1 Scope

This Recommended Practice (RP) defines methods to carry frame accurate time stamps and metadata in the Key Length Value (KLV) format within the Vertical Ancillary Data Space (VANC) of SMPTE 292M (High Definition) 720P and 1080P frame formats. The methods discussed cover both insertion and extraction of time stamps and metadata. Refer to MISB document RP 0603 for methods of time stamping metadata as output from sensor systems.

2 Introduction

The advancement of High Definition (HD) sensors and digital uncompressed video hardware and software has created the ability to carry large amounts of auxiliary data within uncompressed video frames. The additional auxiliary data space makes it possible to directly associate time and metadata together with an individual video frame. This association yields a measurable improvement over legacy uncompressed motion imagery systems, which contain no time information and spread a single metadata packet over multiple video frames.

Frame accurate alignment of the metadata to the individual uncompressed video frame provides a deterministic relationship between the metadata, the embedded SMPTE 12M timestamp, and the uncompressed frame. This deterministic relationship of the metadata to the frame enables the development and usage of highly accurate exploitation tools.

3 References

MISB 3.4 - Motion Imagery Standards Profile version 3.4 Dated 12 January 2006

MISB RP 0603 Time Stamping Digital Motion Imagery using Coordinated Universal Time (UTC)

SMPTE 12M – 1999 Time and Control Code

SMPTE RP 188 - 1999 Transmission of Time Code and Control Code in the Ancillary Data Space of a Digital Television Data Stream
4 VANC Encoding (Normative)

This section outlines the procedures and mechanisms to encode the time code and KLV metadata into the VANC of an uncompressed video frame.

4.1 Encoding and Inserting SMPTE 12M Time Code into the VANC

To ensure interoperability, a SMPTE 12M time code will be used to time tag each uncompressed video frame. The time code shall be inserted into VANC line 14 in accordance with (IAW) SMPTE RP 188. Approved methods for creating and aligning the SMPTE 12M time code to the video frame are outlined in MISP RP 0603.

4.2 Encoding and Inserting Metadata into the VANC

SMPTE RP 214 defines the VANC data packet as a 255 byte data buffer that contains a 1 byte Message ID (MID), 2 byte Packet Sequence Counter (PSC), and the raw 252 byte KLV data. See figure 4-1.

<table>
<thead>
<tr>
<th>MID</th>
<th>PSC</th>
<th>KLV Data</th>
</tr>
</thead>
</table>

255 Bytes

Figure 4-1 KLV VANC Data Packet
The following rules are used when inserting KLV metadata into the VANC:

1. KLV data is inserted IAW SMPTE RP 214

2. Message ID (MID) is populated with one of the following:
   a. Geospatial / Security Data MID will be 0x01
   b. Embedded Images MID will be 0x02
   c. Annotation Data MID will be 0x03
   d. Precise Frame Time Reference MID will be 0x04
      System specific KLV data MID will be 0x05

3. A prioritized method is applied to the order of packet encoding into single or multiple line VANC data encoding systems. This ensures that the data of the highest importance is always decoded regardless of limitations of the data encoder/decoder.

   The highest priority VANC packet is stored in the first VANC space of line 7 in both 720P and 1080P formats. The remaining VANC packets are inserted into the video frame in priority order starting with the first VANC column space of line 8 down to the “last encode line” for each picture frame while skipping line 14, which contains the SMPTE 12M time code. The encode process will continue for all remaining bytes by repeating the process and inserting the VANC packets into the next VANC column space.

   See Figure 4-2 for an illustration of the VANC Packet priority ordering.

4. The “last encode line” for each video type is:
   a. VANC line 23 for 720P
   b. VANC line 39 for 1080P
5 Uncompressed HD Motion Imagery (Informative)

Uncompressed HD motion imagery is uncompressed HD video with KLV and SMPTE12M time code embedded in the VANC. The MISB has approved the HD progressive mode standards outlined in SMPTE 296M and SMPTE 274.

5.1 HD Standards Overview

5.1.1 SMPTE 296M (720P)

SMPTE 296M is 1280 x 720 HD video contain a total of 750 data lines, where 720 lines are used to represent the uncompressed video frame. The 30 remaining lines are the Vertical Ancillary Data Space (VANC) of which 20 lines can be used to store supporting data. The lines 1-5 and 746-750 are utilized as digital buffer/synch space between the usable data lines.
5.1.2 SMPTE 274M (1080P)

SMPTE 274M is 1920 x 1080 HD video contain a total of 1125 data lines, where 1080 lines are used to represent the uncompressed video frame. The 45 remaining lines are the Vertical Ancillary Data Space (VANC) of which 35 lines can be used to store supporting data. The lines 1-5 and 1122-1125 are utilized as digital buffer space between the usable data lines.
5.2 VANC Capacity

SMPTE 291M outlines the procedures for creating and inserting VANC data packets into the VANC space. Each data packet contains 255 bytes of available space. The number of VANC data packets which can be inserted in a line is determined by the number of words in the line. The following section breaks down the 720P and 1080P capacities:

5.2.1 SMPTE 296M (720P)

A 720P frame can contain 5 VANC data packets per VANC line (255 * 5 = 1275 bytes). Therefore, each 720P can contain a maximum of 100 (20 lines * 5 Packets a line) KLV VANC packets (100 packets * 255 Bytes = 25,500 bytes).

5.2.2 SMPTE 274M (1080P)

A 1080P can contain 7 VANC data packets per VANC line (255 * 7 = 1785 bytes). Therefore, each 1080P can contain a maximum of 245 (35 lines * 7 Packets a line) KLV VANC packets (245 packets * 255 Bytes = 62,475 bytes).
6 Sample VANC Encoding System (Informative)

The following sub-sections outline three variants of sample encoding systems and the processes to encode the metadata and time code into the VANC as outlined in section 4. These variants will cover the access unit headers, which include the MID and PSC values, and the prioritization structure. The instructions outlined in MISB EG 104.4 will be used to format the geospatial metadata into KLV sets.

6.1 Sample Layout of Sensor

The following diagram outlines the reference sensor configuration used for the sample encoding systems:

![Diagram of Reference Sensor]

Figure 6-1 Reference Sensor

The HD (720P) sensor outputs a 292M video stream with the SMPTE 12M timestamp in VANC line 14 and an unformatted metadata (which is not formatted in KLV sets) stream. The sample encoding systems will format the metadata and insert it into the appropriate lines of the VANC. The resulting product will be a 292M video stream containing metadata and timecode in the VANC.

The data packets from the sensor contain basic, advanced, and photogramic level of geospatial information along with the timing down to the microseconds of each metadata packet.

6.2 Sample Single Line / Single VANC Data Packet Inserter

In this case, the system only has the capability to insert a single VANC data packet into one line of the VANC. The system designers have determined the following KLV packets are essential for operational purposes:

**Note:** Values in parenthesis are the number of bytes required for each element.
1. Security Universal Set (K = 16, L = 1)
   a. Classification Banner (K = 16, L = 1, V = 14)
2. Predator Universal Set (K = 16, L = 1)
   a. User Defined Timestamp (K = 16, L = 1, V = 8)
   b. Frame Center Latitude (K = 16, L = 1, V = 8)
   c. Frame Center Longitude (K = 16, L = 1, V = 8)
   d. Frame Center Altitude (K = 16, L = 1, V = 8)
   e. Device Latitude (K = 16, L = 1, V = 8)
   f. Device Longitude (K = 16, L = 1, V = 8)
   g. Slant Range (K = 16, L = 1, V = 4)

The combined length of the KLV data to be stored in the VANC data packet is 236. Therefore, the VANC data packet would be formatted in the following manner.

Byte 1 = 0x01 (MID for KLVA is 1)
Byte 2 and 3 = 0x0001 (First packet PSC = 1)
Bytes 4 – 239 = KLV formatted metadata as listed above
Bytes 240 – 255 = 0xFF (Filler Bytes)

The VANC data packet is then inserted into line 7 of the video frame containing a SMPTE timecode (on line 14) which matches the timestamp in the User Defined KLV packet. This is shown in Figure 6-2: Single VANC Packet (720P) in Video Frame.
6.3 Sample Multiple Line / Single VANC Data Packet per Line Inserter

In this case, the system has slightly more capability than the previous encoder because it has the ability to insert a single VANC data packet into multiple lines of the VANC.

The system designers have determined to implement the entire EG 104 Predator KLV metadata set and portions of the EG 102 KLV Security metadata set. The implemented portion of the Security KLV set requires 48 bytes and the implemented Predator KLV set requires 1143 bytes. The entire KLV set will require 1191 (48 + 1143) bytes of VANC storage space, which would need to be spread out across five VANC packets.

The system designers have determined the security, timestamp, and frame center points outlined in sections 6.2 are of the highest priority. Therefore, the KLV sets will be built to first data packet will be formatted in the same manner as the VANC data packet outlined in Section 6.2:

Byte 1 = 0x01 (MID for Geospatial / Security metadata is 1)
Byte 2 and 3 = 0x0001 (First packet PSC = 1)
Bytes 4 – 255 = KLV formatted metadata

The second data packet contains additional Predator KLV data prioritized by the encoding system. The data packet is formatted as:

Byte 1 = 0x01 (MID for Geospatial / Security metadata is 1)
Byte 2 and 3 = 0x0002 (Increase PSC)
Bytes 4 – 255 = KLV formatted metadata

VANC data packets three and four are formatted in an identical manner with the PSC incrementing for each data packet.

The fifth data packet will be formatted in a similar manner as packets one thru four with the exception of the filler bytes. The data packet is formatted as:

Byte 1 = 0x01 (MID for Geospatial / Security metadata is 1)
Byte 2 and 3 = 0x0005 (Increase PSC)
Bytes 4 – 186 = KLV formatted metadata
Bytes 187 – 255 = 0xFF filler bytes

The newly constructed data packets are inserted into the VANC starting with line 7 by matching the SMPTE time code in line 14 for the video frame to the time code in the User Defined Timestamp. This is shown in Figure 6-3: Single VANC Packet (720P) on Multiple Lines.
6.4 Sample Multiple Line / Multiple VANC Data Packets per Line Inserter

In this case, the system has the highest level of capability. It can insert multiple VANC data packets into each line of the usable VANC space. This system is designed to use multiple types of KLV sets and system specific KLV data.

The system designers have determined the need for the following KLV datasets to be utilized:

1. RP 0602 Annotation Universal Metadata Set
2. EG 104 Predator KLV metadata set
3. EG 102 KLV Security metadata set

System requirements:

1. Mechanism to mark an Annotation as high priority.
2. Use the entire EG 104 Predator KLV metadata set.
4. Use system specific KLV keys (High level photogramic data).

The system requirements and design dictated that there are two KLV insertion scenarios. The first is when there is no “High Priority” Annotation and the second is when there is “High Priority” Annotation.
Scenario One – No “High Priority” Annotation:

The system designers have determined the security, timestamp, and frame center points outlined in sections 6.2 are of the highest priority. Therefore, the first data packet will be formatted in the same manner as the VANC data packet outlined in Section 6.2:

Byte 1 = 0x01 (MID for Geospatial / Security metadata is 1)
Byte 2 and 3 = 0x0001 (First packet PSC = 1)
Bytes 4 – 255 = KLV formatted metadata

The second data packet contains additional Predator KLV data prioritized by the encoding system. The data packet is formatted as:

Byte 1 = 0x01 (MID for Geospatial / Security metadata is 1)
Byte 2 and 3 = 0x0002 (Increase PSC)
Bytes 4 – 255 = KLV formatted metadata

The third data packet contains system specific KLV data and is prioritized above the remaining Geospatial metadata elements.

Byte 1 = 0x04 (MID for System specific is 5)
Byte 2 and 3 = 0x0001 (First packet PSC = 1)
Bytes 4 – 242 = KLV formatted metadata
Bytes 243 – 255 = 0xFF (Filler Bytes)

The fourth data packets contain the first of the Annotation data sets.

Byte 1 = 0x03 (MID for Annotation data is 3)
Byte 2 and 3 = 0x0001 (First packet PSC = 1)
Bytes 4 – 235 = KLV formatted Annotation metadata
Bytes 236– 255 = 0xFF (Filler Bytes)

VANC data packets three and four are formatted in an identical manner with the PSC incrementing for each data packet for each data packet based off the MID.

The newly constructed data packets are inserted into the VANC starting with line 7 by matching the SMPTE time code in line 14 for the video frame to the time code in the User Defined Timestamp. This is shown in Figure 6-3: Single VANC Packet (720P) on Multiple Lines.
Scenario Two – “High Priority” Annotation:

The “High-Priority” Annotation data is inserted into the first data packet of the VANC.

Byte 1 = 0x03 (MID for Annotation data is 3)
Byte 2 and 3 = 0x0001 (First packet PSC = 1)
Bytes 4 – 235 = KLV formatted Annotation metadata
Bytes 236– 255 = 0xFF (Filler Bytes)

All other VANC data packets would be formatted as in scenario one but inserted after the “High priority” Annotation packets.


7 Sample VANC Decoding System (Informative)

The following section will outline informative procedures to decode the time code and KLV metadata from the VANC data packets.

7.1 Sample Flow Diagram of Decoder

The basic flow of the decoder is outlined in Figure 7-1.

![Figure 7-1 Decoder Flow Diagram](image)

7.2 Decoding SMPTE 12M time code from the VANC

The SMPTE 12M timecode will be decoded from line 14 of the VANC IAW with SMPTE RP 188.

7.3 Decoding Metadata from the VANC

The VANC decoder software is responsible for reassembling the KLV data packets by utilizing the MID and the PSC and then parsing the KLV datasets.
The decoder software can use any method of pulling the data out of the VANC. However, for decoders that can only parse one VANC data packet, the packet on line 13 shall be the one it will decode.

The sample decoder follows the following procedures to decode the VANC data:

1. Retrieve the SMPTE timecode from line 14 and decode it IAW with SMPTE RP 188
2. Steps through the VANC lines 13 to 7 and remove the VANC data packets
3. Sort the packets into separate buffers based on the MID
4. Order the VANC packets in each MID buffer based on the PSC code
5. Send the ordered buffers to the appropriate KLV Parsers

8 Reference Implementations (Informative)

Sections 8.1 and 8.2 provide details on the data and video signal flows used for the development of a proof-of-concept demonstration. This proof-of-concept demonstrated injection and extraction of time stamped metadata and video in the VANC of a SMPTE 292M HD-SDI baseband video signal. The resolution of the video source was serial digital high definition (HD-SDI) at a resolution of 720x1280 lines scanned progressively. SMPTE 12M time code locked to GPS was injected into line 14 of the VANC. A metadata emulator, functioning as the digital MI sensor, supplied the raw set of geospatial data originally captured during a live airborne collection exercise. The multiplexer function is to inject the data into the VANC following KLV formatting, and then extract the data for presentation and analysis.

This section outlines the reference implementation utilized to conduct the research into writing this standard.
8.1 Data Encode

Figure 8-1: SMPTE 12M Data Encode Flow Diagram

8.2 Data Decode

Figure 8-2: SMPTE 12 M Data Decode Flow Diagram

9 Glossary of Acronyms

C4ISR: Computers, Intelligence, Surveillance, Reconnaissance
DF: Drop Frame Time Code
EG: Engineering Guideline
Fps: Frames per Second
GPS: Global Positioning Satellite
IRIG: Inter-Range Instrumentation Group
LTC: Longitudinal Time Code
MI: Motion Imagery
MISP: Motion Imagery Standards Profile
NDF: Non-Drop Frame Time Code
NLE: Non-linear Editor
RP: Recommended Practice
UTC: Coordinated Universal Time (“Zulu Time”)
VANC: Vertical Ancillary Data
VTR: Video Tape Recorder