POST-FLIGHT 1553 MESSAGE REDUCTION AND PROCESSING SYSTEM

Lee V. Reinsmith

TYBRIN Corporation
1283-A North Eglin Parkway Shalimar, FL 32579

ABSTRACT

This paper describes the application software used in the Message Processing System at the Air Force Development Test Center (AFDTC), Eglin AFB. The focus is on the Alpha AXP application software designed and developed to log, process, and re-format IRIG Chapter 8 1553 data. The main data reduction and editing capabilities of the processing phase are explained: message output selection, message output sampling, message translation, error identification, and IRIG Chapter 8 time editing. The design of and methods used to produce the output files, the BBNProbe STD file, and the 1553 message summary report are described. This software's flexibility and comprehensiveness in processing, reducing, and re-formatting 1553 message data will enable AFDTC to satisfy current and future post-mission processing requirements.

KEYWORDS

Message Processing, Mil-Std 1553, IRIG Chapter 8 1553, BBNProbe, DataProbe

INTRODUCTION

In the past, post-flight 1553 message data was commonly reduced and processed at the telemetry ground station on mainframe and mini-computers running one proprietary operating system and using high-maintenance software. The potentially voluminous amount of data from multiple 1553 buses in one aircraft justified a CPU-intensive solution to process and output it in a timely manner and usable form.. Present day and future flight tests are requiring more aircraft and weapon parameters to be analyzed; hence, almost all traffic on the 1553 buses will be processed in some way. The arrival of the low-cost, high-performance workstation enabled both the processing and subsequent analysis of this multiple bus data to be off-loaded from the "old" mainframes and mini-computers. In networked or stand-alone configurations, the

workstation (along with a state-of-the-art, board-level telemetry rack) can host high-level language software to efficiently process and output this data.

MESSAGE PROCESSING SYSTEM OVERVIEW

According to IRIG Standard 106-93, data from up to eight Mil-Std 1553 dual redundant data buses can be 100 percent acquired by a single system on-board the test vehicle. A multiple track recording technique must be employed to extend recording time while maintaining 100 percent acquisition. The maximum number of tape tracks, or PCM streams, per bus is limited to four. This equates to an absolute maximum of 32 tracks of PCM-encoded 1553 data in a mission lasting no more than two hours. Missions of longer duration would have to use double the number of tracks (64), since one PCM stream would be recorded on two tape tracks; the first track in the forward tape record direction, and a different track in the reverse tape record direction. This presents a monumental challenge for the telemetry ground station in processing this potentially voluminous amount of data. A proper mix of hardware and software is required to handle this I/O-bound, CPU-intensive data processing.

The Message Data Processing System at Eglin AFB is shown in Figure 1 and is split into three sequential passes, or tasks; each containing an independent software process that performs specific functions and an optional software process that can verify the quality of the recorded 1553 data. The system was designed with an emphasis on modularity and flexibility for various reasons. One reason is the ability to quickly modify the software to accommodate Eglin's many different weapons testing projects. Test range customers have varying post-mission processing requirements that may require slight or major changes to the software in one or more passes. Another reason for the separate passes is to utilize the Workstation's multitasking capabilities, while future migration to a networked or stand-alone PC system, each running a single-tasking operating system, will not require software re-design.

In Pass 1, two to four analog tape channels (one 1553 bus of data) are acquired and digitized by an Acroamatics 2210C telemetry system, and recorded to one or two DEC TZ86 tapes by a DEC 3000 Alpha AXP workstation. The Acroamatics is programmed via setup files to suppress the output of 1553 fill words and to merge the PCM streams from one 1553 bus. The Data Logger program on the Alpha will collect the 1553 messages from the Acroamatics and log them to one or two TZ86 tapes using a striping method. Assuming a worst case, full bus traffic with no fill words, the maximum sustained throughput from a 1.0 Mbps 1553 bus to the Alpha TZ86 tapes will be roughly 1.6 Mbps (expanding the 20-bit bus word to a 32-bit computer word), or 200 KBps. A four hour mission would produce 2.88 GigaBytes of data on one 1553 bus. With a maximum logging rate of 6 Mbps to one 6 GB TZ86 tape, one full 1553

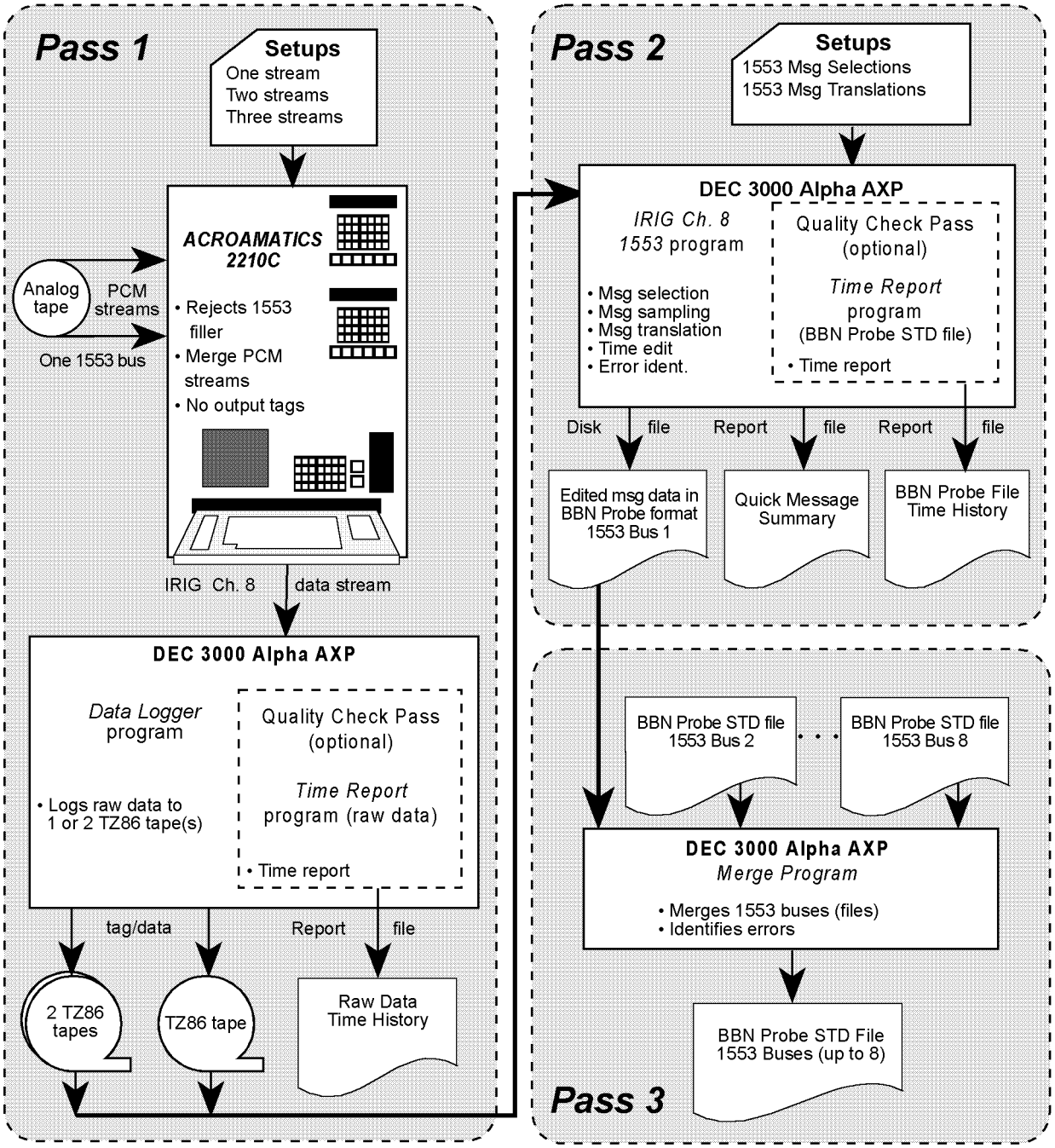

Figure 1. Message Data Processing System

bus of data could be logged to one TZ86 tape at normal tape speed, or recorded to two TZ86 tapes at triple tape speed. With fill words inserted in a typical bus traffic environment, tape playback speed could be doubled to produce one TZ86 tape and quadrupled to produce two tapes.

The IRIG Chapter 8 1553 program, which executes on the Alpha AXP, requires another pass through the now "digitized" message data on the TZ86 tape(s). It performs the functions shown in Pass 2 of Figure 1 and produces an edited data file of one 1553 bus in BBNProbe format as well as a 1553 message summary of all data on

the tape(s). Written in DEC Fortran 6.1 and DEC OpenVMS 1.5, the 1553 program is described in detail further on in this paper. Quality-check passes can be executed for both the raw PCM-encoded 1553 data from the TZ86 tape(s) and the message data from the BBNProbe disk file. These programs produce a time history, highlighting time backups and time gaps within each and every mission pass.
Pass 3 shows the capability to merge two to eight BBNProbe STD files, each containing data from one 1553 bus. This option gives the analyst added flexibility in tracking common parameters between buses and in troubleshooting bus problems. Eglin's experience in playing back and processing PCM-encoded 1553 data prompted this Merge program to be executed independently of the IRIG Chapter 8 program. Time errors, data errors, and bit errors are less complicated to identify, track, and correct if they are isolated in one bus rather than processing several buses concurrently in one program.

Since the Alpha is a multitasking and multiprocessing system, multiple copies of the Pass 2 1553 program can be executed simultaneously on the same workstation. This would require several TZ86 tape drives, one or two for each 1553 bus to be processed concurrently. Future expansion to this system in terms of hardware could be to add one or two Alpha AXP workstations, and/or one or two more Acroamatics telemetry systems, the latter being the more expensive alternative. Turnaround time requirements would determine the tradeoffs between hardware, software, and facilities.

IRIG CHAPTER 8 1553 SOFTWARE DESIGN

The Pass 2 1553 program is a sequential program modularly designed to be reusable, convertible, and comprehensive in satisfying current and future requirements in analyzing 1553 bus parameter analysis requirements. Subroutines are grouped into the following main functions: User Interface, Input, Time Processing, Data Processing, Output, and Reports. The program acquires the IRIG Chapter 8 1553 data, processes time and data, and outputs both to a BBNProbe STD file, all in real-time mode. All information and setup files describing both the inputs and outputs are collected before the actual real-time processing begins. All statistics, information, and performance data are stored in program memory during real-time mode and then written to the report file after all the data has been processed.

The User Interface function executes before real-time data processing begins (i.e., in zero cycle). Message selections and message sampling rates are defined here in an interactive mode. The Input function prepares the program to accept 1553 data from either disks or TZ86 tapes in zero cycle. Disk files are opened, tapes are mounted, and program input buffers for the appropriate media are initialized here. The Output

function creates the BBNProbe disk file and initializes the output buffers, again in zero cycle. The Reports function writes the 1553 message summary file to disk in post real-time mode from the information saved during real-time mode. The Input function starts real-time mode by sequentially filling all of the input buffers with 1553 data from the input media. The Data Processing and Time Processing functions concurrently process the first input buffer and when finished, the Input function then fills this buffer with the next chronological 1553 data, and points to the second input buffer to be processed. 1553 messages to be saved are written to the output buffers by the Output function. This flow continues until an output buffer is full, at which time the Output function writes this buffer to the BBNProbe STD file. This flexible design makes it easy to use as many input and output buffers as available computer memory allows; the number of buffers can be changed for different memory configurations.

IRIG CHAPTER 8 1553 MAIN CAPABILITIES

The 1553 Message Selection and 1553 Message Sampling capabilities enable BBNProbe output to be compressed and/or reduced. These selections and sampling rates are input to the program in one of two methods; interactively through the User Interface or with setup files. The User Interface function can create, use, and save message selection setup files, to include message sampling, all within the execution of the main program and before the real-time processing of data. Once saved, this ASCII setup file can be modified independently of the program with any text editor or word processor. The second method is to have the program read in any of these setup files for subsequent real-time processing and logging to a BBNProbe file. The User Interface cannot read an existing setup file and modify it for current or future use; it can only create one. Figure 2 shows the User Interface screen used by the program.

Messages can be selected and sampled for logging in two ways. In the first option, the user selects the exact 16-bit command word. The second option allows the user to choose each 5-bit part of the command word separately; the remote terminal address, the subaddress, the word count, and then the Mil-Std 1553 message type. Wildcarding, or choosing all possible values, is featured in each one of these four command word parts. Either of these options can be saved and counted as one selection criterion, which is then prompted for a sampling rate from 1 to 9,999 occurrences of that message. Up to 100 selection criteria can be created and saved for the duration of the test item pass. The program loads this data into look-up tables at zero cycle, using the actual command word values as indexes into the tables. During real-time processing and logging, the code quickly and efficiently determines whether the message should be written to the BBNProbe output file or not.

IRIG CH 8 MESSAGE SELECTION & SAMPLING

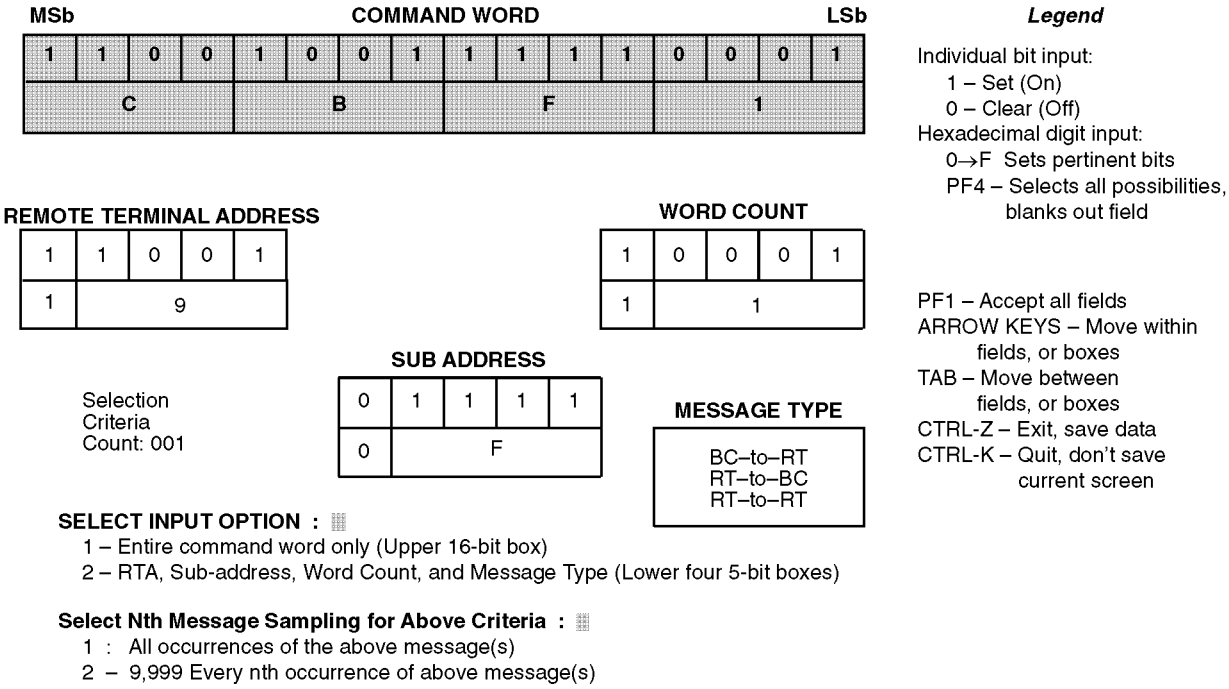

Figure 2. User Interface

The 1553 Message Translation capability has no current user interface and must have an ASCII setup file created for it with a text editor or word processor. This capability "translates" the original 1553 bus command words into "biased" command words with different values and outputs them to the BBNProbe STD file. Groups of original command words can be represented with one translated command word, and the remote terminal address and/or subaddress parts of a command word can also be translated using this capability. For example, if conditional data exists within the 1553 messages, data dependencies could be built into the BBNProbe Data Dictionaries and linked to the Frame ID (Logical Record ID). The Data Dictionary could be made simpler by translating all of the 1553 messages containing these data dependencies into one Logical Record ID. The 1553 program builds a translation table similar to the look-up table above (see Figure 3).

The Data Processing function interrogates all 1553 messages for compliance to Mil-Std 1553 as well as IRIG Chapter 8 structure. The program reads the input buffers a bus word at a time and stores them in memory until it comes to the next command word, at which time the stored "current" message is processed and checked for errors. If errors in the message are identified, the Output function flags the appropriate indicators and the Report function saves statistics for this message. The 1553 errors are categorized and prioritized by the program as follows:

- Maximum words per 1553 message exceeded
- IRIG Chapter 8 1553 buffer overflow
- IRIG Chapter 8 1553 bus error
- Mil-Std 1553 data word errors
- Bus inconsistency within a message (A & B 1553 buses)
- Mil-Std 1553 command word errors
- Mil-Std 1553 time word errors
- Mil-Std 1553 status word errors
- Mil-Std 1553 message type errors
- Mil-Std 1553 remote terminal address errors
- IRIG Chapter 8 1553 fill word errors
- Unrecognizable 1553 message

TRANSLATION TABLE

Translation Command Word	Command Word Value Index
0	0
1	1
2	2
3	3
4	4
•	•
•	•
•	•
30769	31409
30770	31410
30771	31411
30772	31412
30773	31413
•	•
•	•
•	•
65531	65531
65531	65532
65531	65533
65531	65534
65531	65535

← 16 bits →

Figure 3. 1553 Message Translation

IRIG Chapter 8 time within the PCM stream is identified, processed, flagged as erroneous, and corrected if possible by the Time Processing function of the 1553 program. BBNProbe software will produce unpredictable results, or crash, if time backups are encountered in the data records; hence, erroneous time must either be flagged or corrected in all logical records to be written to the STD file. From Eglin's extensive experience in processing Mil-Std 1553 data, time errors fall into three categories: IRIG Chapter 8 inherent time problems, instrumentation and/or recording errors, and analog tape playback errors. The IRIG Chapter 8 problems occur because the high and low order time words are only output at the beginning of every PCM frame, so the software must update their values if they roll over in the middle of a PCM frame. Time errors resulting from the test item's instrumentation or recording cannot be corrected, but are flagged in the BBNProbe data record. Bit errors during analog tape playback are the result of a mistranslation of the state of the bit (high or low) while the telemetry data is being converted from an analog signal to digital data. Identifying and "fixing" these errors is the most complicated task for the software.

IRIG Chapter 8 time words from the PCM-encoded 1553 data go through two levels of processing by the Time Processing function before being converted to BBNProbe format and placed in the record header of the STD output file. The first processing level examines each of the three IRIG Chapter 8 time words and either flags the inherent time rollovers or corrects time backups and time jumps by replacing the

erroneous word with the previous “correct” time word. The second processing level converts the three time words to a floating point time for every message encountered and then compares it with the floating point time from the previous message. Time is adjusted for rollovers if necessary and if time backups or jumps occur, the message corresponding to this time is flagged in the BBNProbe STD file.

IRIG CHAPTER 8 1553 OUTPUTS

Figure 4 shows the structure of the BBNProbe STD disk file created by the 1553 program. Each fixed-length STD file record contains as many variable-length Logical Records as will fit into it and is then zero-filled, while each Logical Record contains a 1553 message in chronological order. Time, LRIDs , and the length of the Logical Record are contained in the Logical Record header while the length of the entire STD record is located at the beginning of the record. These STD records reside in OpenVMS relative files on the Alpha AXP and the fixed STD record size, which can be easily changed, is contained in Fortran Include files. The Logical Records themselves can contain any format and size desired by the user.

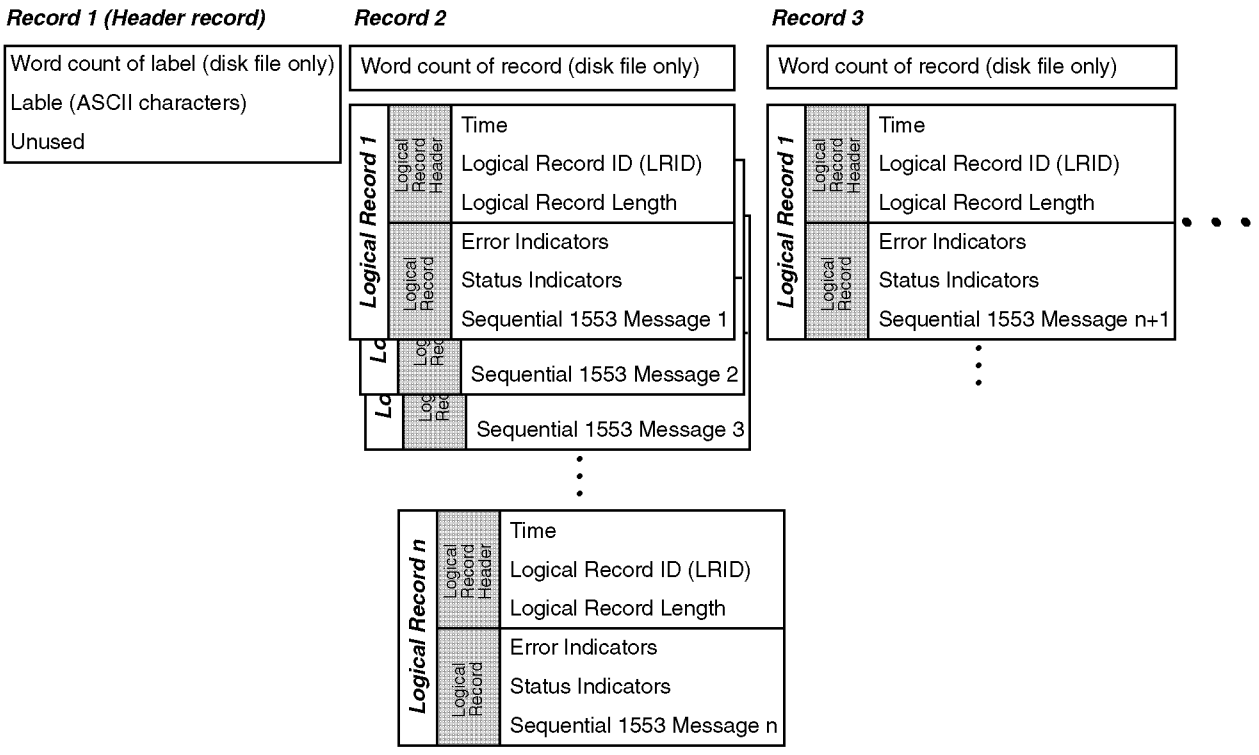

Figure 4. BBN Probe STD Disk File Format

The 1553 Message Summary Report for a particular program execution contains brief descriptions of the setup files used, the 1553 messages that were selected and/or translated for output, the raw data files or tapes containing the PCM-encoded IRIG Chapter 8 data, and the BBNProbe STD file produced by the program. The report then

summarizes each Pass of data from one 1553 bus. The data can be recorded in one or more passes, each pass containing every message on the analog tape between a designated start and stop time. Each unique message is identified by its command word and is summarized with one to four lines in the report. The number of occurrences of each of these unique messages is quantified by validity and error category. The messages that were selected for BBNProbe output, their sampling rates, and their translated command word (if pertinent) are described in each unique message's summary. The following is an example of several message's summaries:

```
Command Word  : 8157   1/123 Msgs Logged,     Number of Valid messages  :        28465
                8037                Translated Command Word
          1 OVER
Command Word  : 81BB   1/1234 Msgs Logged,    Number of Valid messages  :        28463
                803B                Translated Command Word
          1 OVER              6 BUS
Command Word  : 81D6   1/12 Msgs Logged,     Number of Valid messages  :        28464
                8036                Translated Command Word
          2 OVER              1 BUS           2 DWORD
```

CONCLUSION

Current and future post-flight processing requirements for IRIG Chapter 8 1553 data can be achieved using well designed, high level software with an emphasis on flexibility, comprehensiveness, and modularity. The workstation environment provides maximum CPU power as well as desirable I/O bandwidth for this CPU and data intensive application. The 1553 processing program in Eglin's Message Processing System was designed to be generic and mission-independent as evidenced by its main functions and capabilities. The modules are reusable and convertible to any high level language, making future expansion and migration to PC platforms relatively easy.

Overnight turnaround can be achieved in processing data from all Mil-Std 1553 buses from a test vehicle for a mission lasting 2 to 4 hours. Alpha processing performance measurements have yielded an average BBNProbe STD file logging rate of 330 Kbps, while a two hour mission of one 1553 bus (with no fill words) yielded 1.44 GB of raw data. Based on these figures and using two Alpha AXP workstations, eight full 1553 buses can be processed in 10 to 12 hours.

REFERENCES

1. IRIG Standard 106-93 Telemetry Standards, Telemetry Group Range Commanders Council
2. DataProbe System and Database Management Guide, Version 9, BBN Systems and Technologies