DESIGN AND IMPLEMENTATION OF A TOTAL FLIGHT TEST SYSTEM

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ABSTRACT

This paper describes the overall system design and performance characteristics of a complete telemetry system for a new flight test center which Loral Data Systems is currently under contract to provide to a European government. The system encompasses subsystems for airborne data acquisition and flight line check-out, a mobile ground telemetry system, and a fixed facility. The fixed facility includes a ground telemetry system for real time data processing and test control, and a data processing system for postflight analysis.

The system represents a fully integrated approach to flight test systems which addresses the end-to-end requirements from airborne data acquisition and real time flight monitoring through aircraft performance and stability/control analysis. The architecture of the ground systems illustrates how preprocessing can be utilized to create powerful real time telemetry systems even with modest general purpose computer capability.

INTRODUCTION

Figure 1 illustrates the relationship of the various subsystems within the overall flight test center operations. During actual flight tests the aircraft data acquisition systems can transmit telemetry data to either the mobile or fixed ground telemetry stations. The fixed station will normally be used for local flight test operations. In this case, the flight line check-out station is utilized for loading the sample plan data and for preflight checks on the aircraft mounted acquisition hardware. Operations at remote locations will be supported by the MGTS which will be utilized for telemetry reception and test control. If necessary the airborne system format can be modified and loaded directly from the MGTS. PCM data can also be input to the mobile system directly from the aircraft for test purposes. The normal use of the DPS is for processing of data from airborne or ground recorded instrumentation tapes or for post flight processing of data archived to disk from the telemetry stream during flight test operations.

AIRBORNE SUBSYSTEMS

The airborne data acquisition subsystems were required to be general purpose to satisfy the wide range of data acquisition problems normally found in modern aircraft test programs. General requirements included:

- Acquisition and PCM output of normal analog voltage, frequencies and discrete events
- Programmable sampling plans
- Recording and telemetry transmission of PCM
- Acquisition of data from two MIL-STD-1553B busses
- Output of selected 1553 bus words in the PCM stream
- Recording of 100% 1553 data from both busses
- Color video data recording and telemetry transmission

Figure 2 illustrates the typical configuration for a system. General aircraft measurement data is acquired using an EMR 5000 Series Ruggedized Data Acquisition System. This is a remotely multiplexed system which provides a maximum PCM bit rate of 3.2 Megabits per second with a maximum total sample rate of 200,000 samples per second. PCM formats generated may use variable word lengths. This allows analog channels to utilize word lengths of 8, 10, or 12 bits and digital channels to utilize word lengths of up to 16 bits. Each remote signal conditioner chassis may contain up to 16 analog or digital conditioner cards which may contain from 2 to 16 channels each depending on the conditioner type. Format and sample plan data are loaded into the system's EEROM memory via an RS232 port.

An EMR 5500 All Bus Instrumentation System (ABIS) provides for the acquisition of all 1553B bus data from multiple busses in accordance with the recent Inter-Range Instrumentation Group (IRIG) standard. 1553B bus word selection for insertion in the general PCM output is performed by a data selector card which interfaces to the 5000 data acquisition system like a signal conditioner chassis.

Datum 9150 airborne time code generators provide serial time code for recording, and parallel time code for input to the 5500 ABIS for 1553B bus data time correlation. Schlumberger ME4115 airborne instrumentation recorders are provided for direct recording of all data.

Videospection cockpit color video cameras and Teac airborne video recorders are supplied for video data acquisition. Dual L-band telemetry transmitters operating on different frequencies are used for the simultaneous transmission of video and PCM telemetry data. The outputs of the transmitters are mixed in a diplexer and the resulting signal is split between two transmitting antennas normally located on the top and bottom of the aircraft.

FLIGHT LINE CHECK-OUT SUBSYSTEM

The Flight Line Check-Out (FLCO) subsystem provides equipment for decommutation and engineering units display of the PCM data from the airborne system. It performs flight line loading and updates to the programmable PCM system over an RS232 serial port. Also, it supports the acquisition and evaluation of on-aircraft end-to-end measurement calibration data. A block diagram is shown in Figure 3.

PCM input data is synchronized, decommutated and input to the MicroVAX II. The software hosted in the computer provides for real time display of the decommutated data on a color/graphic terminal. Displays available include fixed alphanumeric, scrolling alphanumeric time histories, barcharts, and scrolling graphic time histories.

End-to-end calibrations on the aircraft of measurements such as control surface positions can be performed with this system. The operator can store samples of a specified measurement decommutated from the PCM data stream, and manually enter the corresponding engineering units value as read from a reference standard. Trial curve fits can then be performed and reviewed by the operator. The polynomial coefficients and/or calibration data table can then be stored to cartridge tape.

Airborne system formats are read from cartridge tapes and downloaded to the airborne package via an RS232 port. These formats can also be edited at the FLCO prior to loading.

GROUND TELEMETRY/DATA PROCESSING SYSTEM

The equipment and software installed in the fixed facilities represent two system functions which have been integrated into a single system architecture. An overall block diagram of the system with its combined functions is shown in Figure 4. The integration of the two capabilities has provided several system advantages:

- Some redundancy has been achieved so that the two system functions can back-up each other

- System resources have some flexibility and can be shifted between the two functions

- Independence of operation and the capability for simultaneous operation has been preserved.

The Ground Telemetry System (GTS) supports real time flight test operations and is required to provide the following capabilities:

- Dual axis tracking antenna

- PCM and video telemetry reception and recording

- PCM telemetry or instrumentation tape playback processing

- Real time workstation displays for test director

- Independent real time workstation displays for engineering personnel supporting the test

- Real time control system transfer function analysis (expandable to real time flutter analysis in the future)

- Disk data formatting with intermaneuver playback analysis

The Data Processing System (DPS) is utilized for post flight data analysis and report generation. It is required to perform the following functions:

- PCM and 100% 1553 input from instrumentation tape

- PCM input from Damien cassette tape

- Playback processing from instrumentation tape or disk files

- Central flight test database management
  - Calibration files
  - Airborne sampling plans
  - Measurement processing definitions
  - Telemetry processing hardware configuration

- Aircraft performance, stability/control and other analysis

- Independent color/graphic workstations for engineering analysis

- Report data generation

In the GTS an L-Band dual axis tracking antenna receives the RF telemetry signal containing both the PCM and video data. Dual receivers and a diversity combiner equipped for both pre- and post-detection combining are provided for the PCM data to improve the signal quality. A single receiver is utilized for the video data which may be both recorded and viewed on the monitor. Both the GTS and DPS are equipped with identical Loral Model 9 instrumentation recorder/reproducers for the recording of telemetry data and playback of tapes. The DPS also contains a Damien cassette recorder/reproducer.

The GTS is equipped with a single stream of EMR 8000-Series PCM synchronization/ decommutation hardware which provides a high performance input link for the telemetry data. The DPS is equipped for the playback processing of three simultaneous streams of PCM data from instrumentation tape - one general-purpose PCM stream, and two PCM streams containing 100% of the data from each of two MIL-STD-1553B busses.

All input data streams from both systems are input to an EMR 8715 Telemetry Multiplex Processor. This preprocessor performs all preprocessing tasks including 1553 data decommutation, engineering units conversion, limit/events alarm checking, simple derived calculations and other commonly required telemetry functions using parallel word slice, floating point processors. The device uses a dual bus architecture and performs I/O, decommutation, and parallel processing tasks with a family of plug-in modules. The unit contains a standard VME bus for set-up, control and some low rate data transfer. An 81 bit wide proprietary bus operating at 10 million transfers per second with masked arbitration transfers data between modules.

The two systems utilize separate DEC MicroVAX II hosts, but share the single preprocessor. Each system can operate independently and can load, start, and stop the processing of different data streams and formats even though the preprocessor is shared. This capability is made possible through configuration support software. This software allows the user to define and logically partition the input, output, and parallel processing modules of the preprocessor among multiple input stream processing tasks. Each set of modules can then be independently loaded with a format processing definition and processing can be started, stopped, or reloaded independently of what is occurring within other logical partitions.

Five I/O paths exist between the preprocessor and the host computing network. All set-up and control data is loaded over the Ethernet local area network. Each host is also connected to the system with two parallel paths. One path outputs data into a dual port memory channel on the host for display and processing, and the second channel outputs data to a high speed parallel I/O channel for archiving.

The dual port memory is used to form a Current Value Table (CVT) by depositing successive engineering unit values of each measurement in fixed memory locations. This method allows the CVT to exist in host address space without consuming the use of any host processor or bus bandwidth. Programs running in the host processor for display, distribution or data processing functions can asynchronously access the CVT for input data. The high speed parallel channel performs buffer building and chaining functions to allow data to be continuously archived to disk at maximum system rates.

An array processor is included with the GTS for real time transfer function computation. A separate output port from the preprocessor outputs arrays to the Analogic AP500 Array Processor through its parallel I/O port. The array processor performs FFT and vector arithmetic operations for calculation of transfer functions. A Q-bus interface between the array processor and the GTS host provides for program loading and control and output of processed transfer functions.

An Ethernet local area network interconnects the two host processors, six DEC MicroVAX 2000 engineering workstations with 19" color monitors, and a server with color hardcopy unit and a laser printer for alphanumeric and monochrome graphic output. Any of the six workstations may independently logon to either host for maximum utilization of facility resources. All hardcopy output is queued to the output devices on the server.

The three primary system computing resources are the preprocessor, the host processors, and the workstations. Data processing and software functions are distributed across these resources as shown in Figure 5. All system software on the DEC equipment runs under standard DEC VMS as a local VAXcluster. The host processor is allocated the functions of database management, data acquisition control, data archiving, derived parameter calculation, data analysis and data distribution. The workstations provide the system user interface, perform data display, do hardcopy formatting of displayed data, and run a powerful graphics display editor.

All system functions can be performed from any workstation using a master menu from which all configuration editing and data acquisition control functions can be accessed. All workstations can be used for real time display and playback processing of data being acquired on the host processor on which the workstation is logged. The graphics editor gives the individual workstation user total flexibility to construct his own displays and connect measurements to drive display symbols.

Database editing and management is performed through edit and configuration utilities which result in a series of files from which load images can be constructed and loaded as shown in Figure 6 and Figure 7.

Once all loading functions have occurred and data acquisition has been initiated, the data flow proceeds as shown in Figure 8. Data is normally converted to engineering units in the preprocessor and input through the data channels in DEC floating point format. Data is archived to disk along with 16-bit identifying tags. The data is formatted as single continuous file made up of records whose length is determined by the selected buffer length. Time is treated as a tagged measurement and is interleaved with the data at millisecond intervals. For real time display, the CVT in host dual-ported memory is broadcast over the Ethernet network at periodic intervals. A streamlined protocol rather than standard protocol is utilized to improve the efficiency of the network for CVT broadcasting. Functions other than CVT broadcast utilize standard protocol.

Each workstation retains a copy of the CVT in its local memory which is used as the data source for the displays being viewed. The workstation display contains a fixed header and footer and a display screen area which may be partitioned into up to four windows with various types of display formats defined for each window. Displays may be dynamically swapped out of individual windows and individual measurements may be added or deleted within individual display windows. An example of a display is shown in Figure 9.

Simple derived calculations such as airspeed and Mach number can be calculated at the incoming data rate in the preprocessor and treated as measured data. More complex calculations which are not practical to perform at the real time data rate can be performed in the host processor. The input data is obtained from the CVT and the results are both archived to the disk files and input to the CVT for distribution to the workstations.

The host is also responsible for archived data retrieval. Data can be recalled from the archival files by any workstation for display. Recall can be performed simultaneously with real time data acquisition. The host will retrieve the data set and send it over the Ethernet to the requesting workstation. The workstation may then display archived data in one workstation window while displaying real time data in another window. Since the data is archived in engineering units form, no host or workstation processor time is consumed in file references and engineering unit conversions for playback display.

A Flight Test Applications Software Package (FTASP) is also being furnished for aircraft performance and stability/control data analysis. The input to this package is recorded engineering units data as well as flight-specific information such as engine start weight, stores loading, fuel density and other test-specific information. Aircraft configuration information such as airspeed calibration data and the orientation of gyros and accelerometers is also required for error correction. The FTASP can execute on a workstation or the host and has provisions for both interactive and batch operation.

The airborne system configuration software also runs on the host processors. Airborne formats can be defined and recorded on cartridge tapes which can then be loaded from either the FLCO or the MGTS. A historical calibration library which can maintain the calibration history of the measurements on a particular test aircraft is also supported. Calibration data can be input to this file manually or transferred from cartridge tapes after being acquired and curve-fit at the aircraft on the FLCO.

MOBILE GROUND TELEMETRY SUBSYSTEM (MGTS)

The MGTS is installed in a four-wheel tow trailer and is equipped with a single-axis tracking antenna. A block diagram of the system is shown in Figure 10. Except for the antenna, the hardware configuration is a subset of the GTS. A telemetry preprocessor, host processor, and workstation comprise the processing elements of the system. The system software is identical to that described for the GTS/DPS. Functional requirements for the MGTS include:

- PCM and video telemetry reception and recording
- PCM and 100% 1553 input from tape or umbilical from aircraft
- PCM input from Damien cassette tape
- Airborne encoder loading/programming via umbilical from aircraft
- Real time telemetry or tape playback processing
- Disk data formatting with intermaneuver playback
- Engineering workstation display for test director
- Compatibility with fixed ground processing facilities

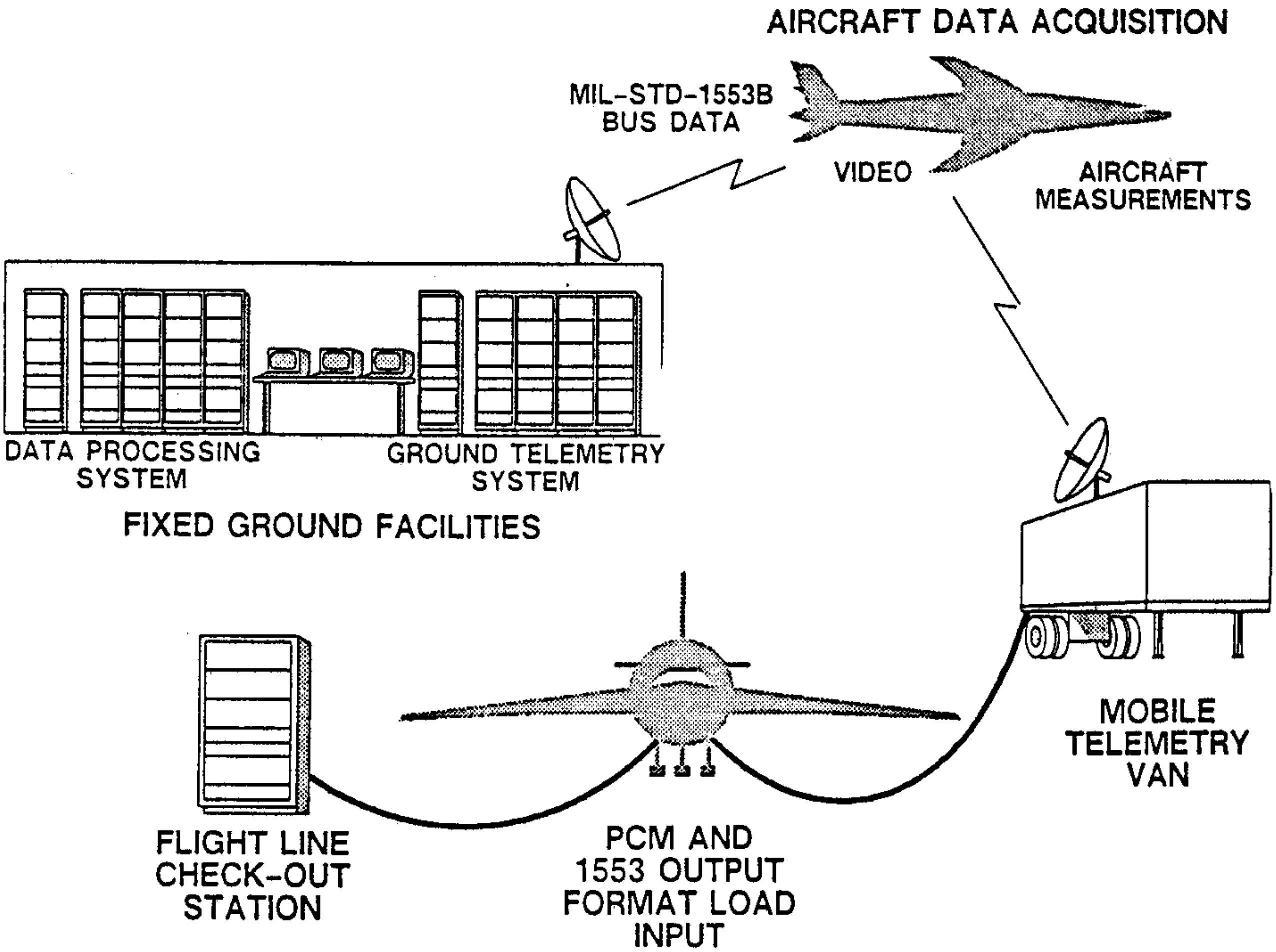

Figure 1. Overall System Relationship

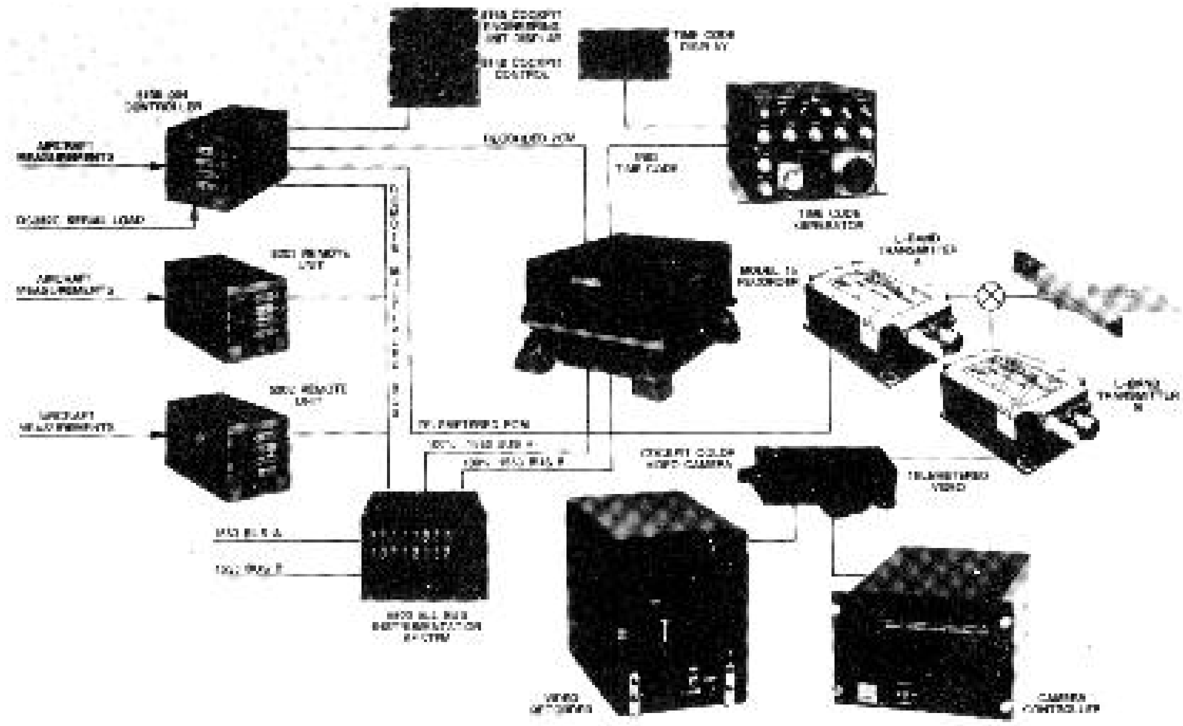

Figure 2. Typical Airborne Subsystem

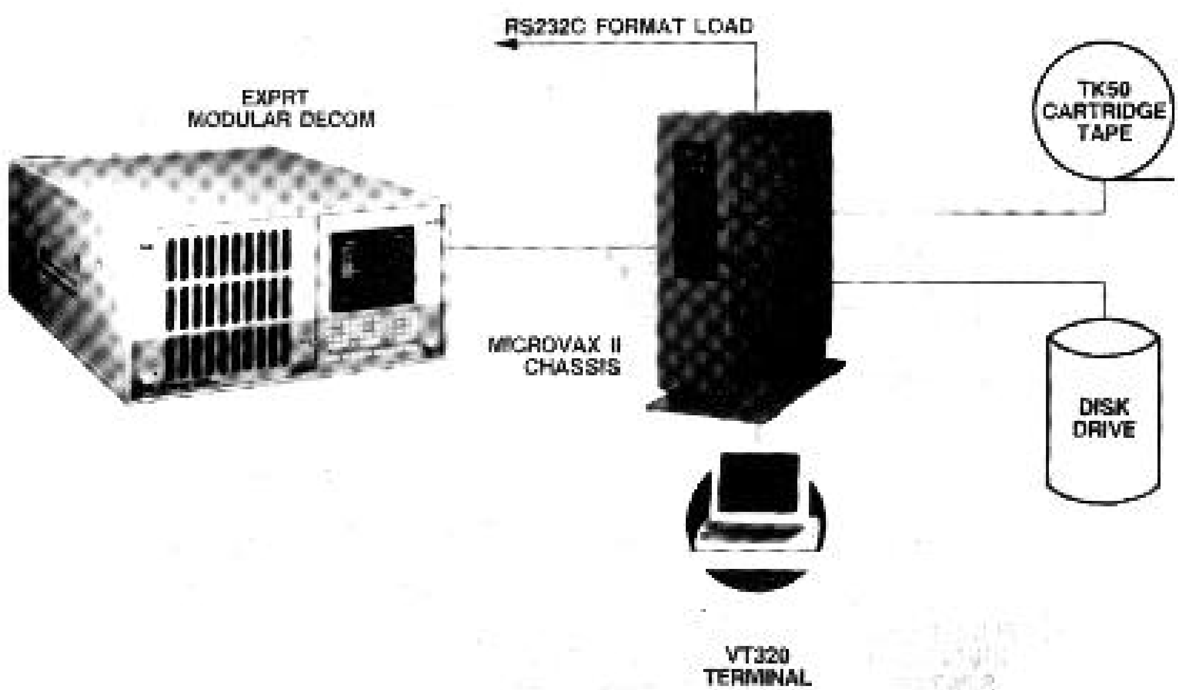

Figure 3. Flight Line Check-Out Subsystem

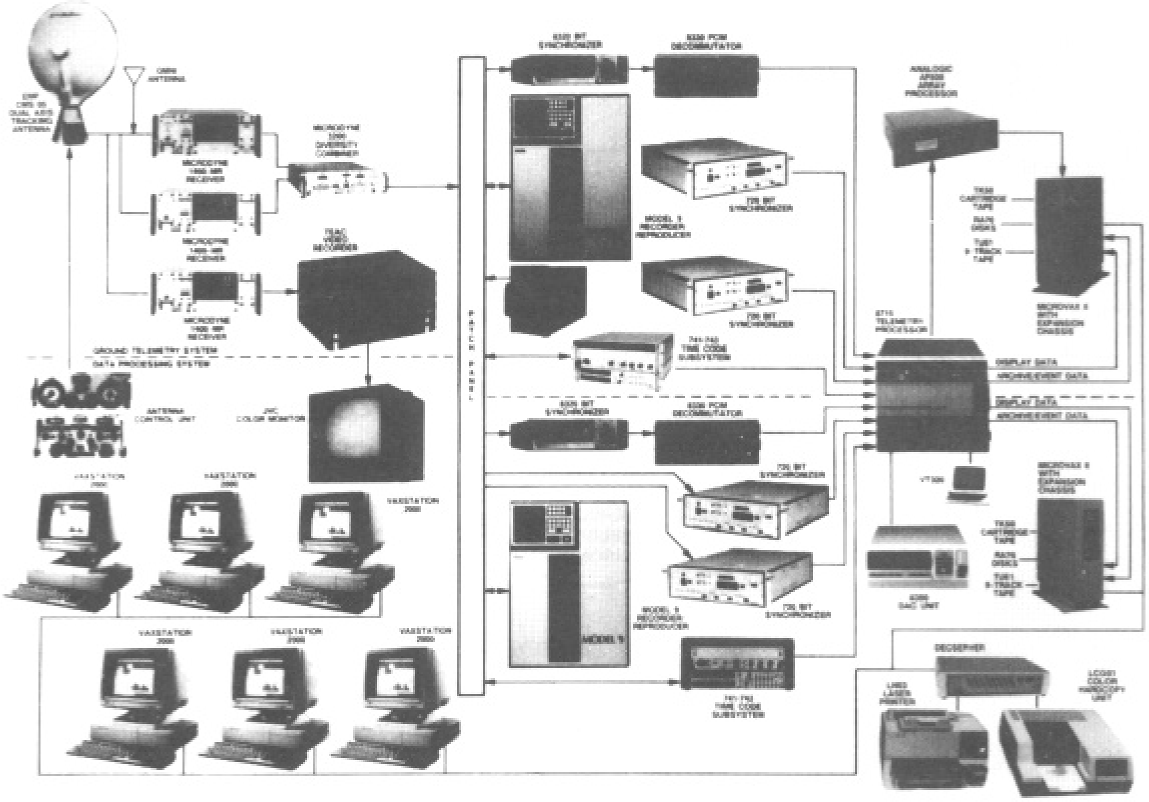

Figure 4. Fixed Ground Facilities

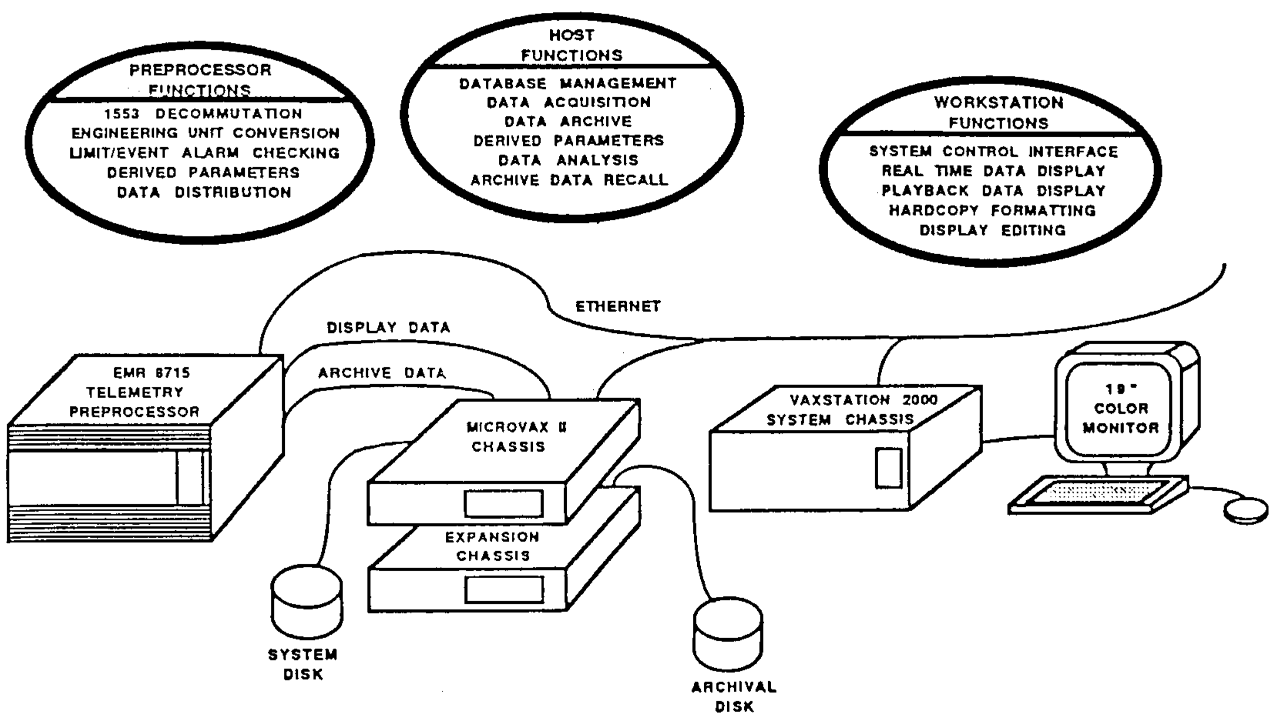

Figure 5. Distribution of System Functions

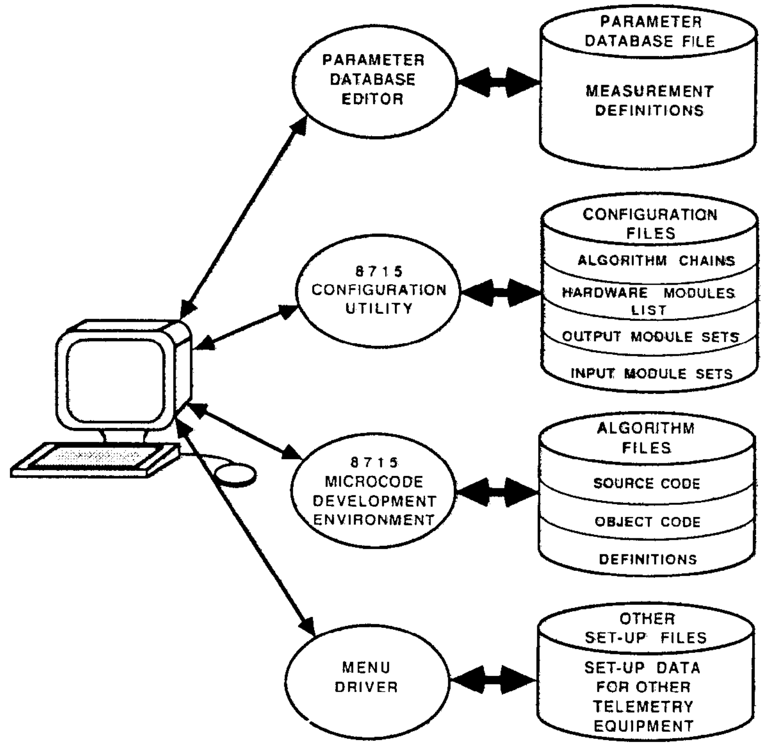

Figure 6. Configuration Definition Software

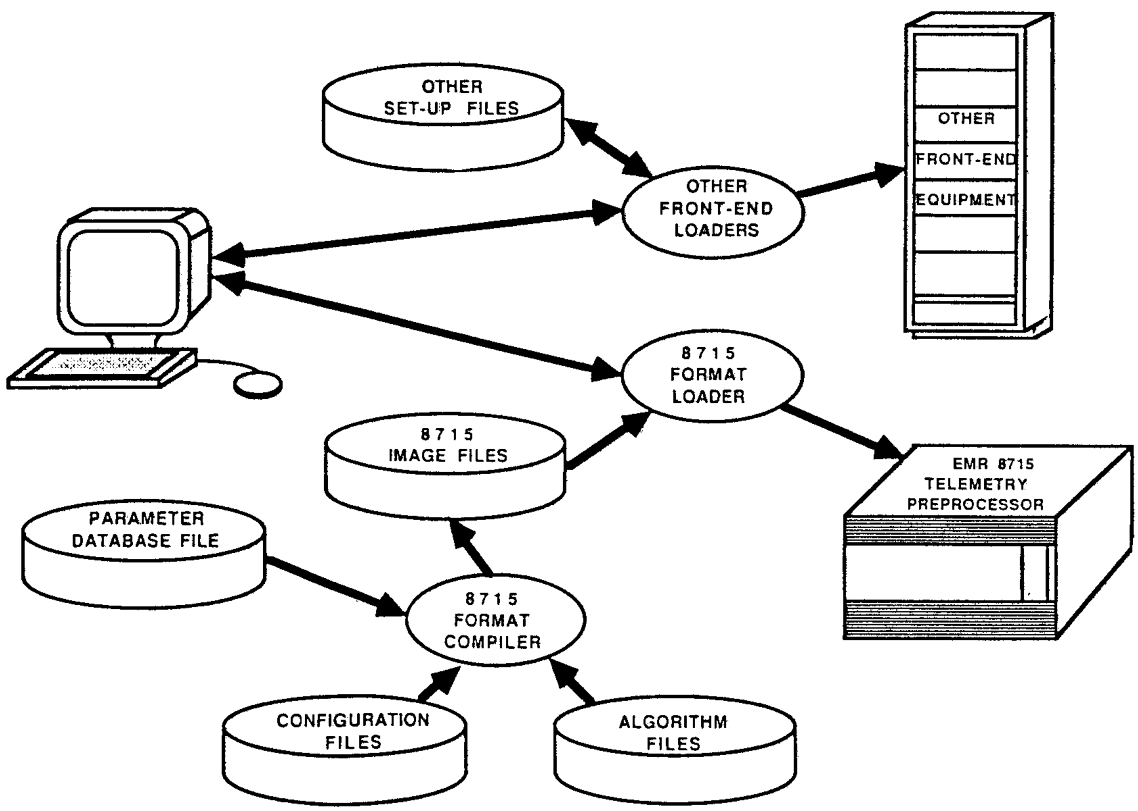

Figure 7. Telemetry Equipment Loading Software

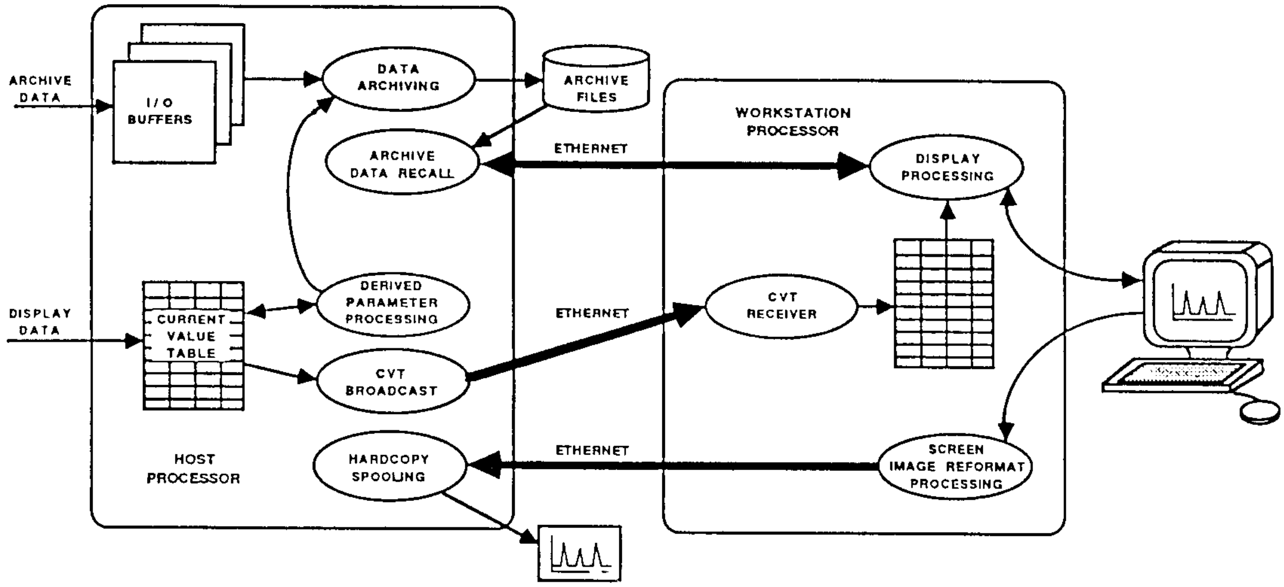

Figure 8. Network System Data Flow

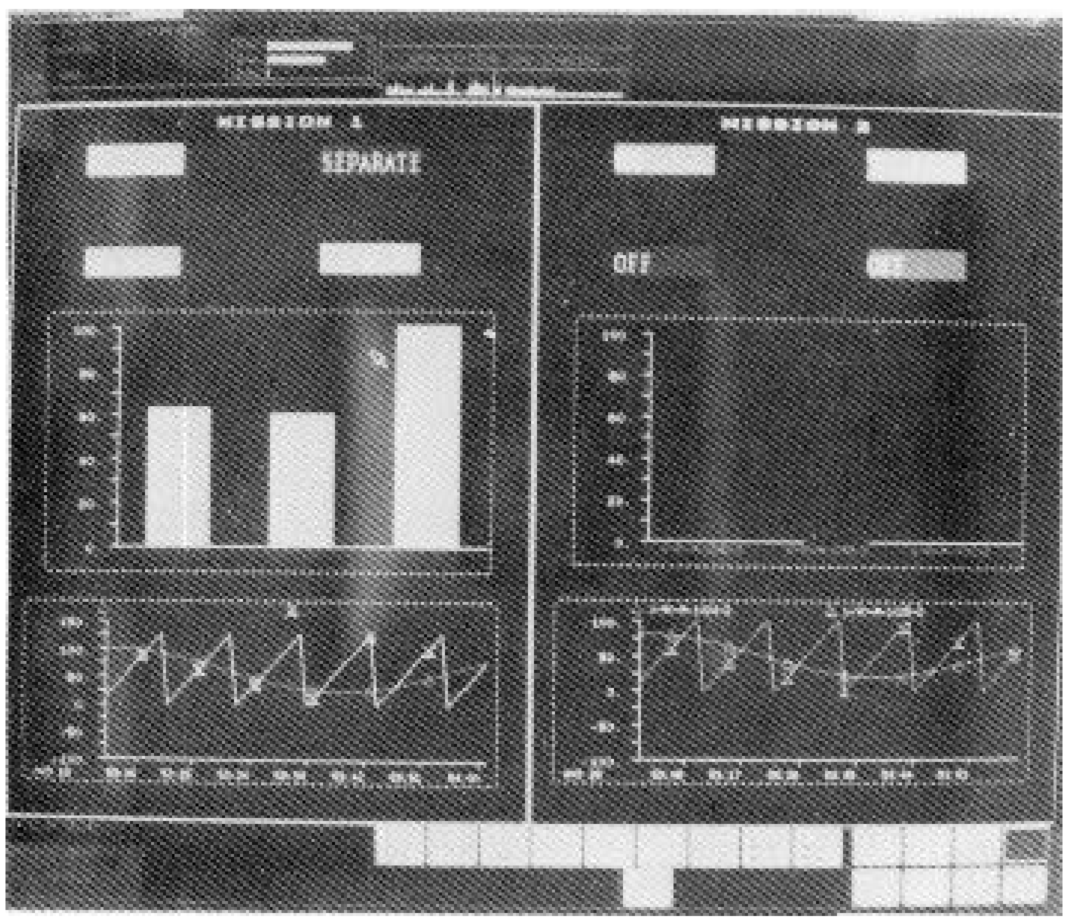

Figure 9. Typical Workstation Display

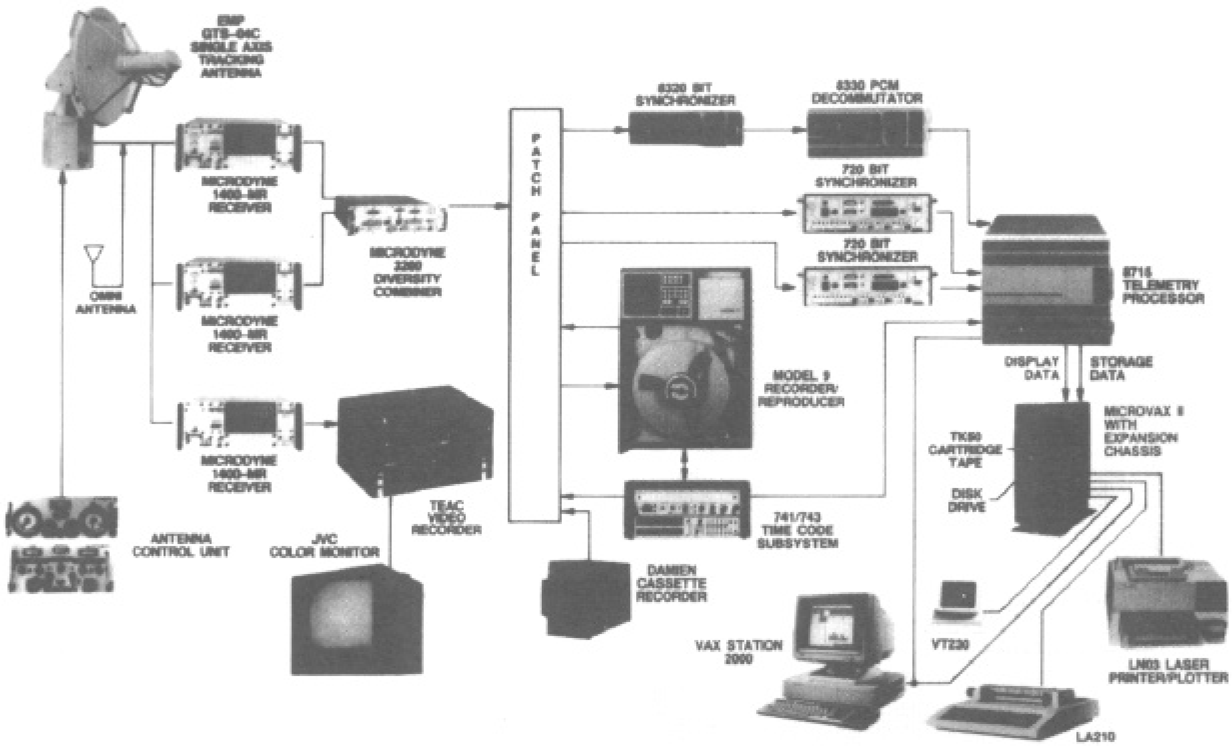

Figure 10. Mobile Ground Telemetry Subsystem