Data Handling and Processing as Applied to White Sands Missile Range

DATA HANDLING AND PROCESSING AS APPLIED TO WHITE SANDS MISSILE RANGE

Presented by

A. L. Kelley
Fairchild Weston Systems Inc.

and

C. P. Malone
White Sands Missile Range, NM

ABSTRACT:

Today's large missile testing ranges are demanding sophisticated processing and displays of telemetry data for real-time decisions. These present-day requirements created a need for better data handling and processing than those of the past. These requirements are driven by higher data rates, more complex formats, and increased real-time decision making (i.e., flight safety area).

White Sands Missile Range's (WSMR's) initial real-time Telemetry Data Processing System was provided by IBM in 1969. This system was augmented several times by adding higher-speed telemetry front ends and preprocessors. However, this was not adequate to keep pace with requirements for data processing and display at WSMR. Presently, WSMR has Fairchild Weston Systems, Inc. (FWSI) under contract for a new Telemetry Data Handling System. This FWSI system will support WSMR's anticipated demands for now, for the next decade's planned growth, and beyond.

This paper defines data-handling tasks at WSMR, explains how these tasks were handled in the past, and how they are presently handled. Next, the new system is described explaining how it fits into WSMR's present and future plans; and how it provides all the telemetry data handling, storage, processing, and display capabilities to support these tasks. Both hardware and software are discussed for this totally turn-key operating system.

TELEMETRY DATA CENTER FUNCTIONS AND CAPABILITIES

The Telemetry Data Center (TDC) was originally envisioned as the interface between WSMR's telemetry system and its central computing complex. TDC was planned as the telemetry center, which was dedicated to condition and perform limited processing on all classes of telemetry data.

The original TDC system was installed in January 1968 and was operating in early 1969. The original TDC system consisted of six major subsystems and two control units: (1) Telemetry Data Handling Subsystem (TDHS), (2) Digital Data Handling High Density Recorder/Reproducer Subsystem (HDRRS), (4) Display Quick-Look Subsystem (DQLS), (5) Timing Subsystem (TS), (6) Test and Control, Calibrate and Status Subsystem (TCCSS), Telemetry Data Control Unit (TDCU), and Output Data Control Unit (ODCU).

TDC had the system capability of accepting input of twelve telemetry multiplexes [two PCMs (from 10 bps to 1 Mbps), six PAM/PDMs (from 1 pps to 50 Kpps), and four FMs] for input into four control memories. The four control memories were contained in the TDCU: one for each PCM, one for the six PAM/PDMs, and one for the four FMs.

The TDC function was to demultiplex, digitize, display, record/reproduce, edit, linearize and scale, identify and time-tag the input telemetry data (telemetry data that was received from outlying sites via the microwave system). Prime emphasis was placed on performing these functions during a real-time test. In a post-test mode, these functions could also be performed. TDC could convert telemetry data to formats suitable for digital processing and recording. All digitized data, time tagged to a resolution of 0.01 milliseconds, could be recorded (combined average input rate of 634 KW/second) on magnetic tape while selected data could also be routed for display and/or to a remote processing computer. The TDC equipment could demultiplex, select, process and display up to 512 data sources from the total system input. The combined average throughput rate of the selected data being processed was effectively 10 KW/second.

EXISTING SYSTEM CAPABILITIES

As the modern weapon-system telemetry formats became more complex, FM and PAM telemetry formats were used less frequently in favor of PCM formats. Therefore, the original TDC had to be upgraded to meet these changing requirements. It was necessary to update the original TDC system with piece-meal WSMR actions. These piece-meal solutions for TDC problems fall short of their goal.

The existing TDC has the capability of accepting an input of two separate six telemetry data streams. These data streams can consist of mixed PCM, FM and PAM telemetry

formats with the emphasis on PCM formats (83 percent). The data rates for the PCM and PAM data streams are up to 10 Mbps and 250-K channels/second respectfully. Each of the six data streams are input to two separate multiplex preprocessors for a combined throughput rate of 300 KW/second for scaled data, and 100 KW/second for selected and tagged data. The scaled data is used for strip-chart recorders, digital and analog displays (for projects and flight safety), and selected and tagged data is output to remote computers for logging, video displaying, listing, and chart recording. Also, the existing TDC can interpret (process) missile burnout and relay it to the remote computer. The TDC has the capability to set up the front end equipment and the preprocessors with one data stream group being set up at one time. Addressable DACs can also be addressed via a word selector unit, thus reducing DAC patching errors.

NEW SYSTEM DEMANDS

In 1980 WSMR made a study for future requirements in telemetry processing systems. It became obvious that WSMR could not continue to upgrade the existing system and meet the demands of the future. More data parameters at higher data rates were being processed in PCM, FM and PAM. The formats were becoming more complicated, such as embedded asynchronous subcomms and dynamic format changes. These format changes may be identified by a unique event in the data stream. More real-time decisions had to be made for mission safety, verification of location, and mission success. WSMR needed a more versatile system that would synchronize, process and display higher data rates with more accuracy than it had at this time.

DEFINITION OF OPTIMUM SYSTEM

A comprehensive investigation for data processing was conducted to define the optimum data processing system. This study involved personnel from the Instrumentation Directorate along with personnel from the Data Processing and Analysis Directorate. Every effort was made to define a system that had the flexibility and power required, and yet maintained a simple man-machine interface that the average telemetry systems operator could operate. By an integration of the facts derived from all of these inputs, the following general system characteristics began to develop.

- The system should be a mission test tool, with the mission controller in control of the data analysis process through real-time system activity.
- It should have a very high availability factor.
- It should use distributed processing techniques to obtain the processing power required.
- Man-machine interface should be via CRT display terminals with a straight-forward telemetry systems language for the Telemetry Operator.

- It should reduce man power required for mission support.
- Time tagging of real-time data.
- Real-time data analysis should emphasize display of analytical results rather than raw data in an effort to reduce post-mission processing.
- Multiple-mission configuration information should be stored on system disk files with rapid set up for a particular mission. This should include a library of flight test analysis routines.
- Versatile, and flexible with a minimum capability to process all IRIG Standard Formats.
- It should have the capability to process multiple missions simultaneously.
- Modular for future expansion.
- Multiple data displays with modern microprocessor-controlled color graphics with large screens.
- A set of diagnostics software to aid in troubleshooting the system problems and minimizing the downtime.
- Capable of processing complex data formats, and higher data rates to support WSMR testing for the next decade.
- Real-time data logging.

These characteristics were incorporated into a specification in 1983. WSMR submitted this specification to vendors, for which we received 5 responses. Out of these, Fairchild Weston Data System Division was selected to supply the system which is known as the Telemetry Data Handling System. (TDHS).

GENERAL SYSTEM DISCUSSION

As these desirable characteristics were examined in detail by FWSI, it became apparent that there were several requirements for TDHS that were unique. These requirements included PCM bit rates up to 20 Mbps, PAM rates up to 250,000 SPS, and higher frequency FM data rates. The PCM formats had embedded asynchronous formats with several hundred words-per-minor-frame. Processing rates were sufficiently high enough to require higher compression ratios and higher real-time processing rates to accommodate the real-time requirements. The man-machine interface must be straight forward enough to guarantee acceptance by mission test personnel, while supporting multiple missions simultaneously.

The TDHS system consists of seven major subsystems. A high-level system overview is shown in Figure 1-1. These subsystems are:

- Input Signal Distribution and Control Subsystem
- Telemetry Front-End Equipment

- Calibration and Simulation
- Preprocessing Subsystem
- Timing and Tape Transport Control Subsystem
- High-Speed Host Computer
- Data Outputs, including Graphic Displays, Video Generation and Strip Charts

The software that brings all of these subsystems together as one operating system is a Telemetry Data Acquisition and Processing System, which is written in FORTRAN.

The data-rate requirements dictated the use of a high-speed data preprocessor in the system. The preprocessor multiplexed digital data streams, converted data to Engineering Units, performed data compression, and distributed the processed data. This allows the host to perform more real-time functions in analyzing and displaying data.

The system characteristics are:

- Simultaneous Inputs
  Six PCM data streams
  Two PAM data streams
  Four FM data streams

- Real-Time Processing
  Data synchronization and formatting
  Data compression
  Conversion to engineering Units
  User defined procedures

- Simultaneous Real-Time Outputs
  Raw data to disk (1.6 Mbyte/second)
  CRT data displays (Graphic and Tabular)
  Strip-Chart Recorders
  Instrumentation Tape Recorders
  Closed-Circuit Video Displays

INPUT SIGNAL DISTRIBUTION AND CONTROL SUBSYSTEM

This subsystem functions as a central facility to distribute all input and output telemetry signals, such as predetected and preselected signals from the range, IRIG A and B carrier timing, and analog recorder signals. It provides the man-machine interface for control and operation of the system. It includes: distribution amplifiers, FM multiplexers, analog tape recorders, FM demultiplexers, and patch panels.

TELEMETRY FRONT-END

The Telemetry Front-End includes three major functions: PCM synchronization, PAM synchronization and FM demultiplexing and digitizing. Each of these receives their input signal via the patch panel in the Input Signal Distribution Subsystem. These signals may be from either RF receivers, analog tape recorders, land lines, or simulation.

The PCM section is composed of six: EMR 8000 Series Bit Synchronizers, Frame/ Subframe Synchronizers, and Digital-to-Analog Converters. These units operate up to 20 megabits per second, have local or computer setup, and on-board diagnostics. Each unit is capable of storing up to four unique formats to provide for fast format switching. For the main data path into the telemetry preprocessor subsystem, the appropriate signal (receiver output or tape output) is selected at the patch panel for input to the bit synchronizer. The bit synchronizer obtains bit sync, reconditions, and outputs the signal along with a clock to the frame synchronizer. The frame synchronizer obtains frame/subframe sync, performs serial-to-parallel conversion, and outputs parallel data through three output ports. The first one outputs all data to the telemetry preprocessing subsystem. The second one outputs embedded data to the preprocessing subsystem. The third one outputs selected raw data to the digital-to-analog converters. The digital-to-analog converter receives and selects data from the frame sync, performs scaling, bit stripping and bit packing, and converts selected words to an analog voltage. It outputs analog data and selected discrete bits for recording on strip charts. The frame synchronizers are capable of handling data formats with variable word lengths (of up to 32 bits long), and asynchronous subframes.

The PAM section is composed of two EMR 700 Series Channel, Frame and Subframe Synchronizers, and two EMR 8000 Series Digital-to-Analog Converters. These units are capable of operating up to 250,000 samples per second with subcommutation capability, and have local control or computer set up. For the main data path into the telemetry preprocessor subsystem, the appropriate signal (receiver output or tape output) is selected at the patch panel for input into the channel synchronizer. The channel synchronizer obtains channel synchronization, reconditions, and outputs the signal to the frame synchronizer. The frame synchronizer obtains frame/subframe sync, digitizes each data sample to twelve binary bits, and outputs in parallel to two ports. Port one outputs all data to the preprocessor. Port two outputs all data to the DACs. The digital-to-analog converter receives and selects data from the frame sync, performs scaling, bit stripping and bit packing, and converts selected words to an analog voltage. It outputs analog data and selected discrete bits for recording on strip charts.

The FM section is composed of four EMR 8000 Series Digital Tunable Discriminators, eight EMR 400 Series Analog Tunable Discriminators, two EMR 4080 FM Calibrators, one EMR 8000 Series Digital-to-Analog Converts (DACs), and patching facilities to

enhance the flexibility of data distribution within the system. For the main data path into the telemetry preprocessor subsystem, the appropriate FM multiplex is selected at the patch panel for input into the tunable digital discriminator. The tunable digital discriminator will demultiplex, filter and digitize up to twenty-four channels of FM data, proportional bandwidth or constant bandwidth, in one multiplex. It will tune to any subcarrier center frequency between 200 Hz and 2 MHz, with deviations between +/-1 percent and +/-40 percent. FM errors induced by tape recorder speed variations are compensated for within the discriminator up to a speed variation of +/-3 percent. The unit has three parallel and two serial output ports. One of the serial output ports is output through a selector switch to the DAC unit. The DAC unit receives and selects the programmed data words, performs scaling, bit striping and bit packing, and converts selected data to an analog voltage. It outputs analog data and selected discrete bits for recording on strip charts.

The other serial port is patched into a PCM bit sync and processed as any other PCM stream. The parallel ports can be input directly to the preprocessor. The single channel tunable discriminators are used to demodulate pre-d signals and single channel FM subcarriers. There are two five-point frequency calibrators, one PBW and one CBW, to help calibrate and setup the FM subsystem.

CALIBRATION AND SIMULATION SUBSYSTEM

The Calibration and Simulation subsystem is comprised of three EMR 8000 Series PCM simulators, and one PAM simulation, one perturbation generator, one noise generator, bit error rate tester, and five low-pass filters. The three PCM simulators are independent simulators that perform the same functions. This will assist in verifying the system is ready to support independent multiple missions. The simulators are configurably locally and remotely by the host computer. They will simulate all standard IRIG formats at bit rates up to 20 megabits per second. Each unit will generate up to 64 unique defined words. The simulator will output a serial PCM data stream, and a 16-bit parallel data output. The PAM simulator will also simulate and output all IRIG PAM formats. The perturbation unit in conjunction with noise generator and low-pass filters are included with the simulator subsystem to perform perturbations on the serial output for system check out under adverse conditions.

The bit error rate tester is used to test the data hardware paths, such as a bit synchronizer, communication path, etc.

PREPROCESSING SUBSYSTEM

The Preprocessing subsystem is the EMR 8715 Multiplex Preprocessor. This unit is a high-speed preprocessor that multiplexes multiple data streams with up to three independent time sources. In this system the preprocessor is designed to accept twelve data inputs, each up to 32 bits wide, however, the flexibility is built in to expand the number of inputs with plug-in cards. The asynchronous input data streams are accepted by the preprocessor where each parameter is assigned unique identification tag. The time is merged with the data where each parameter may be time tagged if desired, or the time can be merged in with the data for processing and output at the highest resolution of the incoming time.

The data and tag is routed to the Distributed Processing Units (DPUs) via a high-speed bus. The bus is 80 bits wide and runs at 10 megawords. The DPUs accepts the data from the bus and processes the data based on the programmed algorithms. The DPU has the ability to chain multiple unique algorithms for each parameter. Each DPU has an on-board FIFO which is 1024 deep, thereby guaranteeing that each of the three DPUs could accept data at a 1,000,000 wps rate for one millisecond without data loss.

The total effective throughput rate of the preprocessor is 750,000 words per second with the following algorithm mix, 80% linear conversions, 10% 5th order polynomial conversions and 10% 32-point look-up table. This rate can be increased to a maximum of 2,000,000 wps by adding DPU modules. The DPU module is a high-speed word slice floating point processor that performs high speed 32-bit real-time data processing. It has a dual port data memory, arithmetic unit, and microcode instruction memory.

Each module resident on the Priority Command Data (PCD) bus, including the input modules, has a priority assignment. The assignments are used to arbitrate which module may have access to the bus whenever two or more modules request such access simultaneously. The PCD bus operates on a 100 nanosecond clock and is capable of transmitting a 32-bit command word and a 32-bit data word simultaneously on each clock cycle. Simultaneous data from any two input ports can be input within a 0.2 microsecond period.

The preprocessor has the capability to demultiplex up to 128 operator selected measurands and route those measurands to internal arrays for subsequent transmission out of the array output port. Each array is double buffered to assure no data is lost, and may be up to 512 samples maximum, operator selectable.

One of the most important task of the preprocessor, and also one of the more simple ones, is the task of data distribution. The ability to multiplex multiple data streams, tag, process

and then distribute the data on a parameter basis relieves the host computer of a task it is not suited for with high speed data. The preprocessor has seven unique outputs, these can be expanded by adding output cards. The seven outputs are:

- Host computer Log Output Port. This module accepts data from the PCD bus and outputs tag/data for integer data and tag/data/data for floating point. Time will be output in sequence with the data with minor time being output each millisecond and major time being output each second. Time correlation of data will be guaranteed by virtue of the fact that time is merged at the input port. This data is normally stored on a mass storage device in the host for post mission processing.
- Host Process Output Port. This port is identical to the log output port. This data is selected processed data input to a Current Value Table in the host for real time display.
- There are two high-speed output ports for DAC data, the tag associated with each data parameter will define which specific DAC the data sample is routed to within the DAC subsystem.
- There are two output ports provided to interface with a second computer. These ports are identical to the log output port for the host computer.
- Array Processor Output Port. This module accepts data from the array modules via the PCD bus and outputs that data in block DMA transfers.

TIMING AND TAPE TRANSPORT CONTROL SUBSYSTEM

The Timing and Transport Control is composed of three each Bancomm Model M80 Timing and Tape Control subsystems. Each unit is capable of receiving IRIG-B timing signals from the analog tape units or range time, automatically synchronizing to the input timing signal, and maintain synchronization to within 10 microseconds. The unit will decode the input timing signal and generate parallel binary and BCD time. This parallel time will be merged with the data in the preprocessor. Should the incoming timing signal be interrupted the unit will automatically continue to generate valid outputs. When the incoming signal becomes valid again the unit will resynchronize to the input. Time will be displayed on the front panel in time of day format. The generator can generate time, using an internal or external oscillator.

The timing and transport control subsystem includes remote tape transport control, up to 6 tape transports per timing subsystem. The functions controlled remotely are; speed select, record, stop, fast-forward, fast-reverse, run, and reverse. It includes automatic tape search control. The tape search is operator-selectable for each tape transport. The tape search will initiate a series of transport commands to search the tape to locate a preset start time, put the transport into “RUN”, and playback until the operator-selected preset stop time is reached, then terminate the process.

The timing and transport control subsystem has the ability to generate a “Magnetic Tape Identification” (MTID), incorporating it into the IRIG-A or B timing, for the purpose of identifying a magnetic tape. The MTID includes a 30-character alphanumeric message.

THE HIGH-SPEED HOST COMPUTER

The Telemetry Control Processor Subsystem is composed of a super minicomputer and peripherals, Model 3280 manufactured by Concurrent Computer Corporation. The Telemetry Control Processor serves as a central control point for all programmable functions implemented in the TDHS System. As such it interfaces with all other subsystems within the TDHS for setup of the subsystems and accepting data from these subsystems. The processor has three internal buses, one medium speed bus to support the lower speed peripherals, and two high speed buses to support DMA devices. The two high speed buses provide an aggregate I/O bandwidth of 20 Mbyte/second. The performance of the Model 3280 processor is achieved using features normally found in mainframe computers. these features include a four-stage instruction pipeline, multiple caches, and a parallel multiplier.

The processor accepts the log data from the preprocessor and logs it on high speed disk or tape. The real time display data is retrieved from the Current Value Table in processor memory and outputs it to the real time displays.

The processor peripherals include 1.8 Gigabytes of disk storage, four Tri-density digital tapes, eight line printers, and five CRT display stations.

DATA OUTPUTS

The Data Output Subsystem is composed of two each Tektronix 4236 graphics terminals, Digital-to-Analog Converts (DACS), and video generator output. The two interactive graphic display subsystem is interfaced to the host processor and provides a medium for the display of high resolution graphics. They provide high quality graphics output in both real time and post mission environments on a 19-inch display.

The DACS are the EMR Series 8000, with 160 DACS and 256 discretes. They are programmed by the system controller to accept digital data and tag from the various TDHS sources. This data is converted to analog voltages and discrete digital bits and outputted to strip chart recorders.

The Video Generator System (VGS) will accept data and instructions from the host processor, convert the data to video and output it through six video channels. The data transmission between the host processor and the video generator system is DMA, allowing the VGS to accept and display alphanumeric and graphic data twice per second per channel in color.

SOFTWARE

Figure 1-2 graphically portrays an overview of the TDHS Software system. The TDHS System operates in three basic modes; (1) File Maintenance, (2) Acquisition, (3) Interactive Display. During the File Maintenance Mode, the user enters system variables for the Telemetry Front End and for the data parameters and specifies data routing for the Host Computer. The user is now ready to load the TFE followed by initiating the data acquisition mode to collect the telemetry data, display in real time and log it to disk or tape. During acquisition of data to disk users can examine data using the interactive display software at the alphanumeric or graphic displays. After the telemetry data has been acquired and logged, the user can replay the data from disk and display it on the screens.

Users enter setup and control information via the File Maintenance and Real-time Processor Functions and store this information on the system disk.

This information may be accessed by the acquisition and analysis display software. The acquisition mode supports real time data from an RF link, land line or analog tape play back. In the acquisition mode data is archived on disk and displayed on CRTs in real time. In the analysis mode data is recovered from disk and displayed on the screens. This software will be covered in more detail in a separate paper.

CONCLUSION AND FUTURE TRENDS

In summary, the TDHS as designed will process the telemetry data that WSMR encounters today, and probably for the next ten years. In specifying the TDHS WSMR looked to future trends in telemetry as a guide. This included areas such as; higher bit rates, MIL-STD Bus Data, complex formats, user outputs, and more processing power. The unknowns of the future dictated a modular system that can be upgraded by replacing subsystems.

The TDHS has been designed with the latest technology available to assure a longer useful life. The areas that are state-of-the-art and will maintain this status for some time are:

- Twenty megabits per second PCM front-end
- Flexibility of the PCM front-end
- Tunable Digital Multiplex Discriminators
- The Telemetry Preprocessor Subsystem
- The Host Computer

ach subsystem is capable of being expanded or upgraded with minimum cost. For example, the processing power required in the system can very easily be increased by adding processing cards to the preprocessor and/or the host processor. The preprocessor can be expanded into a third chassis without affecting the software design. The host processor can be closely coupled to other hosts to increase its capabilities.

A companion system, designated TDHS-B, essentially identical to the system described above is in the contract as a follow up option.

With this system design concept WSMR feels confident in accepting more challenging telemetry data processing requirements.

ACKNOWLEDGEMENTS:

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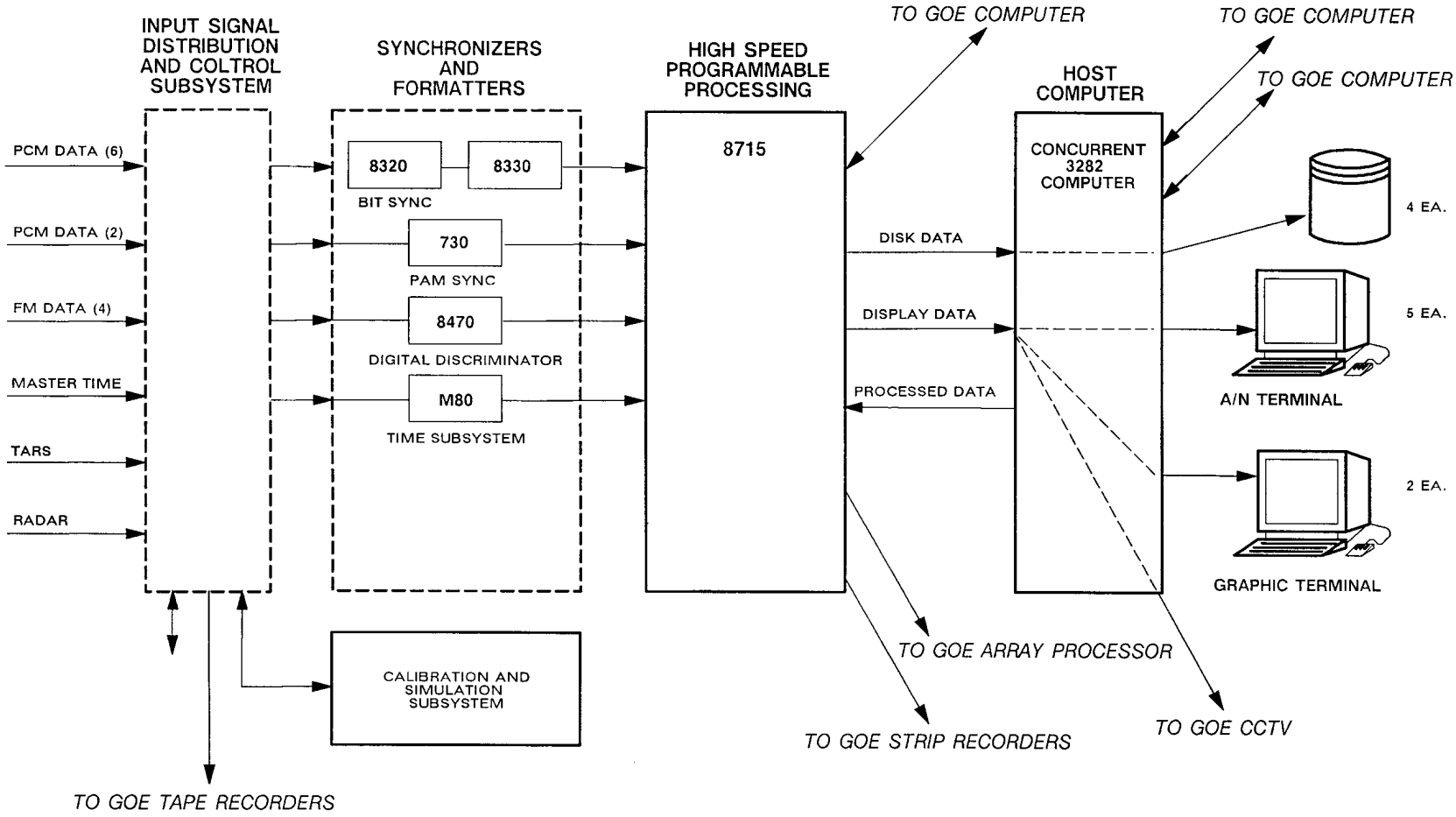

TELEMETRY DATA HANDLING SYSTEM
WHITE SANDS MISSILE RANGE
FIGURE 1-1

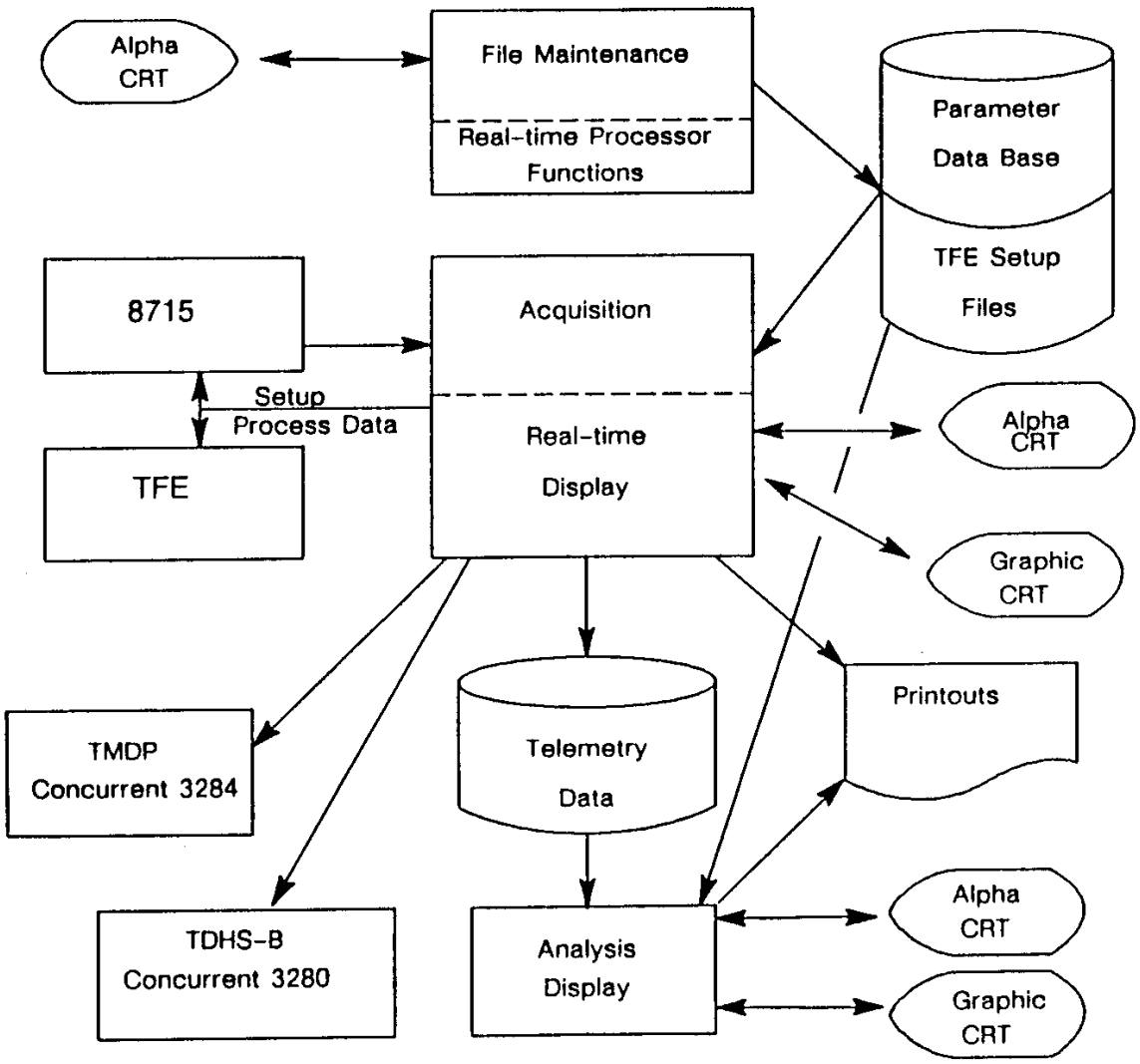

FIGURE 1-2. TDHS-A SPECIAL SOFTWARE OVERVIEW