CHAPTER 10 RECORDING STANDARD UPDATE

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ABSTRACT

The IRIG 106 Chapter 10 Standard has evolved significantly since its inception. This paper covers the background, technology, status, users, supporting vendors and future considerations such as ground-based recording and archiving. Also covered are samples of toolsets available for troubleshooting, validation, data processing and display of Chapter 10 data.

Keywords: IRIG 106 Chapter 10; Solid State Recorders; Archiving; Airborne Recording; Ground Recording; STANAG

INTRODUCTION

Chapter 10 of the United States Range Commanders Council (RCC) Inter-Range Instrumentation Group (IRIG) 106-05 Telemetry Standards defined a Digital On-Board Recorder Standard that is quickly evolving in use throughout the flight and weapons test industries. This standard includes a definition for multiple characteristics of a recorder, most significantly the data format for aggregating a variety of signal types, including PCM, discrete data, computer generated data, audio, video, and other analog or digital signals. The standard defines how signals are to be multiplexed, thus assuring that other standard compliant recorders, playback systems, and software packages for analysis and replay are always able to correctly interpret and reconstruct the original signals while preserving time coherency between the multiplexed channels.

Among issues that impelled the creation of the IRIG 106 Chapter 10 standard were the

- conflicts between multiple proprietary formats in tape recorders (e.g., DCRsi, MARS-II, DATaRec-2, DATaRec-3, etc.);
- increasing rate failures of legacy data acquisition systems (e.g., data loss by legacy tape based recorders during high-G aircraft maneuvers);
- proliferations of vendor unique recorders and ground stations;
- lack of interoperability amongst the proliferation; and,
- cost to convert legacy data archives for long-term retention.

In addressing the issues, the team that created the standard had as their vision the assurance of interoperability for on-board data and video recorders from multiple vendors across the varied U.S. Department of Defense (DoD) branches, supporting common tools and processes, the implementation of a true hardware and software interoperability and reuse capability, and, ultimately, lifecycle cost reduction.

Following its release as a standard in 2005, IRIG 106 Chapter 10 has been quickly adopted for use by test operations at numerous international facilities, including those supporting testing of –

- U.S. B-1 and B-52 bombers;
- U.S. fighter programs including platforms such as the A-10, F-15, F-16, and F-35;
- U.S. helicopter platforms (e.g., Apache Longbow);
- U.S. transport platforms (e.g., C-130);
- Japan Defense Agency F-15 Flight Test;
- Korea Aircraft Industries T-50 Trainer;
- Israeli Air Force; and,
- Several Boeing Company programs (including the Airborne Laser aka ABL).

With the user community being the primary forcing function for the implementation of the IRIG 106 Chapter 10 standard, multiple vendors have incorporated the standard in their product lines. Among those now advertising IRIG 106 Chapter 10 standard compliant recorders are Ampex Data Systems, Enertec SA, Heim Data Systems, Inc., Orbital Network Engineering, and Teletronics Technology Corporation, among others. Interestingly, many of these vendors utilize solid state memory modules from common original equipment manufacturers (OEMs), such as M-Systems. Hence, some solid state memory OEMs have also begun to advertise availability of IRIG 106 Chapter 10 compliant support.

CHAPTER 10 TECHNICAL OVERVIEW

The title of Chapter 10 was changed in the IRIG 106-05 release to “DIGITAL ON-BOARD RECORDER STANDARD”. This change occurred as the scope of the standard was revised to add coverage for recorders that were not based on only Solid State media – recorders are now being produced that utilized traditional disk and tape media.

The standard specifies several requirements for a digital on-board recorder. These include the interface to control the recorder, providing setup information, and downloading the recorded data streams. The standard also specifies the data format definitions for the various data types, and the organization of this data as presented at the recorder download interface. Media declassification is also covered in the standard.

A recorder is required to have a data download port consisting of either Fibre Channel or IEEE-1394B. Additionally, if the recorder contains removable media, its download interface is defined as IEEE-1394B.

A recorder must have discrete control lines for Record, BIT, Erase, and Declassify, and status lines for Record, Fault, BIT, Erase, and Declassify. It must also have a serial communications interface that supports both RS-232 and RS-422 full duplex. This interface supports ASCII commands for recorder control as defined in Chapter 8 of IRIG 106-05.

The download interface presents a standard file system view, operating system independent, of the recorded data adopted from STANAG 4575. This file system consists of a directory containing one or more directory blocks with file entries, followed by the data files themselves. The layout of this information across the media is based on Logical Block Addresses, where each Logical Block has a size in bytes, such as 512, for example. Logical Block 0 is reserved, and the directory starts at Logical Block 1. Each directory block contains the Volume Name, the Number of File Entries, Forward and Reverse Links to additional directory blocks if required, and the File Entries themselves. Each File Entry contains the File Name, File Start Block Address, File Block Count, File Size in bytes, and date and time information. The byte ordering of the STANAG file system utilized by Chapter 10 is Big Endian for the Directory, and Little Endian for the file data.

Some considerations in using a STANAG file system are –

1) Each file is a series of contiguous Logical Blocks with no gaps, so appending is only possible for the last file;
2) If a file is deleted, only a file of equal or smaller size can occupy the space given up by the deleted file;
3) There is no directory hierarchy for the files, so no folder abstraction exists;
4) An operating system (e.g., Microsoft Windows or LINUX) do not provide intrinsic STANAG file system support, so blocks must be processed as a raw device; and,
5) File names are a maximum of 56 characters in length.

When downloading files to the host computing system, the volume name in the STANAG directory block will be used for the directory or folder name. The file name will follow the format "filexxxx_<file create date>_<file create time>_<file close time>.ch10", where xxxx is the sequential file number of the file entry in the directory block. The date is in the format DDMMYYYY, and the times are in the format HHMMSSss. The file name extension can be .c10 if the file system only allows three characters.

A Chapter 10 data stream consists of packets of various types that follow one another in sequence. The first packet must be an IRIG 106 Chapter 9 Telemetry Attributes Transfer Standard (TMATS) setup packet, the next packet must be a time packet, and the third and subsequent packets consist of various types, depending on the data types being recorded. Each packet has three parts, a Packet Header, a Packet Body, and a Packet Trailer. Optionally, a Packet Secondary Header can be used. The Packet Header is 24 bytes long, consisting of a Packet Sync Pattern 0xEB25, a Channel ID, the Packet Length, the Data Length, the Header Version, the Channel Sequence Number, Packet Flags, a Relative Time Counter, and the Header Checksum. The Channel ID is a number unique to the channel. If more than one multiplexer is used, a specified number of most significant bits of the Channel ID are used for the multiplexer number. The number of bits reserved is defined in the setup record. The Packet Length is the length of the entire packet in bytes. The Data Length is the number of bytes of actual data and control information in the Packet Body. The Header Version indicates the version of the standard used for this packet. The Sequence Number is a one byte incrementing number for each channel that starts again at 0 after 255 is reached. It is not required to start at zero. The Packet Flags indicate information about the content and format of the packet, such as the presence of the Packet Secondary Header, a Data Overflow Error, and Data Checksum existence. The Data Type indicates which type of packet, such as PCM, 1553 Bus, Analog, etc. The Relative Time Counter is a 48-bit free running 10 MHz counter common to all data channels belonging to the same multiplexer. The Header Checksum is a 16-bit arithmetic sum of all 16-bit words in the header except for the checksum itself. The Packet Body content is dependent on the data type of the packet. Some have Channel Specific Data Words, Intra-Packet Time Stamps, and Intra-Packet Data Headers. The Packet Trailer is used to provide an optional Data Checksum and maintain a 32-bit alignment boundary for packets. The Data Checksum, if present, can be 8, 16, or 32 bits.

PCM Data Packets for a channel can be in one of three modes: throughput mode, packed mode or unpacked mode. The mode is indicated in the Channel Specific Data Word, which is present in every packet for the channel. In throughput mode the recorder is not frame synchronizing the data, so there is no guarantee of any alignment of the frames to the packet. Throughput mode packets do not contain an Intra-Packet Header, which contains Lock Status and the 48-bit Relative Time Counter (or Absolute Time if enabled). Packed mode and unpacked mode packets contain frame synchronized data, and both must contain the Intra-Packet Headers preceding each minor frame of PCM.

Time Data Packets occur at least once per second (if a time source other than “None”), starting with the first packet following the TMATS setup packet. This packet contains an absolute time along with an associated 10MHz Relative Time from the Packet Header. This allows the absolute time of data in a packet following the Time Packet to be computed by subtracting the relative time of the Time Packet from the relative time contained in the data packet header or Intra-Packet Header, and adding this offset to the absolute time of the Time Packet. Note that the computed time offset is not always positive, since packets may be committed to the stream out of time sequence for different data sources (channels). One important issue is how big the negative delta time is among packets. In order to perform time correlation among streams, a program processing the data needs to buffer enough in time so that proper data sequencing can be done.

If the Chapter 10 stream is being processed in real time, some latency may be attributable to waiting for the out-of-sequence data. This timing issue has been discussed, and one can expect this to be addressed in the next update to the standard. However, the standard does currently address the maximum amount time used to produce data contained in a packet to 100 milliseconds. This insures that packets, once started, will be completed in a timely fashion. Also, all generated packets must contain some data, so no empty or idle packets are allowed.

U.S. DoD Military (MIL) Standard (STD) 1553 (MIL-STD-1553) Bus Data Packets contain an integral number of bus messages, each with an Intra-Packet Header containing time and other information such as gap times and status. One Chapter 10 channel supports one 1553 bus, with the Block Status Word indicating if the message was from channel A or B.

The Analog Data Packet supports a maximum of 256 subchannels (analog inputs) in one Chapter 10 channel. It allows capturing samples at a specified maximum sampling rate or a factor of the sampling rate that is expressed as a power of 2. The actual rate achieved is the maximum sampling rate divided by that power of 2. The primary maximum sampling rate is specified in the TMATS setup record for the channel. The data in the packets may be either packed mode or unpacked mode. Unpacked data has padding bits inserted to occupy either the most significant bits or the least significant bits of a 16-bit word, depending on the packing mode. Analog Data Packets do not have Intra-packet Headers.

The Discrete Data Packet holds events that consist of one to 32 discrete states. Each event is preceded by an Intra-Packet Header containing the time stamp. Events can be triggered either by a time interval or by a state change, as specified in the Channel Specific Data Word. The states can be lsb or msb aligned in the event word.

The Computer Generated Data Packet can be four different formats. Format 0 is used for user-defined data, but only for data types not currently covered by other data types in the standard. Format 1 is used for the TMATS setup record. Format 2 is used for recording events, and Format 3 is used for a recording index.

The Aeronautical Radio, Incorporated (ARINC)-429 (ARINC-429) Data Packet contains one to 256 subchannels (ARINC-429 busses). Each 32-bit bus word is preceded by an Intra-Packet Header consisting of a subchannel id, status bits, and a gap time. The gap time represents the time from the start of the preceding bus word to the beginning of this bus word.

The Message Data Packet supports multiple subchannels of message data in a Chapter 10 channel. A Message Data Packet can contain multiple short messages, or part of one long segmented message. Each message is preceded by an Intra-Packet Header containing time and the message subchannel, status, and length. The length of a message or message segment is measured in bytes.

The Video Data Packet has two formats. Format 0 is Moving Picture Experts Group (MPEG) 2 (MPEG-2), MP@ML, transport stream at a constant bit rate. Format 1 allows the complete MPEG-2 bit streams for both program and transport, and constant or variable bit rates. Also, additional profiles and level combinations are allowed.

Image Data Packets contain one or more fixed-length segments of one or more video images. Intra-Packet Headers containing a time stamp are optional, and are specified in the Channel Specific Data Word.

The Universal Asynchronous Receiver/Transmitter (UART) Data Packet supports multiple subchannels of serial data such as RS-232, RS-422, and RS-485 in a single Chapter 10 channel. The UART ID Word indicates the subchannel, the data length of the message, and parity error status.

The IEEE-1394 (i.e., FireWire, also known as i.Link) Data Packet consists of completed transactions between nodes. Three types of packet body types are available: Type 0 is Bus Status, which will not contain an Intra-Packet Header or a transaction. Instead, the packet will contain the Channel Specific Data Word followed by one 32-bit Event Data Word indicating that a bus reset has occurred. Type 1 is Streaming Data, which will contain no Intra-Packet Header, and will have one transaction in the packet. The synchronization code will appear in the Channel Specific Data Word. Type 2 is the General Purpose packet type that holds complete IEEE-1394 packets, including header and data. Multiple transactions can be recorded in a Type 2 packet.

Parallel Data Packets are used for data from parallel interfaces, including the DCRsi interface. The Type field in the Channel Specific Data Word indicates the number of bits in the parallel data word interface (2-128), or 254 for DCRsi. No Intra-Packet Headers are used.

COMING ATTRACTIONS

The RCC Chapter 10 Recorder Standard has evolved over the past few years, and this year is no exception. Recent committee meetings have covered several new topics, and a number of these are expected in Pink Sheet in the near future. Discussions have covered adding Ground-based Recording to the standard, new data types, and live data streaming. Other changes that are coming include –

- A Data Transfer File to provide a standard way to transfer one or more Chapter 10 files from one organization to another, using media such as tape;
- Support for an optional Ethernet Data Download Interface;
- Support for U.S. DoD 16PP194 Weapons Bus data;
- Support for additional Video Data Types, an additional IEEE-1394 Data Packet Format 1, Ethernet Data Packets; and,
- Command and Control over Fibre-Channel, IEEE-1394, and Ethernet Download Port Interfaces.

In support of the above changes, a section is also being added into the standard for required TMATS setup information.

CHAPTER 10 TOOLS

The Chapter 10 Packet Viewer allows the user to view a Chapter 10 file packet by packet in a format that is easy to understand. The Packet Header fields are displayed with descriptive labels, the packet's IRIG time is computed from the relative time counter and displayed, and the packet's data is formatted. Figure 1 shows a MIL-STD-1553 bus data packet with the individual bus messages formatted and time stamped.

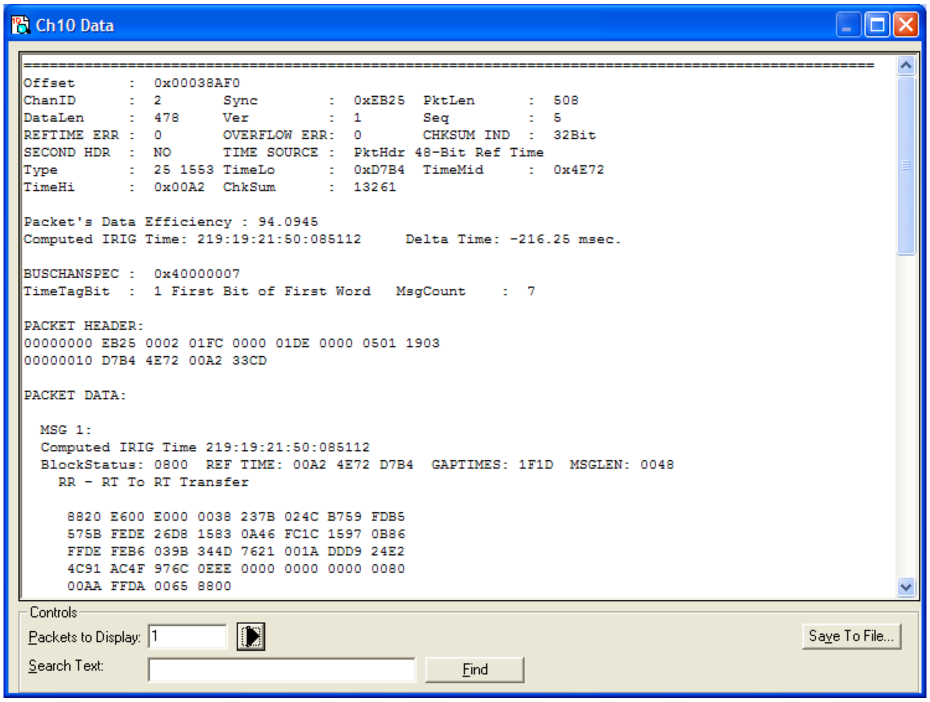

Figure 1: Chapter 10 Packet Viewer – 1553 Bus Data Packet

The Chapter 10 Validator checks a given Chapter 10 file against the data format definitions in the standard. Problems discovered are written to a log file.

The Chapter 10 Recorder Control supports all of the commands defined in the standard. It allows a computer connected to a Chapter 10 recorder over an RS-232 serial port to transmit commands and receive responses. The information transmitted over the serial link can be written to a log file.

The Chapter 10 Ingest Utility supports operation over both download interfaces of Fibre-channel or IEEE-1394B. It displays the STANAG file systems it detects, and lets the user choose one for download. The program then displays the files available in the directory, and lets the user choose which to download.

The Chapter 10 Dubbing Utility provides the user the capability to generate another Chapter 10 file that contains a subset of the original. The user may select channels of interest and time slices of interest. For Video channels, the user may choose to have separate MPEG-2 files produced. See Figure 2 for a typical Dubbing Utility session.

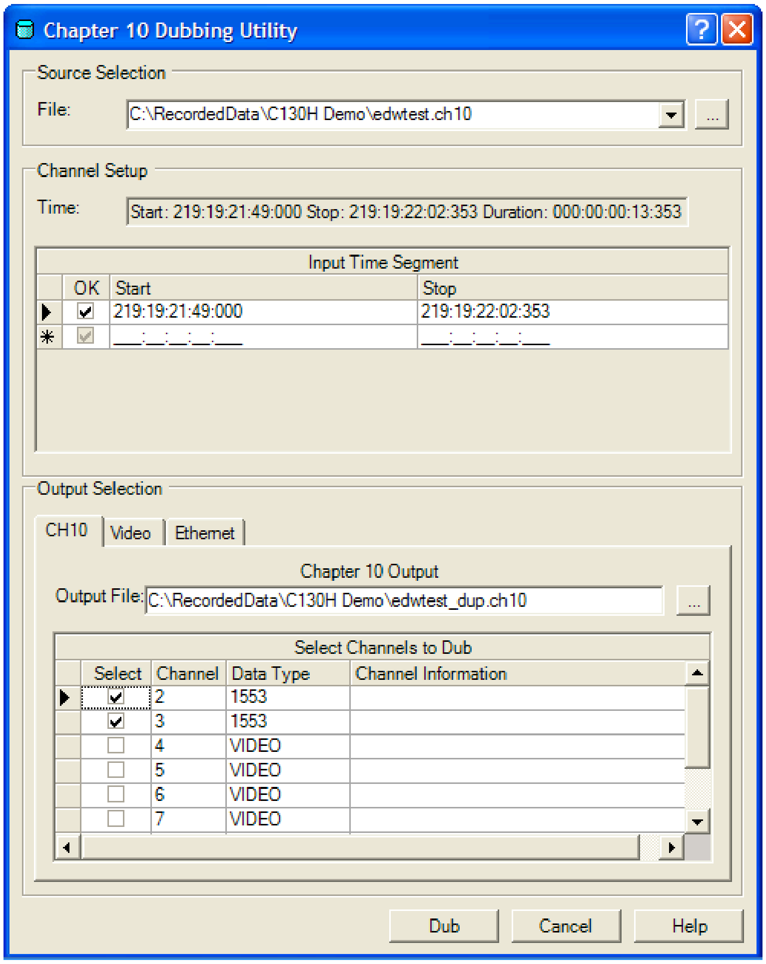

Figure 2: Chapter 10 Dubbing Utility Session

The ILIAD Chapter 10 Playback Utility allows time-aligned display of data from different channels such as PCM, 1553, Video, ARINC-429, Serial, and Analog. Typical displays include scrolling graphs, values, bar charts, strip charts, and custom widgets.

ILIAD Chapter 10 Quick Look is a post-test data processing tool that produces output of measurement data to microsecond precision in the form of reports, CSV files, or binary XDR files.

Odyssey Data Mining provides a capability to quickly search a large number of Chapter 10 files for measurement conditions of interest in a post-test environment. The results are displayed in both a tabular and graphical form. The user can then zoom into areas of interest. Figure 3 shows a screenshot of a query result, and Figure 4 is a zoom screen of one time segment.

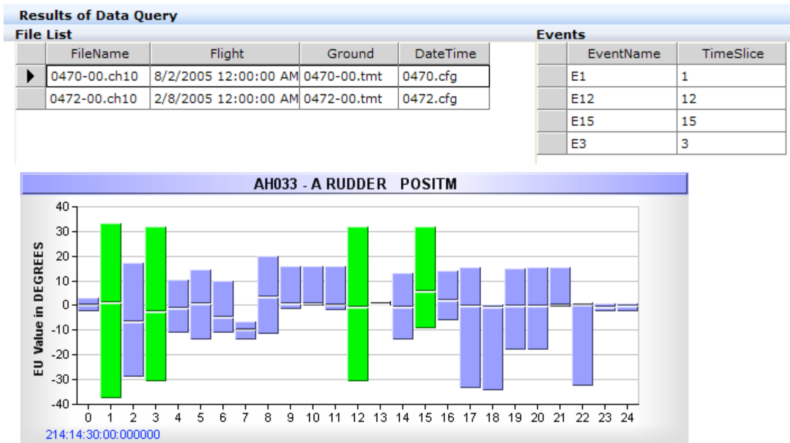

Figure 3: Odyssey Data Mining – Query Results

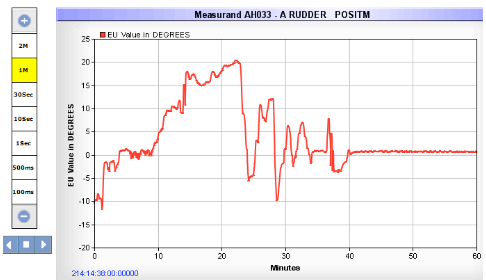

Figure 4: Odyssey Data Mining – Zoom of Time Segment

SUMMARY

The IRIG 106 Chapter 10 Standard has been gaining rapid momentum over the past few years since inception. More vendors are participating in the definition of the standard and are developing recorders for the market. The user community is adopting these recorders into many additional test programs, and software developers are producing many programs to operate with the Chapter 10 recorders and data format.

REFERENCES

[1] IRIG 106-05: Telemetry Standards, Range Commanders Council Telemetry Group, Range Commanders Council, White Sands Missile Range, New Mexico, 2005. Internet site: http://www.jcte.jcs.mil/RCC/manuals/106-05.

[2] NATO Advanced Data Storage Interface (NADSI), Standardization Agreement (STANAG) No. 4575, Edition 2, March 8, 2005, NATO Standardization Agency – Agence OTAN de Normalisation, B-1110 Brussels, Belgium. Internet site: //http:nsa.nato.int.

[3] Flight Recording Revamped, Richard Bond, Research & Development Magazine, 2006. Internet site: http://www.rdmag.com.