WHO MOVED MY TAPE RECORDER FLAVORED CHEESE

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ABSTRACT

For the last 30 years Magnetic Tape Systems have been the primary means of recording data from airborne instrumentation systems. Increasing data rates and harsh environmental requirements have often exceeded the ability of tape-based systems to keep pace with platform technology. This paper examines operational and data reduction benefits when employing the IRIG 106 Chapter 10 Solid State Recorder Standard introduced by the Range Commanders Council (RCC) Telemetry Group (TG). The Standard and this paper address media formatting, data formatting for a variety of different data types, data downloading, and data security, along with serial command and control and discrete command and control of the recorder. This paper also addresses software data processing and raw data reconstruction of Chapter 10 data.

KEYWORDS

IRIG, recorder, packet, media, data, downloading, security, reconstruction, control, processing, TMATS

INTRODUCTION

In the late 90's the 46 Test Wing Flight Test Division found itself no longer able to support its customers with traditional tape based recorder systems. Increasing data rates and harsh environmental requirements exceeded the ability of tape systems to keep pace with technology. Finding it no longer acceptable to risk missions due to limitations of commercial off the shelf devices, the 46 TW Instrumentation Division abruptly changed the method by which data was collected and adopted a Solid State Recorder (SSR) as a means of providing on board aircraft data recording. With change came the realization that traditional means of data encapsulation, reproduction, media declassification, and archiving were no longer applicable. A non-proprietary method of data encapsulation as well as method of controlling and generating archive media was needed. A digital data acquisition Solid State Recorder Standard was required allowing for multiplexing of multiple data streams while maintaining accuracy of data correlated with time. Specifically, a Solid State Recorder standard was required that was compatible with the multiplexing of both synchronous and asynchronous digital inputs such as Pulse Code Modulation (PCM) and

MIL-STD-1553 asynchronous data bus, digital voice, time, discrete, Video, analog, and RS-232/422 communication data.

Facing the prospect of proliferation of non-compatible solid- state formats, the 46 Test Wing Flight Test Division sought the help of the Range Commanders Council (RCC) Telemetry Group (TG). The RCC was established to promote inter-range operability and commonality among the DoD test ranges. These ranges—mostly members of the Major Range Test Facility Base (MRTFB)—support the RCC with membership in its several technical groups. The telemetry group (TG) is primarily concerned with the transmission, acquisition, recording, and processing of data from aeronautical test of aircraft, missiles, unmanned aerial vehicles (UAVs), projectiles, ground vehicles, sea vehicles, and other test platforms.

In the past the RCC TG had formed an ad-hoc committee to develop a computer compatible digital data acquisition standard. This product was documented as IRIG 107 (also known as Consultative Committee for Space Data Systems (CCSDS) format). Several factors prevented this standard from achieving any range interoperability. The failure of the DoD to enforce RCC guidelines in DoD 5000, undefined areas in the standard, and the quickly evolving memory technologies all led to the ineffective status of IRIG 107. With a critical need to support test programs at Eglin AFB and Edwards AFB, a new Solid State Recorder Standard was drafted resulting in the IRIG-106 Chapter 10 standard (pink sheet status). This paper describes the major attributes of the IRIG-106 chapter 10 Standard as drafted by RCC TG Recorder Reproducer Committee.

Existing Standardization Initiatives

The Recorder and Reproducer Committee of the RCC-TG, the originators of the proposed IRIG Chapter 10 Part I SSR standard, has followed the progress of the NATO Advanced Data Storage Interface (NADSI) standard, the NATO Standardization Agreement (STANAG 4575). The NADSI defines the standard for an interface to promote interoperability and to provide basic retrieve capability within a set of defined constraints for the exchange of data among North Atlantic Treaty Organization (NATO) Intelligence, Surveillance, and Reconnaissance (ISR) Systems. Many features of this standard have been incorporated into the pink sheets for the RCC-TG's Chapter 10, specifically:

- Transfer port for a memory module, which will download any data on a file-by-file basis or the full contents of the memory module to any NATO ground station.
- Download rates up to the NADSI limits with no loss of data or data integrity.
- Command and Control protocols
- Straightforward directory and file structure that must be accessible through the NADSI interface
- Fibre Channel-Arbitrated Loop with metal conductors as the interface protocol. Include set-up information, using the SCSI block protocol, and a file system like UDF2.0 or ECMA 167.
- Include additional SSR related commands such as block size.
- Recommend power be +28VDC, +12VDC, +5VDC, +3.3VDC, and +1.8VDC

A removable memory module (RMM) of the airborne recorder can be removed and attached to a ground station to allow access to the reconnaissance data. The interface defined in this STANAG provides a common connection that can be used with this RMM for most technologies. It is noteworthy to mention that the Recorder and Reproducer Committee felt the I/O connector recommendations in NADSI are too limiting and restrictive, i.e., the NADSI recommends a single D50 connector for power and data.

Declassification

NADS TST also addresses and has identified the declassification of solid state, RAID and other advanced recording technology memory elements as an important issue for the successful implementation of the NATO Advanced Data Storage Interface with NSA. The US and other potential users of this standard have raised the issues of declassification, reuse options and applicability of the erase function and format function. Erase times for the advanced technologies, which incorporate current recorder capacities can be significant. New procedures are required for implementing these sanitization recommendations. Command infrastructure and functional capability to perform the necessary operations need to be established in any system that is required to declassify data storage elements.

US documents such as NSA-130-2, DOD 5220.22 and DCI-116 historically covered declassification guidelines/requirements. These documents were focused on declassification of conventional magnetic memory technologies. The technology research and the development of suitable data sanitization methods and procedures, such as those that exist for magnetic tape and disks, is part of the NSA charter. With the advent of advanced, high-density memory technologies, additional guidance must be provided. Two interim guidelines, a 1998 revision of NSA/CSS 130-2 and a C32 Technical report from NSA, provide interim guidelines for sanitization of solid state and RAID storage systems. A new document, which addresses various solid-state, hard disk, floppy disk, RAID and other storage media sanitization, is being developed in the National Telecommunications and Information Systems Security Policy (NTISSP-9) working group for U.S. Policy. When completed, NTSSIP-9 is expected to provide specific and detailed guidance for all new technologies used in DoD systems. It is intended that this document will become the official guidance for declassifying advanced technology data storage system media when it is approved and released.

In the interim, the proposed IRIG Chapter 10 is incorporating the NADSI (STANAG 4575) declassification procedure in its entirety. Although the NADSI is still pending NSA endorsement, the processes identified forms a good baseline for vendors to use in obtaining recorder systems approval from the responsible program utilizing their product. While the formal NSA guidance is pending this procedure is been worked closely with NSA and related security organizations and is currently used by several manufacturers. One of the declassification concerns is in regards to non-data path memory. In order to comply with NSA guidelines, the declassification process should access all memory. It is recommended that a communiqué be added to the beginning to note that all non-volatile memory be accessible for this purpose.

It is of particular interest to note that NSA is looking toward “risk management vs. risk avoidance” and placing the responsibility on the Program Managers (PM) to assess the threat and take appropriate measures. NSA will provide 'guidance' but the PM's will approve procedures. One of SSR vendors, Calculex, Inc., has provided declassification procedures to the STANAG. This procedure writes 55_H followed by AA_H. This procedure also assist in identifying bad memory cell/blocks and how to determine if they are unusable, i.e., one go back to that stuck memory cell (one out of 16 in a data word) and determine if any valid data remains in that stuck cell. Meanwhile, differences in secure erase procedures continue to differ between programs and amongst commands. Due to the anticipated ratification of the STANAG and its technical documentation, Allied Engineering Documentation Publication (AEDP), in December 2002, the final declassification guidance is pending.

IRIG 106 Chapter 10 Data File and Packet Formats

Chapter 10 defines both the formats of the individual data packets, which are data type dependent, and the organization of those packets into files on the recording media.

The Chapter 10 file organization is adopted directly from STANAG 4575. This NATO standard was developed to ensure data download interoperability between recorders from multiple vendors. Three primary criteria had to be satisfied. First, the file organization on the recorder media had to be operating system independent. Ground support computers from different vendors running Windows®, Linux, Solaris™, or Irix®, for example, needed to be able to all access the media. Second, the file organization needed to support very large file sizes, to 100 gigabytes or more. Finally, the file organization needed to be independent of the block size of the recorder media.

Each directory block contains 64 bytes of common information followed by in integral number of 112-byte file entries. The number of file entries in a directory block depends on the media block size. Only complete file entries are allowed, so filler is used at the end of the block if the block size is not 64 + (N x 112) where N is an integer. The only requirements are that Block 0 is reserved, that the first directory block begin in Block 1, and that each user "data file" be stored in a contiguous sequence of blocks. Figure 1, copied directly from the STANAG 4575 document, shows both the content of a directory block and file entry. The forward and reverse chain pointers in the directory blocks enable the second and subsequent directory blocks to be located anywhere on the media. The use of a single starting block pointer for each file entry in the directory block forces each file to be recorded in contiguous blocks.

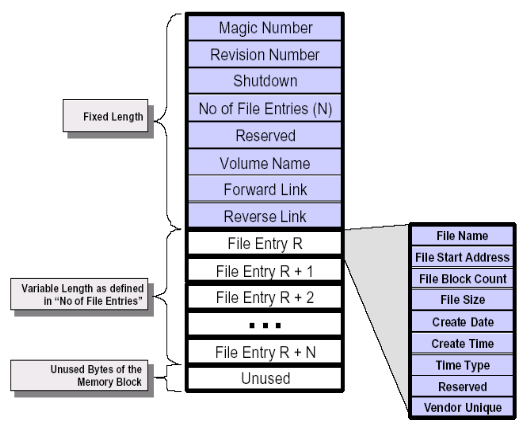


Figure 1. Directory Block and File Entry

The Chapter 10 data packet format supports multiple data types (PCM, MIL-STD-1553, IRIG Time, Ethernet, Fibre Channel, Video, Computer generated, etc). Each packet has a packet header with the same format regardless of data type, a packet body that is data-type dependent, and a packet trailer containing a checksum of

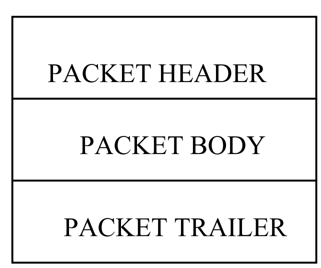


Figure 2. Packet Structure

the contents of the packet body. Figure 2 shows the generic Chapter 10 packet structure.

One of the key features of the Chapter 10 packet format is that an independent, precision 10MHz reference counter is used to capture and record the relative timing of all of the data channels in a recording. IRIG time from an external time source is captured and “stamped” with the internal reference count, the same as any other data input source. One IRIG time packet is generated for each IRIG frame. The 10MHz reference count is stored in each packet header, and depending on data type, again within the packet body with each “unit” of user data. For PCM, a unit is a minor frame, and each minor frame is also stamped with the reference count. For MIL-STD-1553, a unit is a bus message, and each message is stamped with the reference count.

Chapter 10 stipulates that the identification and configuration of the individual data channels in the recording be defined in a Chapter 9 Telemetry Attributes Transfer Standard (TMATS) file that is encapsulated in a Chapter 10 “computer generated data” packet and output as the first packet in a recording. This requirement ensures that the configuration information used to make a recording is preserved with the recorded data.

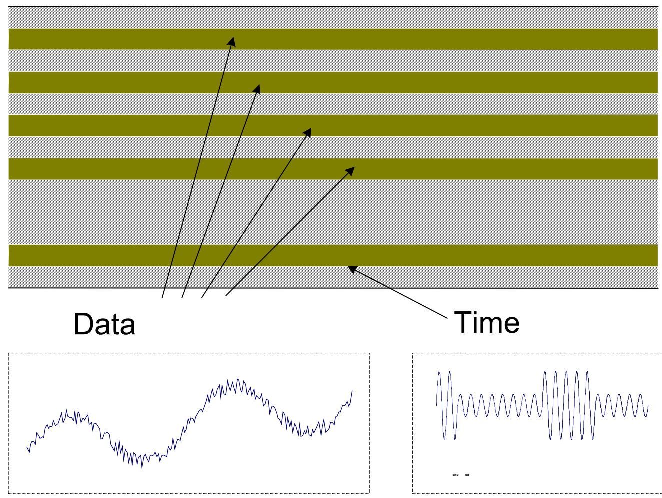
Chapter 10 packets for a single data channel (other than IRIG time) can be variable length, and the format support large packets. For example, one or more complete PCM major frames may be encapsulated into a single Chapter 10 packet. Each file in a Chapter 10 recording contains multiplexed (interleaved) packets from multiple channels. For each data channel, the reference counts in consecutive packet headers must be in ascending count sequence. However, when multiple channels are interleaved in a single recording, the reference counts in consecutive packets may not be in ascending count sequence.

IRIG 106 Chapter 10 Data Reconstruction

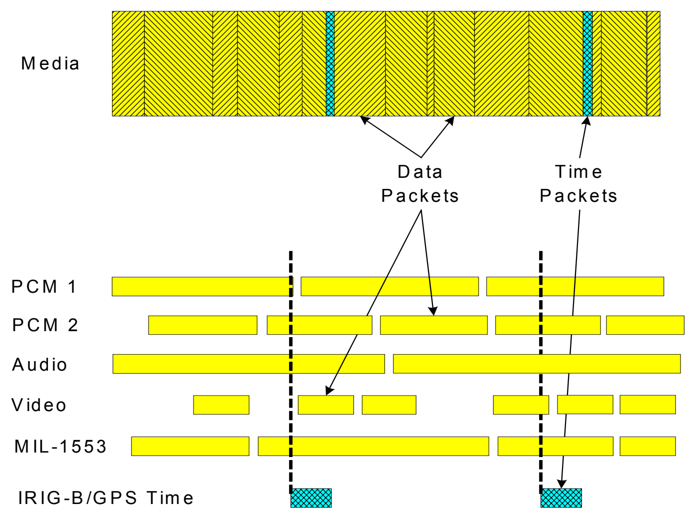
IRIG-106 Chapter 10 provides all the benefits for allowing data be analyzed and processed by state-of-the art Personal Computers PC’s and software. However the requirement still exists for ground stations to allow for data to be reconstructed back to its original form (i.e. PCM, MIL-STD-1553, Discrete, Analog, Video, etc. The key requirements for a ground replay station are as follows:

- The replay station should reconstruct all the recorded audio, video or analog data with its original dynamic range, distortion and quality.
- The digital data reconstruction (as PCM streams, bus data) should reconstruct all the recorded data bits with its original frequency without jitter.
- Data recorded from different sources are to be reconstructed with the best possible time accuracy relative to each other.
- The original time reconstruction in different formats like IRIG time code, GPS time, on-screen time display should be synchronous with the data streams being replayed.
- The user must be able to select any portion of a given recording, and the replay should start from any position with the above described time accuracy.
- Different than original speed replay is necessary. Sometimes the replay station must adapt for older existing equipments, which can handle only slower data streams. In other cases the user wants a quick check-up, or faster analysis is possible - so to reduce analysis time the faster replay is required.

Traditional Tape vs. Packetized Digital Data Replay



Traditional tape recording techniques used separate tape tracks for recording each different data source. In addition to the several data sources, one track was dedicated to time - which was generally coded as an amplitude modulated sine wave.
The synchronicity of the data in simple cases was relatively good, depending mainly on the geometrical placements of the recording and replay heads - and on the differences in the channel electronics.
While tape replay was easy, the time related computer analysis based on this technique was more complicated - the computer programs had to digitise and interpret the amplitude modulated time code signals. In most cases an external IRIG time reader with some kind of digital interface was used to run in parallel with the digital data capture.

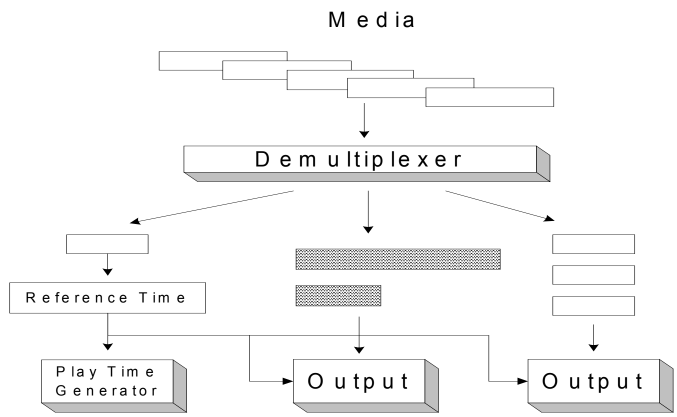


Digital recording techniques require a different method for keeping track of data synchronicity and timing. In this case, all data is first digitised, and then placed onto the media (still tape, solid state memory, optical or hard disc). The data block from different sources are placed on the media identified by their source ID in the packet header. The absolute time is placed also as one data block similarly.

The size of the blocks can be very different, and the time span covered by these packets are also different. It is not even guaranteed, that the packets are placed into the data stream always in the sequence as they are generated. Most importantly all data packet contains a digital time stamp, which allows the reproduction process to demultiplex the packets and assign to them correct timing.

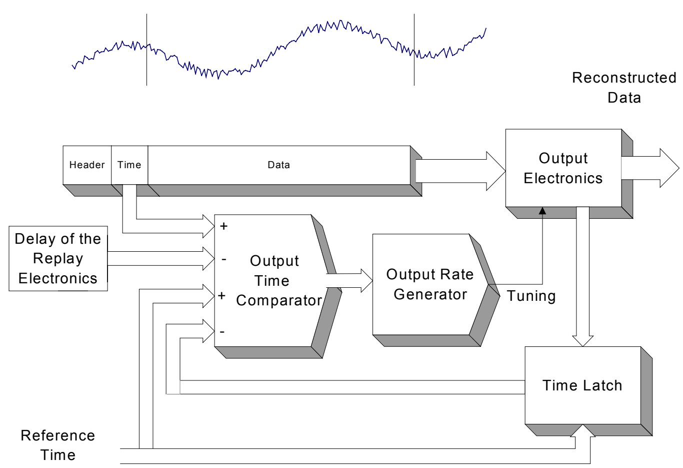
Data Demultiplexing

The ground station application must reverse the packetization process. Each data packet is selected and de-multiplexed to the sink identified by its source identifier. The packets are placed by source in different data queues. The replay time is handled similarly.



For replay the reference time is running free. In order to allow enough time for the interfaces to prepare for the replay, the reference time is started from a value that is typically about 2 seconds early, then the reference counter extracted from the time packet. After the time generation is started, the time source will run free and serves as master for all the output interfaces - leaving the time synchronisation task for all the reconstruction interfaces. The continuous synchronisation of the output interfaces results in a very simple and very accurate replay system architecture. The above mentioned output rate adjusting results in a final absolute time accuracy better than 1 microsecond

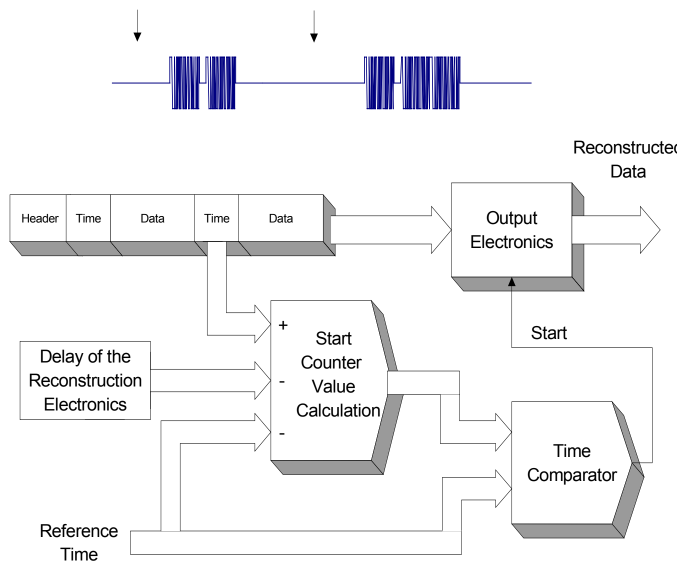
From the reconstruction difficulty level point of view there are basically two type of data: continuous or with other words evenly spaced - and burst or unevenly spaced data. Continuous data are generally PCM, audio, and analog data.



The continuous data replay interfaces have to guarantee that the first data is output at the exact time captured as time stamp in the first packet.

Later the interface has to measure back the time of the outgoing words and compare it to the time stamp of the following packets. The difference gives the tuning value of the output rate generator (PCM bit rate, analog sample frequency), which must be a fine tuneable generator. Using this method a time accuracy of 1 µs can be achieved.

All output interface electronics have some delay. Using digital decoders for video stream or delta-sigma D/A converters for audio or analog data this delay sometimes can be very long (1-100ms). The correction of these delays is easy for the starting and also for the continuous tuning by using digital techniques.



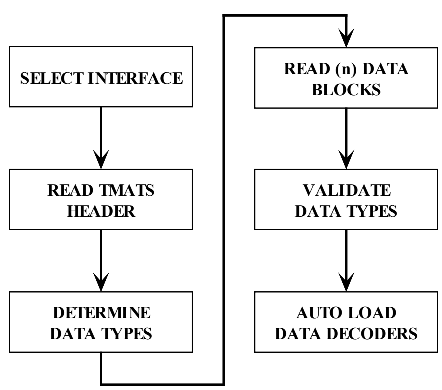
The burst data replay is even simpler than the continuous rate data reconstruction, and higher accuracy can be achieved. In this case the interface is working continuously in "Initial" mode. When the next time stored in the packet is reached, the time comparator enables the next burst to start replay. The electronics knows the length of the burst, and stops the transfer automatically when it is reached.

The timing accuracy is even better - in most of the cases the recorded 100 ns accuracy can be achieved because generally no output rate jitter is produced.

The correction of the delay of the output electronics can be achieved in the same way as it is done for the continuous data reconstruction.

IRIG 106 Chapter 10 Windows OS environment

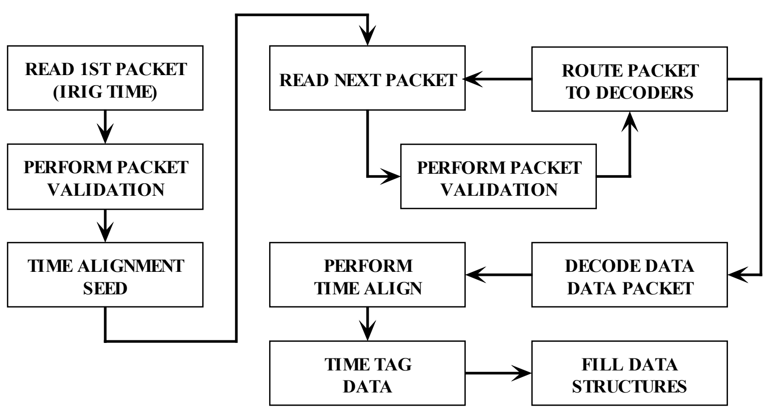
The IRIG-106 Chapter 10 format provides an open standard for the implementation of data acquisition, processing and analysis in the Windows Operating System (OS) environment. All of these functions can be performed on a Personal Computer (PC) platform and/or across PC networks. Conforming to the Open Systems Interconnect (OSI) model that allows the application layer to perform data de-capsulation and decoding then presenting it to the end user removes the constraints of proprietary formats and support software applications required for their use. Being a truly open standard IRIG-106 Chapter 10 allows multiple vendors and/or organic support within the flight test community for the post recording data processing environment. Utilizing common PC interfaces from the COTS industry such as the Small Computing Systems Interface (SCSI), Emitter Control Logic (ECL) and/or Fiber Channel (FC) recording downloading and processing of the data becomes a Plug-n-Play type scenario for the end user.



If the appropriate interfaces are present in the Windows OS environment the Solid State Memory modules containing the data can be presented as a drive volume in the Windows shell. Utilizing registered Component Object Module (COM) objects the data can be decoded and processed on the fly during the debriefing process from the selected IRIG-106 Chapter 10 data files. The data recording can also appear as nothing other than a drive, directory, and file hierarchy within the Windows OS. Much like other registered files types IRIG-106 Chapter 10 files then can be decoded with a simple right button click of the mouse, launching the associated file application just as if you were opening a Microsoft Excel file. The format of Chapter 10 data provides the necessary hierarchical environment for the user to navigate straight to the data of interest. Operating in the windows OS also allows complete drag and drop, file copy and paste capabilities for local and/or networked users.

Time Alignment

Individual data source time alignment can easily be accomplished with the information provided by the IRIG-106 Chapter 10 format. Not only does the format contain an IRIG time channel but also each packet contains 48 bits of time information on the data within the packet. Each recording also contains a value in the TMATS header, which represents a time offset between the IRIG "On Time" mark and the packet header reference counter fine time latch. By having this timing information available to the decoding process it is now possible to accurately align data from each channel in software. Once the decoding process has performed the alignment on all the data channels it becomes possible to provide dissimilar data to time history processing or display.



Implementation of Standard in Government Developed Product (ILIAD)

The ILIAD product (Instrumentation Loading, Integration, Analysis, and Decommutation) is a ground support tool for the Instrumentation Engineer. It provides three tools supporting the IRIG 106 Chapter 10 data format. A packet editor decodes the raw data file, and presents the user with a formatted output of the packet headers and data. The second tool is an IRIG 106 Chapter 10 Data File Validator. This validation tool processes the Chapter 10 data file packet header, trailer, and body to make sure that each conforms to the standard. The third tool is an IRIG 106 Chapter 10 Player, which provides the ability to process the data file through the ILIAD Data Server. The data source can be a disk file or a tape file.

CONCLUSION

The Range Commanders Council exists to seek, preserve and enhance the nation's war fighting superiority by ensuring that affordable technical capability and capacity are available to test and operate the worlds most effective weapons systems and to train the war fighters who use them. In support of that vision, the Telemetry Group (TG) is involved with facilitating the transfer of telemetry data between users and test ranges and between ranges with the goal of fostering improvements in overall telemetry system performance and compatibility. The Recorder and Reproducer committee address issues involving ground and airborne recorders, media (tape), recorder multiplexers, data reconstructors, and test methods for these devices. The committee promotes the sharing of resources (equipment, access to purchase contracts, lesson's learned) and the adoption of standards to promote inter-range commonality.

The proposed standard addressed in this paper is a continuation of this vital mission. The RCC-TG and its member ranges are struggling with the rapid advance of recorder technology along non-standard devices. Current RCC (aka IRIG) standards align along ANSI and commercial off-the-self devices. These standards (namely the IRIG Longitudinal tape recorder, ANSI ID-1 tape recorder, ADARIO Multiplexer, Metrum VLDS tape recorder, and Calculex ARMOR Multiplexer) have been competing with non-standard systems being implemented on today's ranges. The committee needed to move fast to prevent the same situation from happening with Solid State recorders.

This is the right standard. It presents an open architecture that is being widely adopted across multiple users (RCC, NATO). It has been prototyped, tested, and is well documented. It addresses media formatting, data formatting, data downloading, and data security, software data processing, and raw data reconstruction along with serial command and control and discrete command and control of the recorder.

This is the right time. Increasing data rates and harsh environmental requirements have exceeded the ability of tape-based systems to keep pace with technology. The next step is Solid State Devices.

IRIG 106 Chapter 10 is currently being distributed for comments. Comments are due back to the committee by 31Dec02. At that time the committee will address the comments and propose a final version of the standard to the RCC Telemetry Group (Feb 03). If approved by the RCC-TG, it will be available for publishing and use Mar 03.

For more information please refer to the public RCC website at http://jcs.mil/jist3