MISB Motion Imagery Standards Board **STANDARD** **Common Time Reference for Digital Motion Imagery Using Coordinated Universal Time (UTC)**	**MISB STD 0603.1** **9 June 2011**

1 Scope

Digital motion imagery is employed by the Department of Defense (DoD) / Intelligence Community (IC) for a wide range of applications throughout the world and is correlated with information from many sources including other motion imagery systems, other sensor systems, other intelligence systems, and DoD services' operations. Time is one critical reference to correlate information from these systems and operations. The DoD/IC community uses Coordinated Universal Time (UTC) as a common time reference.

This Standard defines the use of UTC as the deterministic common time reference for correlation of motion imagery frames and metadata and to facilitate interoperability among DoD/IC systems and other systems.

There are two objectives for implementing a deterministic common time reference in digital motion imagery systems:

1) Correlation of digital motion imagery frames with the sensor/platform metadata to produce metadata associated with each motion imagery frame selected. Examples include: image center and other metadata for frames for situational awareness and precision metadata for frames to perform photogrammetric analysis and targeting mission support.
2) Interoperability and exchange of common time referenced motion imagery and motion imagery products with other sensor systems, other collection systems, other intelligence systems, and the war fighter. Examples include: cooperative motion imagery sensors/platforms supporting a single mission objective, and multi-INT exploitation of digital motion imagery with other intelligence or information sources.

This Standard is designed to be the parent document of a series of MISB documentation for time stamping uncompressed, compressed and other motion imagery formats as illustrated in Figure 1. The child documents contain specific time stamp formatting requirements.

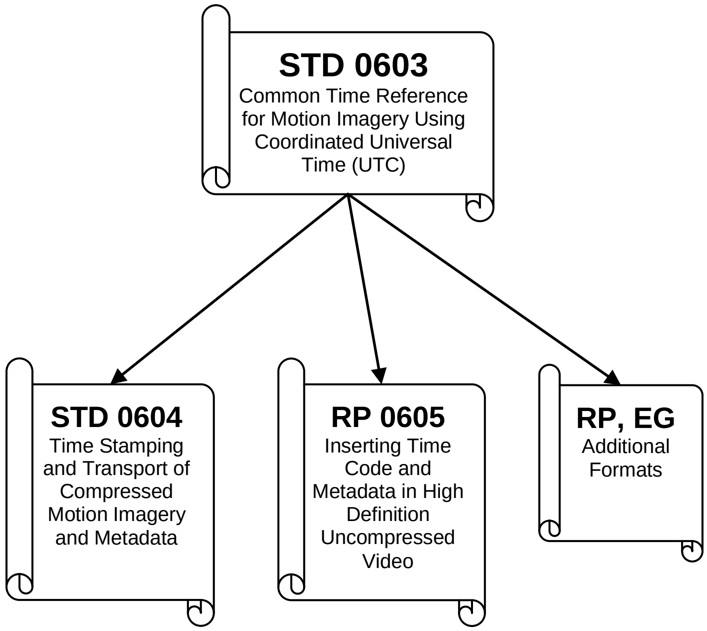

Figure 1 - Time Stamping Document Structure

2 Normative References

[1] Assistant Secretary of Defense for Command, Control, Communications and Intelligence, *Global Positioning Standard Positioning Service Performance Standard*, Sep 2008

[2] MISB STANDARD 9708, *Imbedded Time Reference for Motion Imagery Systems*

[3] MISB STANDARD 9715, *Time Reference Synchronization*

[4] SMPTE 12M-1-2008, *Television, Time and Control Code*

[5] SMPTE 309M-1999, *Transmission of Date and Time Zone Information in Binary Groups of Time Control Code*

[6] MISB STANDARD 0605.3, *Inserting Time Code and Metadata in High Definition Uncompressed Video*, Jun 2011

[7] MISB STANDARD 0604.2, *Time Stamping and Transport of Compressed Motion Imagery and Metadata*, Jun 2011

[8] SMTPE EG40-2002, *Conversion of Time Values between SMPTE 12M Time Code, MPEG-2 Program Clock Reference (PCR) Time Base and Absolute Time*

3 Introduction

This Standard identifies time stamping objectives and practices for real-time insertion of required time stamps into streaming motion imagery and associated metadata. Technical implementation details for each system implementation are within the system engineering “trade space” for each system and each system’s mission requirements. These implementation decisions will drive the system complexity, performance, cost and size/weight/power. Specific implementation decisions will determine the accuracy and precision with which motion imagery and associated metadata needed to meet mission requirements such as war fighter situational awareness, intelligence imagery exploitation, operational targeting missions, library services, etc.

Figure 2 illustrates the relationships of the time references and formats defined in this Standard.

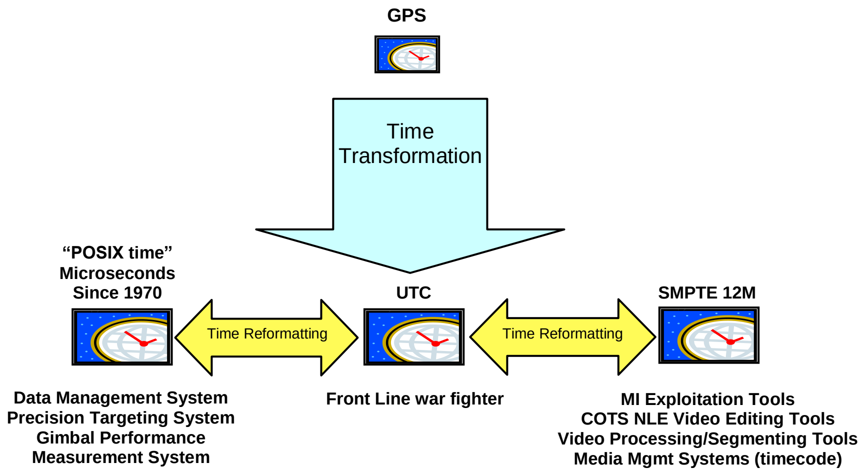

Figure 2 - Time Type Use Cases

UTC is the normative time reference for motion imagery systems required by this Standard. UTC is a high-precision atomic time standard used as the basis for military and legal civil time all over the Earth. UTC can be obtained from a number of sources; however, using the Global Positioning System (GPS) [1] operated by the United States is the recommended time reference source for this Standard.

This Standard specifies that the US Global Positioning System (GPS) be the authoritative time reference source for use in calculating UTC.

Annex A informatively provides a method to reformat GPS time to UTC and a method to reformat UTC to POSIX "Microseconds since 1970" time which is often used as a precision time format for metadata capture, event capture, and precise metadata calculations.

NOTE: For time stamps to be completely meaningful they must be specified with known accuracy in relation to both the imagery point of capture and the metadata point of capture. The qualification of time stamps accuracy is not well characterized presently in the MISB standards, but it is a future objective of the MISB to provide such qualifications.

4 Time Stamps Formats

This Standard identifies two time formats for use in digital motion imagery systems:

1. Commercial Time Stamp: An HH:MM:SS:FF time code generally supported by commercial video equipment. It takes a number of different formats depending on where it is being used, but one example is Society of Motion Picture and Television Engineers (SMPTE) 12M time format.

2. Precision Time Stamp: A more precise time stamp used within the MISB-supported community. This time stamp may not be supported by some commercial products. It is based on the 64-bit POSIX "Microseconds since 1970" time format used in computer-based applications.

4.1 Commercial Time Stamp

System designers should be aware of the accuracy requirements of the time stamps in their system. MISB Standard 9715 [7] "Time Reference Synchronization" states that:

> Coordinated Universal Time (UTC, also known as "Zulu"), clock signals **shall** be used as the universal time reference for DoD/IC/NSG SMPTE 12M time code systems, allowing systems using time code to accurately depict the actual Zulu time of day of motion imagery acquisition/collection/operations.

Commercial Time Stamp (time code) is a relative timing reference developed by the commercial broadcast industry for relating content in stream manipulation, editing and playback. Time code is not to be used as an absolute time reference for motion imagery and metadata; this is the function of the Precision Time Stamps discussed above. However, as more commercial equipment is leveraged into government applications, inserting time code will reduce the need for equipment manufacturers to add it downstream prior to usage within their environments.

Thus, while Commercial Time Stamps are not to be used as the correlating reference for essence streams within a transport stream program, it is **recommended** that the Commercial Time Stamp be added to each motion imagery elementary stream with a value derived from the same UTC time stamp that is used to generate the Precision Time Stamp inserted into the video elementary stream (see [14] for such conversion).

The usefulness of the Commercial Time Stamp has some limitations:

- 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.
- The Commercial Time Stamp includes a time, but not a date. The date information, if needed, must be extracted from the KLV metadata in the stream.
- The accuracy of the Commercial Time Stamp is limited to a frame.

4.2 Precision Time Stamp

The Precision Time Stamp provides for an absolute timing reference that may be traceable to UTC. It is intended to provide a higher level of accuracy and resolution than the Commercial Time Stamp, allowing it to be more useful in the post processing of video and metadata as well as in the correlation of video and metadata with other sources of information that are also referenced to UTC.

5 Timing Requirements in Legacy and Downstream Processing

- The timing data as defined by this standard **shall** be included in all <u>future</u> MISP compliant streams.
- Legacy systems are not subject to the timing requirements specified by this standard.

- For systems that process motion imagery and metadata downstream from the initial point of image capture:
  - If timing information exists in the ingest stream it **shall** not to be changed unless the timing accuracy can be improved.
  - If timing information does not exist in the stream it can either be:
    - Left out in the resulting stream. In this case, the time relationships are unknown, or
    - Estimated using other sources and inserted into the resulting stream. In this case, there are flags which **shall** be set to indicate that the time accuracy is unknown.

6 UTC from GPS as the Common Time Reference for Motion Imagery

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 with each satellite transmits frequency, time and date information to airborne and ground based GPS receivers. The use of UTC—derived from GPS—as the common time reference for time stamping motion imagery enables the frame-accurate temporal fusion of motion imagery streams from multiple sensors located worldwide.

6.1 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 enabling temporal fusion for post-mission analysis.

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 corresponding frame period of 500 to 17 milliseconds, global synchronization of shutters and time stamp can be obtained to sub-frame accuracy.

6.1.1 GPS and UTC

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 calculates for leap seconds that 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.

Many GPS receivers output UTC time and also a one pulse per second (1-PPS) synchronization signal; others output 1-PPS but report GPS time and UTC offset separately requiring an external calculation of UTC = GPS - Leap Seconds. Leap seconds are often provided by the GPS receiver. Some GPS receivers may output Inter-Range Instrumentation Group (IRIG) time formats which provide equivalent synchronization and time information.

Annex A of this document provides informative methods to convert GPS to UTC time and UTC time to "Microseconds since 1970" POSIX time format. Conversion between UTC and SMPTE 12M time code for different motion imagery frame rates can be found in [8].

7 Motion Imagery and Metadata Time Tagging

The following are requirements for all motion imagery/metadata sequences:

1. Every motion imagery frame **shall** contain a Precision Time Stamp.
2. Every motion imagery frame SHALL contain a Commercial Time Stamp (in the case of MPEG-2, every GOP Header SHALL contain a Commercial Time Stamp) [2-5].
3. The Precision Time Stamp and the Commercial Time Stamp **shall** represent the identical time (within the resolution of the Commercial Time Stamp encoding).
4. The motion imagery time stamp **shall** (to the extent possible) represent the capture time[1] of the motion imagery frame.
5. When required to be time stamped, metadata **shall** contain a Precision Time Stamp.
6. The metadata time stamp **shall** (to the extent possible) represent the time of birth of the metadata.
7. The motion imagery time stamps and the metadata time stamps s**hall** be related to the same timeline and **shall** be derived from UTC time (typically using GPS).
8. Time stamps **shall** be inserted using methods defined in [6], and [7].

[1] Note: [future] Need further metadata to refine the definition of capture time.

Annex A - Time Conversion Formulas (Informative)

1 GPS Time to UTC Conversion

Some receivers only provide 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)
```

2 Reformatting of UTC to "Microseconds since 1970"

"Microseconds since 1970" are identified as a machine readable unsigned 64 bit integer containing microseconds since midnight January 1st 1970. "Microseconds since 1970" can be utilized in synchronous systems to efficiently compare 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
Microseconds = (1,000,000 × tmpSeconds)
Where,       Leap_days occur in tmpYears divisible by 4 except
             tmpYears divisible by 100; but do occur in tmpYears
             divisible by 400.
```