds; not a significant difference in systems fielded to date, but may become more relevant with increasingly stringent timing requirements.

- Issue: POSIX time does not include leap seconds; however, POSIX is not a linear scale of time. At leap second boundaries POSIX time may add (or subtract) one second of time. This produces a "double" (or "missing") count in time values.

  Rationale: In the POSIX standard, leap seconds are not included, thereby deviating from UTC. Keeping POSIX in synchronization with UTC – or not – is implementation dependent; different methods for performing synchronization are used. For example, by either counting an extra second and then jumping back to delete that extra count (i.e. count 0-60 instead of 0-59), or holding the count for one second at the leap second update. This results in a non-linear, non-uniform counts of time, which impacts applications when computing time differences.

- Issue: POSIX does not define the second to be based on the International System of Units (SI) second. Effectively, a second in POSIX time is different from the SI Second.

  Rationale: POSIX does not define the duration of a second. Thus, there is no guarantee from system-to-system the duration of a second is the same. Over periods of time these differences impact calculations. Considering the goal is to define a measurement of time (i.e. the Precision Time Stamp) to mark temporal events, so that calculations on collected data can be facilitated accurately, the pre-advised use of POSIX time does not serve this intent, where computing differences in timestamps may be in error by as much as one second. With technology progressing in higher image densities and frame rates, and the associated maturation of data-processing algorithms, accurate timestamps are increasingly becoming more important.

Changes to the guidance creates the following issue regarding the Universal Label (UL) for the Precision Time Stamp:

- Issue: Within the SMPTE RP210v13 dictionary, the assigned key for the Precision Time Stamp carries the name “POSIX Microseconds.”

  Resolution: In RP210v10 the name was “User defined Time Stamp – microseconds since 1970.” This definition is consistent with the new guidance; the later definition in RP210v13 introduces confusion. Assuming this key name remains, the recommendation is to interpret this key name to mean “microseconds as referenced to the POSIX Epoch”. The POSIX Epoch is the same as the UNIX Epoch, which is the same Epoch in the MISP Time System. Nothing has changed across all ST 0603 versions regarding the Epoch. With this interpretation POSIX Microseconds is a count of microseconds since the POSIX Epoch – which is effectively the guidance found in ST 0603.4.

Other changes:

Earlier versions of MISB documents, such as ST 0601, refer to UTC, POSIX and UNIX timestamp almost interchangeably; these documents were authored prior to the introduction of the Precision Time Stamp. Most, if not all, of these documents have been updated to use terminology consistent with ST 0603.4. Be aware when referring to these earlier documents of these differences.

Please consult the Motion Imagery Handbook [2] for a more thorough discussion on time systems and the recommendations made in this document.