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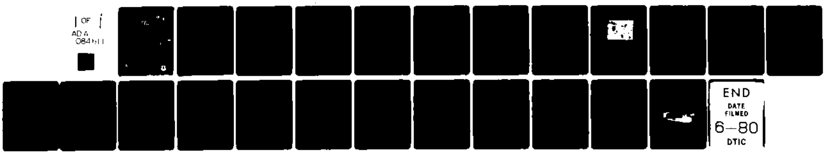

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AFGL Balloon Telemetry Facility

ARTHUR A. GIANNETTI
J. CRAIG ERICKSON

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HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF

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FOR THE COMMANDER

John Howard

Chief Scientist

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This paper describes the recently modernized permanent and mobile facilities for recovering and processing PCM and FM telemetry data from balloon-borne scientific experiments and engineering tests at Air Force Geophysics Laboratory, Detachment 1, Holloman Air Force Base, New Mexico. Mobile units are run either as stand-alone ground stations for launches from remote launch sites, or with telephone communications link to extend the operable range from the permanent ground station on Holloman AFB.

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Illustrations

AFGL Balloon Telemetry Facility

I. INTRODUCTION

This report describes the data acquisition and display capability available to scientific experimenters for developmental projects utilizing a balloon vehicle from the Air Force Geophysics Laboratory (AFGL), Detachment 1, Holloman AFB, New Mexico.

Under IHWU 66650804, the capability to provide real-time data reduction and display using a PDP 11/40 minicomputer and a PCM ground station was developed.

The average experimenter or "user" is primarily concerned with the balloon-borne scientific apparatus or test package that is the basis of his mission. For collection, telemetry, recording and display of the data, and command-control of the experiment, the scientist usually relies upon the personnel and instrumentation at the test facility. This paper discusses the capabilities available at AFGL Det 1 for reception, collection, manipulation, and display of telemetry data transmitted from the balloon-borne instrumentation.

The ground system operates either with standard, balloon-borne PCM data encoders provided by AFGL, or in special circumstances, with encoders supplied by the experimenter. Multiple displays present information in real time from the on-board scientific apparatus. The collected data are recorded on analog and digital magnetic tapes for analysis either at the ground station, or later, at the user's

(Received for publication 22 January 1980)

home station. The ground station is configured about a Digital Equipment Corporation PDP-11/40 computer and its peripherals and EMR telemetry equipment.

A modernization program has been underway to improve the ground-support instrumentation at the permanent station and in mobile units. The Aerospace Instrumentation Division of AFGL, and the Physical Sciences Laboratory of New Mexico State University under AF Contract F19628-78-C-0070, have been implementing this program. Motivation for this program has been to replace some aging, inadequate equipment with modern, more reliable and versatile electronics and to minimize the cost of these support functions. Economies can be realized through commonality and standardization of support hardware and software. The unique requirements of each experiment are not constrained; in fact, the experiment usually is enhanced by taking advantage of the extensive experience and equipment available at AFGL Detachment 1.

2. GENERAL DESCRIPTION

The AFGL Detachment 1 balloon flight facility is located in Building 850 on Holloman Air Force Base, near Alamogordo, New Mexico. All real-time data collection and scientific display capabilities are conveniently located within a single room. Figure 1 is a photograph of this room. Directly across the corridor is "mission control". Here the mission controller is primarily concerned with balloon launch, flight control, safety and recovery operations.

This AFGL facility has a very versatile communication system for in-flight data recording, display and uplink commands. Both Frequency Modulation (FM) and Pulse-Code Modulation (PCM) telemetry systems are available with a variety of equipment which allows the scientific user accurately to recover, display and record data from balloon-borne experiments. A block diagram of this system is shown in Figure 2. Line printers, cathode ray tubes (CRT's), analog pen recorders, nine-track digital tape units, and disks allow the user to record and/or monitor vital data received from the balloon in real time. By utilizing the information on the display system, the scientist can make timely decisions to alter experiment operations, or to change the balloon trajectory. With such powerful tools as the PDP-11/40 digital computer, the experimenter can manipulate the received signals so that data parameters can be displayed in scientific form for ease of interpretation. All recorded data can be replayed at real-time speed or more slowly, either to verify operational readiness, or in preparation for subsequent flights. For in-depth data reduction and analysis, the data recorded from the system can be compatible to large-scale, data-reduction facilities. The base facilities at AFGL, Detachment 1 can provide scientific support in real time for balloon-borne devices at operating ranges as far as 250 miles away when the balloon altitude is 50,000 ft or higher. This coverage allows routine operational support for launches at Holloman AFB and the various other sites in and around White Sands Missile Range (WSMR), adjacent to Holloman AFB.

Figure 1. Fixed Telemetry Facility

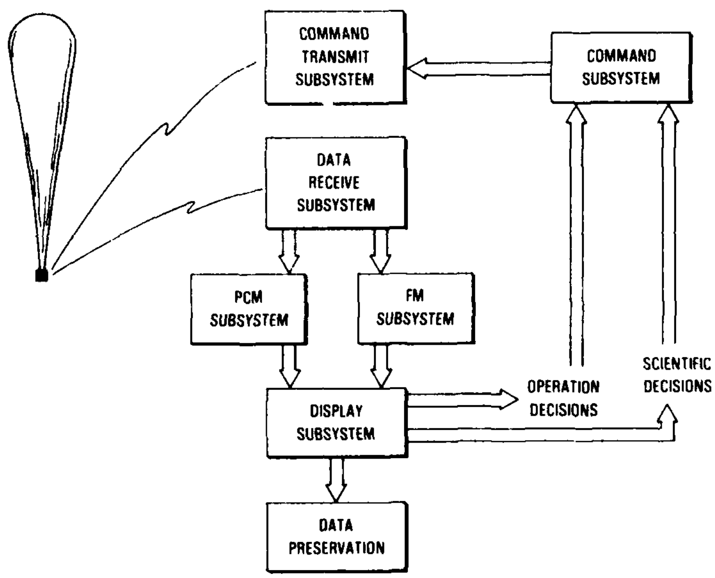

Figure 2. Telemetry Support System

A mobile facility with similar data acquisition capabilities is also available to the user who requires coverage from remote launch locations, or extended coverage for flights from Detachment 1. For the latter purposes, that is, at ranges greater than 250 miles, the mobile facility can be strategically located, with a telephone communication link to the base facilities. This arrangement will provide continuous display of scientific data back at the base facility, but because of the limited data rates achievable over standard telephone lines, only subsets of the total data packages will be displayed.

Due to the flexibility of the PCM system, the bit rates, bit order, word sizes, and data content can be adapted to a wide range of formats. Nominal data rates for most applications is in the lower kilobit range. Data rates as high as 512, 000 bits per second and 1600 frames per second have been successfully received and processed and the data displayed. Bit rates as high as 2, 000, 000 bits per second could be handled. Standard software is available for the "standard" data set, and special programs can be developed for users with individual requirements. For example, Dr. Earl Good of AFGL recently conducted an experimental program to obtain data for modeling upper atmosphere turbulence. Special data-manipulation software was generated together with special displays that enabled him to continuously monitor the status of his experiment and make immediate decisions to control it.

3. RECEIVING SUBSYSTEM

The receiving subsystem is the "front end" of the telemetry data system. Signals are received from the balloon-borne transmitters and are routed to the subsystem which can convert it back into intelligent data. An Andrews Corporation steerable-antenna system is used to receive these signals. A functional block diagram of this system is shown in Figure 3.

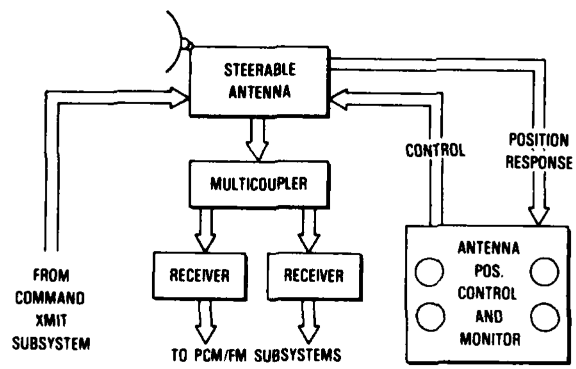

Figure 3. Data Receiving Subsystem

Signals can be received during setup for launch and while the balloon is moving out of the launch area. The manually-controlled antenna can be pointed in any direction in order to optimize reception of the signals. From the antenna system the signals are routed to a multicoupler. The multicoupler accepts the single input and generates multiple outputs. These outputs are presented to two Microdyne 1100 AR receivers.

The receivers can be tuned to discern the preassigned transmitter frequency signals from among others that may be present. With inputs in the S-Band frequency ranges, the receiver provides outputs which can be presented to either the PCM subsystem or the FM subsystem.

4. PCM TELEMETRY SUBSYSTEM

Within the telemetry system there are two distinct capabilities, PCM and FM. In general, the PCM system provides more flexibility in data encoding and transmission. The PCM subsystem is configured around the Digital Equipment Corporation (DEC) PDP-11/40 digital computer. Data flows into and out of the computer via the flexible DEC UNIBUS. A block diagram of the PCM subsystem is shown in Figure 4.

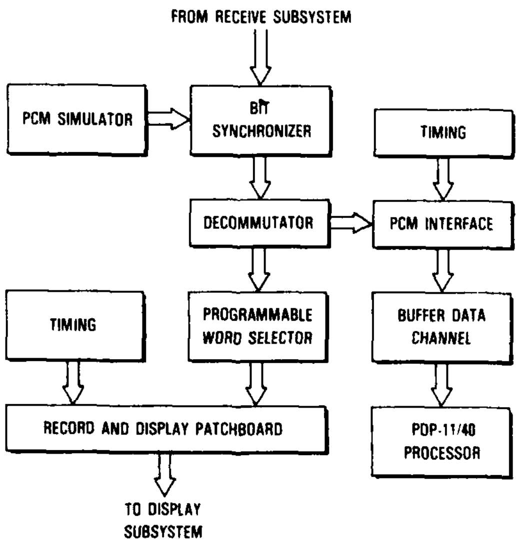

Figure 4. PCM Subsystem

Data is obtained from the two receivers of the receiving subsystem. The information is presented to an EMR 720 Bit Synchronizer. The Bit Synchronizer accepts the PCM data in the presence of noise and other perturbations and generates reconstructed, coherent PCM data and multiple clock outputs. EMR can process all standard Inter-Range Instrumentation Group (IRIG) PCM codes, which include NRZ-L, NRZ-M, NRZ-S, Biϕ-L, Biϕ-S, BiϕM, RZ, DM-M and DM-S. The unit offers a high level of performance over the range of 1 bps to 5, 000, 000 bps. It can handle from one to four different signal inputs. Currently, these include the two receivers and a PCM Simulator. The 720 can be either manually controlled or controlled by the PDP-11/40. The multiple inputs allow rapid selection of the different signal sources so that data reception and system testing can be optimized.

The NRZC PCM data and timing outputs of the EMR 720 Bit Synchronizer are routed to an EMR 710 Decommutator which performs frame synchronization and serial-to-parallel conversion, and provides a parallel data multiplex output with synchronization information. Any frame-synchronization pattern between four and 33 bits, with frame lengths of up to 512 words and bit rates as high as 2, 000, 000 bps, can be accommodated. The 710 parallel output and synchronization information is presented to an EMR 713 Programmable Word Selector. Serial NRZC data from the 720 Bit Synchronizer, and frame-synchronization information from the 710 are presented to the computer interface.

At the EMR 713 Word Selector, the received PCM data and frame-synchronization information is used to convert selected 8-bit and 12-bit data words to analog form. The selection process is done by a manual patchboard which can select up to 32 different data words in each frame. Both main-frame data words as well as subframe-data words can be selected. Output analog data words are represented by a dc voltage of 0 to 10 volts. These 32 analog channels are updated at the frame and subframe rate of the incoming data. Data word least-significant-bit (LSB) and most-significant-bit (MSB) alignment takes place at the patchboard so that data from any balloon-borne encoder can be accommodated. Each of the 32 analog output data channels is routed to a display patchboard for assignment to selected analog display devices optimum for the scientific user.

The serial NRZC PCM data output of the 720 Bit Synchronizer and the frame-synchronization information from the 710 Decommutator are routed to the special purpose PCM interface unit. This unit is specifically designed to meet the varying needs of the PCM subsystem. Its purpose is to preprocess the incoming PCM data, multiplex time-of-day information with it, and pass the parallel data to the PDP-11/40 processor. By utilizing a patchboard within the unit, the data presented to the computer can be optimized so that data-word formats will essentially remain constant in light of inputs which will vary from one balloon-borne experiment to another. Such things as data-word bit alignment (LSB/MSB reversals), placement within the computer word, automatic parity checking, and deletion of unneeded data words within the mainframe are performed by the interface. The resulting PCM data is then merged with the time-of-day (TOD) information for data time tagging. Time tags selected can be from milliseconds, to the day of the year, according to the user needs. Flexibility exists for the user to be able to select the event to which the TOD information is applicable, for example, to the mainframe sync, the first data word, etc. Additional status information is also merged into the data buffer which is then transferred to the computer. This frame/data word processing and time multiplexing can take place at frame rates of several thousands per second, limited only by the PDP-11/40 processor.

The parallel data from the PCM Interface are then presented to an EMR 2763 Buffered Data Channel. This unit, under program control and initiation, will transfer data words from the interface into program-selected segments of the PDP-11/40 processor memory. This transfer takes place under Direct Memory Access (DMA) and interrupt control, which minimizes attention required by the program and maximizes throughput rates. Up to 250, 000 16-bit words per second can be transferred to the processor memory by this device. Communication between the 2763 and the PDP-11/40 is through the PDP 56-line UNIBUS. At this point, selected PCM data received from the balloon-borne experiment are presented in real-time to a digital program being executed within the PDP-11/40 processor. The data are available for display or manipulation according to algorithms defined by the scientific user. Output displays and permanent recordings are also selected according to the data collection requirements.

For pre-mission testing and system evaluation, an EMR 2795 PCM Simulator is used to generate signals like those to be received from the balloon-borne telemetry package. 2795 formats can be generated with up to 599 words in the mainframe and up to 599 words in the subcommutated frame, and with word lengths from one to 33 bits. Serial PCM signal outputs can be in any one of eight codes which include NRZ-L, NRZ-M, NRZ-S, RZ, Biϕ-L, Biϕ-M, Biϕ-S, and DM-S at bit rates from 1 bps to 2, 000, 000 bps.

5. PDP-11/40 PROCESSOR

The center of the PCM processing system is a PDP-11/40 Computer. This computer accepts the PCM and time inputs, processes selected data according to pre-defined algorithms, and outputs the results to displays or permanent storage devices. The digital real-time program which resides in the processor controls this data flow and performs the data manipulations. A block diagram of the PDP-11/40 processor subsystem is shown in Figure 5.

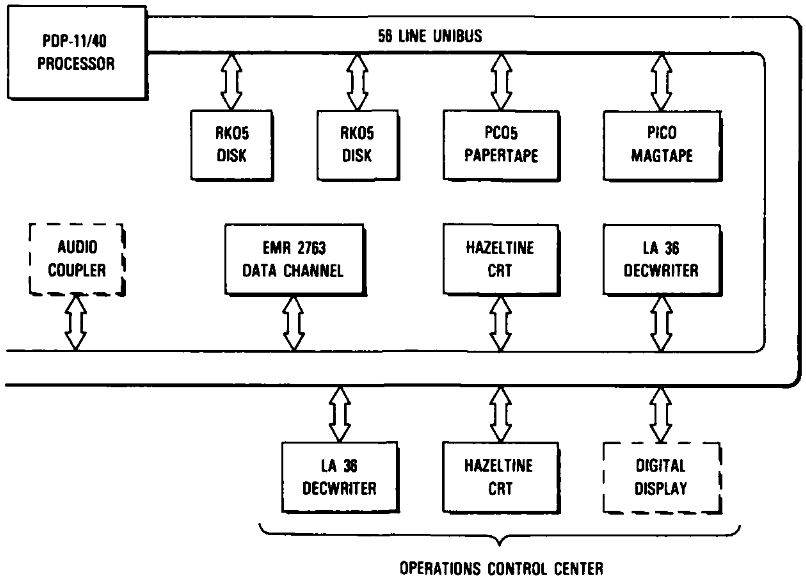

Figure 5. Processor Subsystem

The PDP-11/40 computer is a 16 bit, general purpose, parallel logic, microprogrammed computer using single- and double-operated instructions and "2's complement" arithmetic. The system contains a multiple-word instruction processor which directly addresses up to 28, 000 words of core memory. All communications among the system components (including processor, core memory, and peripherals) are performed on a single high-speed bus, the UNIBUS. Because of the bus concept, all peripherals are compatible, and device-to-device transfers can be accomplished at the rate of 2. 5 million words per second.

The central processor unit (CPU) is a KD11-A which decodes the instructions; accepts, modifies and outputs data; performs arithmetic operations; and controls allocation of the UNIBUS among external devices. The processor contains 16 hardware requestors, eight of which are programmable. The processor recognizes four levels of interrupts with each major level containing sublevels. The priority level of the processor is itself programmable, allowing a running program to select the priority level of permissible interrupts. Additional speed and power are added to the interrupt structure through the use of the fully vectored interrupt scheme.

Contained within the CPU is the Extended Instruction Set option (EIS) which provides the capability of performing hardwired fixed-point arithmetic. Also within the CPU, is the Floating Point Unit option which allows the execution of four special instructions for floating point addition, subtraction, multiplication and division. Together, the EIS and Floating Point capabilities allow significant execution time and program implementation improvements over the comparable software routines. In effect, complex mathematical algorithms can be performed in less time, thus enabling the processor to handle larger user-task routines.

Core memory of the processor is a MF11-U which is a read/write, random access coincident current magnetic core type, with a maximum cycle time of 980 nanoseconds (ns) and a maximum access time of 425 ns. The word length is 16 bits and consists of 32, 768 words (32K words), of which only 28K are program accessible.

6. PDP-11 PERIPHERALS

A number of peripherals are attached to the PDP-11/40 to optimize program development, user output display, and system control. These units consist of hardcopy units, CRT's, disk drive, magnetic tape drive, numeric display, paper tape system and an audio coupler. Two hardcopy devices are used within the system: an LA30 and an LA36 DECwriter. The LA30 DECwriter is a dot-matrix impact printer and keyboard capable of printing a set of 64 ASCII characters at a speed of up to 30 characters/second on a sprocket feed 9-7/8-inch wide continuous form. Each line is 80 character positions in length with a spacing of 10 characters per inch, and a vertical spacing of six lines per inch. This unit is located in the balloon operations control center as an output device for balloon operational information such as altitude, temperature, pressure, etc.

The LA36 DECwriter II hardcopy device is located in the telemetry/display room where information for the scientific user can be displayed. An LA36 DECwriter II is a medium-sized, interactive data-communication terminal with a standard ASCII-coded keyboard (consisting of alpha-numeric characters and non-printing characters) and prints at a horizontal spacing of 10 characters per inch with a maximum of 132 characters per line, and a vertical spacing of 6 lines per inch. The printer is capable of handling continuous multipart- and multiform-line printer paper from 3 to 14-7/8 inches wide. The print rate is selectable from 10, 15 or 30 characters per second. In addition to being available as a scientific data output device, it is also used as the primary program setup and initiation input device by the operator.

For real-time processing program development and for program execution use, there are two RK05 Disk Drives. The RK05 Disk Drive is a self contained, random access, data-storage device which uses a high-density single-disk, 12-sector and 16-sector cartridge as its storage medium. Two movable heads can record or read up to 406 data tracks which can store up to 25 million bits of on-line data. Maximum bit transfer rate is 1.44 million bits per second.

For maintenance test program loading and use as a special storage medium, the PC05 Paper Tape System is used. It is available for use between a user computer system and the AFGL data support system, but isn't normally used because of its low speed.

The PC05 High-Speed Paper Tape Reader is an electromechanical tape-feed system from which information is read from eight-level, 1-inch perforated tape, at a maximum rate of 300 characters per second. The tape punch is also an electromechanical tape-feed and punch system capable of punching five-, seven-, or eight-level tape.

Two CRT units are incorporated into the system to display dynamic data to the viewer. One CRT is located in the operation control room where the mission controller can access special routines within the processor. Utilizing the two-task program execution system of the processor, the mission controller can call up special programs for execution. These programs yield information such as ballasting or valving effects versus amount of ballast dropped, or amount of helium valved with considerations such as altitudes, pressures, temperatures, time of day, etc. Positioning programs could also be used for locating the balloon with respect to any local OMEGA station. Other special routines, such as parachute drift, time to impact, etc., could be called up for assisting in recovery decisions.

The second CRT is located in the telemetry/display room and is available for display of user-selected parameters. Generally, the data displayed is dynamic information updated at the sampled frame rate. Battery voltages and currents, positions, etc. can be displayed in a fixed format on the CRT. Additional assists to the user are available by defining critical parameter-monitor algorithms, for example, allowing the processor to automatically monitor battery voltages, and providing output alerts to the operator via the CRT if they exceed predefined values. These algorithms can be as versatile as needed by the specific user.

The two CRT's used in the system are Hazeltine 1500's. The 1500 has both a video terminal as well as a keyboard for data entry. The keyboard is the same as a standard typewriter plus a keypad which together include the upper- and lower-case ASCII character set. The video screen will accommodate 24 lines of information with 80 characters per line with both foreground and background display modes. Also available to the user is full cursor control using direct cursor addressing plus individual cursor control keys.

For primary PCM data recording, a magnetic tape unit is available. Raw input data or the intermediate and/or final results of calculation can be recorded on digital tape which is compatible to most user computer facilities. A Precision Instrument, PI-1400, Digital Magnetic Tape System is used for recording this data from the processor. The 1400 accommodates reel sizes up to 10-1/2 inches in diameter with computer-standard hubs. The tape medium is 1/2 inch wide by 1.5 mil thick mylar, standard computer tape. The data is placed on the tape in nine tracks at a speed of 37-1/2 inches per second. Recording densities are selectable from either 556 or 800 bits per inch using either even or odd parity. The physical characteristics are common for data to be reel compatible with other large-, medium-, or small-scale computer systems.

An audio coupler is also present within the system to allow remote input of data over telephone lines. This capability will be used when data is captured, assimilated and sent to the PDP-11/40 from a remote site.

7. SOFTWARE

The PDP-11/40 processor can process, display and record telemetry data as received from the balloon. This is achieved by special real-time software which resides in, and is executed by, the computer. Within the software are contained the algorithms necessary to perform all required tasks, such as data conversion, data recording, operator display, real-time logging to the hard copy devices, and real-time computations.

In order to make the system as flexible as possible, the software has been structured as a collection of closely related but independent modules required to perform the desired tasks. Many functions such as Input/Output handlers have been coded at the assembly level and integrated into the RT-11 operating system. Other more "mission specific" functions are coded in FORTRAN to allow easy modification as requirements dictate. This concept is depicted in Figure 6.

More flexibility is also realized by utilizing a priority structure whereby the more time-critical functions are performed at the expense of the less critical functions such as hardcopy logging. This keeps the slower I/O devices from slowing down the rest of the system.

For program development and real-time executions, the RT-11 F/B Operating System is used. The RT-11 is a high-performance Foreground/Background Operating System with user-oriented software. The RT-11 Operating System actually provides two monitors, the single-job monitor and the F/B monitor. The F/B monitor allows two programs to operate, where the real-time program is accomplished in the foreground which has priority. For ease of use, the user-oriented algorithms are implemented using FORTRAN IV language as defined in the ANSIX3.9 1966 Standards. Other languages such as BASIC could be used if the need arises.

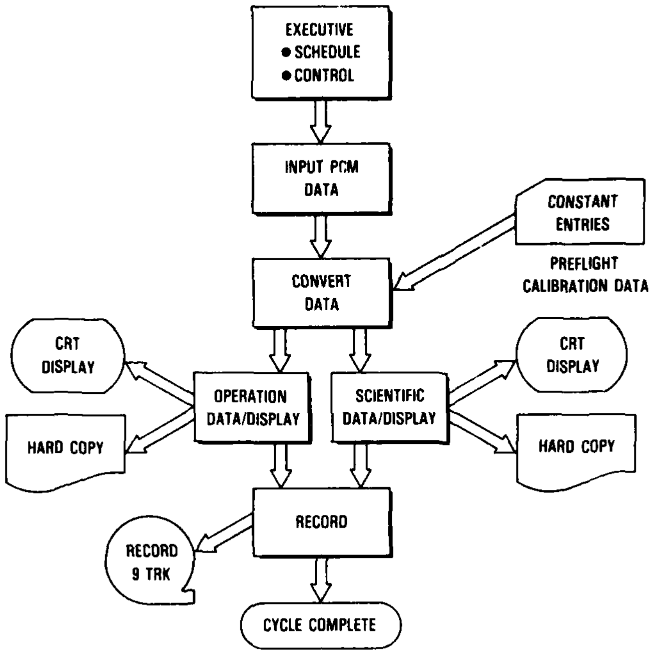

Figure 6. Real-Time Program

Real-time and support programs are the two types of programs employed at the facility. The support programs are those which are structured to do various special purpose tasks such as system checkout, maintenance, calibration, etc.

The primary program will be the real-time program. Execution in real-time implies that the dimension of time must be incorporated into the execution of the instruction sets. For the telemetry system, this will be accomplished by subdividing each second into equal intervals. Within each interval the operational program set of instructions will be executed. When completed, the processor will "idle" until the start of the next interval. This process is repeated for each interval. If there are more tasks to be executed in any given cycle than there is time to do it, those functions (or tasks) with the lowest priority will be deferred until a later cycle.

Real-time data processing is highly dependent upon the quantity of input data and its input rate, and the amount of processing required. As described earlier, the raw data is presented to the computer from the special purpose PCM Interface. Recall that the data received at the computer is a composite of scientific information as well as balloon status data, which is further merged with time-of-day and ground-system status, graphically represented in Figure 7. The specifics of the data rates and contents shown in Figure 7 are from a recent scientific balloon flight from HAFB.

To maximize the available computer computational time, the PCM Interface is utilized as a raw-data edit device. For example, if a balloon-bone encoding system is sending a new frame of data to the ground every 625 microseconds (1600 frames per second), the computer could not keep up with the tasks of receiving, processing, displaying and recording. Through the use of the PCM Interface, however, only one out of 10 frames would be passed to the computer in real time, or a rate of 160 frames per second (Figure 8). Each of the 160 frames is equally spaced in time.

These 160 frames per second are further edited by the real-time software so that only 10 frames per second result, as shown in Figure 9. These 10 frames per second are also equally spaced and are subjected to a special software routine which will average the 10 data points to yield a single data point per second as shown in Figure 10. This single point is then used throughout the rest of the real-time data manipulations.

Of course, the entire 1600 frames per second data set is continuously recorded on analog magnetic tape so that no data is lost. Post operations usually include digitizing of all data during selected periods of interest using the PDP-11/40 computer, with different programs being executed. In this phase, all 1600 frames per second of data are formatted and placed on nine-track tape in a form which is compatible to the users large-scale data processing center. (Throughout the above

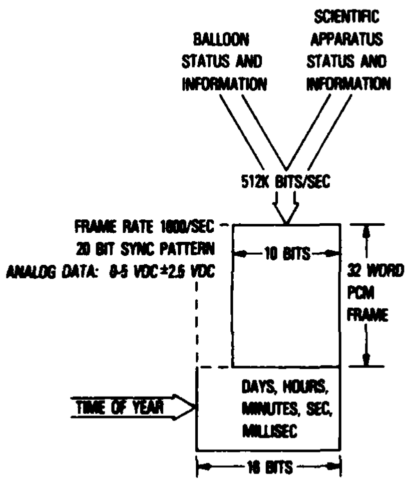

Figure 7. Example of PCM Data Set Format

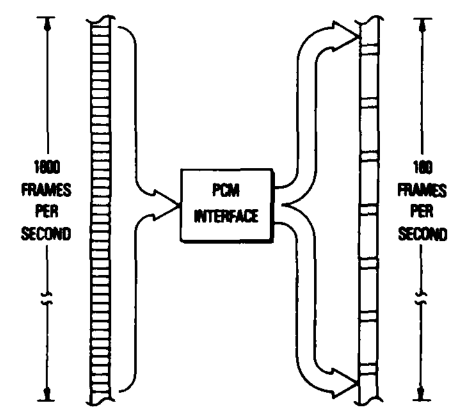

Figure 8. PCM Interface, Raw Data Edit

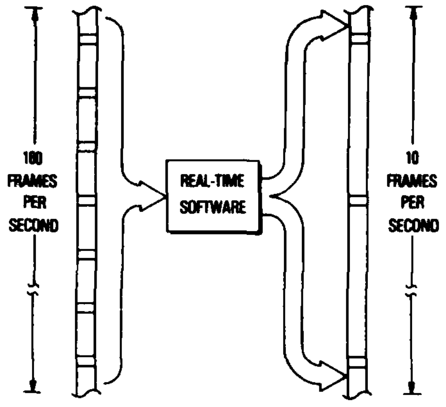

Figure 9. Real-Time Program, Raw Data Edit

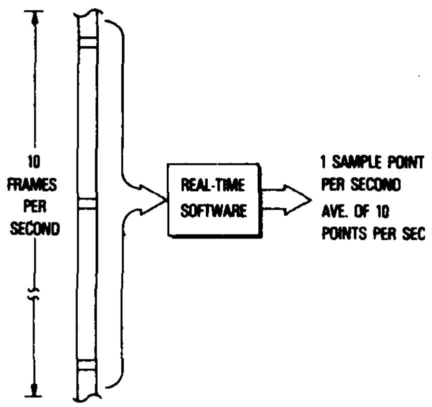

Figure 10. Real-Time Program, Raw Data Average

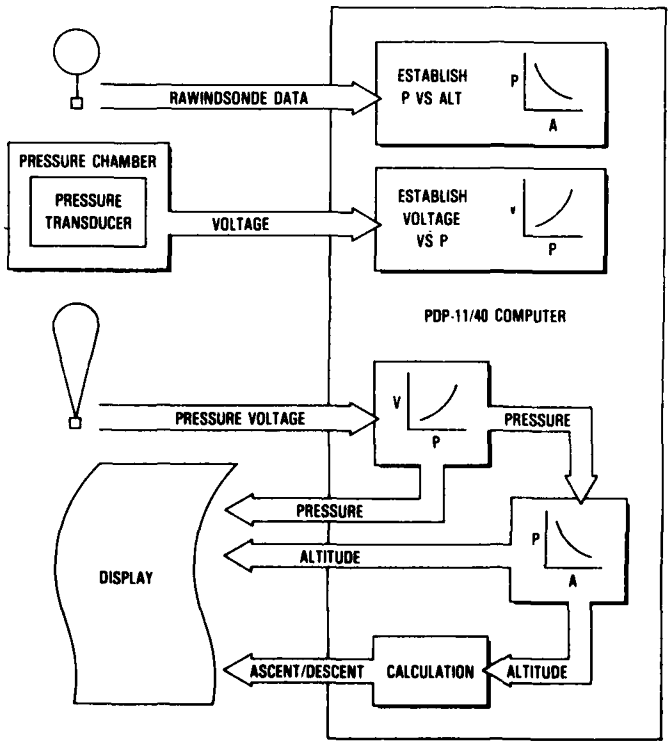

Figure 11. Pressure/Altitude

example, the use of 1600 frames per second is only one of several which have actually been used; the system can be set up to handle other data rates and formats.)

The continuous calculation and presentation of balloon altitude is an example of a typical real-time computation used both by the scientist as well as the operational personnel. The altitude computation involves several stages, as shown in Figure 11. Prior to a balloon flight, the normal procedures include the acquisition of Rawinsonde data which define the relationship of pressure versus altitude for that particular time. Further, calibrations of the balloon-borne pressure transducer are also entered into the computer to establish the relationship between the transducer voltage and actual pressure.

During the balloon flight (in real time), the single-averaged transducer voltage data point is received and converted to pressure using the pre-flight data base. With a pressure value, the altitude can then be quickly calculated from the Rawinsonde data base. These two parameters are then dynamically displayed. Further calculations can be made using the altitude information to yield ascent and descent rates.

8. TIMING

For all experiments or missions, it is important that the element of time be involved in order to assure later reconstruction of the operation or for data reduction and correlation. A station WWV receiver is used to synchronize the time decoders within the system to a standard source.

The output of the WWV Receiver is routed to a Datametrics SP-100 Time Code Generator. This unit generates timing in IRIG formats for recording on the analog recorder and use on the strip-chart recorders.

A second time code reader, a PSL Model 10938 Time Code Reader/Generator, is also incorporated into the system. The time code reader will accept the output of the Datametrics generator, or the recorded time on the analog tape, in order to generate parallel time for the PCM interface. In the event time is not available, the generator portion of the unit can provide this output. Additionally, time can be routed to the analog devices if required. The Model 10938 is capable of decoding or generating any of 13 different line-level, carrier-modulated standard IRIG/NASA time codes.

9. DATA DISPLAY SUBSYSTEM

In any real-time operation it is very important to the flight control personnel as well as the scientific user to be able to monitor received data visually in real time. Based upon the information received, the cognizant personnel can make judgmental decisions for continued experiment operations. A functional block diagram of the recording and display subsystem is shown in Figure 12.

Information can be displayed in both digital and analog form. For the display where trends as a function of time are desirable, analog strip-chart records can be used. Five Brush recorders, models 260 and 481 (6 channel and 8 channel) provide 36 channels of analog data displays. Each recorder can be continuously annotated with time-of-day (TOD) information for interval correlation of multiple data comparison. The recorders can be run at various speeds to optimize the details of the displayed parameters.

Where information regarding the instantaneous relationship of a parameter with maximum or minimum values is desired, the analog meter bank can be used. This display device contains 20 analog voltage meters, each accessible from the display and record patchboard.

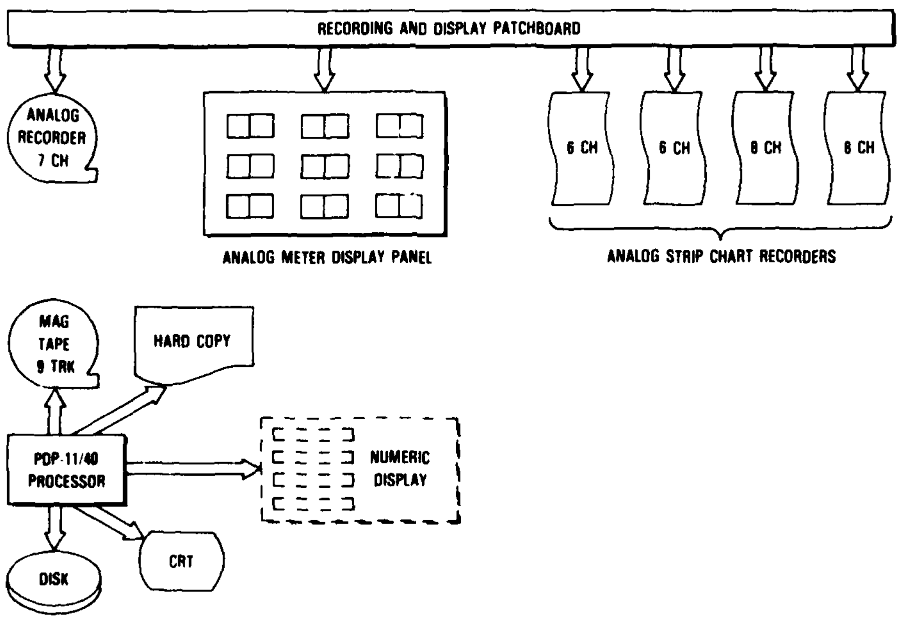

Figure 12. Record and Display Subsystem

Standard information from the PCM data received from the balloon is processed by the computer and is displayed in such forms as altitudes, pressures and temperatures. This is accomplished through various algorithms defined by relationships between sampled pressures by instruments on the balloon and preflight radiosonde data. Such processing can yield data which can be displayed for use by the scientific user. By implementing these scientific user pre-defined algorithms and relationships in a digital program prior to the mission, valuable information can be displayed to assist the scientist. These information outputs can be assigned to various digital display devices dependent upon the type of data.

The capabilities of the hardcopy devices (LA30 and LA36) are explained in earlier sections. Each data set or event to be hardcopied can be time tagged for correlation with other data. Typically, this would be information significant to the operational or experimental decision-making processes so that the resulting time history can be reviewed during post-operation analysis.

Instantaneous values of various parameters can be displayed on the CRT's. This data is generally updated at input frame rates. Warning messages can be displayed to alert the user of parameters which are exceeding pre-defined bounds. Other displays such as the numeric displays are also used in the system to facilitate the conduct of the operations.

10. DATA RECORDING

The end result of most experiments is the data which is collected during the mission. This data is generally used for further in-depth analysis at the experimenter's laboratory. It is therefore important that the user be able to get data in a medium compatible to whatever reduction facility may be used. Digital and analog recording are the two primary forms of data recording used.

The digital recordings are made via the PDP-11/40 processor subsystem. Whatever is recorded on the nine-track output tape (described in the PDP-11/40 Processor Subsystem section) is completely selectable by the data requestor. All raw data, or only selected data, may be recorded, always with time information. If specific formats are required they can be provided. The digital data tapes of the PCM data are usually made after the mission, so that the experimenter can select segments of interest instead of reviewing several hours of non-usable data.

Whenever information is being received from a balloon-borne experiment, it is recorded by a Sangamo SABRE IV analog recorder. This is a 1/2 inch, seven-channel device capable of recording PCM high data-rate signals as well as FM data. Playback features allow the replaying of this data for subsequent digitizing or special display.

11. MOBILE GROUND SUPPORT

A mobile van for field deployment has functioned with a capability similar to the base facility described above. The mobile van contains a PCM and FM/FM telemetry system with somewhat limited computational capabilities. The computer is a PDP-11/10 which is somewhat slower and has less memory available than its counterpart in the base facilities. However, the mobile system can provide adequate support for almost all applications. That software is transportable between the PDP-11/40 and the PDP-11/10 provides for further advantages. A picture of the mobile van is shown in Figure 13.

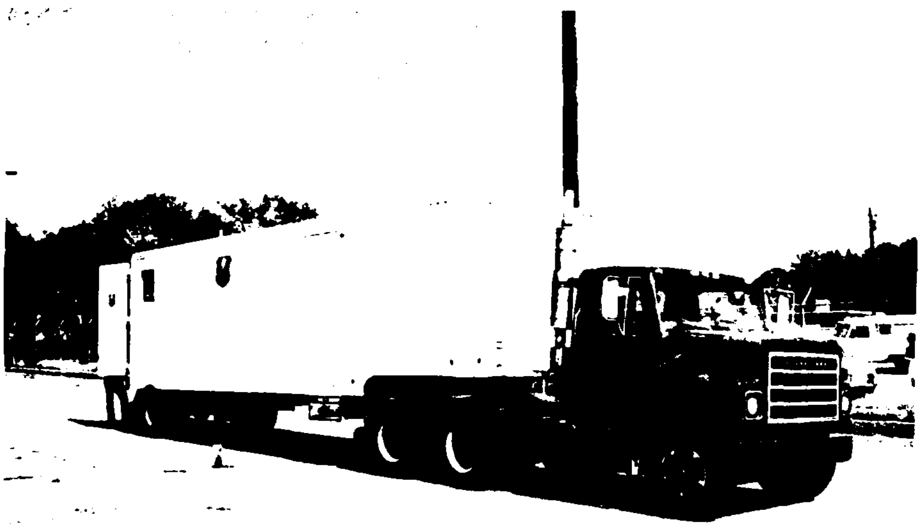

Figure 13. Mobile Telemetry Facility