INTEGRATED REALTIME SOFTWARE FOR BOTH AIRBORNE FLIGHT TEST SYSTEMS AND PCM GROUND STATIONS

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ABSTRACT

Flight test activities can be completed quicker if the test engineers can evaluate test data in realtime on-board the aircraft or at the PCM ground station. Teledyne Controls is developing a software package for several customers that provides realtime EU data in several formats. Data presented to the test engineer includes: stacked or overlayed scrolling EU curves, limit exceedance tests and alarm generation, tabular EU data presentations and operator requested hardcopy of CRT presentations supplemented by the classical raw data strip chart recordings. Incorporated into this software are facilities permitting semi-automatic calibration of sensors installed in the aircraft during preflight operations as well as generation of tape headers for automatic PCM tape reading by the ground station. Other features include semi-automatic processing of sensor calibration data gathered in the calibration laboratory for entry into the ground station's data base, and a software/hardware link coupling the data reduction software in the PCM ground station to the generation, loading and test of the data cycle map in the airborne PCM system.

INTRODUCTION

Several major aircraft manufacturers such as Aerospatiale, Boeing and Douglas have shown that flight certification schedules for a new aircraft can be significantly reduced if realtime data can be presented in engineering units to pilots and/or test engineers on-board the aircraft. The same is true for realtime data presentations to test engineers in the PCM ground station when a telemetry link is used with smaller aircraft, such as fighters, where the flight test engineer cannot be on-board the aircraft. Similar savings in time apply to research and test aircraft used for navaids certification, aerial topography mapping and aircraft component or subsystem flight testing. To provide solutions to these requirements Teledyne is developing a realtime data processing software package that can be used on-board an aircraft and/or in a PCM ground station. The realtime data processing hardware and software allows the test engineer select up to 24 channels of data (or multiples thereof) from any time slot location in an IRIG PCM data cycle map containing supercommutation,

commutation and subcommutation. The data can be used directly or compressed, limit exceedance tested and converted to engineering units for display in tabular, bar graph or scrolling graphics format.

Graphic data is presented as from one to six stacked or overlaid moving EU curves on a color graphics CRT terminal with tabular EU data simultaneously presented on one or more B&W CRT terminals. Hardcopy records of the realtime data presentations are operator selectable. The same realtime man-machine interface software is used on-board the aircraft as is used in the PCM ground station. This permits the test engineer to operate the system in the aircraft or at the ground station using the same procedures.

For pre- and post-flight test support, special software permits semi-automatic calibration of pressure, temperature and/or position sensors in the aircraft. Another program generates PCM tape headers which permit the ground station to automatically setup and read PCM data tapes with any size data cycle map. A format generation program automatically links the data reduction software to the generation of the airborne data cycle map and loads it into a pluggable program load module (PLM) in the ground station which can be carried to the aircraft and plugged in for downloading and checkout of the on-board PCM system. Finally a sensor calibration program permits semi-automatic generation of sensor calibration files from a multiplexer and CRT terminal located in the sensor calibration laboratory and connected to the ground station. Entry of these data into the systems data base is initiated by the operator with calibration file data being retrievable by aircraft serial number, flight number and flight date.

Software support functions, useable primarily in the PCM ground station include: automatic time or event tape search for processing or for PCM to 9-track tape conversions of selected channels (or all channels) from operator defined time periods. Additional support functions include tabular and plot hardcopy of sensor calibration data, generation of PCM backup tapes on the ground during realtime processing through the telemetry link, conversion of FM/FM data tapes to PCM or 9-track tapes, and the re-running of PCM flight data tape from any test flown during the past five years.

FUNCTIONAL REQUIREMENTS

The functional requirements were developed jointly between Teledyne and our cutomers as a part of technical negotiations. A key operational requirement of this integrated system concept is to provide the same man-machine interface for both the aircraft computer system and the ground station computer so that the same software and operating procedures may be used in either environment. Thus the same test engineer can operate both the airborne system and the ground station.

The on-board computer requirements are divided into two categories; (1) limited EU alphanumeric displays for the pilot's use when no test engineer accompanies the flight and (2) full realtime capabilities equivalent to the ground station for the on-board test engineers), plus the limited A-N displays for the pilot. The pilot display is generated by a powerful microcomputer system while the test engineer's display are generated from a minicomputer system which is essentially a subset of the PCM ground station's computer. Thus the pilot and test engineer(s) can access different data. The primary application of the on-board minicomputer system is for use in transport aircraft of business jet size or larger to present realtime EU data to the test engineer in the aircraft. This is especially important on research or test flights where it is not practical to use a telemetry link. Test flights of this type include aerial mapping, civil airways route certification, navigation system tests and general flight tests where line of sight telemetry links are difficult or impractical to maintain. For test flights such as range, endurance or route certification, where of necessity the aircraft must land at or operate out of an airport away from the base where the PCM ground station is located, it is possible to use the on-board minicomputer system to process key test data not monitored during the flight in order to validate the test objectives. The pilot's microcomputer/display system can be applied to test flights in any size aircraft from a fighter plane to a large transport. The software must support either or both types of on-board computer plus the ground station computer. The pilots display unit must serve a multifunction purpose of interface to the PCM system for realtime decommutation, program load and test during pre/post-flight operations, a portable test set, a laboratory test set and a peripheral of the PCM ground station.

A major new requirement of an integrated air/ground system not generally used in present flight test applications is to provide a software/hardware link between the data reduction software in the PCM ground station and the data acquisition hardware system in the aircraft. This link couples the data reduction software's data cycle map to a program that generates the binaries of the data cycle map to be used in the on-board data acquisition system. The requirement is to provide a small, light, nonvolatile storage media to permit easy transfer of the sampling program between the ground station and the test aircraft. The storage media is a pluggable E^2ROM memory card that is unplugged from a pilot's control/display unit located in the ground station, carried to the aircraft, and plugged into an identical unit which downloads and tests the sampling program in the airborne multiplexer system. The control/display unit which provides this link between the ground station and the on-board data acquisition system is packaged in a compact, avionics control panel size case, which can be mounted in the cockpit for use as the pilot's data display during the flight. The requirments for the pilot display are to provide up to six parameters of EU data in the cockpit updated twice a second. EU data for the flight test engineer(s) in the cabin of the aircraft are the same as these provided in realtime at the PCM ground station when the telemetry link is used.

Another key software requirement is to be able to semiautomatically generate sensor calibration data for pressure, temperature or position sensors that must be calibrated after they are installed in the aircraft. These data must then be able to be transferred either via PCM tape or the telemetry link from the aircraft for entry into the ground station's sensor calibration file data base. The only operator interaction on the aircraft is to tell the system what the calibration point is and when it should take the calibration data and process it for entry into the files. At the ground station an operator looks at the data to ensure it's accuracy before permitting it to be entered into the calibration file data base. This same procedure is to be used for the calibration of sensors in the test facility's sensor calibration laboratory. Data entry in to the ground station's calibration file data base is achieved via operator interaction with a CRT terminal at the ground station or in the sensor calibration laboratory. The calibration file data base is designed to permit rerunning of any flight test PCM data tape with the proper calibration data for up to 5 years after the test. The data base is to be maintained by aircraft serial number, flight number and date of the flight. This will permit the proper calibration data is used for each sensor, irrespective of the number of different recalibrations that sensor has had during its useful lifetime.

To reduce data processing time, an important feature being automated is the setup of the PCM decomm hardware for reading flight tapes. This includes selection of the appropriate sensor calibration files and other support functions necessary to read and process test data from any PCM tape irrespective of the data cycle characteristics recorded on that tape. This function is presently accomplished by the operator reading the data cycle map characteristics logged on a label attached to the tape reel and then manually entering the hardware setup commands into the computer through the system terminal. Automating this feature will save significant time and effort in the recreation of flights from a PCM data tape. This will be especially important when different size data cycle maps are used on different aircraft, or on subsequent tests of the same aircraft, so as to restrict PCM data bandwidths to those necessary to achieving a given flight's test objectives.

All of the classical requirements of a modern PCM ground station are also provided. These include; dubbing copies of PCM flight tapes, conversion of PCM flight tapes to industry standard computer compatible 9-track tapes, generation of backup PCM tapes on the ground from the telemetry link, reading and digitizing of FM/FM data tapes, reading of operator selectable time slices of PCM or FM/FM flight tapes, decommutation of data into files by parameter number for use by the data reduction software, recording of EU data on 9-track tapes, hardcopy printouts of tabular or graphical EU data presentations and, support of software development for future test programs.

AIRBORNE SYSTEM HARDWARE

Before describing the software functions in detail it is necessary to review the typical hardware complements possible in the airborne system which the software must support. The airborne system is composed of two subsystems; (1) the Data Acquisition and Recording System [DARS] including the pilot's data display and the telemetry transmitter when used and, (2) the Computer/Display System [CDS]. The DARS is composed of the PCM system and it's signal conditioners, the IRIG time code generator the PCM tape recorder, the pilot's data display unit and the telemetry transmitter and antennae when used. An optional element of the DARS is the crash recorder system and underwater locator beacon used on critical test flights such as flutter tests or exploration of the periphery of the safe flight envelope. The CDS is composed of a PCM decomm system and a mini- computer system using the same man-machine interface hardware as is used in the PCM ground station. A small aircraft DARS is shown in block diagram form on Figure 1 while Figure 2 is a block diagram of a DARS with a larger channel capacity and the CDS added.

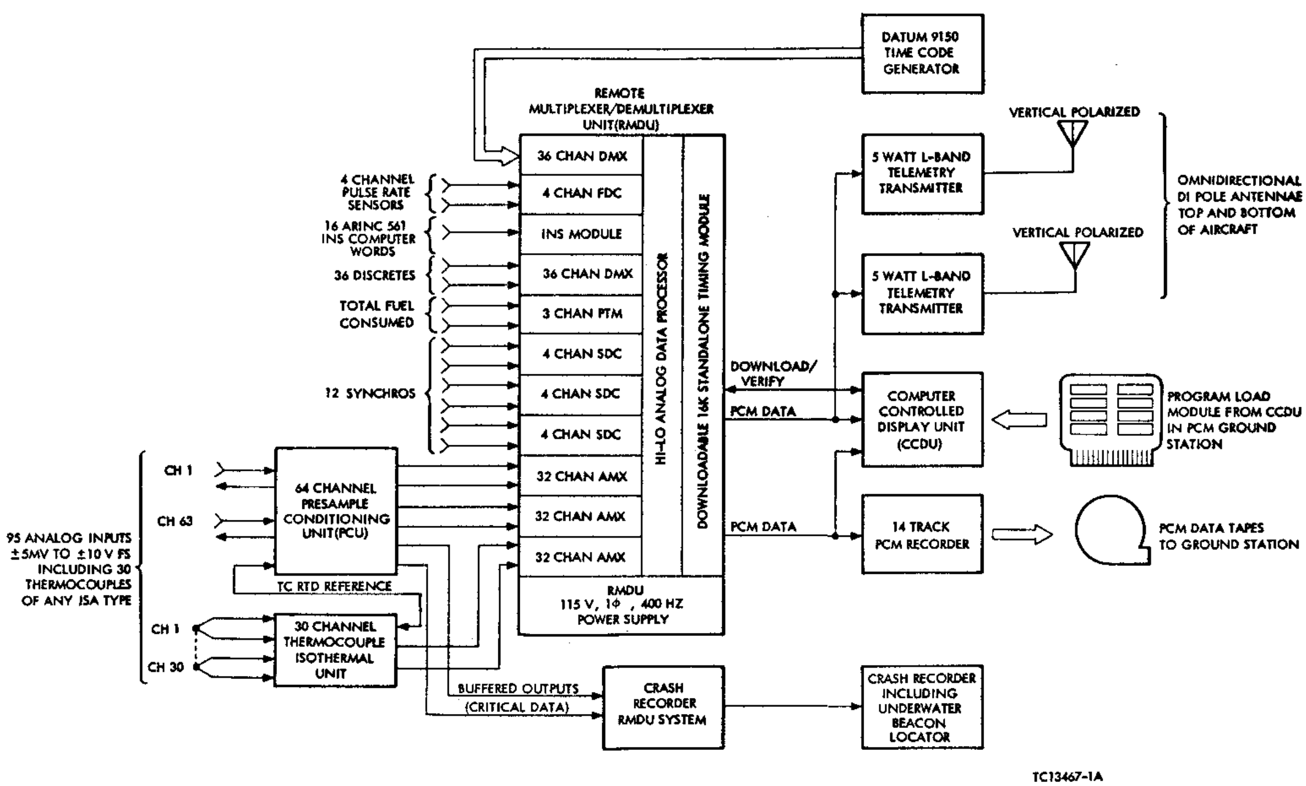

Figure 1. Typical Small Airborne Data Acquisition/Recording System

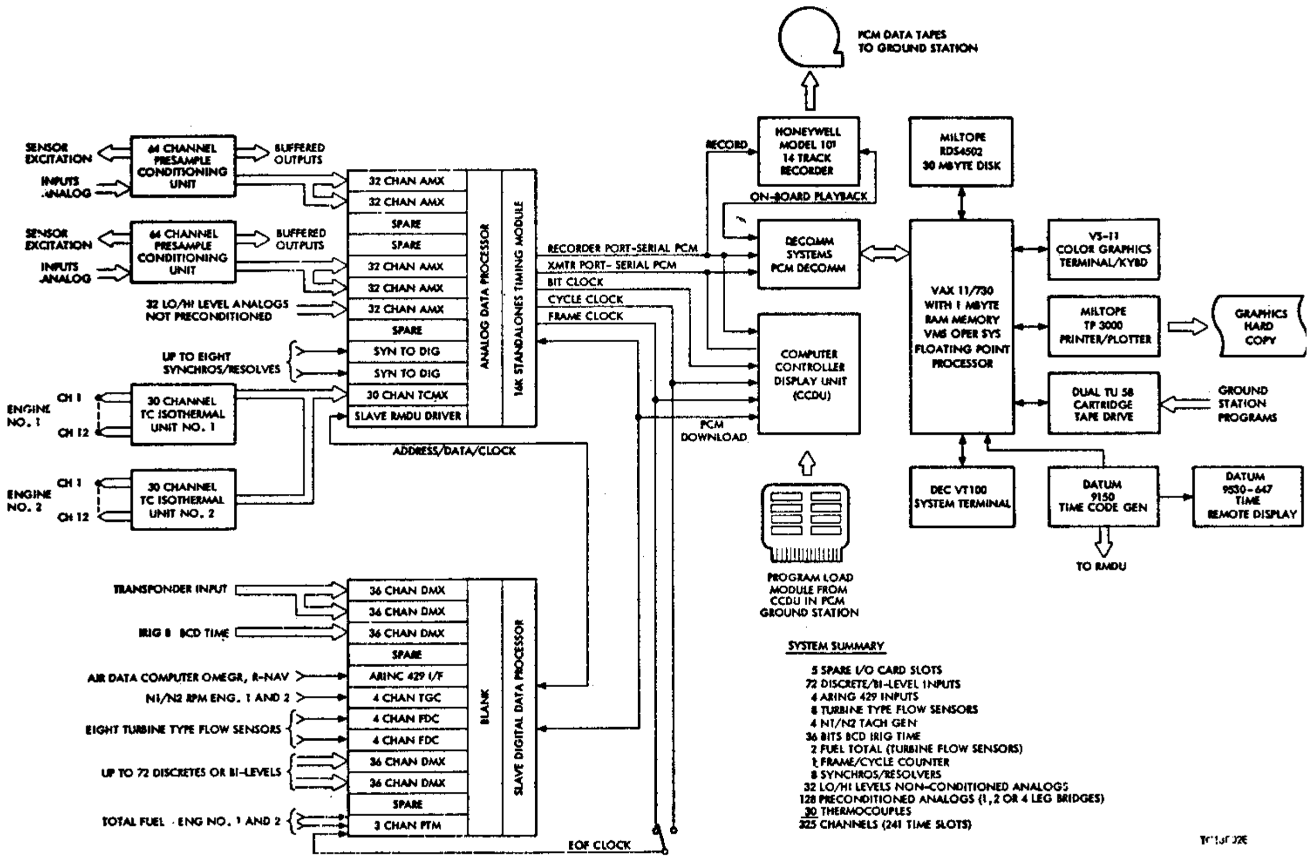

Figure 2. Airborne DARS and CDS

The Computer Controlled Display Unit [CCDU] of the DARS is mounted in the cockpit to give the test pilot up to six parameters of data displayed in alphanumeric EU format in realtime during the flight. It is used during pre- and post-flight tests to download, test, inspect and/or modify the PCM data cycle map stored in the Multiplexer [RMDU]. The CCDUs pluggable Program Load Module [PLM] is programmed from another CCDU connected to a serial RS422 port of the ground station computer. The PLM storage media is non-volatile E^2ROM. Once the airborne system is loaded and tested the PLM used for system setup is removed and an applications PLM is installed. The applications PLM contains the appropriate sensor cal data and the realtime application program to provide the pilot's presentation during the test flight. This PLM has a user definable mix of E^2ROM and RAM to augment the basic memory of the CCDU microcomputer.

The airborne CDS is a DEC VAX-11/730 computer system with the standard DEC backplane and pluggable PC cards mounted into an aluminum chassis with cooling fans and an airborne 115 Vac 400 Hz power supply. A Miltope ruggedized Winchester disk is used so that DEC's standard VMS operating system can be used. At the same time, the 11/730 CPU was selected as the on-board computer because its large memory addressing capability permits it to use the same key peripherals in the aircraft that are used in the ground station. These include the color graphics terminal, the B & W A-N terminal and the printer/plotter.

The program transfer media between the ground station computer and the CDS is a ruggedized floppy disk, a portable disk or a cassette tape. The man-machine interface for the CDS is composed of two CRT terminals; (1) DEC's VS-11 color graphics CRT for the realtime graphics display, and (2) DEC's VT-100 or VT-125 B&W CRT for the tabular data and bar graph displays. The airborne hardcopy device is a Miltope TP3000 printer/plotter.

The realtime data source for the airborne CDS is a standard Decomm Systems Inc [DSI] bit synchronizer, frame synchronzier and 24 channel PCM word selector. All CDS hardware is installed in shock mounted 19" rack cabinets. A mechanical installation showing the ADARS and CDS configured for installation in a Cessna Citation II is presented in Figure 3 and Figure 4.

Because the same PCM decomm hardware and CRT terminals are used in the aircraft as are used in the PCM ground station, the same software and operating procedures are used in both systems for setup and dynamic control of the system. The full decomm system permits the CDS to read PCM flight tapes when the aircraft is on the ground at a remote airport. Time-tape search however in the airborne system must be limited to reading IRIG time imbedded in the data stream as there is no tape search controller in the airborne system. Also because there is no 9-track tape transport, it is not possible to make tape to tape conversions in the aircraft. All other features of the PCM ground station realtime software however are available to the test engineer in the aircraft.

PCM GROUND STATION HARDWARE

The PCM ground station is a DEC VAX-based PDP-11/780 or a 11/750 32-bit computer system using the same PCM decomm and man-machine interface hardware used in the airborne DCS. Figure 5 is a top level functional block diagram of an 11/750 based PCM ground station. Different users of this ground station have minor differences in the number of Unibuses and Massbuses and the sizes and quantities of disk and 9-track tape transports connected to the computer. All systems, however, have the same hardware for the decomm, sensor calibration (laboratory multiplexer) color graphics and bar graph/tabular CRT displays so that the same software works on all systems.

A Datum time code generator/reader provides the IRIG time base for the ground station and it is configured mechanically so the airborne TCG can be temporarily connected to it for the jambing of time to synchronize the airborne TCG with the ground station. The airborne TCG has a 24 hr battery to permit it to be carried to, and installed in the aircraft,

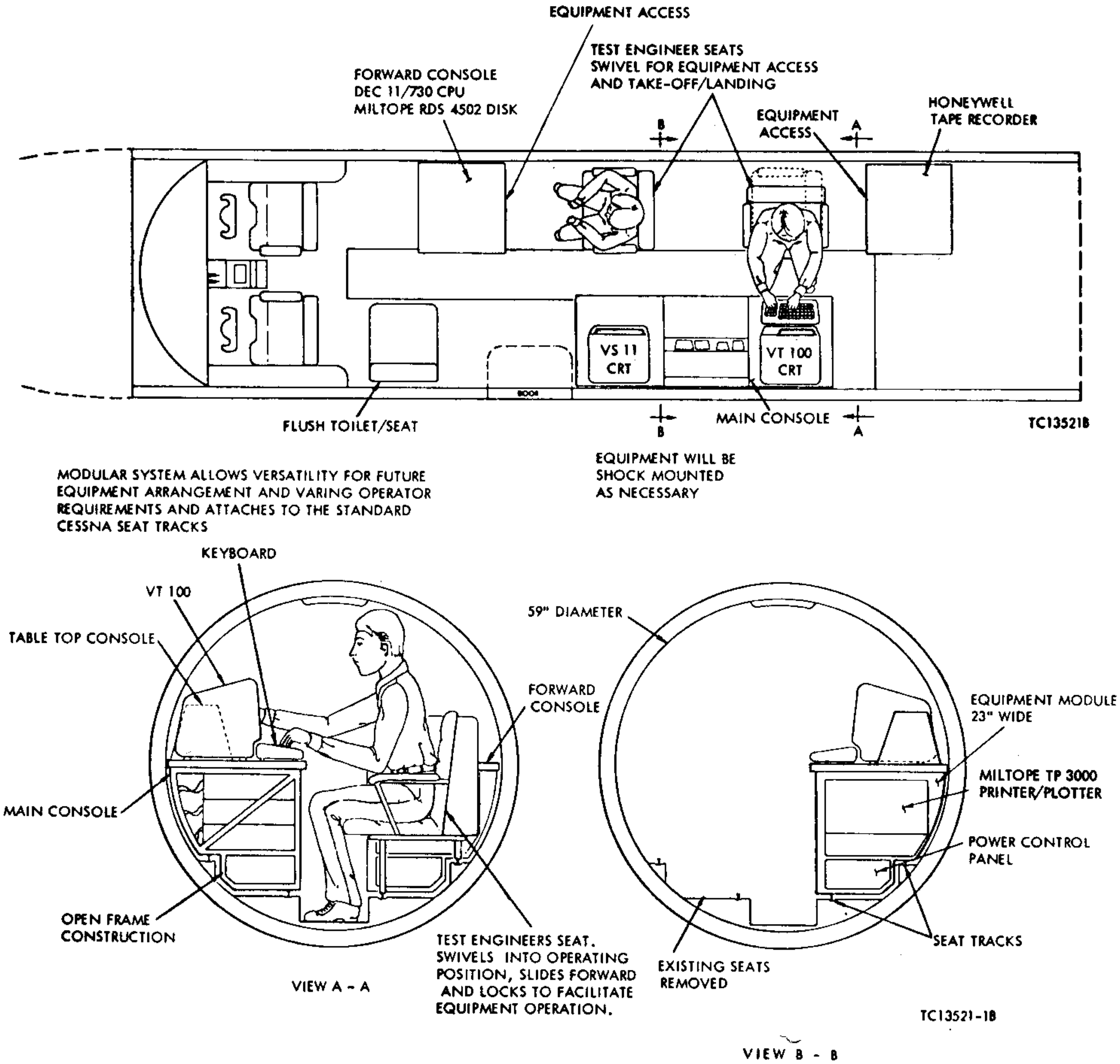

Figure 3. CDS Configured for Installation in Cessna

without resynchronization. A Datum time/tape search controller and two CPU interfaces complete the PCM tape search system which provides for time search from either IRIG time imbedded in the PCM data stream, or from time recorded on a dedicated IRIG B time track.

As depicted in Figure 6, a functional block diagram of the ground station pre-processor system, a signal patch panel interconnects all preprocessing hardware such as the telemetry receiver system, the PCM tape recorders, the crash recorder, the FM discriminators, the multiplexer/ADC, the PCM decomm units and the strip chart recorder. All systems will be delivered initially with provisions for FM/FM tape processing and two will have a L-Band

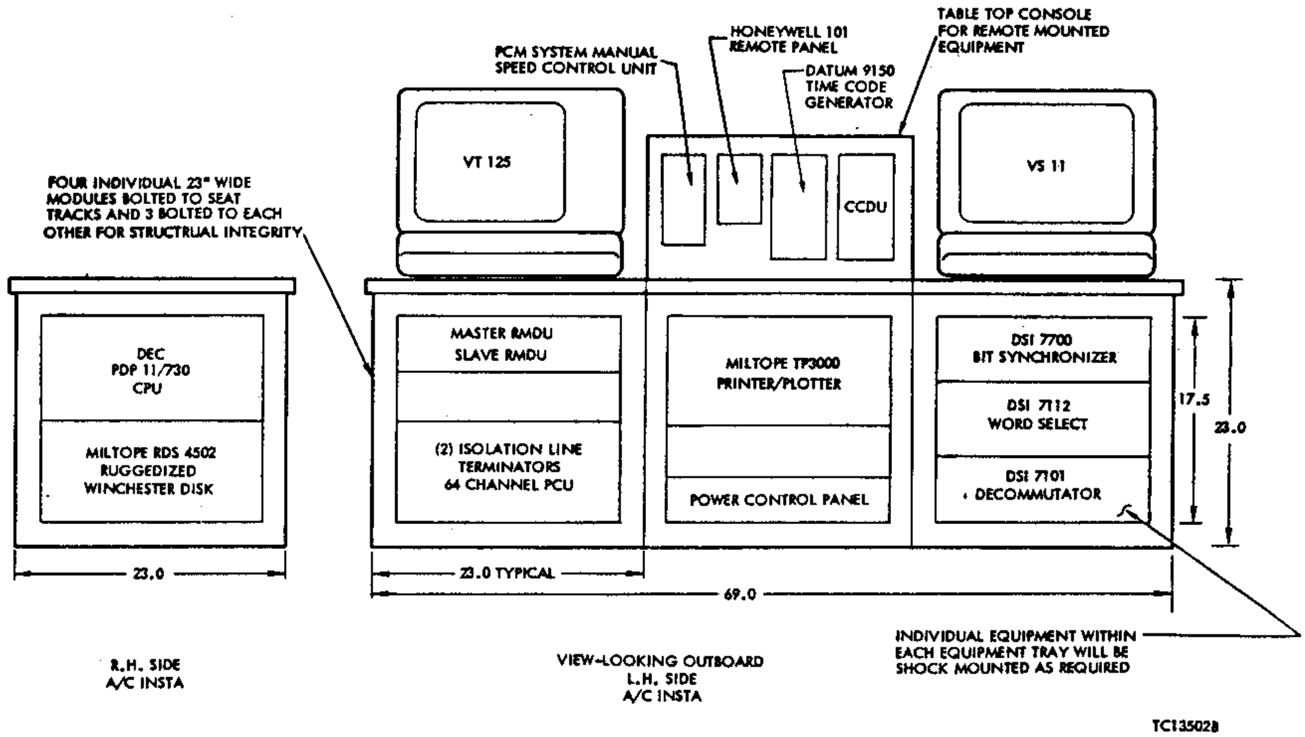

Figure 4. CDS Main Console Equipment Configuration

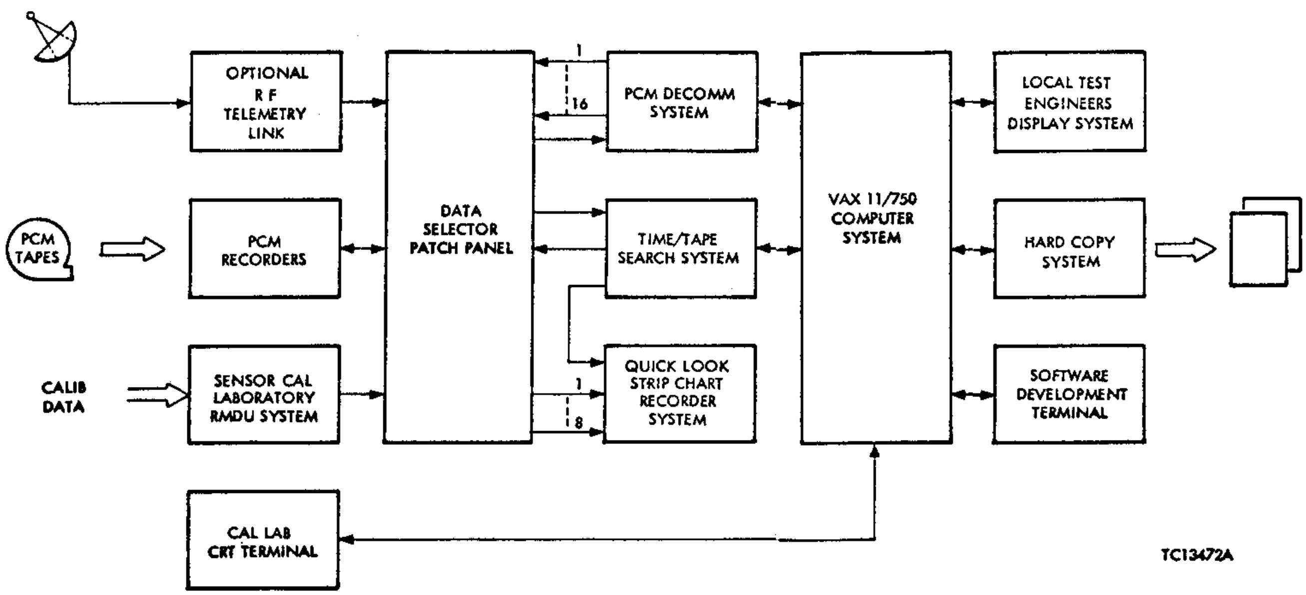

Figure 5. PCM Ground Station Top Level Functional Block Diagram

telemetry link while the other two have provisions for future installation of the telemetry link. Provisions are also being made for the future addition of a second PCM decomm system that will double as a portable quick-look system for remote site tests and as a second PCM link to perform tape-to-tape conversions of previous flight tapes while the telemetry link and realtime software are supporting a live flight test.

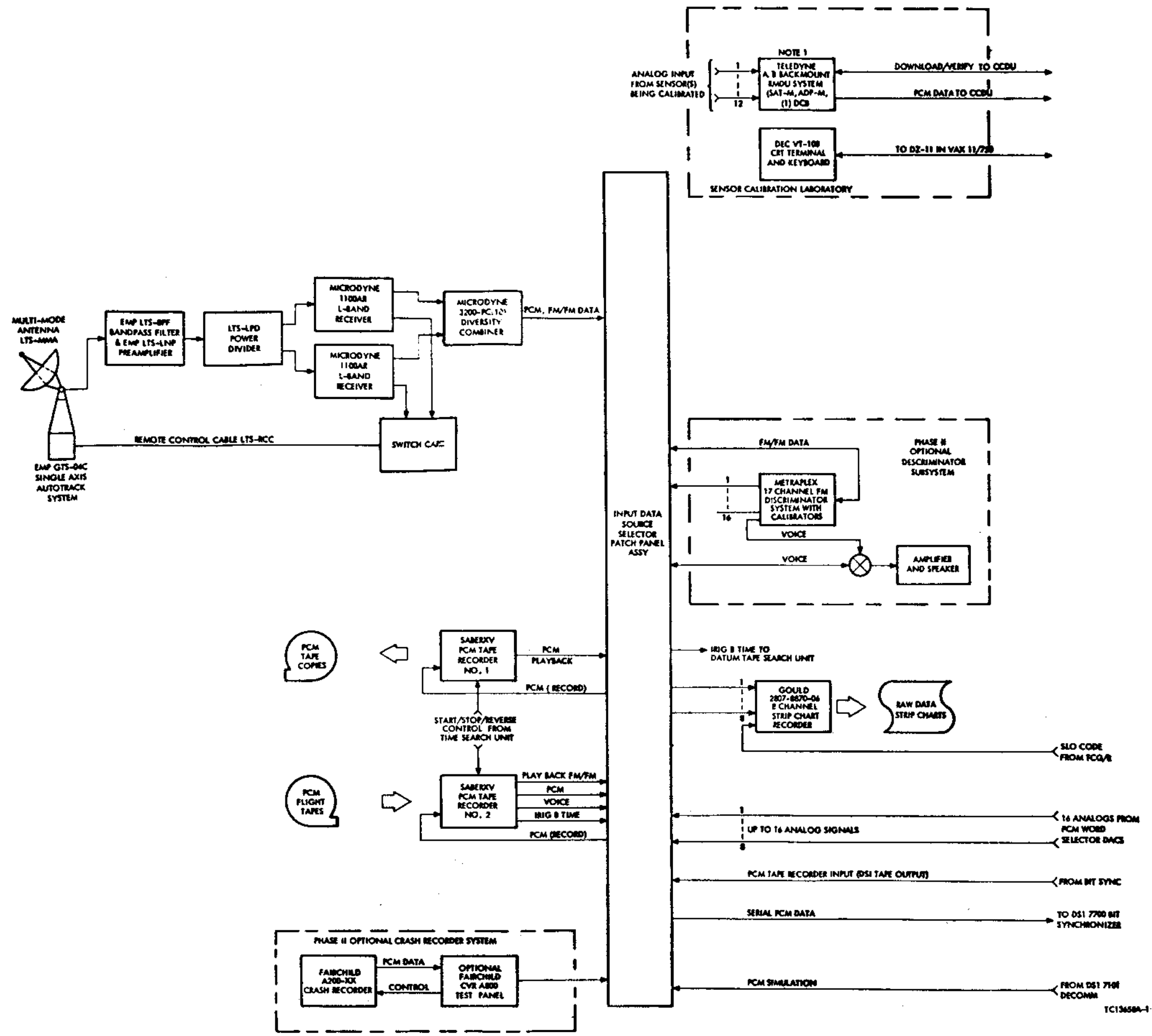

Figure 6. PCM Ground Station Preprocessor System

Other minor differences in CPU peripherals between systems are in the numbers of those peripherals. One ground station has two VS-11 color graphics terminals and one Versatec printer-plotter for all realtime hardcopy. Another has two Versatec printer/plotters and one VS-11 graphics terminal. Each system has a different number of VT-100 or VT-125 B&W CRT terminals which are used for various functions, from that of the computer's system terminal to realtime display of tabular EU data, bar graphs and alarms. One VT-100 terminal is dedicated to the man-machine interface for the facility sensor calibration laboratory along with an airborne multiplexer.

The multiplexer for the sensor calibration laboratory can also double as the multiplexer to sample and digitize the analog outputs of the discriminator system when FM/FM tapes are used to process extremely wideband test data such as acoustic surveys. By using the programmable airborne multiplexer in these ground applications the ground station has more flexibility. Dedicated hardware is not required for functions that only occur periodically such as sensor calibration and processing FM/FM tapes. The use of the airborne multiplexer also provides a serial PCM data stream, in addition to the path directly into the computer, so that during quick-look processing FM/FM tapes can be converted to high density PCM tapes for more efficient data storage.

The airborne Computer Controlled Display Unit [CCDU] connected as a computer peripheral provides the ground station with the facilities for programming, testing and running of the multiplexer time-shared between the sensor calibration laboratory and FM tape processing. It also serves as the hardware interface for program transfers between the ground station and the airborne data acquisition and recording system. PCM tape header programs, flight test sampling formats, on-board sensor calibration formats and CCDU application programs are all developed in Fortran on the ground station computer and then loaded via the CCDU's microcomputer into the pluggable PLM which is transferred to the aircraft.

By having an airborne multiplexer and CCDU in the ground station, the PCM tape headers which permit automatic reading of PCM flight tapes can be recorded either on the airplane using the airborne recorder or at the ground station using it's multiplexer and PCM recorder with the tape reel carried to the airborne recorder after the tape header is recorded.

The ground station multiplexer and CCDU are not needed to support realtime processing so they can serve as backup spare units for the airborne DARS. Conversely spare cards and modules for support of the airborne system can also serve as spares for the ground station units. This increases both air and ground availability figures for these units and reduces the facility's overall spares requirements.

As depicted in Figure 7, a block diagram of the PCM ground station computer system, it is divided into two separate functions; (1) the test engineers control/display system and (2) the computer system and its peripherals. The control/display system is composed primarily of man-machine interface hardware such as the raw data strip chart recorder(s), the VS-11 color graphics terminal(s), the B&W tabular data display CRTs and the Versatec printer-plotter(s). These units are located in a separate room adjacent to the computer system but isolated from the noise and high ambient light levels required in a computer laboratory. The test engineer's consoles also contain the ground station intercomm system and controls for the VHF/UHF voice links with the test aircraft (provided by the customers). The test engineer's room has provisions for controllable ambient light levels so as to minimize operator eye strain.

The computer room is a conventional raised floor air conditioned area with high intensity ambient light levels. It contains the VAX computer and its peripherals not located in the test engineer's room. These include the tape recorders (PCM and 9-track), the disks, the system terminal, the time code hardware, the PCM decomm hardware, the discriminator subsystem, the CCDU and multiplexer, the input signal patch panel and the telemetry receiver subsystem. The single axis autotrack antenna system when added will be installed on the roof of the buildings where the ground stations are located.

Serial cable links between the ground station and the remote multiplexer and CRT terminal permit the sensor calibration laboratory to be located up to 400 ft from the computer room. Optional fiber optical cable links could extend these remote hardware elements up to several kilometers from the computer room should future facility requirements dictate such a link. A floor plan of the computer and test engineers rooms are presented in Figure 8.

SENSOR CALIBRATION

Sensor calibration software provides a data base that is sorted by aircraft serial number, flight number and flight date for a minimum period of five years. The calibration file data base has three sources for it's data; (1) the airborne multiplexer/thumbwheel switch feeding the PCM tape or telemetry link for sensors calibrated in the aircraft, (2) the calibration laboratory multiplexer/CRT for sensors calibrated in the laboratory and, (3) a computer room CRT terminal input for lookup tables. Data kept for each sensor includes; the sensor mnemonic, sensor class, sensor type, sensor serial number, log number, range, calibration date, full scale voltages, EU conversion coefficients or lookup table.

Data from sensors calibrated in the aircraft are received from the airborne multiplexer system via the telemetry link or from a PCM test tape generated in the aircraft. Each calibration point requires the monitoring of four channels of data; (1) the sensor being calibrated, (2) a manually set indicator identifying the channel of the sensor being

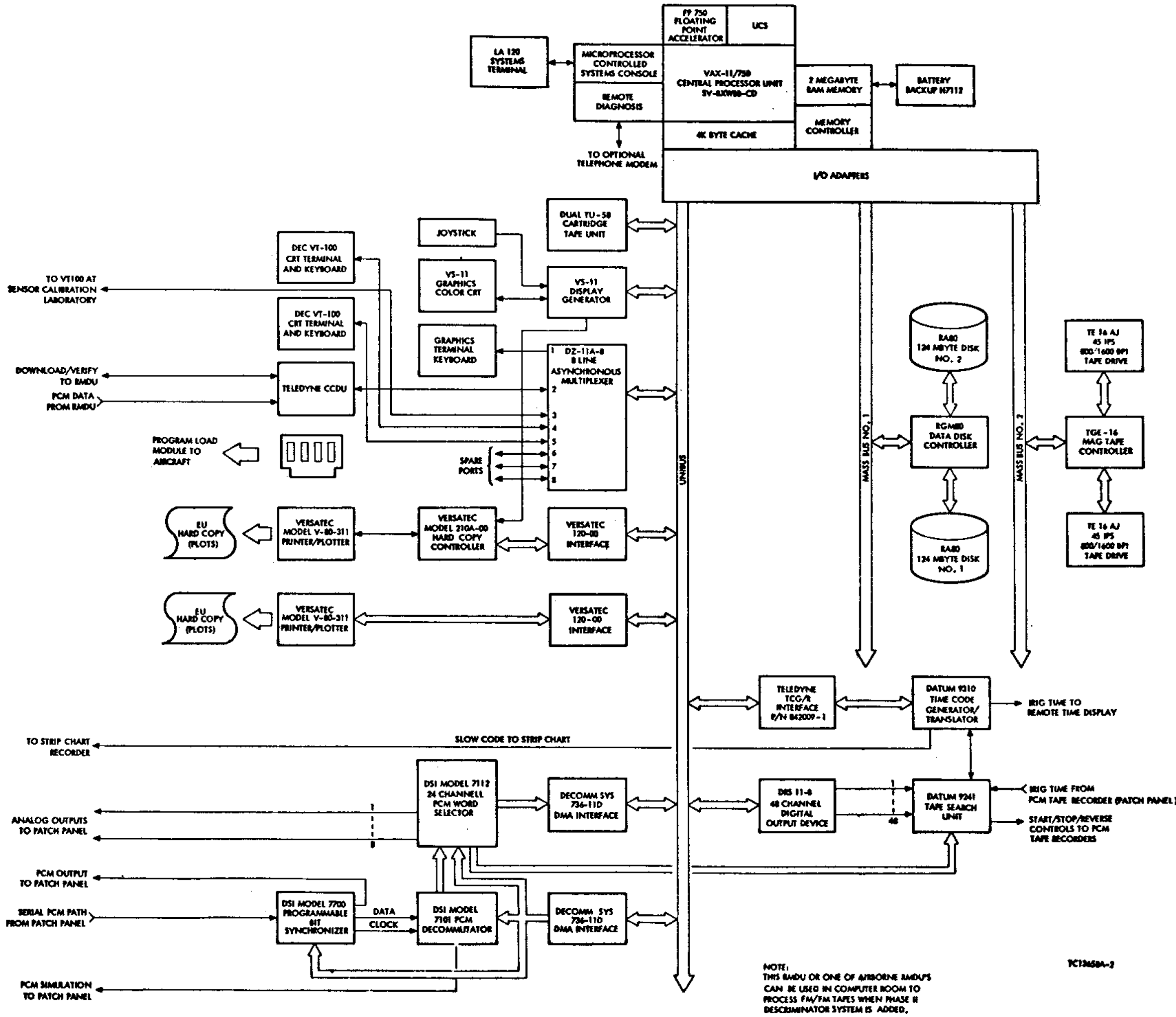

Figure 7. PCM Ground Station Computer System

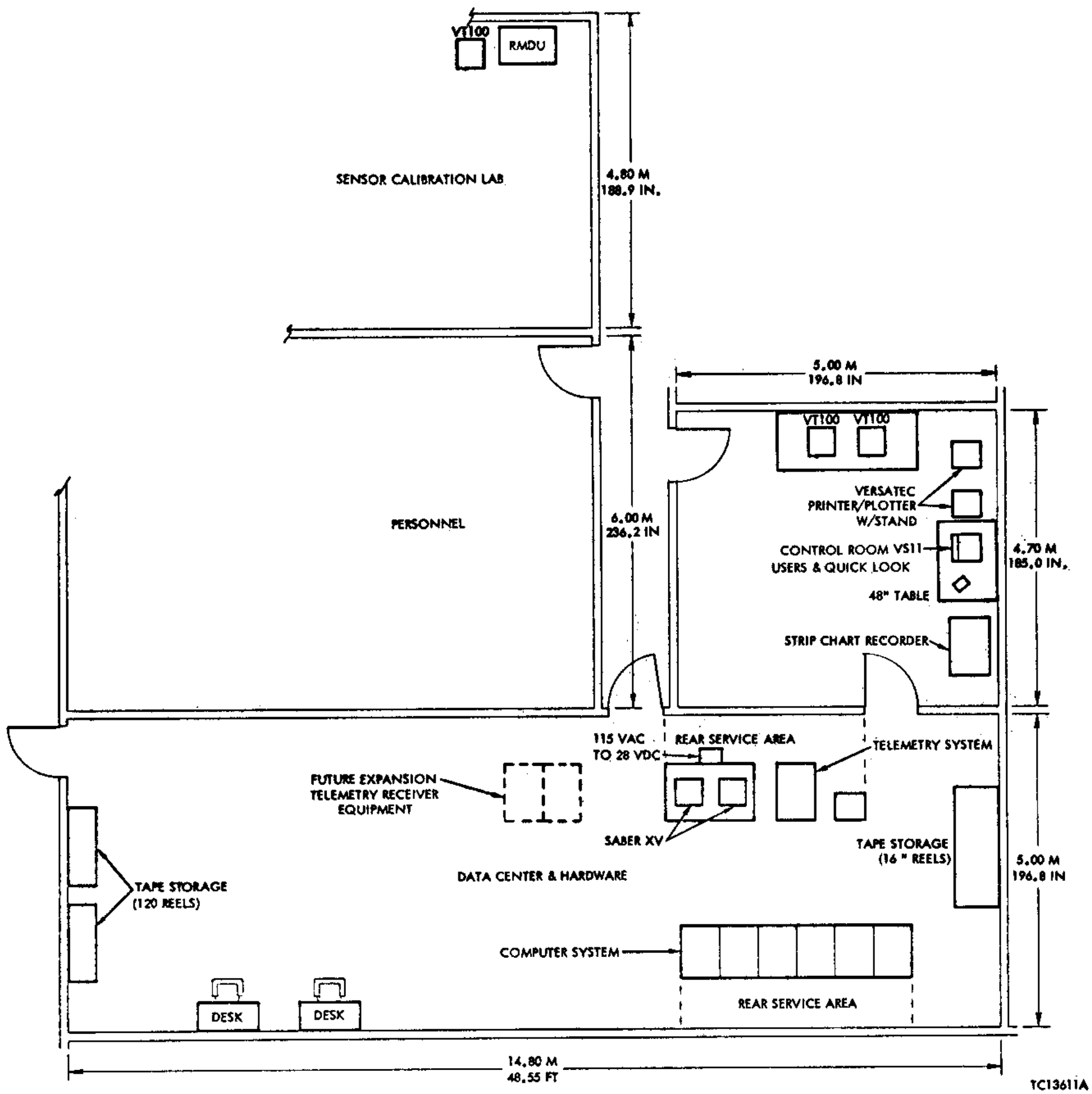

Figure 8. Computer and Test Engineers Rooms Floor Plan

calibrated, (3) a manually set indicator channel defining the physical value of that calibration point, and (4) a discrete defining when the desired calibration point is achieved. The data becomes valid when the discrete switch input is energized by an operator on the aircraft (operator defines these channels) indicating the point of calibration has been reached. The decomm software monitors the discrete as a limit exceedance.

The operator from a CRT terminal can cause automatic entry and display of the planned and actual physical quantities of each calibration point. The transducer output versus the input is obtained when the operator initiates the sampling, wild point discarding and averaging of 100 data samples for each operator defined calibration point of a sensor being manually calibrated. The raw data values and the averaged value to be stored in the sensor calibration file are displayed first on a CRT for operator assessment. The operator makes a selection of the calibration polynomial based on visual analysis of the tabular and hardcopy plot of the sensor calibration data. The calibration files are kept by sensor type, serial number and calibration date.

An example of an aileron position sensor calibrated in the aircraft showing position to counts calibration is shown in Figure 9.

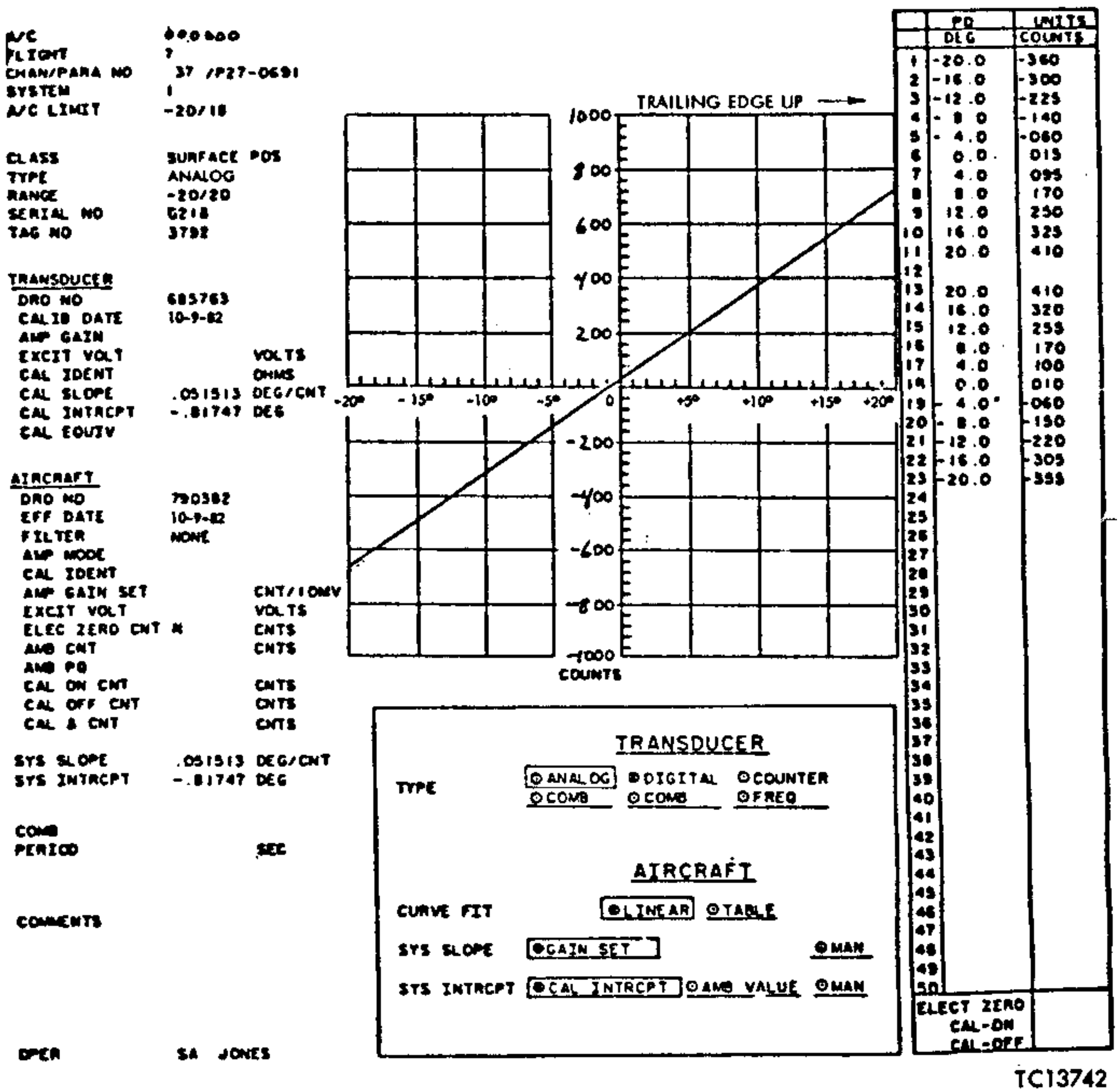

Figure 9. Tabular/Plot Presentation of Position Sensor Degrees to Counts

Calibration data taken from sensors in the calibration laboratory is entered into the data base in the same manner as that of aircraft sensors with it first displayed on a CRT terminal so the operator can determine if it is acceptable. Data from the calibration laboratory multiplexer uses the same wild point discard, 100 sample averaging algorithm as is used for aircraft sensor calibration. The operator visually analyzes the calibration data, selects the appropriate polynomial to be used for EU conversion (first through fifth order) and enters the calibration data into the sensor data base.

If lookup tables are to be used for EU conversions of non-linear sensors such as some types of thermocouples, the operator manually selects the table data and enters it through the CRT as if all calibration points had been manually recorded. The calibration data can be displayed in both tabular and graphic format and also provided in hard copy format as depicted in Figure 10 a tabular/plot presentation of sensor calibration in physical quantity of G's to mv.

DATA CYCLE DEFINITION

The starting point for both data acquisition and realtime data processing is the data cycle map which defines the sampling sequence of each parameter in the test aircraft. The run time reference for all sensors is the parameter number and name such as; rudder position, no. 1 EGT, no. 2 Fuel Flow, etc. Each parameter in a data cycle map is defined by the following:

- Parameter Number
- Parameter Name
- Parameter Description
- Sensor Mnemonic
- EU Conversion Coefficients (analog only)
- Upper Limit in EU
- Lower Limit in EU
- EU Measurand (PSI, degrees C, etc)
- PCM Word Identifiers (MF wrd/SF)
- Data Bandwidth

Sensors requiring more than one PCM word such as N1/N2 rpm, total fuel consumed, INS computer words, MIL-STD-1553B avionics bus words, etc. have more than one PCM word identifier. The parameter name is used to define parameters destined for realtime processing and display.

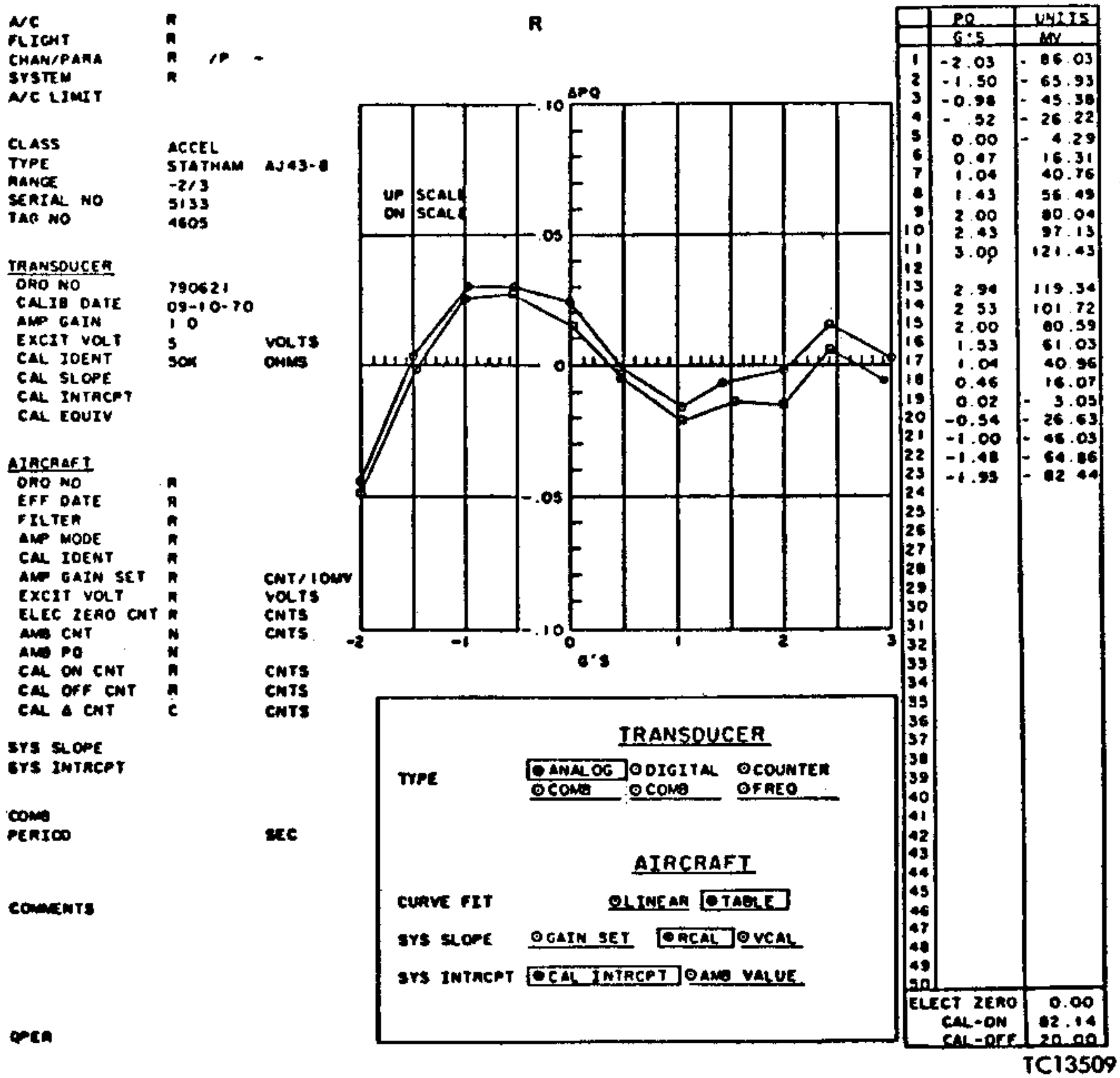

Figure 10. Tabular/Plot Presentation of Sensor Calibration Data (G's to millivolts)

The PCM word definition table is used to define the physical characteristics of data in each time slot (PCM word identifier) in the data cycle map. Each entry in the PCM word definition table contains the following information:

- PCM Word Identifier
- Sampling Rate
- RMDU Number
- RMDU Card Slot
- RMDU Card Channel
- Presample Filter Gain (if applicable)

- Presample Filter Cutoff Frequency (if applicable)
- R-Cal (if applicable)
- GPA Gain (analog)
- GPA Offset (analog)
- Valid Bit Positions
- Associated Parameters

The identifier for a PCM word of discrete data has all parameters in the word identified by bit position. The relationship between parameter name and PCM word identifier is thus classed as; one to many, one to one or many to one.

The format generation program for the airborne multiplexer takes the data from the PCM word definition table and converts it to the 16 bit words representing each RMDU time slot address in the PCM data cycle map and downloads it to the CCDU for storage in the PLM and subsequent transfer to the airborne data system. Both tabular listings and plots may be made of each time slot in a data cycle map. The data sequence listing contains all the data of the PCM word definition table with the addition of:

- Mainframe Word Number
- Subframe Number
- Sensor Class
- Sensor Type
- Sensor Serial Number(s)
- Sensor Calibration Date
- Lookahead (MF or SF next)

A short form tabular listing for testing of the airborne system may be printed out containing only; associated parameter numbers, PCM word identifiers, associated parameter names, RMDU/card/channel. The graphical plot of the data cycle map contains only the parameter number in each time slot.

REALTIME PROCESSING

For realtime processing the operator may select up to 24 PCM data words from the complete data cycle for strip chart (raw data) recording and/or for DMA transfer via ping-pong buffer files in the CPU memory for EU conversion and display. Each file to be limited to from one to n data cycles of the 24 words is operator selectable. The functions that are associated with the control and management of the data link that transfers these 24 words of continuous data, or n number of complete frames of the telemetered or playback data to computer memory is performed by a collection of software services referred to as the Data Acquisition software. Specifically, it consists of three basic services. These are the Decom Manager, Buffer Manager and the Device Driver.

The Decom Manager controls the mode of operation of the bit synchronizer/ decommutator equipment. It supports three modes of operation; single scan, multiple scan and continuous modes.

The Buffer Manager service is responsible for the setup and control of the data flow to the CPU memory. In the course of this process the Buffer Manager controls the allocation of dual buffer areas utilized in a ping-pong fashion where, at any given time, one of the buffers is allocated to the reception of current input data while the content of the other one completed in the previous cycle is available for other user programs, such as data recording or realtime processing. At the completion of the current buffer update, the role of the buffers is interchanged.

Raw Data Strip Chart Recording

Up to sixteen analog channels of the 24 PCM words selected for realtime processing (depending on the recorder configuration) may be applied to the DACs of the PCM word selector unit for raw data strip chart recording. Any of the five selectable slow-codes from the time code generator can be applied to the strip chart recorder to provide a hardcopy time base. The DACs can be calibrated under software control.

Alarm (Limit Exceedance) Tests

The operator may select up to ten of the analog or discrete parameters processed in the realtime group of 24 PCM words which can be processed for limit exceedances and alarms. This process compares the raw input to operator defined high and low values established as part of the offline test configuration procedure. When an input value is found to be outside the range defined by the upper and lower limits, the content of the exceedance counter is incremented and tested. If the counter exceeds its operator set limit, an alarm condition message is dispatched to the operator. The utilization of the exceedance counter acts as a filter to preclude wild point false alarms and provides a programmer-definable noise tolerance. An operator selectable filter algorithm can be applied to analog limit exceedance tests to prevent false alarms from wild points and/or ensure that a true alarm condition exists prior to alerting the operator. The upper and lower limits for analog limit exceedance tests are operator selectable in engineering units even though the CPU makes the limit tests on raw data.

Any limit exceedance is alarmed to the operator in EU along with IRIG time of exceedance (displayed in the overhead portion of the CRT) and logged on the printer along with the IRIG time when the exceedance occurs. The alarm will flash in red on the VS-11 until acknowledged by a keystroke of the operator at which time the alarm will turn white and be logged on the line printer. When an alarmed channel's data value recedes below the alarm point, the alarm will disappear from the display and automatically log on the printer the IRIG time the channel went out of alarm.

Graphics EU Displays

The realtime graphics software will permit the operator to select from one to six parameters versus time or one to six cross-plots of one parameter versus another for display in EU on the color graphics CRT. The curves can be presented in either a stacked format or an overlay format with different (operator selectable) colors for each curve and its vertical scale presentation. Vertical scale physical limits will be scaled to the number of stacked curves simultaneously presented on the screen,e.i., for 6 curves, one-sixth the available vertical screen space per curve; 5 curves, one-fifth the screen space; 4 curves, one-fourth the screen space, etc., down to a single curve using all the available vertical screen space.

For overlaid curves, the vertical scale(s) will use all the available screen space reserved for plotting with the abscissas for each curve located on the left side of the screen and presented in the same color as the data curve.

The vertical scale factors for any curve can be operator selectable to provide vertical scale expansion of the curve; i.e., if full scale for the parameter "Altitude" is sea level to 50,000 ft and cruise data is taken for some time at a cruise altitude of 30,000 ft, the altitude scale factor could be selected to show 25,000 ft as the bottom altitude with 35,000 ft as the top altitude mark. If the data goes off scale the scale factor would automatically be doubled until the full scale limits of that channel were reached (assuming the curve went off scale more than once in the same direction) or the operator manually selected another upper and lower limit for the abscissa values.

An overhead space is reserved at the bottom of the screen for display of test unique data such as aircraft number, flight number, pilot, date of flight, IRIG time, alarms and other key documentary data to be operator defined. The non-operator defined static (constant) documentary data will be obtained from the configuration header of the PCM tape. An example of a six-curve presentation is shown in Figure 11. The EU curves plotted on the color graphics terminal are dynamic scrolling curves with the R.H. edge of the screen representing current time and the curve moving from right to left. The operator can select the time base for the curve(s).

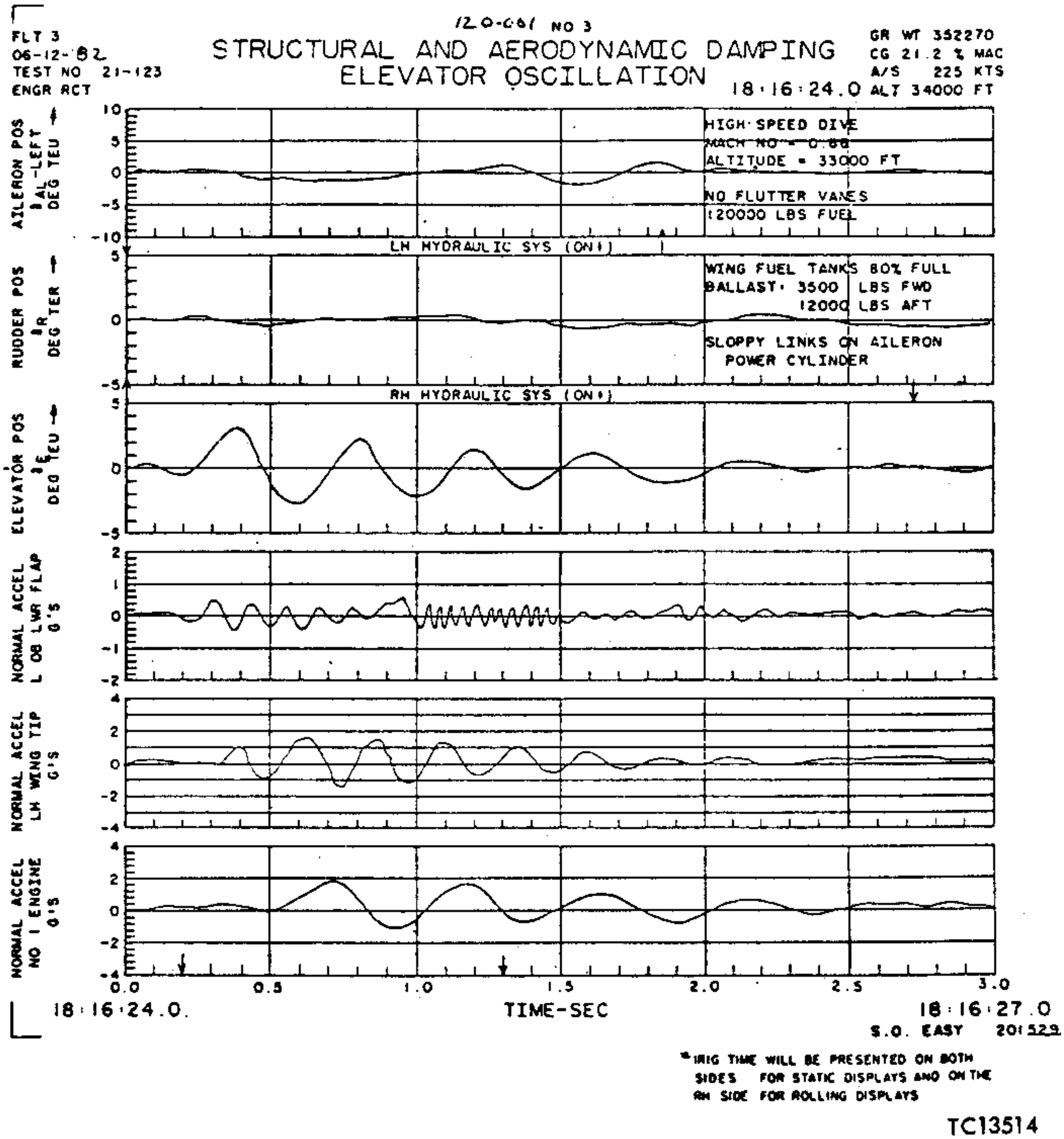

Figure 11. Time History Display of 6 Stacked EU Curves

The plotting software will use Newton's interpolation (forward difference) formula to eliminate wild points. Smoothing must be operator specified. Special vertical time base event marker lines can be enabled by the operator to be drawn the full height of the screen across all curves based on discrete events or analog limits exceeded and detected by the limit exceedance program. These same vertical lines can be placed on the screen by operator actuated keystrokes which place the line at the R.H. (current time) edge of the screen. Up to six different events of the 10 limit exceedance channels can be used to cause a vertical event marker line to be drawn on the screen. This line can also be drawn by coincidence of IRIG flight time with predefined IRIG time(s). When a time mark is automatically displayed (or manually selected by operator) it causes a dump to the printer in tabular EU form of all 24 PCM words being processed in realtime. In addition, the EU values of the curves are displayed numerically on the CRT adjacent to the intersection of the vertical time mark line and the data curve.

Another method of generating a vertical time mark line is by joystick positioning of the cursor to an operator selected location on the time base followed by the keystroke activation of the line.

Whenever a vertical time mark line is drawn on the CRT the IRIG time of the line in hrs:min:sec is displayed at the bottom of the line and the channel name or event is written at the top of the line. For example: A landing gear "sqwat" switch might trigger the time line. At the bottom of the presentation would be the time the switch was actuated; at the top it would display "touchdown" as shown in Figure 12.

Horizontal scale factors for the graphics display may be operator selectable with values of 1 sec, 10 sec, 30 sec, 1 min and 3 min on the horizontal time base. When cross-plots are being made, the time base of each parameter will be the same. All curves displayed simultaneously on the same picture have the same time base.

Tabular and Bar Chart EU Display

In addition to the realtime display of graphics data and alarm limit exceedance tests, up to 10 channels of the 24 PCM words processed in realtime may be displayed in tabular form as a horizontal tabular display on one of the VT100 or VT125 black and white CRT terminals. The RH side of the horizontal tabular display is reserved for operator entered remarks when the CRT is frozen for transfer of the data to hardcopy. In addition to the horizontal tabular display up to six parameters may be simultaneously displayed in EU on a vertical display format.

Tabular EU data displays can be updated 2 times per second in realtime or up to 10 times per second in non-realtime (offline at reduced tape speed or online from a time snapshot displayed in non-realtime).

In addition to either vertical or horizontal tabular displays a 10 channel horizontal bar graph display may be presented on one of the B & W CRT terminals. The bar chart presentation may be either raw data or EU scaled 0 to 100% F.S.

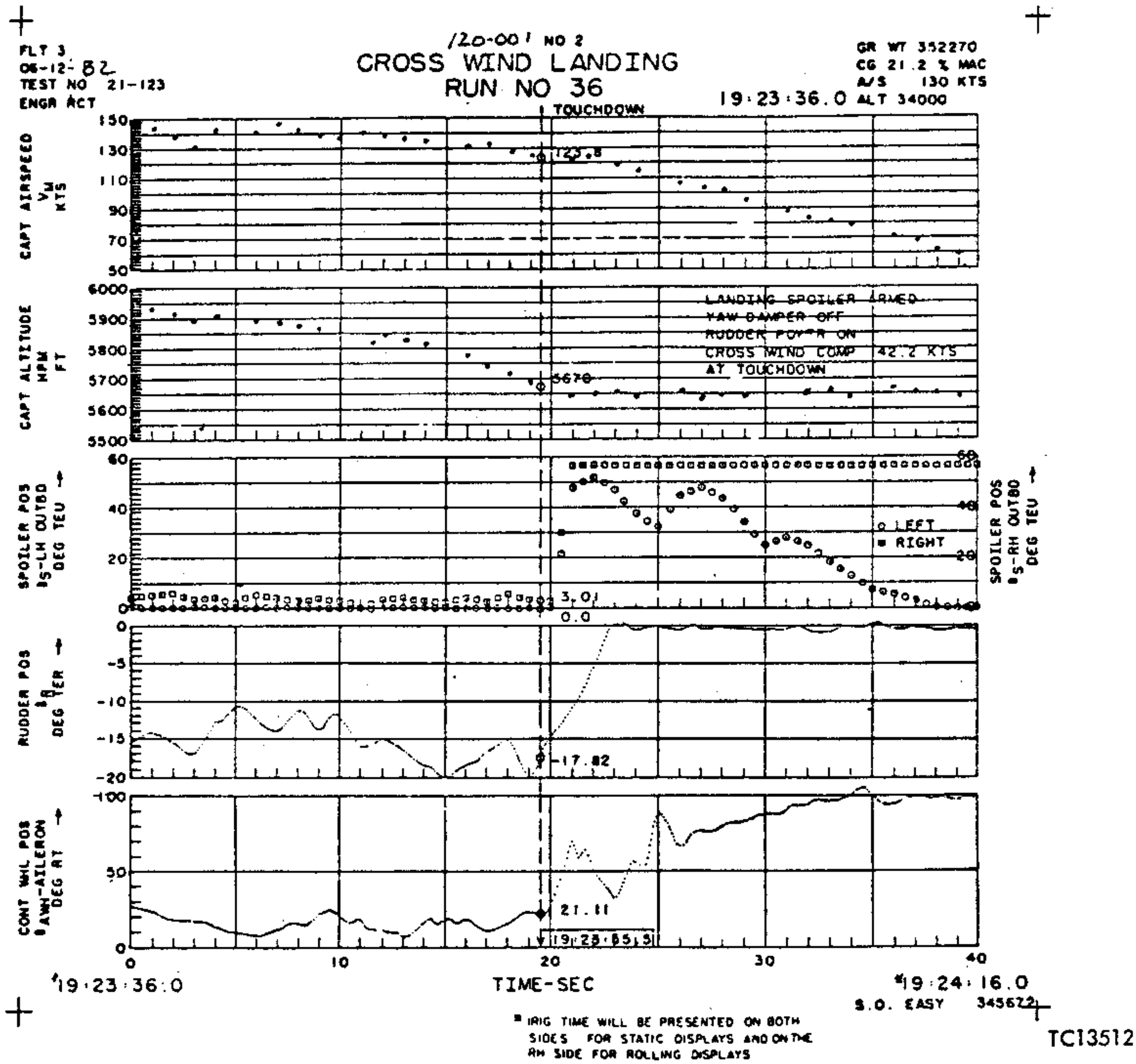

Figure 12. Stacked/Overlaid Plot with Discrete Triggered Vertical Time Line

The intervals for presentation of tabular data are operator selectable from 0.1 sec (10 times/sec for non-realtime) upward. The longer time intervals will be 0.5 sec, 1.0 sec, 10 sec, 1 min and 3 min.

Graphics/Tabular Display Hardcopy

It is possible for the operator to freeze the graphics or tabular displays at any time via a keystroke. When the picture is frozen, the operator with a second keystroke can request a hard copy of the graphics presentation to be plotted on the Versatec or the color printer/ plotter. The tabular presentations may be hardcopied on either the Versatec or the system line printer.

If the data source for the graphics presentation is the playback of a PCM flight tape, the picture freeze command to transfer the data from the graphics terminal to the Versatec printer/plotter automatically stops the PCM recorder. This does not apply to realtime data coming through the telemetry link where the PCM recorder must continue to record all telemetry data as long as there is an acceptable signal present at the output of the bit synchronizer. Once the hardcopy is complete, an automatic command restarts the PCM recorder and plotting continues in the same manner as it was being presented prior to the freeze and/or hardcopy command. If a hardcopy is not made of the frozen picture, the operator can resume the plot sequence (i.e., start the recorder) via a separate keystroke command.

Discontinuities in data are experienced from the time the picture is frozen, until the time PCM sync is re-acquired after recorder startup, or when the operator resumes plotting via a keystroke, unless the operator elects to manually command the recorder to rewind for a few seconds prior to manually restarting the plot sequence.

It is possible to request 8 1/2" x 11" or 11" x 14" hardcopy of graphics presentations. Hardcopy size is operator selectable.

Plotted data points can be composed of more than one PCM word as is the case for INS data (24 bits), 1553B data (16 bits) and PTM data (20 bits). The number of PCM words per data word (when more than one per parameter) proportionally reduces the number of channels subjected to realtime processing except in the case of discrete data where 12 channels are packed in one PCM word. In order to process more than 24 PCM words a second 24 channel PCM word selector must be added to the systems hardware complement.

Finally, when EU curves are being plotted, the EU values of the curves for each plot point may be simultaneously recorded on 9-track tape. Nine-track tape recording of plot data is made via operator command to start and stop the recording. EU tabular data presentations can also under operator command, be recorded on 9-track tapes.

When two Versatec printer/plotters are connected to the computer, simultaneous and/or independent copies of either graphic data or tabular data may be made simultaneously by separate operators with the hardcopy command issued from its individual CRT keyboard. An example of the tabular hardcopy printout of EU data presentations on the VT100/125 is presented in Figure 13. In addition to vertical and horizontal tabular hardcopy, within the bandwidth limitation of the Versatec, up to 6 channels can be plotted continuously in realtime but presented as sequential 8 1/2" x 11" completed graphs on fan-fold paper. In this manner continuous strip chart EU recordings are made but in a continous page by page format for convenient filing in notebooks.

FLT 3
DATE 00/00/00
TEST NO 02-009
ENGR RCT

121001

TEMPERATURE SURVEY

RUN NO 12

11:57:59.0

GR WT 35227
CG 21.2 % MAC
A/S 225 KTS
ALT 34000 FT

CAPT AIRSPEED V_M KTS CHAN 302 P90-1111	CAPT ALTITUDE H_{PM} FT CHAN 73 P80-2354	TIME HR:MIN:SEC	TEMPERATURE T_M-OUTSDE AIR °C CHAN 86 P39-7337	TEMPERATURE T_{T2}-INLT DUCT °C CHAN 120 P82-5403	TEMPERATURE T_{T7}-TAILPIPE °C CHAN 7 P29-4536
222.5	35300	11:59:57.0	-30.00	-10.00	300.0
221.6	35290	11:59:58.0	-30.00	-10.00	300.0
222.7	35285	11:59:59.0	-30.12	-10.23	300.4
223.8	35285	12:00:00.0	-28.76	-10.24	310 2
225.6	35300	12:00:01.0	-29.56	-12.45	310.5
225.1	35302	12:00:07.0	-30.00	-12.00	309.9
224.9	35308	12:00:03.0	-31.02	-11.79	312.1
223.5	35300	12:00:04.0	-30.09	-10.25	300.1
220.2	35298	12:00:05.0	-29.02	-11.13	301.6
219.1	35312	12:00:06.0	-32.15	-11.17	302.3

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Figure 13. Time Correlated Tabular Display of Five Parameters in EU

PCM Decommutator Health Test

The realtime software reports to the operator the occurrences of a fault in the PCM decommutator and the IRIG time of the fault. The PCM decommutator hardware generates a health test word that is stored in a register in the CPU Interface Module. When a fault which would result in the loss of good data occurs in any decommutator channel, an interrupt is generated. A flashing alarm message is displayed on the CRT when this interrupt occurs to notify the operator of a loss of synchronized data from the PCM decommutator system. The alarm message and the IRIG time is also logged on the printer.

OFFLINE PROCESSING

Test Setup Support

Software to setup and control the configuration of the FTDAS hardware and to process realtime data from the telemetry link and/or the PCM tapes is accomplished via an interactive fill-in-the-blanks menu selection process from the system CRT terminal. Front end hardware controlled via the setup and control software includes; the bit synchronizer, the frame synchronizer, the 24 channel word selector, the PCM tape recorders, the time/tape search unit, the time code generator/translator, the CCDU and the Cal lab RMDU.

PCM Tape Search

Time slices of data from a PCM tape are selectable for processing under software control. The start/stop times of the portions of PCM tape to be read can be selected from either, IRIG time, Discrete event or, a Limit exceedance. An IRIG time may be specified as the start time of data processing with the operations continuing until stopped by an operator command or another IRIG time. Discretes imbedded in the PCM stream may also define the interval for data transfer. A specific discrete event may be designated as the start of recording and a second specific discrete event may be designated as the stop of recording. Finally, limit exceedance may be used to select the portion of data to be transferred in one of two ways. The limit exceedance of one parameter may start the transfer and the limit exceedance of another parameter may stop the transfer. The parameter selected to stop the transfer is not limit checked until the start of the transfer has begun. The transfer period may also be defined as occurring while the limit exceedance condition exists for a single parameter.

PCM Tape Header Generation

Software is provided to generate a PCM tape header which permits any PCM flight tape, regardless of the data cycle map configuration, to be automatically read by the ground station. The PCM tape header is a pre-recorded constant format data cycle which contains the test system’s data cycle map and the associated sensor data, parameter data and PCM word description data for that particular test flight. Specific flight information such as aircraft serial number, flight number and the date of the flight are also included in the header along with documentary data such as PCM code, PCM word rate, parity, word length and recorder speed needed to setup the ground station hardware to read the flight data tape.

A tape header is downloaded to the RMDU so the RMDU system and the PCM tape recorder can run for a few seconds with the header information PCM format being recorded on the tape. The on-board recorder footage indicator is used to ensure an adequate blank tape gap is achieved between the system setup header and the start of the flight's PCM data when the tape reel is mounted on the airborne recorder.

UTILITIES

Offline software tasks which perform the physical movement of all telemetry data between physical storage devices, include: the copying of PCM tapes to 9-track tapes, conversion of FM/FM tapes to PCM tapes and decommutated disk files, as well as the EU conversion and transfer of the raw data contained in the disk files to 9-track tape.

PCM to 9-Track Tape Copy

The PCM tape to 9-track tape copy task reads a PCM tape or time slice sections of the tape and transfers the raw data in multiplexed format to a 9-track tape. The header of the 9-track tape contains the data cycle map, the channel data and the sensor data associated with the raw data.

PCM Tape to Disk

The PCM tape to disk task reads the operator selected time slice of a PCM tape. The raw data is decommutated and written to the disk in DEC's Files-11 format with one file for each PCM word identifier. The tape interval to be transferred may be defined by any of the time/tape search methods.

FM/FM to PCM or 9-Track Tape

Software is provided to allow for the future addition of reading and digitizing FM/FM tapes and storing the raw data on PCM or 9-track tapes when defined and requested by the operator. This function includes the setup and calibration of the discriminator subsystem and the setup and operation of the RMDU which digitizes the analog outputs from the discriminators and inserts them into a PCM data stream.

Disk to 9-Track Tape

The decommutated raw PCM data residing on the disk in DEC's Files-11 format can be converted to engineering units and written to 9-track tape. The converted data is operator specified by PCM word identifiers and start/stop times.

PCM Tape Copying

Two ground station customers are in a consortium building and testing the same aircraft but with each one conducting different tests. Thus provisions are made to copy PCM tapes for test data interchange.

CONCLUSION

By linking the data reduction software to the generation of PCM sampling maps for the airborne system it is ensured that the realtime data processing should be error-free as far as parameter identification. By configuring the airborne computer system with the same PCM decomm and man-machine interface hardware as are used on the ground station, a subset of the ground station software can be used for realtime processing in the aircraft so that the same test engineer can operate either system using the same procedures. The use of fixed format PCM tape headers will speedup the reading of PCM tapes in the recreation of a test flight offline at the ground station. Software for semi-automatic calibration of sensors in the aircraft, and the use of an airborne multiplexer is the sensor calibration laboratory with this same software for laboratory calibration of sensors, should speedup the creation and maintenance of sensor calibration files. Finally, the availability of realtime EU data to the test engineer (or pilot) in the aircraft and/or at the ground station will shorten the certification period of new aircraft.