MOTION IMAGERY STANDARDS BOARD	MISB ST 0603.2
STANDARD	
Common Time Reference for Digital Motion Imagery Using Coordinated Universal Time (UTC)	**27 February 2014**

1 Scope

An absolute, reliable, common time reference is essential in time stamping 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 UTC as the deterministic common time reference for correlating both uncompressed and compressed motion imagery and metadata. Conversion from UTC to POSIX time and SMPTE time code is discussed along with suggested methods.

2 References

2.1 Normative Reference

The following references and the references contained therein are normative.

[1] Assistant Secretary of Defense for Command, Control, Communications and Intelligence, *Global Positioning Standard Positioning Service Performance Standard*, 4^{th} Ed. Sep 2008

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

[3] SMPTE RP 210.13, Metadata Elements Dictionary, Feb 2012

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

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

3 Terms and Definitions

Accuracy The statistical difference between a measured or computed value of a physical quantity and the standard or accepted value for that quantity.

Precision The ability of a measurement to be consistently reproduced.

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

4 Abbreviations and Acronyms

GPS Global Positioning System
UTC Coordinated Universal Time
TAI International Atomic Time

5 Revision History

Revision	Date	Summary of Changes
0603.2	02/27/2014	• Revised to conform to EARS for requirements • Modified guidelines for Commercial Time Stamp • Added definitions • Incorporated language from MISB ST 9715

6 Introduction

This Standard specifies both an absolute time stamp – the Precision Time Stamp, and a relative time stamp – the Commercial Time Stamp for time stamping motion imagery and metadata both derived from Coordinated Universal Time (UTC). The relationships among GPS, UTC and the two time stamp types are shown in Figure 1.

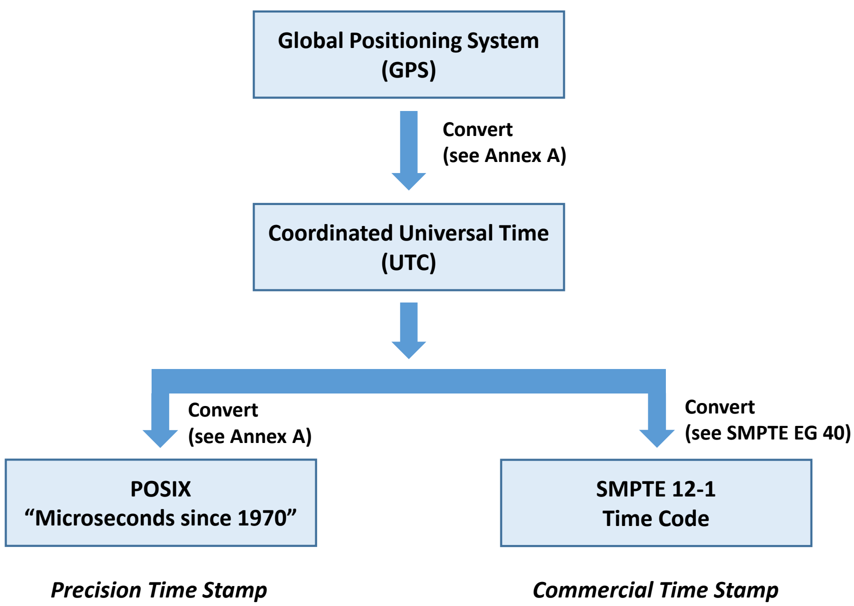

Figure 1: Time Stamp Types Derived from GPS/UTC

7 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 video 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.

The use of UTC – derived from GPS – as the common time reference for time stamping motion imagery and metadata enables frame-accurate temporal fusion of motion imagery streams from multiple sensors located worldwide.

7.1 GPS

GPS provides position and time information enabling geo-location anywhere on the earth. The GPS system consists of a constellation of satellites orbiting the earth, where each satellite transmits frequency, time and date information to airborne and ground based GPS receivers.

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

7.2 Deriving 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 changes in the earths' orbit and adoption of changes in the duration of the TAI second, GPS time reference is no longer exactly the same as UTC time reference, differing by discrete time offsets known as "leap seconds", which are updated periodically by US and international standards bodies. UTC accounts for leap seconds and are added to adjust for slowing of the Earth's rotation due to tidal and lunar effects. Since the GPS signal went online there have been 15 leap seconds (approximately one leap second occurs every 18 months), which means GPS time is exactly 15 seconds slower (as of 1 January 2009) than UTC. Most GPS time server systems account for this 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.

UTC shall be used as the timing reference source for deriving the timestamps defined in this standard.

Requirement	
ST 0603.2-01	Coordinated Universal Time (UTC) [1] shall be the time reference source for deriving the time stamps defined in this Standard.

ST 0603.2-02	The US Global Positioning System (GPS) shall be the authoritative time reference source for UTC.

Annex A provides a method to convert GPS to UTC.

8 Time Stamps – Types

A Time Stamp is a sampling of a time reference, which represents a specific instant in time limited to the resolution of the clock sampled. There are two types of time stamps defined in this Standard: 1) Precision Time Stamp and 2) Commercial Time Stamp.

8.1 Precision Time Stamp

The Precision Time Stamp is a 64-bit unsigned integer representing the "Microseconds since 1970" derived from UTC. This is similar to the POSIX time and has the same epoch (starting point). Note: the rollover date is half a million years away (584,942 years away). The Precision Time Stamp is foundational to all MISB Standards and guidelines. It provides sufficient temporal resolution to time stamp imagery and metadata events in high frame rate motion imagery.

Annex A provides a method to convert UTC to the number of "Microseconds since 1970".

Requirement	
ST 0603.2-03	The Precision Time Stamp shall be derived from Universal coordinated time (UTC).
ST 0603.2-04	The Precision Time Stamp shall be a 64-bit unsigned integer representing "Microseconds since 1970".

Systems that time stamp motion imagery and metadata with a Precision Time Stamp will have differing requirements for the precision and accuracy of the time stamp. Such metrics should be specified so that users of the data understand what can be expected in data analysis.

The Precision Time Stamp is not recognized by commercial tools, such as a video editor. Motion imagery in government applications requires knowledge of when the motion imagery and metadata are captured; the Precision Time Stamp provides this necessary information.

8.1.1 Time Stamp Status

The Time Stamp Status is a one-byte value that provides additional information regarding the source of timing reference for a time stamp. The Time Stamp Status, as defined in Table 1, is typically inserted into motion imagery essence streams along with the Precision Time Stamp. The Precision Time Stamp is often derived from a local clock reference, which is either synchronized with the UTC reference (i.e. locked), or is operating as a systems-internal free running oscillator (clock). Bit 7 of the Time Stamp Status signals this condition. Bit 6 indicates that time is incrementing properly, or if there is a discontinuity in the clock source; such as either a forward or reverse jump due to relocking the clock to a UTC source or other correction. Bit 5 signals either a forward or backward increment in the time reference so that systems which are assuming the time source is a monotonically increasing value can properly handle this discontinuity.

Table 1: Time Stamp Status

	Source Time Reference Status (Byte value)	
bit 7	0 =	Locked to valid UTC reference (internal oscillator clock locked to UTC)
	1 =	UTC Lock Unknown (internal oscillator clock not locked to UTC)
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 Time Stamp Status may be embedded within other data constructs as a one-byte value, or at an individual metadata element.

8.2 Commercial Time Stamp

Time code was developed by the commercial broadcast industry for content manipulation, non-linear editing and playback, and is the principle timing reference in those systems. One example is the SMPTE ST 12-1[4] time format HH:MM:SS:FF (hours:minutes:seconds:frames). The resolution of time code is one video frame; thus it is a coarser timing indicator than the Precision Time Stamp. It also is a count that rolls over periodically, so it is not date sensitive. Because of its limited nature, time code is not used as the time reference for motion imagery and metadata; this is the function of the Precision Time Stamp.

In this Standard, time code is designated as the Commercial Time Stamp, and although it is an optional time stamp its inclusion in a motion imagery stream is recommended. The Commercial Time Stamp is derived from the same UTC reference source used to produce the Precision Time Stamp. SMTPE EG 40[5] describes an algorithm for converting UTC to SMPTE ST 12-1 time code. It should be noted that commercial tools – if used – may alter time code during editing; thus, there is no guarantee that the time code value as inserted will persist.

The following summarizes the limitations of the Commercial Time Stamp:

- The accuracy of the Commercial Time Stamp is limited to a motion imagery frame.
- The Commercial Time Stamp is a relative time, not absolute and generally not persistent.
- When a video is edited, the time code often may be modified.

Requirement	
ST 0603.2-05	The Commercial Time Stamp shall be derived from Universal coordinated time (UTC).

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 12-2 [4].

Annex A - Time Conversion – Informative

GPS Time to UTC Conversion

Some receivers provide only GPS Week and GPS Seconds parameters. The offset of GPS Seconds is defined relative to the beginning of the current GPS week. GPS time is referenced to a UTC zero-time point originally defined as midnight (00:00 UTC) before the morning of 1980-01-06. The GPS Week parameter is 10 bits where weeks range modulo 1024, so the GPS week cycle is 1024 weeks (7168 days, or 19+ years); the latest zero point was 1999-08-22 00:00 GPS time (more modern GPS navigation systems use a 13-bit field that repeats every 8,192 weeks.) The following algorithm provides for calculation of the date and time to within one second (further precision may require provisions such as a local oscillator synchronized to the GPS signal):

Formula: UTC = GPS - leap seconds

Since,	GPS =	GPS Week + GPS Seconds + 1999-08-22 00:00
Then,	UTC =	(GPS Week + GPS Seconds) + 1999-08-22 00:00 – leap seconds
	=	GPS Week + (GPS Seconds – leap seconds) + 1999-08-22 00:00

Algorithm:

```
/* If (GPS Seconds - leap seconds) < 0, add in one week to the
GPS Seconds count and subtract one week from GPS Week count
(avoids negative time) */

If (gpsSeconds - Leap_Seconds) < 0
      gpsSeconds = gpsSeconds + (7 × 24 × 60 × 60) /* add week */
      gpsWeek = gpsWeek - 1   /* subtract week */
End If

tmpBeginning_of_current_week = (7 × gpsWeek) + 1999-08-22 00:00
tmpDay_of_week = (gpsSeconds - Leap_Seconds) / (24 × 60 × 60)
tmpSeconds_from_midnight = (gpsSeconds - Leap_Seconds) %
(24×60×60)
utcCurrent_date = tmpBeginning_of_current_week + tmpDay_of_week
utcHours = tmpSeconds_from_midnight / (60×60)
utcMinutes = (tmpSeconds_from_midnight % (60×60)) / 60
utcSeconds = tmpSeconds_from_midnight % 60

Where,   ×   is multiplication
         /   is integer division without rounding
         %   is the modulus operator (remainder after integer
             division)
```

Reformatting of UTC to "Microseconds since 1970"

"Microseconds since 1970" is a MISB-coined term that describes a machine readable unsigned 64-bit integer that represents the number of microseconds since midnight January 1, 1970. "Microseconds since 1970" can be used to correlate video, audio, and metadata time stamps. Note: All computers do not implement "Microseconds since 1970"-01-01 00:00 identically, so this count must regularly be recalibrated to UTC by adjusting the computer real-time clock.

The following algorithm can be used to reformat UTC to "Microseconds since 1970" to within one second (further precision may require provisions such as a local oscillator synchronized to the GPS signal):

Algorithm:

```
tmpYears      =  utcYears - 1970
tmpDays       =  utcDay_of_year + Leap_days + (365 × tmpYears)
tmpSeconds    =  (24 × 60 × 60 × tmpDays) + (60 × 60 × utcHours)
                 +(60 × utcMinutes) + utcSeconds
tmpMicrosec   = (1,000,000 × tmpSeconds)
Microseconds  = tmpMicrosec + utcMicroseconds

Where,   1) Leap_days occur in tmpYears divisible by 4 except
            tmpYears divisible by 100; but do occur in tmpYears
            divisible by 400.

         2) utcMicroseconds = 0, if unavailable
```