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STRUCTURES TESTING ANALYSIS REAL-TIME NETWORK (STARNET)

R. L. Denison

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AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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The computer network employed for data acquisition and processing in the Structures Test Facility of the Air Force Wright Aeronautical Laboratories, Building 65, Area B, Wright-Patterson AFB, is extensively described. The report includes a system overview and discussions of subsystem characteristics and interconnections, system software, applications software, system operation, and a review of a large-scale network mode application. This computer network, called STARNET, is an on-line, real-time system.

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PREFACE

This report documents the final architecture, software and operation of interconnections for the Structures Testing Analysis Real-time NETwork called STARNET. STARNET serves the Structures Test Facility (Building 65, Area B, WPAFB, Ohio) as the Data Acquisition and Processing System in support of the testing of specimens ranging from coupons to full-scale airframe structures. Much of the work of developing the STARNET was done in-house in the Structures Test Branch (AFWAL/FIBT) under work unit 13470101, "Concurrent Multi-Test Capability for the FDL Aerospace Structures Test Facility" and work unit 24010501, "Data System Optimization by Automation and Related Improvements". No attempt is made to document each of the specific accomplishments under these work units. The report incorporates these individual developments into an extensive description of the whole STARNET.

Mr. Robert L. Denison was work unit engineer on each of the work units cited above and wrote the report. Mr. Adam M. Grube and Mr. William K. Buhrmaster contributed much of the data and wrote portions of Section III, "Subsystem Characteristics and Interconnections". Mr. Bernard E. Davis wrote portions of the report or provided data on the subject of SEL 86 software, notably Section V, paragraph 2.d. The equations for data processing, which are given in Section V, paragraph 2.d were contributed by Mr. Frederick E. Hussong. Mr. James N. Marable, creator of the Eight Program Monitor, (EPM) contributed data on EPM and in collaboration with Mr. Davis, much of the material on Applications Software in Section V.

The final report was submitted by the author in February 1981.

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INTRODUCTION

The United States Air Force through its Flight Dynamics Laboratory (FDL) operates a large and complex Structures Test Facility (Figure 1) at Wright-Patterson Air Force Base, Ohio. The facility and its staff are devoted to aerospace structures testing in the interest of the Air Force mission in providing national defense. The scale of testing performed at the facility runs the full spectrum from basic evaluation of fracture and fatigue characteristics of joining techniques, through intermediate scale testing of conceptual structures to full-scale testing of complete flight vehicles.

Testing of intermediate and large size structures is accomplished on the facility's main test floor. The test floor is 256 feet long by 170 feet wide with a vertical clearance of 86 feet. Testing of small coupon specimens is accomplished in various subfacilities located in the same building as the main test floor but physically separated from it. Composite, metallic and hybrid structures are all readily accommodated. Most testing performed in the facility can be included in the broadly defined areas of static strength and both low and high cycle fatigue testing. This testing is accomplished at reduced (to -326°F), ambient and elevated (to 3200°F) temperatures as required by the individual test programs. Testing of individual specimens run from a few seconds for nuclear heat-pulse simulations to more than two years for full-scale aircraft static and fatigue programs. Force is applied to the test specimen by electronically controlled hydraulic power systems. These power systems have a net capability of 1700 gpm at 3000 psi. Elevated temperatures are applied by radiant heating systems. A total capacity of 50400 kw of electrical power is available for short duration radiant heating tests. Reduced temperatures are applied by a liquid nitrogen cooling system. Both the heating and cooling systems are also electronically controlled. Closed loop control is achieved by use of a number of interconnections of minicomputers and hard-wired analog controllers. Load control for ambient temperature static tests is often manual. The number of control loops required for other types of tests

Figure 1. Structures Test Facility

varies from 1 on small coupon tests performed at ambient temperatures to over 100 for large structures requiring both force and thermal environments. The number of test parameters to be concurrently measured for a single specimen can be as few as 1 or more than 500. Typical parameters measured are time, strain, pressure, load, displacement, flow, temperature and heat flux. The number of test programs requiring simultaneous support varies from one to six or more as a function of size, complexity and speed. Figure 2 depicts three major full-scale aircraft setups on the main test floor of the facility. Figure 3 depicts a number of test machines used to perform basic evaluations of small specimens in one of the associated subfacilities.

Since the principal product of a test facility is timely, accurate and understandable test data, it follows that a sophisticated and reliable data acquisition and presentation capability must exist. This is particularly important in a multiple test full spectrum facility.

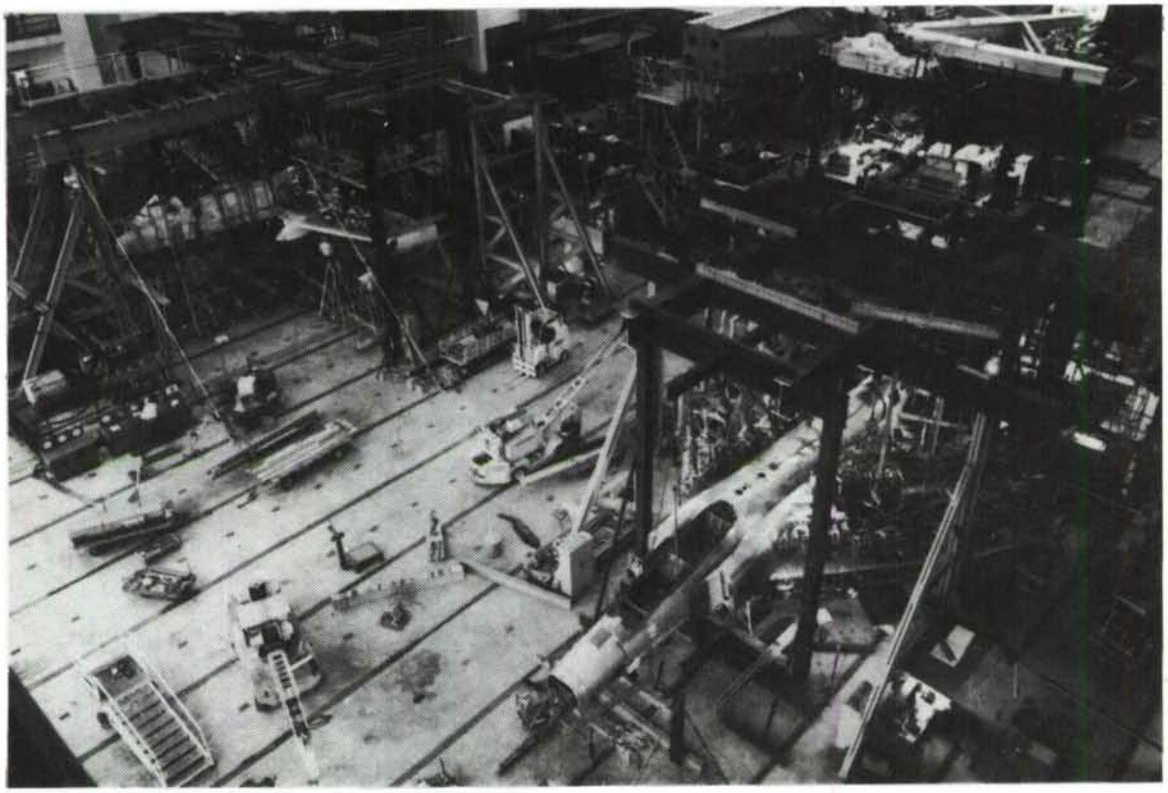

Figure 2. Main Floor - Structures Test Facility

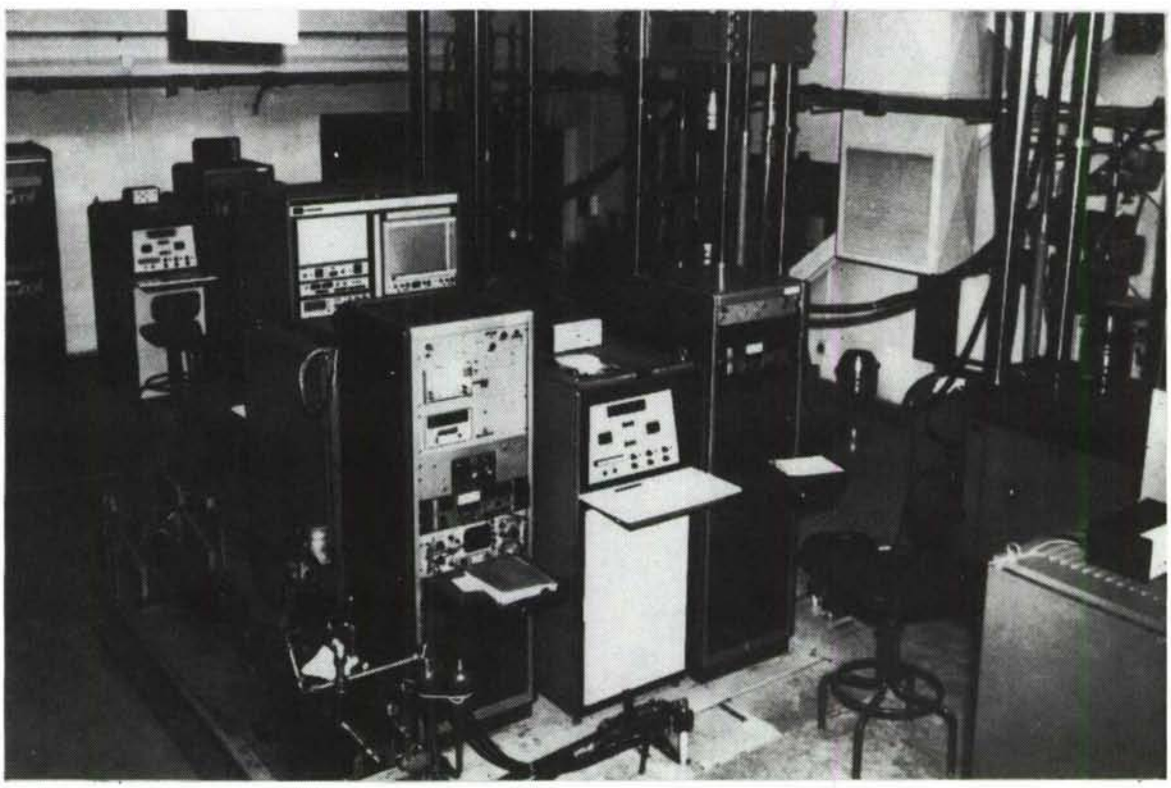

Figure 3. Fatigue and Fracture Subfacility

This publication describes the philosophy, implementation and function of the system which provides this capability to the Structures Test Facility. The system was developed under Flight Dynamics Laboratory in-house work units 13470101 and 24010501. It has been named STARNET, which is an acronym for Structures Testing Analysis Real-Time NETwork. It is a multiple computer data acquisition, monitoring, analysis and display system configured in accordance with the kinds of testing to be supported, the control systems with which it is required to communicate, and the requirements posed by the physical plant of the facility itself. Discussion of these items is included in the text where it is useful in explaining features of the STARNET.

SECTION II

SYSTEM OVERVIEW

1. HISTORICAL BACKGROUND

In the 1950's, advances in structural technology and the consequent increases in sophistication of testing requirements significantly impacted the requirements for test instrumentation and data acquisition as well as programming and test control. It became necessary not only to measure and record the traditional parameters of strain, load, pressure, displacement and temperature, but also to relate the measurements to a test-time base and to present information that would be useful to test personnel while the testing was proceeding. In other words, it became necessary to acquire and present data in an on-line, real-time environment. Fortunately, during the 1950's, electronic and computer technologies were also advancing rapidly, and in 1960 a High Speed Data Acquisition and Processing System was successfully developed and installed in the Structures Test Facility to meet the instrumentation and data acquisition requirements (Figure 4). The system was developed by Convair (San Diego) Electronics in response to a performance specification prepared by Structures Test Facility engineers. It was named DAISY II by its designers at Convair. This was an acronym for Data Acquisition & Interpretation SYstem Version II. (Version I was an off-line system owned by the company). It consisted of eight Transmitter-Multiplexer Units, a System Control Console, an Ampex FR 314 One Inch Tape Recorder, a Limit Alarm Console, a Stromberg Carlson SC 4020 Microfilm Printer-Plotter, a companion SC 1000 CRT Display System and a Control Data Corporation 1604 Large-Scale Digital Computer and its Peripheral Equipment. It was the first system to include a dedicated large-scale digital computer as a component. The Transmitter-Multiplexer Units were located on the facility's main test floor. All other equipment was located in an environmentally controlled data room elsewhere in the facility complex.

Each Transmitter-Multiplexer contained analog signal conditioning for 104 thermocouples, 79 strain gages, 20 deflection potentiometers, 20 load cells, and 23 miscellaneous transducers. Each also included a 256 channel

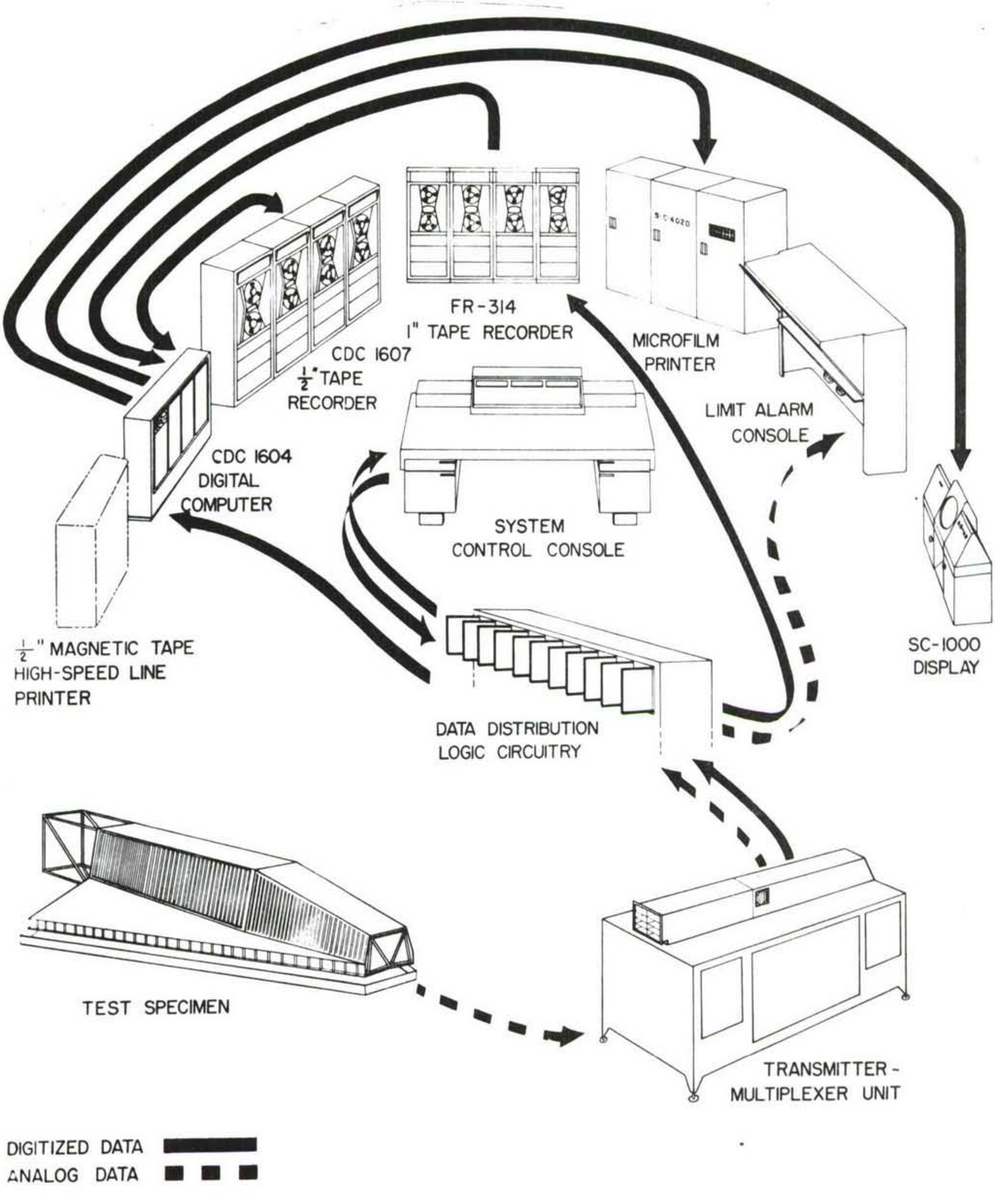

Figure 4. Data Acquisition and Interpretation System - DAISY II

fixed-format low-level electromechanical multiplexer, a bank of amplifiers, a 14 bit bipolar binary analog to Digital Converters and Line Driving Amplifiers to transmit Digital Data to the remote data room.

The total system was computer assisted in the sense that (a) the Transmitter-Multiplexer Units operated under their own control, (b) the System Control Console was operated by an instrumentation engineer, (c) the Limit Alarm Console, which presented analog data as bar graphs on CRTs, operated under control of connected Transmitter-Multiplexer Units, and (d) the One Inch Tape Recorder provided magnetic tape recordings under the combined control of the Control Console and the Transmitter-Multiplexer Units. The computer controlled only the flow of data from the Transmitter-Multiplexer Units directly to the computer itself, from the Tape Console to the computer itself, and from the computer to the Stromberg Carlson microfilm and display equipment. Furthermore, it had on-line access to only four of the eight Transmitter-Multiplexer Units. It had off-line access to all units via the tapes recorded on the One Inch Tape Recorder.

In the original system the computer was used for real-time acquisition of data on up to 1024 channels (four Transmitter-Multiplexer Units). It recorded this data on its own magnetic Tape System, performed real-time computations on up to 256 channels (one Transmitter-Multiplexer Unit) and displayed the computer data on the Stromberg Carlson Display Tube. Its on-line data acquisition rate was software limited to approximately one sample per channel per second. It had off-line access to all 2048 channels (eight Transmitter-Multiplexer Units) via the One Inch Tape Recorder, and was used in the nonreal-time environment for data analysis and hard copy output. When the system was installed, there was no Fortran Compiler available for the 1604 Computer, nor had an operating system been developed. Consequently, all software for the system was custom tailored and written in 1604 Assembly Language (CODAP) by professional mathematicians/programmers.

Although a Fortran Compiler and a Batch Operating System were later written by CDC for the 1604, neither was ever used in the Structures Test Facility to support real-time testing; the batch architecture of the operating system (and the computer itself) and the overhead of the compiler were incompatible with the requirements of real-time testing.

The Data Acquisition and Processing System as acquired in 1960 was highly modularized. During its first decade it underwent several configuration changes to increase its capability and reliability. However none of these changes altered the basic system concept. It remained a computer assisted system with a fixed-format continuous sequential scan multiplexing system. Furthermore it would support only one test at any given time.

In the early 1970's a Digital Equipment Corporation PDP-11 Minicomputer and two Computer Products RTP 7400 Computer controlled Random access electronically multiplexed Multiplexer/Analog-to-Digital Converter Systems were acquired by the facility. The RTP 7400s were connected to operate under control of the PDP-11. The PDP-11 was connected to operate under control of the 1604, or as a stand alone system, as a function of the requirements of a given structures test project. The purpose of this interconnection was to permit utilization of computer controlled multiplexer/analog-to-digital converter subsystems in a system which included the 1604, and to test the two level network scheme of interconnected computation for real-time testing. Operational experience with this configuration confirmed its utility and the concept (in expanded form) was incorporated into the STARNET system when initial development on it began.

2. ARCHITECTURAL CONCEPTS

a. System Philosophy

The system philosophy developed by FDL engineers that ultimately resulted in creation of the STARNET system was based on assessment of the technologies of digital systems and measurement instrumentation, the requirement to simultaneously support a full spectrum of testing, the reuseability of capital resources already owned, the constraints imposed by the physical arrangement of the facility, and the lessons learned during the life of DAISY II.

There were both positive and negative aspects to the lessons learned from DAISY II. It was an advanced system for its day; in addition to its pioneering use of a computer on-line, it featured multiplexing and analog-to-digital conversion at the test site with digital transmission of data to the computer room and an on-line cathode ray tube display which provided tabular and limited graphical output of live test data processed into engineering units. Its essential limitations were that it could support only one test at a time, its real-time capability was limited by the speed, storage and reliability limitations typical of the computer technology of its day, and its display equipment was not interactive and could be used only in the data room.

The philosophy that resulted from the assessment had twelve key elements:

(1) Systems engineering/integration would be accomplished by the facility staff to maximize design flexibility and responsiveness to requirements change.

(2) The architecture would be open ended so that increased capability could be achieved by adding equipment modules or by replacing old modules with new higher performance ones.

(3) The system would be required to simultaneously support multiple test projects; the number of tests to be a function of size and complexity of each one.

(4) Network architecture would be used involving multiple interconnected computers with various computing tasks distributed among them.

(5) Maximum modularity of noncomputing equipment would be used for flexibility, maintainability and growth potential.

(6) The functions of analog signal conditioning, multiplexing and analog-to-digital conversion would be accomplished at individual test sites (within the facility).

(7) The computing equipment would be centralized in the room originally built for DAISY II in order to provide a consistently controlled environment and operation by one person per shift.

(8) Terminals (CRT & Hard Copy) for input and output functions would be portable and be capable of being used at individual test sites as well as in the computer room.

(9) New equipment required would be acquired individually and integrated into the system.

(10) Signal conditioning equipment, the RTP 7400s and the PDP-11 acquired during the life of DAISY II would be integrated into the system.

(11) Functional overlap among the computing equipments would be used to minimize the effect of malfunctions.

(12) All data transmission between the test site and the computer room would be digital.

b. System Realization

The STARNET, as implemented, is a real-time high-speed system for on-line acquisition, monitoring, manipulation, analysis, recording and presentation of Structural Testing Data in support of multiple simultaneously running test projects.

STARNET is an interconnected network, including a real-time oriented medium-scale computer, 4 minicomputers, a number of microcomputers, 2 programmable CRT vector graphics systems, 19 analog/digital Signal Data Converters (SDC) and more than 2,000 channels of signal conditioning equipment. The resources of the medium-scale computer and graphics systems are normally shared among multiple test projects. However, they can be dedicated to one very large test project if necessary. On test projects with large and sophisticated on-line data acquisition and analysis requirements, the minicomputers operate under the supervision of the medium-scale computer and are dedicated to individual test projects. For test projects with smaller and less sophisticated data requirements each minicomputer can be shared among up to eight projects concurrently.

Testing within the Structures Test Facility is accomplished on the main test floor and in a number of remotely located (in the same building) subfacilities. Except in cases where testing involves health/ safety hazards the test conductor and the test crew operate in the immediate vicinity of the individual test structures (in these special cases operation is performed from the computer room and/or control room). STARNET acquires data from various sensors and equipments to evaluate the performance of test control systems, confirm the value of applied parameters and determine the response of test structures to these parameters. To accomplish these functions it is required to have direct communications access to all test locations and all control equipment locations within the total facility. It has been possible to meet this requirement because of the distributed nature of the system; particularly the provision for analog signal conditioning, multiplexing, analog-to-digital conversion, and keyboard/CRT terminals at the test sites.

Figure 5 is a simplified block diagram of STARNET. The various equipments that make up the system are divided into 5 functional subsystem classes. These classes are (1) analog signal conditioning, (2) analog/digital SDCs, (3) minicomputers/microcomputers, (4) medium-scale computer and (5) monitor/display subsystems. These subsystem classes are identified to correspond to physical equipments (with separately identifiable functions) within the STARNET system. Figure 6 is the interior of the computer room and Figure 7 is a typical test site equipment arrangement. Note that although sensors and transducers are essential they are not identified as system elements in this publication.

STARNET architecture is open ended. The many physical separate interconnected functional blocks can be replaced and new ones can be added without incurring total system downtime.

3. INTRASYSTEM COMMUNICATION

Analog signal conditioners used in a specific test program are portable and located at the individual test site. The analog/digital SDCs required to support the connected analog conditioners on a specific program are also portable and located at the site, typically within 5 meters of the conditioners. Cabling from the transducers to the conditioners and from the conditioners to the SDCs is the only cabling used for Analog Signal Transmission. All other systems interconnections, including permanently installed cables, use digital transmission. (This is the same method of interconnection used in DAISY II).

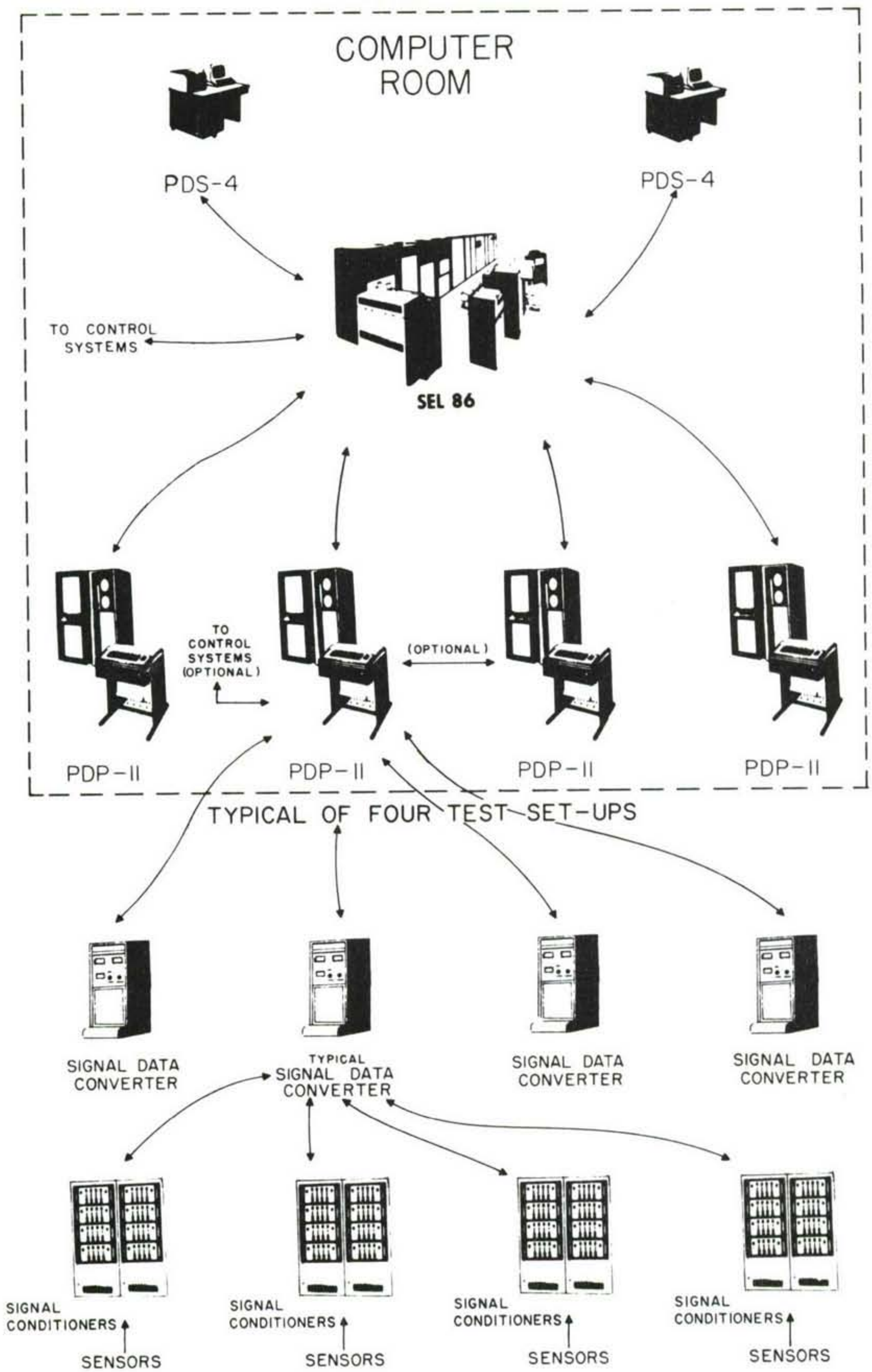

Figure 5. Typical STARNET Configuration

Figure 6. Computer Room

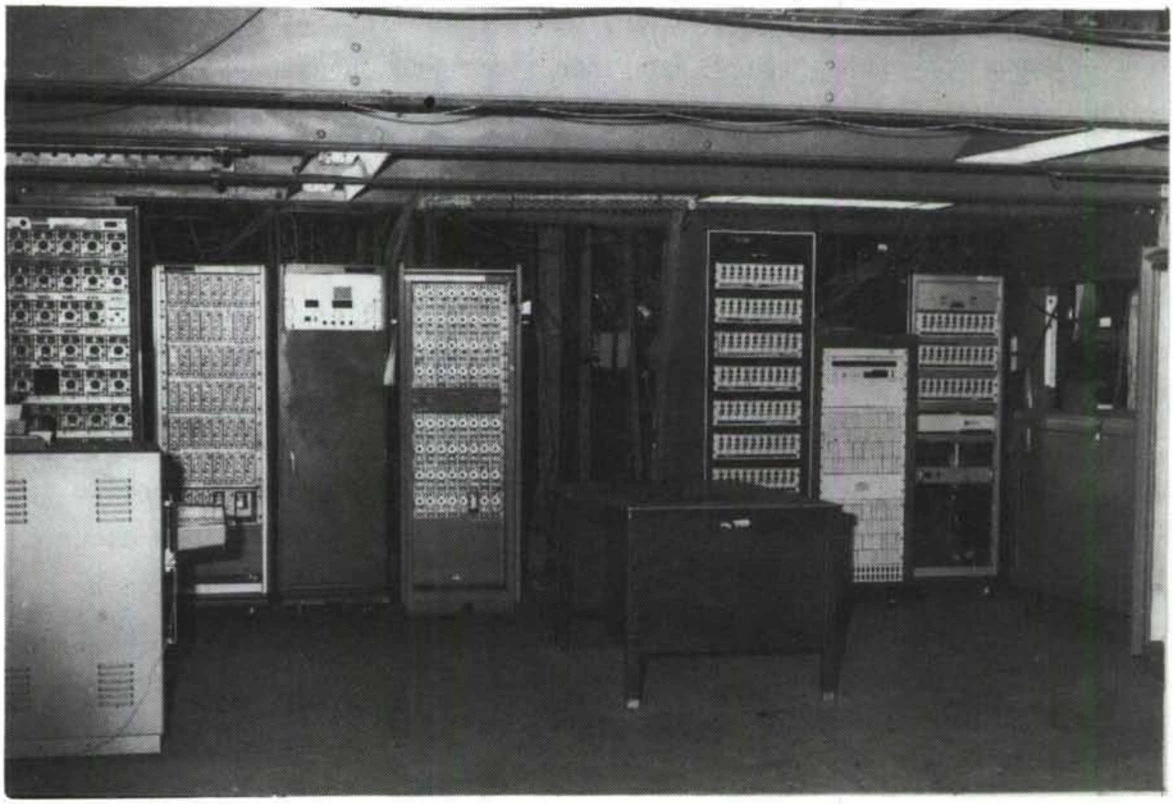

Figure 7. Typical Test Site Equipment Arrangement

The SDCs are all minicomputer/microcomputer controlled devices. All of them are random access; some of them also have programmable gain. The STARNET minicomputers are all centrally located in a controlled environment computer room. They communicate with the connected SDCs over cables up to 250 meters in length via parallel controllers which were designed by FDL engineers as part of the system. Each minicomputer controls up to eight SDCs using eight individual controllers. (This is not an inherent limit; the number of controllers can theoretically be extended until the minicomputer external device address space is used.) Microcomputers are dedicated to single SDCs.

The medium-scale computer is also located in the computer room. Because of the high-speed bidirectional communication required between the medium-scale computer and the minicomputer, it is necessary that all minicomputers be located within 15 meters of the medium-scale machine.

The monitor/display systems are CRT devices with built-in general purpose and display processors. External communication takes place between the general purpose processor and the medium-scale computer via an asynchronous serial line. The processors are located in the central computer room for environmental considerations and operator access. However, the displays and associated keyboards can be operated in the computer room or at individual test sites as a function of test requirements. Remote operation of the display tubes is accomplished by FDL designed video line driver/receiver circuitry. Keyboard (ASCII) information is successfully transmitted without special circuitry.

4. AVAILABILITY CONSIDERATIONS

Availability, in the sense used here, includes such factors as reliability of the equipment, methods of keeping the system in service or returning it to service with minimum disruption when malfunctions occur, ease of access to the system by users, and flexibility as indicated by the ease with which system elements can be redeployed. High availability is an essential function in a successful data system and is addressed by the STARNET subsystem classes and system architectural features in several ways.

a. Signal Conditioning Equipment

Most STARNET signal conditioning equipment is modular in nature. Failure of a single transducer or conditioner will have minimum effect on system integrity. Modules can be installed/removed without powering down the system. Therefore, malfunctioning units can be changed quickly during setup and with some limitation while running. The important considerations are that other data is normally not affected and that power-on trouble-shooting does not disrupt operation.

b. Signal Data Converters

The Signal Data Converters (SDCs) are connected to minicomputers/microcomputers by individual controllers. As part of the software control strategy, each minicomputer/microcomputer evaluates the communication response of its connected SDCs during operation. When the minicomputer/microcomputer identifies a malfunction it suspends data sampling and notifies the user by presenting a message on the associated CRT terminal. As a function of individual test requirements, the malfunctioning SDC can be bypassed and testing continued at reduced channel capacity, or testing can be stopped for repair of the unit.

c. Minicomputer Hardware

When operating in network mode, minicomputer operation is monitored by the medium-scale computer (and conversely). Failure of a minicomputer requires that testing be suspended for repair or replacement of the malfunctioning unit. The minicomputers in STARNET are essentially interchangeable although exchange of a small number of cables is necessary to effect the interchange. A malfunctioning machine can be replaced in approximately 15 minutes (when a replacement is available).

d. Microcomputer Hardware

Microcomputers are normally operated stand alone. They may be downline loaded from a minicomputer or loaded from their own peripheral equipment. Malfunction requires repair/replacement.

e. Medium-Scale Computer

The medium-scale computer is monitored by its operating system and when in network mode by the on-line minicomputers. During testing in which real-time monitoring and evaluation is essential the machine must remain in operation. For less critical applications there is an overlapping of capability with the minicomputers which permits use of individual minicomputers for acquisition and storage of test data. Therefore, for tests which do not have critical real-time monitoring requirements, the medium-scale machine can go off-line without terminating testing.

f. Display Systems

The display systems provide information to the testing teams on a real-time basis and also provide these personnel the capability to control STARNET operation. The medium-scale computer indirectly monitors the performance of these systems by evaluating the quality of communication between the machines. Multiple transmission retrys are used when required and an error log is kept by the operating system.

Since it is possible for multiple display systems to be on-line to the medium-scale computer, it is also possible to fall back to a secondary display should the primary fail. If all display hardware malfunctions during testing it is possible to fall back to a mode in which critical real-time computations are performed by the medium-scale computer, but no displays are generated. In this situation STARNET control is totally in the hands of the computer operator.

g. Data Transmission Method

All multiplexing and analog-to-digital conversion is accomplished at the individual test sites, consequently all communication/data transmission between the sites and the STARNET computer room are digital. This eliminates the necessity of providing long runs of several thousand insulated, shielded, twisted analog pairs between the test sites and the computer room. This reduces costs and improves signal integrity since long low-level analog lines are classically noise sensitive. There is no permanently installed analog cabling; it is all portable.

h. Interchangeability

All SDCs and minicomputers are plug compatible at both input and output. This maximizes compatibility and minimizes cable inventory. Most (but not all) signal conditioners are also plug compatible.

i. Centralization of Computers

Centralization simplifies the environmental control problem since all computing equipment is in one controlled environment room. It reduces operating costs by providing for convenient operation of all machines by one person. Since the room has direct cable access to all test and equipment sites in the facility, it provides maximum flexibility by giving the capability for nearly instant redeployment of system resources from one test program to another in the event of malfunction or facility committal to more test programs than the system can concurrently support.

SECTION III

SUBSYSTEM CHARACTERISTICS AND INTERCONNECTIONS

1. SIGNAL CONDITIONING SUBSYSTEMS

Parameters of primary interest in structures testing include temperature, heat flux, displacement force, pressure, strain and time. The FDL Structures Test Facility normally uses thermocouples to measure temperature; fluxmeters (thermocouple based devices) to measure heat flux, potentiometers to measure displacement; devices based on the metallic foil strain gage to measure force, pressure and strain; and computer internal clocks to measure time. Linear variable transformers are sometimes used to measure displacement. There is an occasional requirement to measure other types of parameters (flow, etc.) and for using other types of transducers. When these situations arise they are handled on an as required basis. Typical transducer/signal conditioner combinations yield signals that are floating differential varying DC voltages and the SDCs are designed to accept this kind of signal. Full-scale range for various transducers varies from ±20MVDC to ±10VDC.

a. Signal Conditioning for Thermocouples

The basic signal conditioning required for a thermocouple device consists of a method of establishing a fixed temperature at one of the two junctions of the device. At the Structures Test Facility 50 channel "Universal" 150°F reference units are used to provide this function (Figure 8). The 150°F reference temperature is established by an electrically heated thermostatically controlled aluminum block. Two different models are in use. One was custom built by the Convair Division of General Dynamics and the other is a product of Research, Incorporated. In both models thermocouples are routed into the unit and the reference junctions are completed via special connectors within the unit. Net thermal emfs are outputted from the units via copper conductors and MS3100 series threaded coupling circular connectors.

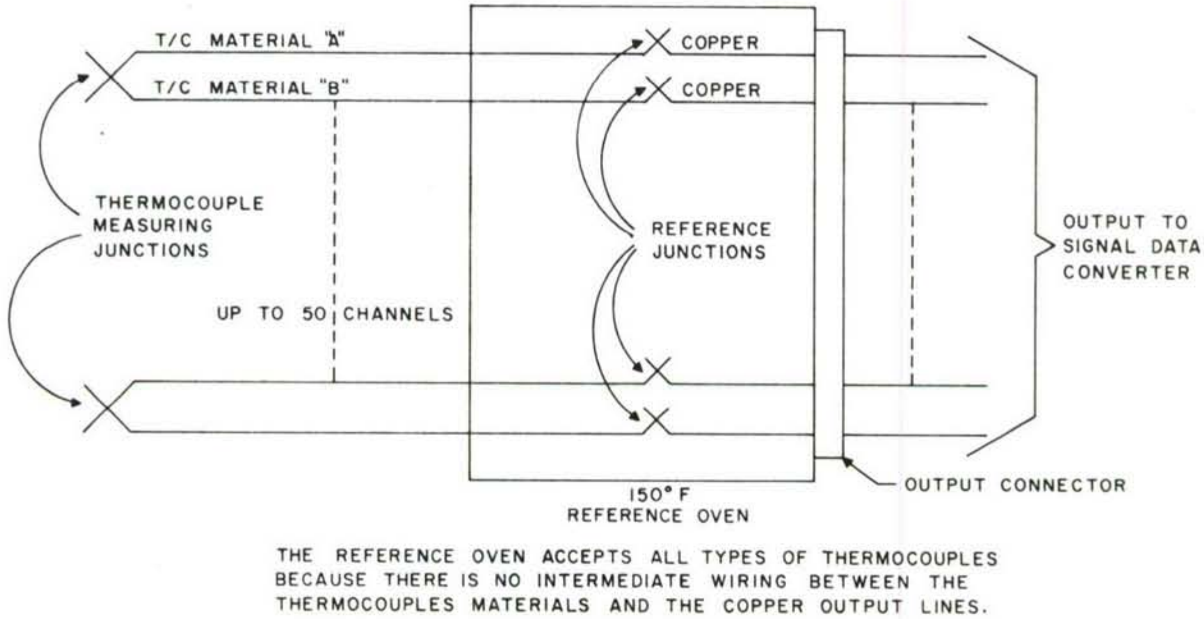

Figure 8. Basic Thermocouple Signal Conditioning

b. Deflection Measurement Subsystems

(1) Deflection Potentiometers

A deflection potentiometer is a variable resistance transducer in which the wiper of the potentiometer is connected to a test specimen and the body of the potentiometer is held fixed. These transducers are connected in potentiometric bridge circuits which convert the changes in wiper position into equivalent electrical signals. An individual control module is used with each transducer (Figure 9). The module contains bridge conditioning circuitry, a floating DC power supply for bridge excitation, relays for calibration, and other related circuitry. Excitation voltages of +10VDC and +5VDC are used. In the basic potentiometric bridge, output voltage can be equal to excitation voltage at full excursion of the wiper. In some units used at the Structures Test Facility internal signal attentuators are used to minimize the scaling workload to the SDCs and minicomputers. In all cases the power supplies are floating and the signal is differential. The system in use at FDL is a product of Research, Inc.

(2) Linear Variable Differential Transformers (LVDT)

LVDTs are used for small deflection and in low force and relatively high frequency applications for which potentiometers are unsuitable. The LVDTs used by the Structures Test Facility are DC input - DC output devices with internal electronics packages. Conditioning circuitry for these units include power supply and output scaling networks (Figure 10).

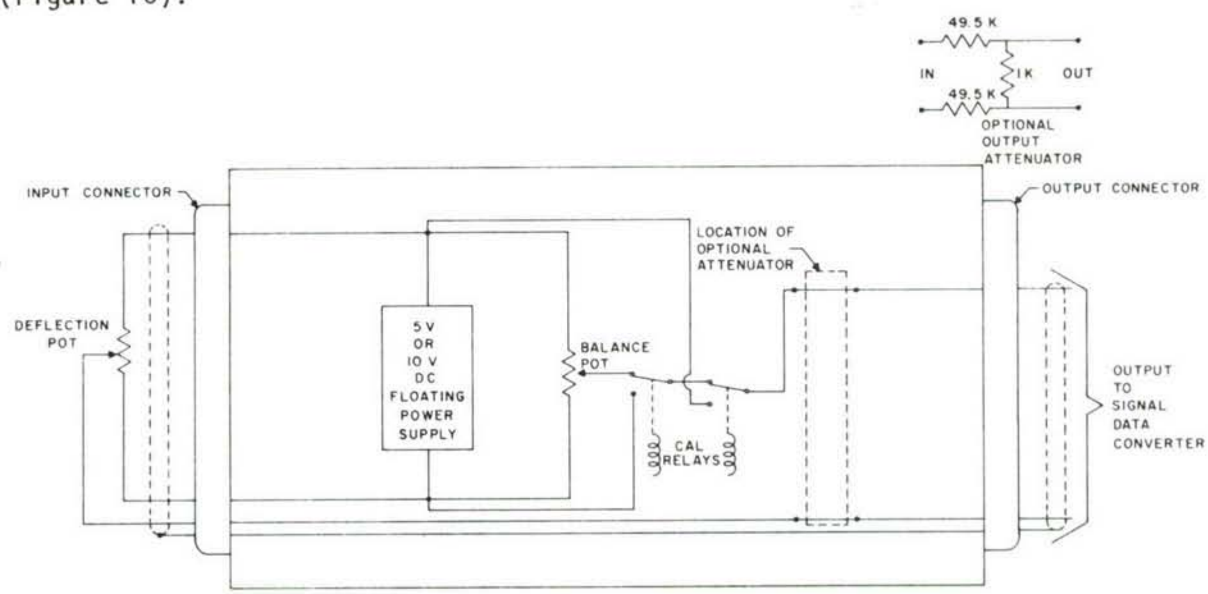

Figure 9. Deflection Potentiometer Signal Conditioning

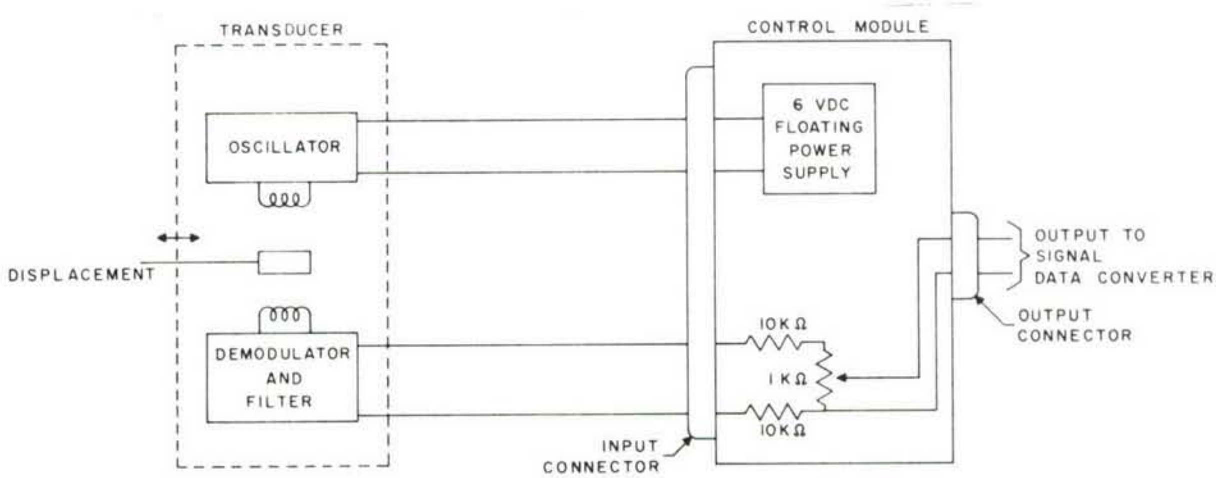

Figure 10. DC LVDT Displacement and Signal Conditioning

c. Strain Gage Based Subsystems

Metallic foil strain gages are used in large number in the Structures Test Facility. Strain gage based transducers such as load cells and pressure transducers are also used in large numbers. The Structures Test Facility uses DC voltage excited Wheatstone bridge signal conditioners for these devices (Figures 11 and 12). The conditioner modules include provision for a bridge completion network, a floating precision DC power supply with a range of 0-30 volts, a bridge balance circuit and a means of calibrating the bridge by inserting known resistances in parallel with one (or two opposites) arms of the bridge. (This is the traditional Shunt Calibration Scheme). Seven different models of strain gage conditioning modules from five different manufacturers are used in the STARNET. All but one model include an individual power supply for each channel. Input and output connectors are standardized for the various equipment. Different input cables are used as a function of the kind of transducer connected. The input connector is a three-point bayonet lock quick disconnect circular connector. Individual connectors are used for each channel. Output connections are completely standardized. A standard MS3100 series threaded coupling circular connector provides the output from each channel of equipment.

d. Miscellaneous Subsystems

STARNET can directly interface to any transducer/conditioner combination whose output is a DC (or varying DC) voltage signal. Event transducers, turbine flowmeters with conditioners, etc., are in this category. Devices with digital outputs require special handling by the computers directly. This is also true for instruments using the IEEE 488 bus, Mil 1553 bus, etc.

2. CONDITIONER/SCD INTERCONNECTIONS

Each family of signal conditioning devices has its individual output connector configuration. However, every STARNET SDC channel has exactly the same input connector configuration. Consequently any signal conditioner output may be connected to any STARNET channel.

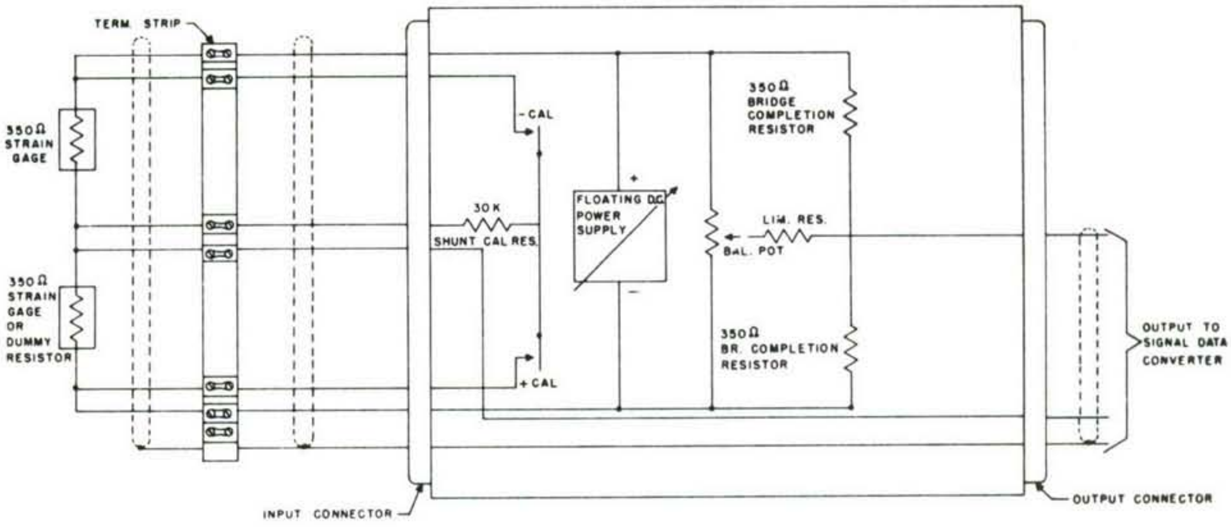

Figure 11. Basic Strain Gage Conditioning (1 or 2 Active Arms)

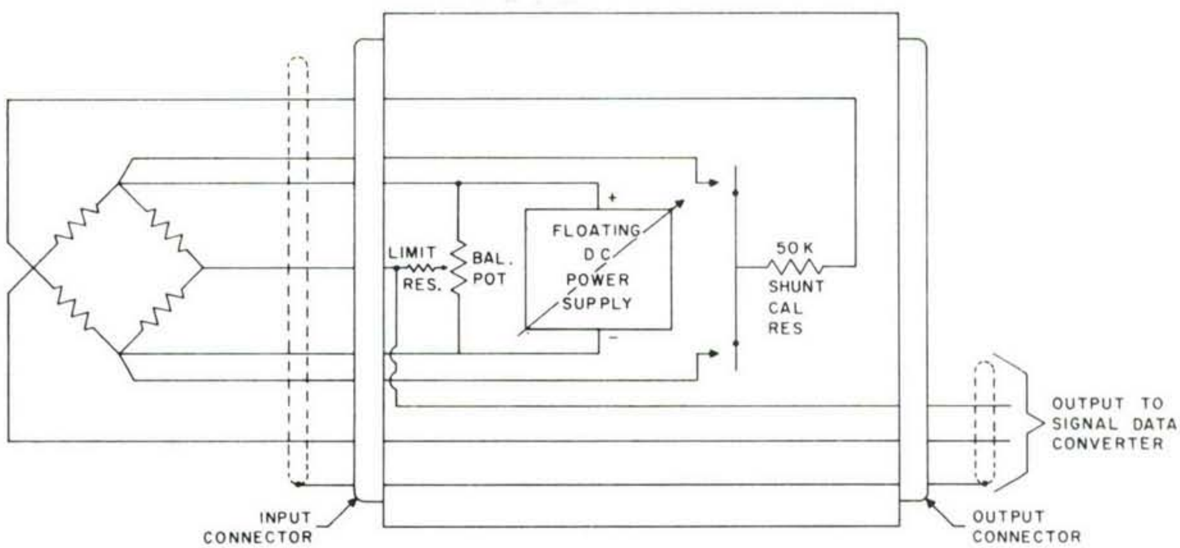

Figure 12. Basic Four Active Arm Bridge Conditioning (Load Cells, Pressure Transducers, etc.)

3. SIGNAL DATA CONVERTER SUBSYSTEMS

Each STARNET SDC provides the function of analog signal multiplexing, amplification, analog-to-digital conversion and local display. In normal operation the units are controlled by PDP-11 minicomputers or LSI-11 microcomputers. However, each unit includes a front panel display and a set of controls to provide local display of selected channels on a one at a time basis, and access to a calibrated voltage signal. These functions provide a convenient means of setup and checkout of transducer/signal conditioner installations. A number of different types of SDCs are in service. The largest units have 128 multiplexed inputs and the smallest have 16. Some of the units have computer controlled gain, some have an amplifier per channel, and some use a two stage multiplexing scheme with multiple shared amplifiers. All the units have binary data output with two's complement representation of negative numbers (negative input voltages) and all are random access devices. Some units provide 12 bit data and some provide 14 bit data. The sign bit is extended to the 16th bit position by the hardware in all cases to accommodate handling as a signed number by the controlling PDP-11 without preliminary manipulations. All units are plug compatible and all use the same cabling and communication protocol with the controlling computers. Each unit uses a consistent subset of the commands that the computer can issue. For example, if a gain setting command is issued to a unit with fixed or manually set gain, it is ignored but communication proceeds. Similarly, if a 64 channel unit is issued a command to scan 128 channels in sequence, it scans 64 channels twice. In this way hardware and software compatibility of dissimilar units is achieved.

a. FDL Designed Subsystems

(1) FDL Type I Subsystem (Figure 13)

The Type I Subsystem in included in this report for historical purposes. It was part of the initial complement of STARNET subsystems but has now been removed from the inventory.

The Type I Subsystem is a 128 channel, double multiplexed system with a Preston type 8500 MHD 14 bit analog-to-digital converter. All analog input channels are relay multiplexed at low-level into 8 Neff

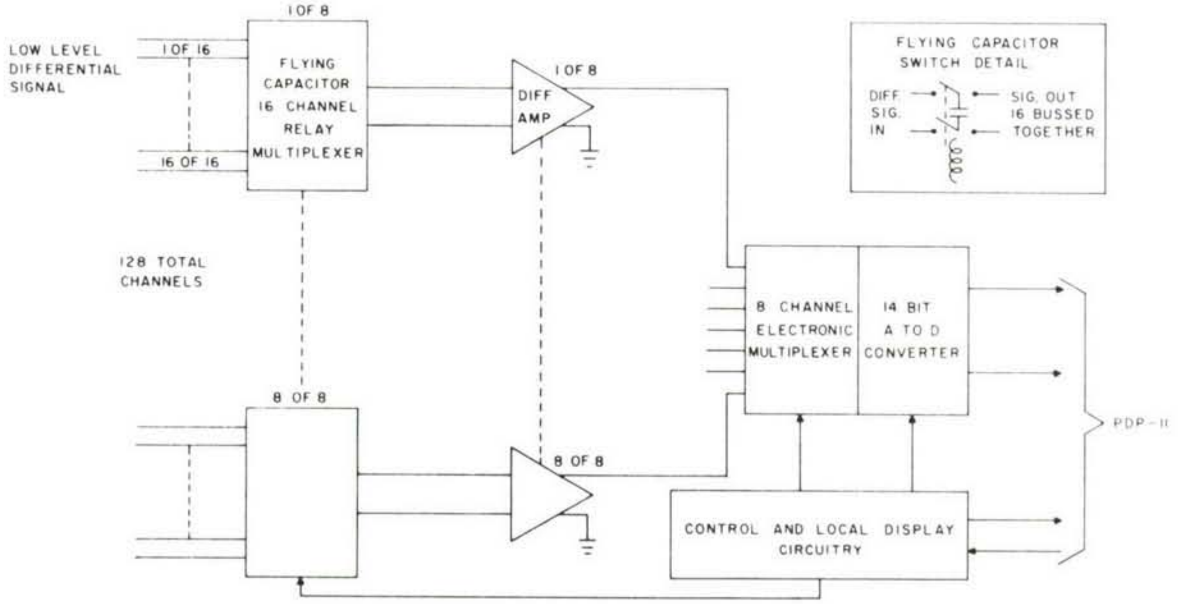

Figure 13. Block Diagram FDL Type I SDC

Type 121 instrumentation differential amplifiers. The high-level outputs of the amplifiers are multiplexed electronically into the analog-to-digital converter.

Each low-level multiplexer channel contains one switching relay configured as a "flying capacitor" switch (128 relays). The flying capacitor can be thought of as an RC charging/discharging circuit with two different time constants. In the Type I Subsystem the RC product is typically less than .01 second when the capacitor is across the transducer. When the capacitor is across the amplifier the product approaches 10 seconds. In typical operation (ignoring switching time) the capacitor is across the transducer approximately 90 milliseconds and across the amplifier approximately 10 milliseconds for each 100 milliseconds elapsed time. Under these conditions the frequency response of the circuit is determined by the capacitor/transducer connection and the capacitor/amplifier connection can be considered to be a sample and hold circuit with relatively little drop in signal. There are 8 low-level multiplexers, each one containing 16 channels. Channels are arranged so that each eighth channel is in the same amplifier. Therefore when channels are scanned sequentially, amplifiers are also scanned sequentially and at 16 times the channel scanning rate. The double multiplexing scheme provides a relatively high-speed sampling rate with some flexibility in gain setting. The subsystem has an overall maximum sampling rate of 1280 samples per second and is intended for quasi-static testing.

(2) FDL Type II Subsystem (Figure 14)

The Type II Subsystem is a 64 channel high-speed amplifier per channel device. Total channel access time is 45 microseconds. This provides an average sampling rate of 22,000 samples per second. Each channel is equipped with a Preston type 8300S instrumentation amplifier, which provides continuously adjustable gain with the range of 1 to 1000, adjustable bandwidths of DC to 10, 100, 1000, 10,000 HZ or unfiltered, a zero balance adjustment input impedance above 10 megohms and common mode rejection at 60 HZ above 140 db. The output of each amplifier is provided with a digitally actuated, solid-state analog switch which, on command,

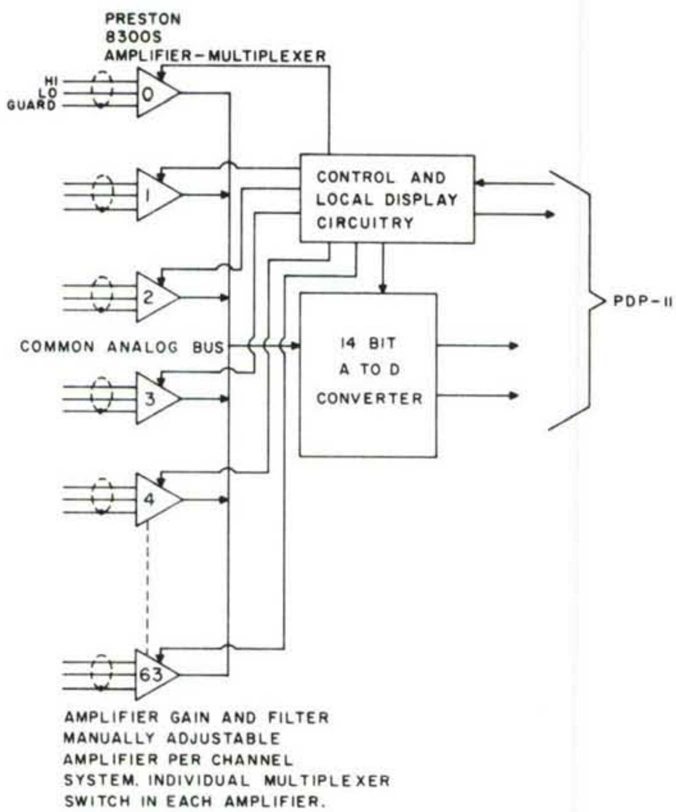

Figure 14. Block Diagram FDL Type II SDC

connects the amplifier to a single 64 channel analog bus (the switch is built into the amplifier). When the driving computer asserts the "activate" control line, a Preston Model 8500-VHS A/D converter probes the analog bus and generates a digital representation of the voltage. The A/D output is returned to the computer as a 14 bit parallel word, along with a "data ready" reply signal.

When the "computer/monitor" toggle switch located on the operator's panel is placed in the "monitor" position, the driving computer is effectively disconnected from the subsystem. In this mode, the system scans all 64 channels sequentially at greatly reduced speed. "Monitor" mode is useful primarily for maintenance and pretest setup and checkout of the system.

(3) FDL Type III Subsystem (Figure 15)

The Type III Subsystem is a 64 channel subsystem which uses a Computer Products Transformer coupled multiplexer and a 12 bit analog-to-digital converter. The control and interface logic was designed by facility engineers. The Type III Subsystem features individually removable low-level switch circuit cards, address and data amplitude readouts and programmable gain. It provides an 8,000 HZ sampling rate, 120 db common mode rejection at 60 HZ, 8 programmable full-scale gain ranges ($\pm$5.0 millivolts to $\pm$1.0 volt) and will withstand 300 volts RMS common mode voltage without damage to the low-level switches or the subsystem logic. The Type III Subsystem has a sample rate vs. input impedance tradeoff for individual channels. The typical value of input impedance drops from 10 megohms at 50 HZ to 62.5 kilohms at an 8,000 HZ rate.

(4) FDL Type IV Subsystem (Figure 16)

The Type IV Subsystem is a 16 channel amplifier per channel system. It is capable of data acquisition rates of 50,000 samples per second. Gain on each analog channel can be independently (manually) adjusted from 5 to 1,000; each channel has a 12 db/octave active low pass filter with switch selectable upper frequency limits from 10 HZ to 10,000 HZ. This allows the gain and filtering to be selected for each of the 16 analog input channels. Common mode rejection is 130 db at 60 HZ.

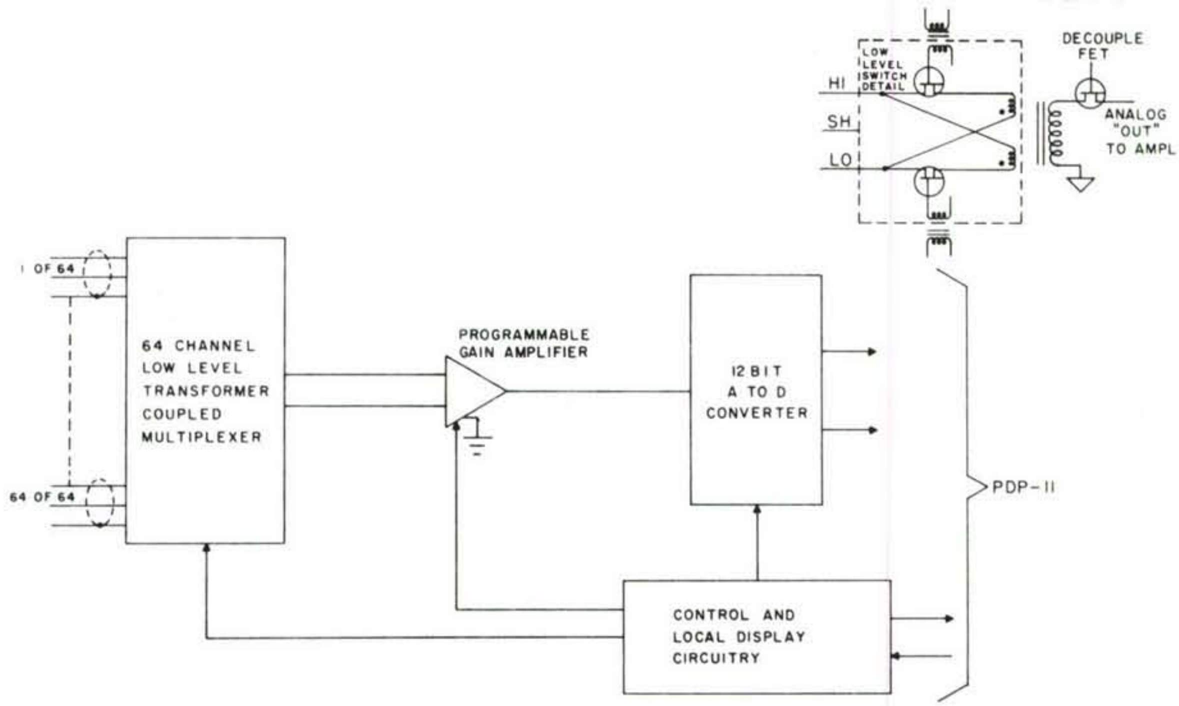

Figure 15. Block Diagram FDL Type III SDC

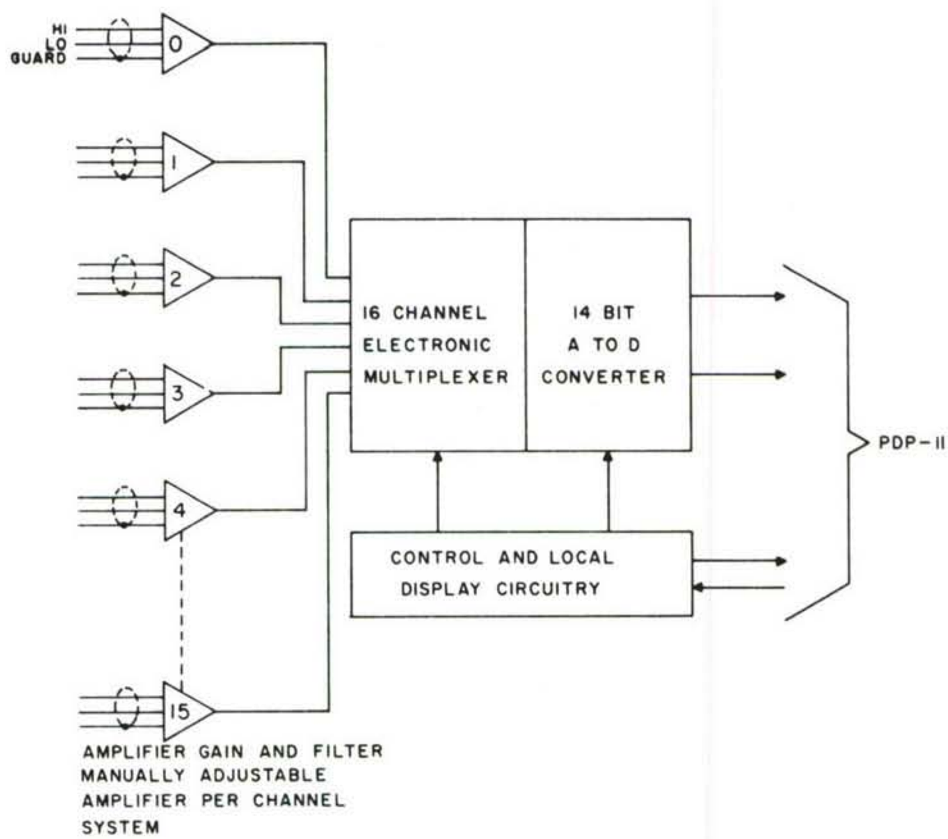

Figure 16. Block Diagram FDL Type IV SDC

The analog-to-digital converter is a 14 bit high-speed unit which also contains the 16 channel high-level multiplexer. The high conversion rate of the Type IV Subsystem allows it to be used for burst data on catastrophic type testing such as failure tests.

b. Vendor Supplied Subsystems

(1) Computer Products RTP 7400 (Figure 17)

The RTP 7400 (Real-Time Peripheral Series 7400) is a 128 channel subsystem, manufactured by Computer Products. It is based on a standard product but is custom designed to meet Laboratory specifications. It consists of two semi-independent 64 channel devices with shared control and display circuitry. Its characteristics are the same as the FDL Type III Subsystem except for the implementation of the digital circuitry and the number of channels.

(2) Preston Scientific GMAD-1 (Figure 18)

The Preston Scientific GMAD-1 is a 128 channel subsystem. It is manufactured by Preston Scientific Incorporated to FDL specifications. It incorporates a low-level, floating, differential input multiplexer which provides complete isolation between the input to the multiplexer channel and multiplexer bus output and a 14 bit analog-to-digital converter. The GMAD-1 provides complete random access to analog input channels at a sampling rate of 20,000 samples per second and full-scale ranges from ±10MV to ±1.0 volt. The low-level switch is an all solid-state, transformer coupled plug-in unit and will withstand 350V peak AC or DC common mode voltage. Common mode rejection is 140 db at 60 HZ. Input impedance is 10 megohms. Unlike the RTP 7400 systems there is no sampling rate/impedance tradeoff.

4. SIGNAL DATA CONVERTER TO MINICOMPUTER INTERCONNECTION

Permanently installed cabling runs from a data patch panel in the STARNET computer room to data patch boxes located on the facility main test floor and in the various subfacilities within the building. Connection to the patch panel and boxes is via MS3100 series threaded coupling circular connectors. Portable cabling is used to connect each SDC to a patch box. Mating cables run from the patch panel to the various

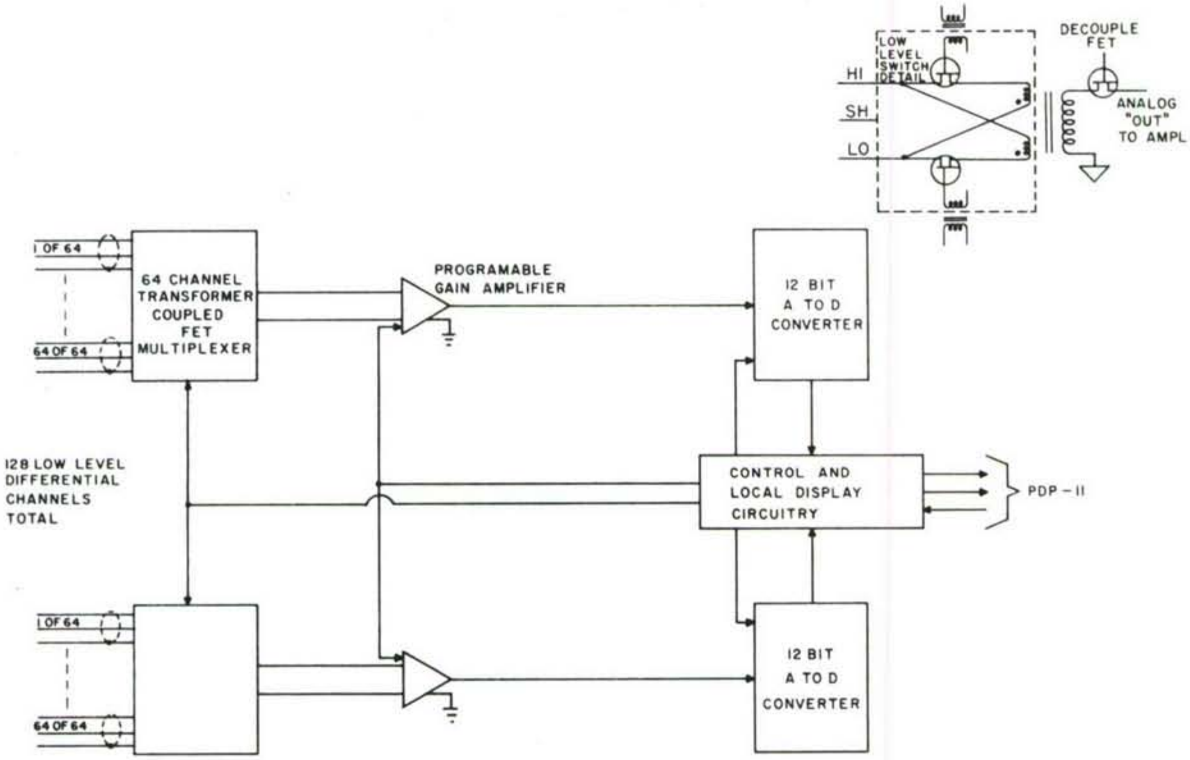

Figure 17. Computer Products RTP Block Diagram

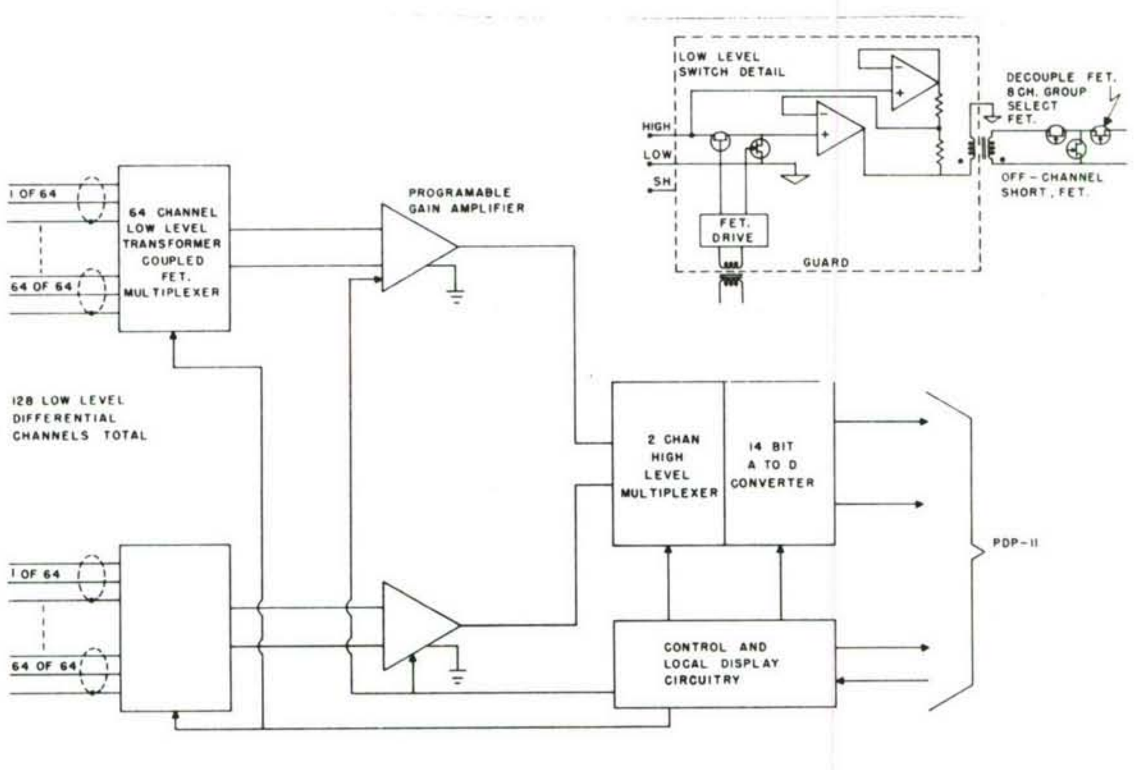

Figure 18. Preston Scientific GMAD-1 Block Diagram

minicomputer SDC ports. Therefore, any port on any computer can readily be connected to a specific SDC located anywhere within the facility. The installed cabling is fabricated from conventional multiconnector cable. Where necessary, terminating/loading circuitry is installed in the SDCs and the minicomputers.

5. MINICOMPUTER SYSTEMS

STARNET minicomputers are members of the Digital Equipment Corporation PDP-11 family. The PDP-11 is a 16 bit machine with a single communication bus (Unibus).

a. General Characteristics

One machine is a Model 20 and three are Model 40s. Each machine is equipped with 16K words of magnetic core memory and 12K of MOS memory. Each machine is equipped with 9 track 800 CPI 36 KCPS tape drive, ASR 33 Teletypewriter and I/O hardware to support 4 to 8 SDCs, 4 to 8 serial terminals and parallel communication to the SEL 86 Supervisory Computer. The Model 40s have hardware multiply divide; 2 have 2 megabyte single platter disk drives. Two have controllers for Varian "Statos" electrostatic printer/plotters and one has high-speed paper tape I/O. One unit is equipped with a 200 CPM card reader and a 300 CPM line printer to provide a software development capability independent of the medium-scale computer and to provide limited test data processing in the event the medium-scale computer is unavailable.

b. SDC Control/Communication

(1) General Description

The SDC Control/Communication interface is a special purpose PDP-11 I/O channel designed by Laboratory engineers. It is located within a PDP-11 system. Eight (or more) can be installed in one PDP-11. It provides a 16 bit wide data path from a program selectable SDC. Transfers are accomplished via a direct memory access link operating in cycle stealing mode. The PDP-11 processor specifies the initial channel number, the number of channels to be transferred from the subsystem, and the memory location at which the initial channel is to be stored. Once initiated, the transfer proceeds to completion without processor intervention. Any block of valid sequential PDP-11 bus addresses can be used as a read-in area. Note, however, that the PDP-11 must be addressed at even boundaries since exchanges take place in 16 bit words rather than 8 bit bytes.

(2) Interface Register Description

Four registers are associated with this interface. All 4 are 16 bit registers.

(a) TMADR - A register-counter which carries the address of the current bus operation. It is loaded with the initial address of the PDP-11 read or write area and is incremented two counts at the end of each word transfer.

(b) TMMUX - A register-counter which carries the current subsystem channel number, the desired channel gain and subsystem designation. Bits 00-08 form a counter which is incremented at the end of each word transfer.

(c) TMCSR - A control and status register. The register contains an interrupt enable, a ready flag and a time-out flag. The time-out flag can only be set by the interface. It can, however, be cleared and/or read by the PDP-11.

(d) TMWC - A register-counter which is initially loaded with the two's complement equivalent of the desired block length. An address selector decodes the bus and generates the strobe pulse necessary to clock information into the register. At the end of each word transfer, the register is advanced one count by the interface. When an overflow occurs, the register generates a pulse which is applied to the clock input of the ready FF thereby clearing it and terminating the transfer operation. This register can also be read by the PDP-11.

(3) Time-Out Errors

Any attempt to access a nonexistent bus address will cause a time-out error. The time-out feature provides protection against hanging the bus as the result of a program (or hardware) error. The existence of a time-out error is indicated by the presence of a "1" in bit 15 of TMCSR. A time-out condition can be cleared by loading a "0" into bit 15 of TMCSR or by executing a System Initialize.

(4) Summary of Register Bit Assignments

The highest order bit is designated bit 15; the lowest order bit is designated bit 00; this is in accordance with standard PDP-11 terminology.

(a) TMCSR Bit Assignments (Address 764XX0)

Bit 06: Interrupt Enable - When set to "1" immediately after initiation of a Read Subsystem operation, executes an interrupt when operation terminates. Normally cleared by interrupt subroutine. Can also be cleared by System Initialize. Read/Write.

Bit 07: Block Ready Flag - Flag switches from "0" to "1" when a read operation terminates. It is cleared by initiation of the next operation. It is set by System Initialize and time-out errors. Read only.

Bit 15: Time-Out Flag - Set by program error or hardware failure (attempting to access nonexistent memory). When set, clears aborted bus cycle and returns control of bus to processor. Can be cleared under program control or by System Initialize. Read/partial write.

(b) TMWC Bit Assignments (address 746XX2)

To initiate Read Subsystem operation, the register is loaded with the two's complement equivalent of the number of words to be read. When register overflows, read operation is automatically terminated and ready flag of TMCSR is set. Read/Write.

(c) TMADR Bit Assignments (address 746XX6)

Loaded with initial address of PDP-11 read-in prior to initiation of Read Subsystem operation. Throughout operation, contents of register indicates PDP-11 bus address at which next incoming word will be stored. Read/Write.

(d) TMMUX Bit Assignments (address 764XX4)

Bits 00-06:

Channel Counter - Loaded with the octal number of first subsystem channel to be transferred to the PDP-11. Throughout Read Subsystem operation, contents indicates number of next subsystem channel to be transferred to PDP-11 storage. Write only.

Bits 07-08:

Normally loaded with the low and middle order bits of the desired channel gain designator. If necessary, can be added to channel counter (bits 00-06) to increase range to 000-777. Write only.

Bit 13:

High order bit of channel gain designator. Used with bits 08 and 07 to select one of eight possible channel gain values. Write only.

Bit 15:

Set by the PDP-11 to select the subsystem for operation. Write only.

(5) Auxiliary Bus

Most of the interface output data lines are fanned into an auxiliary bus. Information from this auxiliary bus is then transferred to the Unibus. The purpose of the auxiliary bus is to minimize the loading effect caused by attaching several drivers to the same Unibus Signal Line.

(6) Communication Speed

Each interface functions as a Direct Memory Access (DMA) device when inputting data to the computer. In its standard configuration the interface can address up to 200_8 (128_{10}) individual channels in an attached SDC. For each block of data to be inputted there is a hardware overhead of 21.5 microseconds (16 microseconds is setup time and 5.5 microseconds is latency time). In addition 12 microseconds are required to complete each data transfer (5 microseconds for data line stabilization, 3 microseconds to achieve bus control, 1 microsecond to transfer word and 3 microseconds for multiplexer line stabilization). For a 128_{10} channel read this gives a hardware word transfer rate of 82 KHZ. For a 64_{10} channel read this drops slightly (to 81 KHZ) because of the increased significance of overhead. For a single channel, the overhead is the controlling factor and 30 KHZ is the maximum possible rate. Since there is only one bus, there is a transfer rate tradeoff when multiple interface units are active. The additional overhead incurred can be neglected for most purposes; for example if four interfaces are active and the same transfer rate is requested on all units then the maximum rate for a

128 channel transfer is 82/4 or 20.5 KHZ for each unit, etc. Therefore, in the typical operating environment the hardware transfer speed is limited by the SDC and not by the interface or the connecting line. There are situations in which the reverse is true, since some SDCs are capable of operating at 30 KHZ or higher, but these are less commonly encountered. Furthermore, this analysis does not include any limitations imposed by software and this can be significant especially in a bus type computer with single port storage.

c. Computer-To-Computer Communication Hardware

(1) PDP-11/SEL 86 Computer Communication

A half duplex 16 bit wide 200,000 (16 bit) word per second (basic hardware speed) communication capability is provided between each PDP-11 and the SEL 86 medium-scale computer. DMA is provided to each PDP-11 and four independent DMA channels are provided in the SEL 86 computer. Therefore concurrent communication between the SEL 86 computer and all the PDP-11s is possible.

(2) PDP-11/PDP-11 Communication

(a) Parallel Communication

Parallel Communication between STARNET PDP-11s can be provided by connecting the machines together via SDC interface channels. These channels are designed to provide DMA read capability for the host PDP-11. However, because of the organization of the system they can also provide Program Controlled Output. Therefore the machines can communicate over the interface channels in this hybrid mode.

Parallel communication with remotely located control computers is accomplished via standard vendor supplied (DEC DR11C compatible) program controlled interface units.

(b) Serial Communication

Serial asynchronous communication between PDP-11s is possible using vendor supplied (DEC DL11C compatible) interface units which normally provide terminal communication. These units operate at selectable rates up to 9600 BAUD.

d. Terminals

TEC Inc. Model 140x alphanumeric CRT Terminals are used for operator/engineer communication with STARNET PDP-11s. They may be located in the STARNET computer room or at individual test sites. These units provide a dot matrix display of 80 x 12 characters. Keyboards provide the ASCII upper case and control character subset. Up to eight units may be connected to each PDP-11. They are connected via individual serial interface controllers. The communication rate is 9600 BAUD full duplex and asynchronous. No modems are used. Operation at standard EIA voltage levels per RS-232 is satisfactory for the distances involved (less than 500 meters).

e. Printer/Plotter

Two Varian Statos 31 Electrostatic printer/plotter units are used to provide hard copy graphical data. These units produce both quick-look data during testing and final data after testing. They operate on-line as peripheral equipment to two of the PDP-11s. These units were modified by FDL engineers for remote (parallel) operation by addition of line terminations and by derating the internal clocks to compensate for signal transit time.

6. MICROCOMPUTER SYSTEMS

STARNET microcomputers are members of the DEC LSI-11 family. Each one can communicate with an SDC over a channel similar to the SDC control/communication interface used by the PDP-11s. They can also communicate with a TEC terminal and another computer (normally a PDP-11) via serial channels. At present they are used primarily for dedicated stand alone tests. However a future possibility is to extend the network concept to these powerful little machines.

7. MEDIUM-SCALE COMPUTER SYSTEM

a. General Characteristics

The STARNET supervisory computer is a SEL 86. It is a 32 bit machine specifically designed for multiple task real-time operation. The machine is equipped with 112K words of 600 NS four-port core memory which is addressable down to the individual bit level. The system includes two 100 megabyte disk drives, two 160 KC tape drives, a 600 LPM line printer, a card reader and a card punch.

b. High-Speed Data Terminals

The high-speed data terminals are the devices used to implement communication with the STARNET PDP-11 minicomputers. Four terminals are installed to provide independent direct memory access to the SEL 86 by each PDP-11. The terminals are capable of operating in excess of 400,000 bytes (200,000 halfwords) per second. In practice, communication is limited to approximately 95,000 halfwords per second by line and protocol considerations.

c. Low-Speed Data Terminals

The low-speed data terminals are implemented as a Systems Engineering Laboratories MACS (Multipurpose Acquisition and Control System). The MACS has four serial I/O channels which operate at program selected rates up to 28.8 kilobaud. Operation is asynchronous and normally uses ASCII coding. The system is used to communicate with the IMLAC display systems and with remotely located control computers. Communication with the control computers is at 9600 BAUD. Communication with the IMLACS is at 28.8 kilobaud. (This is the maximum rate at which the software handler behaves in a stable manner.)

8. DISPLAY SYSTEMS

a. General Characteristics

The STARNET systems are IMLAC PDS-4s. The PDS-4 is an intelligent system with an internal 16 bit general purpose processor and a display processor which shares memory with the general purpose processor. The displays are stroke writers with full graphical and alphanumeric capability. A software character generator is used. STARNET includes two PDS-4s. One machine has dual independent displays, 16K memory and paper tape I/O. The other machine has only a single independent display. Both have keyboard and light pen capability and both are normally operated on-line to the SEL 86.

b. External Communications

The PDS-4s communicate with the SEL 86 over a serial line at 28.8 kilobaud. Asynchronous communication and ASCII/binary codes are used. Communication to the SEL 86 is via a MACS channel.

c. Internal Communication

As used here, internal communication refers to communication between the IMLAC display processor and the display/keyboard units. Remote operation of the display/keyboard at distances up to 200 meters is possible in STARNET. Special video circuitry to drive the CRT display units was designed and fabricated by FDL engineers to provide this capability. ASCII inputs to the processors from the keyboards is achieved at this distance without special circuitry. No attempt is made to use the light pen at this distance because of synchronization problems due to signal transit time considerations. The light pens are useable when the PDS-4s displays are in the computer room.

9. POTENTIAL HARDWARE DATA RATES

Data rates under the following seven operational concepts are considered in this discussion:

PDP-11 Only - Data to Main Storage

PDP-11 Only - Data to Disc Storage

PDP-11 Only - Data to Magnetic Tape

PDP-11/SEL 86 - Data to SEL 86 Main Storage

PDP-11/SEL 86 - Data to SEL 86 Disc Storage

PDP-11/SEL 86 - Data to SEL 86 Magnetic Tape

PDP-11/SEL 86/IMLAC PDS-4

In the following discussion the highest speed SDC (50 KC) is assumed. This minimizes input limitations for the different conditions.

a. PDP-11 Only - Data to Main Storage

Operation in which data is acquired and stored only in main storage is useful only for short bursts of high speed data. A potential application is in catastrophic failure testing in which onset of failure can be accurately determined.

In this mode of operation approximately 16K words of storage can be made available for data, and speed is limited by the SDC(s). (The fastest SDC (FDL Type IV) can generate up to 50,000 16 bit words per second. Main storage (1.1 μsec/cycle) can handle over 900,000 words per second.) When a Type IV is running at maximum speed, data can be acquired and stored for about 0.3 seconds (16,000 words of storage/50,000 words per second). If data is acquired at a lower rate, more time will be available.

Finally if more than one SDC is in use at the same time, then the maximum input speed from each SDC is limited by the control interface to 82,000 words per second divided by the number of SDCs active.

b. PDP-11 Only - Data to Disc Storage

STARNET PDP-11s have a single disc drive with a capacity of 1.1 million 16 bit words and a transfer rate of 91 KC. It can be assumed that for specialized operations that 1.1 million words are all available for storage of acquired data.

In this mode of operation speed is also limited by the SDC (50 KC if one is operating) and by the control interface (82 KC total if more than one SDC is operating). For the single SDC operating at 50 KC, data can be acquired and stored on disc for approximately 22 seconds. As is typical, lower rates result in more time being available.

When operating in this mode, data can be acquired at the same rate as in the main storage only mode, but for a much longer time.

c. PDP-11 Only - Data to Magnetic Tape

STARNET PDP-11s have a single tape drive with a capacity of 11 million words and a transfer rate of 18 KC.

In this mode of operation speed is limited by the tape drive. The SDCs and control interface can run much faster than the tape drive. Consequently this mode of operation is not useful for acquiring bursts of very high speed data. It is very useful for acquiring moderate amounts of data over a long period of time and in the mode used for operation under EPM software (Section V, paragraph 3.b.).

d. PDP-11/SEL 86 - Data to SEL 86 Main Storage

Four PDP-11s are connected to the SEL 86 via special interface hardware. The hardware transfer speed between one PDP-11 and the SEL 86 is 95 KC as presently configured. When two PDP-11s are operating concurrently they can each communicate with the SEL 86 at 57 KC, three can each communicate at 41 KC and four can each communicate at 32 KC. The SEL 86 operating system must be taken out of service to achieve these rates. When in service its overhead reduces the possible rate by a factor of 5 to 10.

Approximately 96 K (16 bit) halfwords of memory can be made available in the SEL 86 in special cases. The cycle time of the memory is 600 nanoseconds.

In this mode of operation, with no operating system in the SEL 86, and with one PDP-11 operating, the data acquisition rate is limited in the same way as for the PDP-11 only - Data to disc storage case. That is, it is input limited. When more than one PDP-11 is active, throughput is limited by the PDP-11/SEL 86 interface system. For a single PDP-11 with a single SDC operating at 50 KC data can be acquired and stored for approximately 2 seconds in this mode (96,000 16 bit halfwords/ 50,000 words per second).

e. PDP-11/SEL 86 - Data to SEL 86 Disc

The SEL 86 has two 100 megabyte disc drives and one of these can be dedicated to data storage. The system can transfer halfwords at an average rate of 145 KC and 100 megabyte equals 50 million 16 bit halfwords. This is faster than the possible transfer rate between PDP-11s and the SEL 86. Therefore the data acquisition rate limitations are the same as on PDP-11/SEL 86 - Data to SEL 86 Main storage. However data that is acquired at a 50 KC rate can be acquired for 1,000 seconds (50,000,000/ 50,000).

f. PDP-11/SEL 86 - Data to Magnetic Tape

The SEL 86 has two tape drives. The capacity of each tape is 22 million bytes (11 million 16 bit halfwords), the same as the PDP-11 tapes. However the transfer rate is 160 thousand bytes (80,000 16 bit halfwords) per second. This is slightly lower than the maximum data rate

(82,000 WPS) into a single PDP-11 from connected SDCs. It is also lower than the maximum transfer rate between each PDP-11 and the SEL 86. Consequently this mode is output limited by the hardware. Ignoring start-stop time and record gaps, data can be recorded by a single tape drive for approximately 144 seconds in this mode. It is therefore both slower and lower in capacity than recording to disc.

g. PDP-11/SEL 86/PDS-4

This is the maximum hardware configuration and is used when the system is operating in network mode (Reference Section V). The hardware communication speed limitation in this mode is the SEL 86/PDS-4 channel which operates (serially) at 28,800 bits per second. In this mode, a large amount of real-time computation and display is used and throughput speed is traded for this complex processing. When all software features are in use the throughput is presently limited to approximately 1,000 data points per second. When sophisticated real-time processing is not required, throughput speed can be increased. The hardware speed limits can be approached as real-time processing requirements approach zero.

SECTION IV

SYSTEM SOFTWARE

1. OVERVIEW

The computing hardware of STARNET is distributed; consequently the software is also distributed and capable of establishing communication between the various interconnected hardware elements. The SEL 86, the PDP-11s and the PDP-4s are all programmable. Application flexibility is of primary importance in STARNET. Therefore no effort is made to freeze software design. As a consequence of this, the distribution of intelligence among the various processors can be changed to accommodate individual test requirements. There is a tendency to concentrate intelligence in the SEL 86 when the system is operated in network mode because it is the largest and fastest machine in the system, and the only one which is always run under control of a software operating system.

2. SEL 86 SOFTWARE

The STARNET SEL 86 is operated in a Systems Real-Time Monitor (RTM^R) environment. RTM^R is a disc based operating system designed to provide real-time multitask foreground processing together with a single background batch stream. It uses a combination of hardware interrupt and software priority levels to form a continuous priority scale from the power fail-safe trap (highest) to the background processing priority (lowest). Languages used in the STARNET SEL 86 are SEL extended Fortran IV and the SEL MACRO ASSEMBLER. Assembly language code may be imbedded in a Fortran Source Program (if Fortran syntactical rules are followed) to increase flexibility and utilization of special hardware. Foreground tasks can be declared Resident by an operator command to RTM^R. A Resident Task will remain in core memory whether active or inactive. Application Tasks providing on-line data acquisition and manipulation for major testing projects are often declared Resident on the STARNET computer.

3. PDP-11 SOFTWARE

The STARNET PDP-11s are not normally used in an operating system environment. A variation of the Digital Equipment Corporation Paper Tape Software (PTS) is used. The language used is a special version of PAL-11 which is the assembler associated with PTS. During test operation object code generated by the assembler is the only code in memory. This method of operation was selected for speed and efficiency because the PDP-11s function as dedicated units when operating in network mode, and because of the large number of special peripheral equipments connected to them. The special version of PAL-11 is a dual computer package which supports the use of punched card source programs and direct printing of assembler listable output via the card reader, are read by the SEL 86 reader, images are downline loaded to the selected PDP-11 which performs the actual assembly, and listable output is returned to the SEL 86 for printing. Object code is normally outputted to magnetic tape by the PDP-11. This operating can take place on any of the four PDP-11s in the STARNET. (One of the PDP-11s has a card reader and a line printer and can use the special assembler on a stand alone basis.

4. IMLAC PDS-4 GRAPHICS SYSTEM SOFTWARE

The STARNET PDS-4s are not used in an operating system environment. IMLAC Corporation Paper Tape based software is used. The language used is ASMT-4 which is a Paper Tape Assembler. Various IMLAC Corp. Diagnostic Programs as well as a Paper Tape Editor and Debugger are also used.

Application Programs are developed at the IMLAC console and the unit is operated as an independent device for this function. When satisfactory object code is achieved, a copy is stored on the SEL 86 disc system as a permanent file. Subsequently, when STARNET is being prepared for test operation the object code is downline loaded to a PDS-4 for execution. During testing the PDS-4s are dedicated to real-time test display and cannot support program development.

5. SEL 86/PDP-11 HIGH-SPEED COMMUNICATION SOFTWARE

The High-Speed Terminal handler operates in the SEL 86 as part of RTM[R] and is designated H.SD01. I/O is performed in Block Transfer Mode from a single unshared Device Controller Channel (DCC).

There are four entry points into the handler:

a. Open file control block file

b. Read

c. Write

d. Attention (which acknowledges the desire for data transfer from the PDP-11 or which can initiate the transfer)

These are handled by separate calls to the monitor.

A subroutine designated HSDT was written to handle those four entries. It requires only the desired operation, block size and buffer location to/from which data is to be written/read. This provides a simple means for the user to operate on the high-speed terminal.

The interrupt transfer sequence in the PDP-11s are presently imbedded in the application programs. Initial communication between the SEL 86 and a PDP-11 is established by the SEL 86. Once communication is established individual data transfers are initiated by the PDP-11.

The following text describes the general nature of the communication process:

a. Two File Control Block (FCB) files are opened in the SEL 86 via monitor calls. The first FCB file is used to identify direction of data flow. The second FCB file is reserved for actual data. The interrupt vector and priority for the DR11B is set in the PDP-11.

b. PDP-11 interrupts SEL 86 when it has data to send or requires data.

c. SEL 86 program unsuspends (if suspended) and interrupts the PDP-11 via the Attention bit. (If the SEL 86 does not respond to the interrupt from the PDP-11, the PDP-11 counts down a counter and tries again. After a preset number of unsuccessful attempts the PDP-11 displays a message to identify that communication has not been achieved. However, since the lack of response may be legal, it keeps trying).

d. PDP-11 checks legality of Attention bit by reading status register (DRST).

e. If attention was legal, SEL 86 transfers one word to the PDP-11. This word established block size and data direction. (If the attention was not legal it is ignored).

f. PDP-11 examines the word transferred in e above and sets up for main transfer.

g. Data block is transferred.

h. PDP-11 counts down number of words transferred. When last word is transferred the interrupt vector is reinitialized.

The SEL 86 also counts down the number of words transferred. The SEL hardware expects a continuous series of Service Interrupts (S/Is). If an S/I has not occurred within the alotted time, a time-out error occurs and the program is aborted on the basis of an assumed malfunction.

i. Steps b thru h are repeated as required by application program until it is terminated.

6. SEL 86/PDP-11 LOW-SPEED COMMUNICATION SOFTWARE

The low-speed terminal handler, H.MACS, will handle up to 16 DADS (Duplex Asychronous Data Set) on a single Multipurpose Acquisition and Control System (MACS) chassis. All I/O is performed in the single ASCII character mode.

H.MACS provides EAR (External Asynchronous Request) resume and EAR link services. The EAR link service is a hardware priority service requiring the user program to be privileged.

The low-speed terminal service desired is accomplished by particular monitor calls including a job termination service required to delete any outstanding EAR service requests upon an abort, since any service is interrupt controlled and after the initial monitor calls no additional user coding is required, the calls are included in the application program.

The software requirements on the PDP-11 side are also included in the user program. (The PDP-11 hardware is from the DL 11 series). As a single character is placed in the Data Buffer Register, an interrupt occurs at the DADS channel and a Transmitter ready is generated, allowing for the next character. If desired, this action can also generate an interrupt at the PDP-11.

7. SEL 86/IMLAC PDS-4 SOFTWARE

Communication between the SEL 86 and the IMLAC PDS-4s is in asynchronous half duplex mode. Hardware used in the SEL MACS in the SEL 86 and a TKA-41 in the PDS-4s.

Intelligence is concentrated in the SEL 86. The total software package consists of an assembly language (SEL MACRO ASSEMBLER) task and a set of Fortran subroutine for the SEL 86 and two assembly language (ASMT-4) programs for the PDS-4.

Software for the SEL 86 is classified as IMLAC Communication, Data plotting, Data Tabulation or supporting software. The PDS-4 programs are for system initialization and processing of display lists provided by the SEL 86.

a. SEL 86 Communication Software

This software consist of a SEL 86 Assembly language subroutine (IMDRIVER) and a SEL 86 Fortran subroutine (IMREAD). IMDRIVER handles communication with the PDS-4 Via MACS hardware and software. IMREAD provides a convenient means for user tasks to retrieve messages for the PDS-4 which are stored in Global Common.

b. SEL 86 Data Plotting Software

This software consists of the three Fortran subroutines: AXES, NOTE and DRAW. They are conventional subroutines to enable the user to plot data on the PDS-4s display screens. Since one of the PDS-4s is a dual screen unit, a parameter is included in the calling sequence to identify the target screen.

c. SEL 86 Data Tabulating Software

This software consists of the two Fortran subroutines TABULATE and HEADINGS. HEADINGS sets up the tabulation display list format and displays the name of each parameter to be tabulated. TABULATE converts the numeric data value into character strings and displays them to the right of the appropriate heading. Sixty parameters may be displayed concurrently.

d. SEL 86 Supporting Subroutines

This software consists of the three Fortran subroutines: IMCHECK, TIC SET and CCODE. IMCHECK checks the status of IMDRIVER; TIC SET sets the TIC marks on graphical plots and CCODE converts digital numbers into ASCII character strings for outputting to the screen.

e. PDS-4 Programs

There are two PDS-4 Programs. They are named ICORES and ICONTROL. Both are written in ASMT-4 and both are storage resident at the same time. ICORES generates a display to show that the system is in operation. It also includes all the character generating routines for the system (characters are software generated in the PDS-4).

ICONTROL controls the PDS-4 asynchronous interface, handles keyboard communication and builds and modifies display lists. It must run in conjunction with ICORES; otherwise it does not have access to the character set and cannot display tabular data.

f. Varian Plotting Software

Software for the Varian Plotters is based on that part of VARIAN DATA PLOT III which was designed for on-line operation of the plotter by a PDP-11. The DATA PLOT III software was modified to run on a SEL 86/PDP-11 two computer system.

DATA PLOT III includes a set of Fortran subroutines for data manipulation, axis generation, tabulations and other related functions, and a set of PDP-11 assembly language subroutines to control the operation of the plotter. The FDL modification consisted of conversion of the Fortran code to run on the SEL 86 and retention of the plotter control assembly language code in the PDP-11. This provides the capability for plotting on the Varian unit on an on-line basis using data which has been manipulated by the SEL 86. This is particularly useful in providing immediate hard copies of data displayed on the IMLAC PDS-4.

SECTION V

APPLICATIONS SOFTWARE

1. OVERVIEW

STARNET applications software runs in three basic system modes. These modes are: NETWORK, INDEPENDENT, and MIXED. In network mode all computing and display systems are concurrently operating and all systems are operating on-line to the SEL 86. Network mode provides the means of performing multiple concurrent large-scale test projects requiring extensive on-line monitoring and data storage. The first use of STARNET was on two such projects. Both were flight-by-flight fatigue tests requiring on-line monitoring over a long period of time. The present network mode software reflects the specific requirement of these projects.

In independent mode all computing systems are operated independently with no intercomputer on-line communication. This mode provides for use of individual PDP-11s for small-scale test operation; for software development involving a specific machine; for nonreal-time data processing; and for continued reduced capability operation in the event of a SEL 86 malfunction.

Mixed mode is simply a combination of network and independent modes in which one or more (but not all) of the PDP-11s are operating on-line to the SEL 86 and the remaining PDP-11s are operating independently. The PDS-4s are usually (but not necessarily) on-line to the SEL 86 in this mode.

Hardware and hardware interconnection is the same in all modes. The mode in use at any time is a function only of the software in use at that time.

2. NETWORK MODE SOFTWARE

a. General Information

Operation of a test project in network (or mixed) mode requires at least one dedicated PDP-11, a real-time program in the SEL 86 and a PDS-4 display and keyboard. The instrumentation engineer communicates with and controls the operation of the system only by use of the PDS-4 display and keyboard. (These units are normally at the test site).

Direct communication with the SEL 86 can only be accomplished by operating personnel in the computer room. Direct communication with a PDP-11 is made available to personnel at the test sites if the PDP-11 is used for the Program Validation function. (See subparagraph c below).

Multiple PDP-11s may be deployed as a function of test requirements. A frequent requirement is to provide Program Validation of loading sequence and amplitude signals generated by facility control computers.

The SEL 86 is not normally dedicated to a single test but it can be if a project of sufficient size requires support. When the single display PDS-4 is assigned it is dedicated. When the dual display PDS-4 is used only one display/keyboard is dedicated.

There are two phases to network mode operation; a SETUP phase prior to startup of tests when all systems are initialized and operation is validated and an OPERATION phase which extends throughout the actual testing period.

Every test project requires some specialized software; however standard application software is provided and can satisfy most requirements of test projects. As new requirements are generated, special software is written and added to the STARNET library.

b. PDP-11 Network Data Acquisition and Presentation Software

The dedicated PDP-11 must have one to four SDCs, a CRT/Keyboard terminal, a magnetic tape drive, and (optionally) an electrostatic printer/plotter connected. Each SDC can contain up to 128 data channels. Therefore the PDP-11 can handle 512 total data channels. The network mode Data Acquisition Program in the PDP-11 is named MINIDATAQ. It is an assembly language program, and all input/output control (including SEL 86 communication) is imbedded within it. MINIDATAQ provides the following functions:

(1) Control of the SDCs

(2) SDC malfunction reporting

(3) Acquisition of data from the SDCs

(4) Forwarding of acquired data to the SEL 86

(5) Recording of data on magnetic tape to provide a redundant record (for use in the event of a nonrecoverable system crash)

(6) SEL 86 nonresponsiveness reporting

(7) Acceptance of data from the SEL 86 in Varian 3113 Printer/Plotter format and control of the printer plotter.

Operator communication with the PDP-11 is via the attached TEC CRT/keyboard terminal. Data recorded by the PDP-11 magnetic tape system can be read back and transmitted to the SEL 86 (simulated test operation). The 86 in turn handles it exactly like live data.

c. PDP-11 Program Validation Software

(1) The Validation Concept

A PDP-11 used for control computer program validation requires one SDC, a disc drive (if the flight load spectrum is too large for core) and a parallel digital link to each control computer whose operation is to be validated, as well as the usual link to the SEL 86. Figure 19 shows a typical configuration.

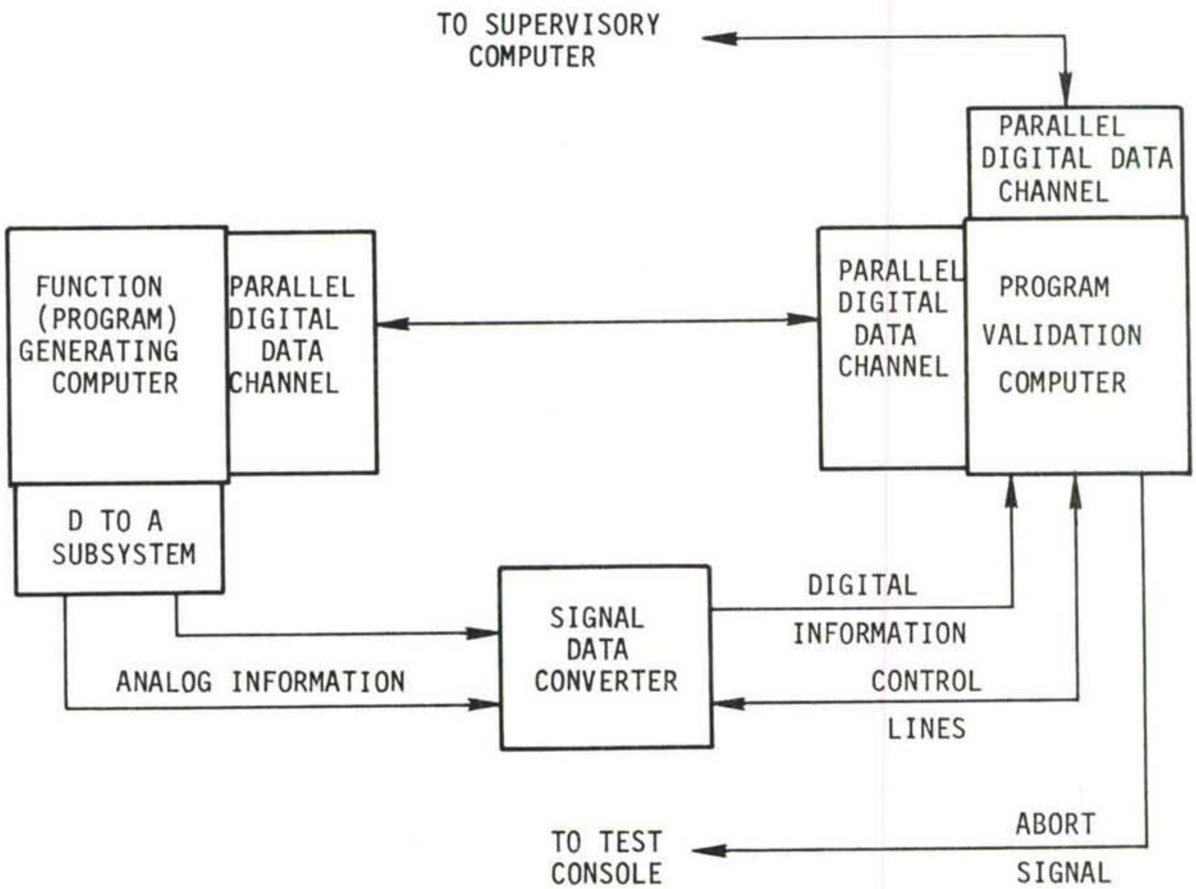

Figure 19. Typical Interconnection for Program Validation

The validation function is intended to perform an independent evaluation of the real-time output of the computers used in the test facility to generate the flight-by-flight load spectrum signals which ultimately result in loading of the test structure. The output of these computers is in the form of parallel analog signals. The number of control channels on a single test is typically between 1 and 50.

The facility uses both hybrid control (digital function generation with analog controllers) and direct digital control. In hybrid control the outputs evaluated are the demand signals applied to the analog controllers. In direct digital control the output evaluated is specially generated from the internal digital signals.

The validation process consists of sequence checking and amplitude checking. When the control computer is ready to generate a set of output changes it signals the validating computer and sends it the identification of the proposed changes. The validating computer compares these values with the values it expects. If the values are identical the control computer is allowed to proceed. If the values do not agree the validating computer terminates testing and identifies the problem.

If the sequence check is successful, the control computer proceeds. The validating computer then continuously samples the output of all the control computer's D to A converter channels via its SDC and window tests the converted values. Failure of any reading to pass the window tests will cause the validating computer to terminate testing and identify the problem.

The validating computer also may send the sequence identification information to the SEL 86 computer for use in real-time processing of measurement data.

The validation software is coded in assembly language. It is also custom written for each project because of the wide variation of storage and processing requirement necessitated by project-to-project variation in complexity, format and size.

(2) Simplified Validation Process (Reference Figure 20)

(a) Typical Sequence of Events

Control computer sends start half cycle flag (which contains "go to" information) to validating computer.

Validating computer compares received "go to" information with expected information

If not equal, error condition is displayed on terminal and load is dumped.

If equal, windows are established for the ensuing half cycle for all load changes. (Window range is normally from minimum expected value less 2% to maximum expected value plus 2% and can be adjusted).

Sampling and digitization of analog signal begins.

If a measured value falls outside the window the appropriate error condition is displayed and load is dumped.

Process is repeated for next half cycle.

(b) Explanatory Notes

Flags are software flags which include half cycle identification.

A half cycle is defined as the connection between two plateaus and the plateau which occurs later in time. The curve between point 1 and point 2 constitutes a half cycle as do the curves between points 2 and 3 and points 3 and 4. By definition the curve between points 2 and 3 is called a half cycle even though no change in sign of slope follows it.

The validation computer stores (or generates) a complete set of identification data for each half cycle of each flight. This is the "expected" information. The information transmitted to the check computer by the program computer must match it exactly.

The values come from two different machines and two different programs written by two different programmers. This minimizes the possibility of the machines agreeing on a value which is a wrong value because this would require either two coding errors leading to the same result or two hardware errors leading to the same result or a coding error in one machine and a hardware error in the other machine.

The proper restart point is manually entered in the validating computer from the CRT terminal keyboard after a load dump.

The software accounts for sign reversals (Tension-compression or compression-tension cycles).

Figure 20 implies linear ramps between load plateaus. It is not necessary for the signal to behave linearly. It is only necessary that it fit within the limits of the window. Neither is it essential to hold constant load levels at the plateaus. This is normally done to insure that demand load actually gets into the structure under test. That is, it allows the total system to catch up with demand.

Within a half cycle the analog signals generated by the function computer are each sampled at a 50 sample/second rate by the validating computer. No attempt is made to synchronize the computers during this interval.

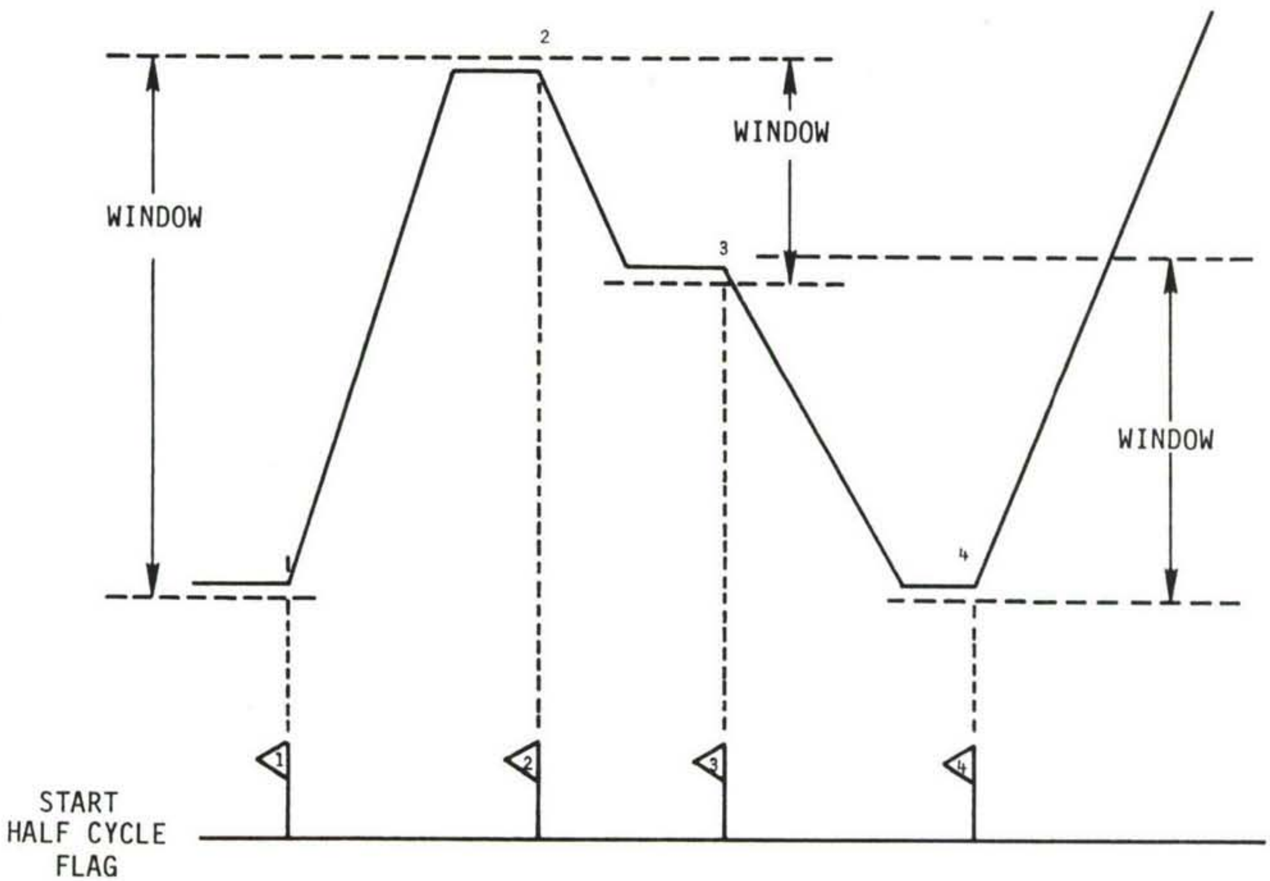

Figure 20. Typical Control Computer Analog Signals and Validation Computer Windows

d. SEL 86 Network Software

The standard SEL 86 program is called XPERGO (it is renamed when specialized for a specific test project). It is written in Fortran IV with some in-line assembly code and runs in an RTM[R] environment. XPERGO has a family of associated Fortran IV subroutines named CAL, PROCESE, ROSETE, and TC for processing structural test data.

XPERGO (together with its associated subroutines) provides the following functions:

(1) Acceptance of data from the PDP-11
(2) PDP-11 nonresponsiveness reporting
(3) Recording of data on magnetic tape
(4) Processing of all incoming data into engineering units for possible display on a PDS-4 CRT as tabular or graphical data
(5) Comparison of live data with stored baseline data at selected intervals throughout the test
(6) Outputting of tabular data as required
(7) Processing for hard copy plots via a PDP-11/Varian 3113
(8) Provision of nonlinear data monitoring to identify onset of yield in the test specimens
(9) Provision of exceedance monitoring by extrapolation.

CAL enters transducer calibration data into core (whether new and live or restored from disc). It interrogates input from the PDP-11 for proper calibration codes and stores commonly used calibration constants.

PROCESE handles the processing of commonly used transducers, specifically load cells, strain gages and deflection potentiometers. Following are a summary of terms and the equations programmed by PROCESE and ROSETE.

SUMMARY OF TERMS

E - Raw Data Signal

C_0 - CAL 0 (offset)

C_1 - CAL 1 } transducer calibration signals

C_2 - CAL 2 } transducer calibration signals

GF - Gage Factor

R_{CAL} - Shunt Calibration Resistance

M - Calibration Slope

Y - Modulus of Elasticity

V - Voltage Supply to Transducer

ε_A - Corrected A Leg Strain

ε_B - Corrected B Leg Strain

ε_C - Corrected C Leg Strain

$\hat{\varepsilon}$ - Uncorrected Strain

μ - Poisson Ratio of Test Material

δ - Displacement

K_A, K_B, K_C - Transverse Strain Sensitivities

γ - Shear Strain

μ_m - Manufacturers Poisson Ratio Associated with K_A, K_B & K_C

R_G - Strain Gage Resistance

R_S - Shunt CAL Resistance

σ_{max} - Maximum Normal Stress

σ_{min} - Minimum Normal Stress

τ_{max} - Maximum Shear Stress

ϕ - Principal Stress Direction Relative to Rosette A Leg

SINGLE ACTIVE ARM GAGE:

$$\hat{\varepsilon} = \frac{2 \times 10^6}{GF} \times \frac{(E-C_0)}{\left(\frac{2R_S + R_G}{R_G}\right)(|C_2-C_0|)-(E-C_0)}$$

based on shunt of active arm which produces a negative output. (Our convention is that tension is positive).

$$\text{UNIAXIAL STRESS} = \sigma = Y\hat{\varepsilon} \times \frac{1-K\mu_m}{1-K\mu}$$

DEFLECTION POTENTIOMETER:

$$\text{DEFLECTION} = \delta = \frac{(|C_1|+|C_2|)_{CAL}}{(|C_1|+|C_2|)_{TEST}} \times M(E-C_0)$$

where the ratio is called the standardization factor for deflection which is not used if the deflection transducer is a differential transformer.

LOAD CELL:

$$\text{LOAD} = \frac{|C_1-C_0|_{CAL}}{|C_1-C_0|_{TEST}} \times M(E-C_0),$$ where the ratio is the standardization factor for load.

ROSETE processes strain gages rosettes in conjunction with PROCESE and using the following equations:

A LEG CORRECTED:

$$\varepsilon_A = \frac{\hat{\varepsilon}_A\ (1-\mu_m K_A)-K_A\hat{\varepsilon}_C(1-\mu_m K_C)}{1-K_A K_C}$$

B LEG CORRECTED:

$$\varepsilon_B = \frac{\hat{\varepsilon}_B (1-\mu_m K_B)(1-K_A K_C) - K_B\left[\hat{\varepsilon}_A(1-\mu_m K_A)(1-K_C) + \hat{\varepsilon}_C(1-\mu_m K_C)(1-K_A)\right]}{(1-K_A K_C)(1-K_B)}$$

C LEG CORRECTED:

$$\varepsilon_C = \frac{\hat{\varepsilon}_C (1-\mu_m K_C) - K_C \hat{\varepsilon}_A (1-\mu_m K_A)}{1-K_A K_C}$$

RECTANGULAR ROSETE EQUATIONS:

$$\varepsilon_{\substack{max \\ min}} = \frac{\varepsilon_A + \varepsilon_C}{2} \pm R \qquad R = \tfrac{1}{2}\sqrt{(\varepsilon_A - \varepsilon_C)^2 + \gamma_{AC}{}^2}$$

$$\gamma_{max} = \varepsilon_{max} - \varepsilon_{min} \qquad \gamma_{AC} = 2\varepsilon_B - (\varepsilon_A + \varepsilon_C)$$

$$\phi = \tfrac{1}{2}\,TAN^{-1}\,\frac{\gamma_{AC}}{\varepsilon_A - \varepsilon_C}$$

$$\sigma_{\substack{max \\ min}} = \frac{y}{1-\mu^2}\left(\varepsilon_{\substack{max \\ min}} + \mu\varepsilon_{\substack{min \\ max}}\right)$$

$$\tau_{max} = \tfrac{1}{2}(\sigma_{max} - \sigma_{min})$$

TC processes thermocouples in conunction with PROCESE. Since thermocouples are nonlinear devices a polynominal approximation is used.

Other nonstandard equations are programmed and incorporated as needed.

e. PDS-4 Software

PDS-4 Programs used are ICORES and ICONTROL as described in Section IV (System Software). Since intelligence is concentrated in the SEL 86 there is no requirement to write specialized application software for PDS-4 network mode operation. (Concentration of intelligence was a software design decision not a hardware limitation).

f. Software Interconnections

The interaction among the Data Acquisition and Presentation software elements in the interconnected computers for a single test project is depicted in simplified form in Figure 21. RTM^{R}, the SEL 86 operating system is not explicitly identified in the figure but all software in the machine operates under its control.

When a second major test requires Data Acquisition and Presentation support, a second PDP-11 with its own set of peripherals and copy of MINIDATAQ is used. Communication with the SEL 86 is established via H.SD01. A single copy of H.SD01 services all PDP-11s connected to high speed data terminals.

A second copy of XPERGO is loaded into the SEL 86 to support the second project. The copy is revised and renamed to fit the specific project requirements. Extra copies of the subroutines associated with XPERGO are not loaded. All copies of XPERGO share these subroutines. Two different PDS-4 configurations are possible for dual test support.

One of the PDS-4s is a dual display unit with individually addressable displays and keyboards. The first configuration uses this unit to simultaneously support two test projects. ICONTROL is coded to direct displays to a target screen identified by a parameter passed from a using copy of XPERGO. When two tests require support each copy of XPERGO accesses one display. No hardware or software changes are required to support two projects in this configuration.

The second PDS-4 is a single display unit. The second configuration uses one PDS-4 for each of the tests requiring support. In this configuration there are two complete PDS-4s connected to the SEL 86 each with an individual copy of ICONTROL and ICORES loaded. The second unit is connected to the SEL 86 via a second MACS channel. H. MACS operates all channels in the MACS. Therefore only a parameter change in a using copy of XPERGO is required to direct display information to the second unit.

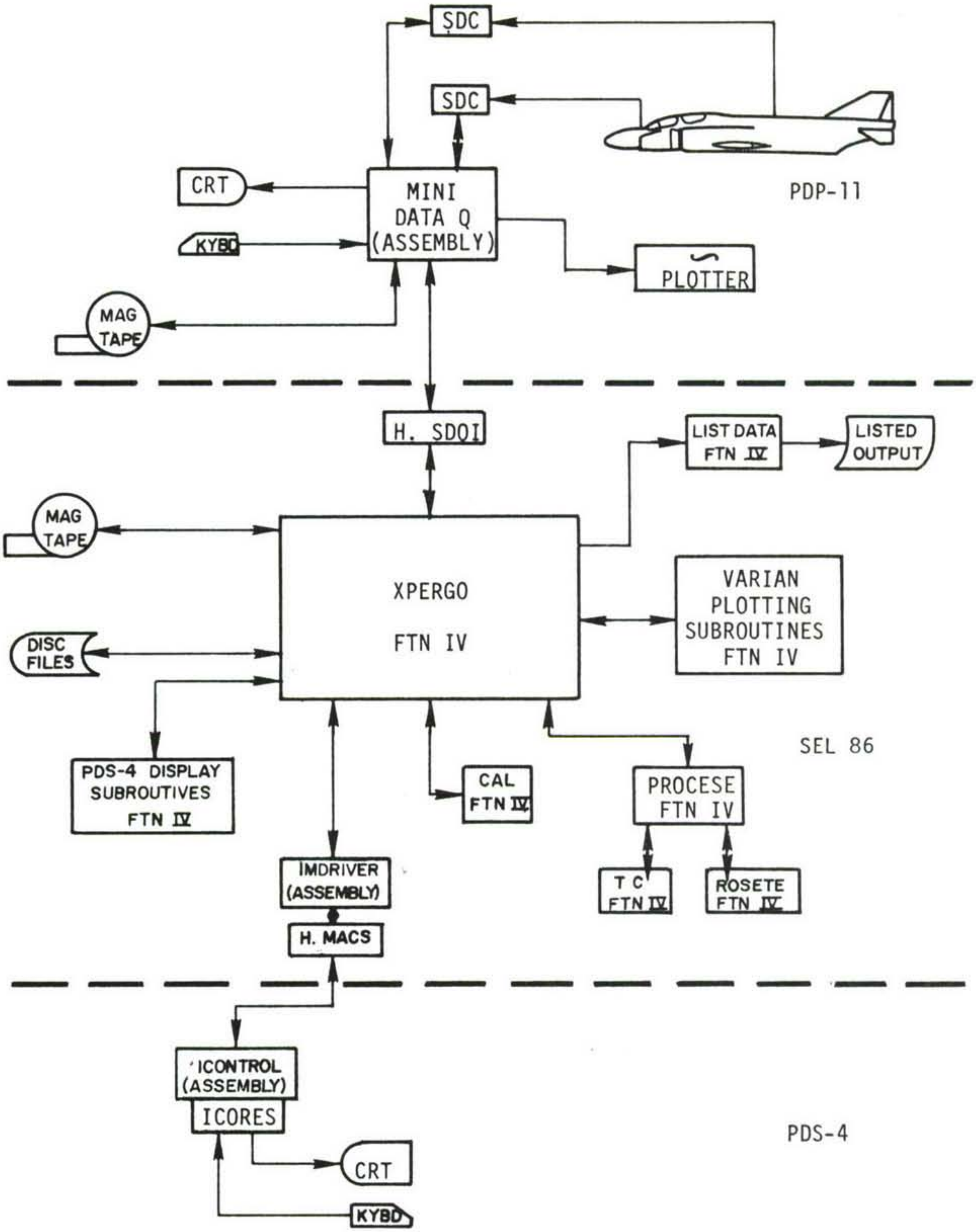

Figure 21. Typical Real-Time Network Mode Software Interconnections

g. Simulation

Simulation on STARNET means simulated real-time network operation and is a function of the Data Acquisition PDP-11. The PDP-11 reads a previously recorded raw data tape (Figure 22). It then transfers this data to the SEL 86/PDS-4 where it is operated on exactly as if it were live data. Simulation is used to recreate a completed test for engineering review, to provide a means of processing data acquired by the PDP-11 during stand alone operation following a SEL 86 malfunction and for system troubleshooting.

h. Eight Program Monitor Data Transfer

The Eight Program Monitor records data from up to eight tests using a single PDP-11 in independent mode. The data is interspersed on a single tape. The data transfer process requires network mode operation (Figure 23). During data transfer the PDP-11 reads a previously recorded tape and transfers the data to the SEL 86 where it is rewritten on disc as individual blocked files. Further processing by the SEL 86 is in independent mode.

i. INTPLOT

A software package called INTPLOT (Interactive Plot Routine) allows an individual to set up individual plots from data recorded and transferred from the EPM system or data recorded on-line to an SEL 86 tape.

The operator interacts through the SEL 86 console TTY to set up the desired scaling, labeling and channels to be plotted on the PDP-11 controlled Varian plotter. Up to five channels may be plotted against any single parameter be it another channel output, time, percent test load or stress (P/A). ROSETTE principle strains or stresses can also be plotted against the independent variable.

This package allows an amount of flexibility in setting up test data plots not found in fixed routines.

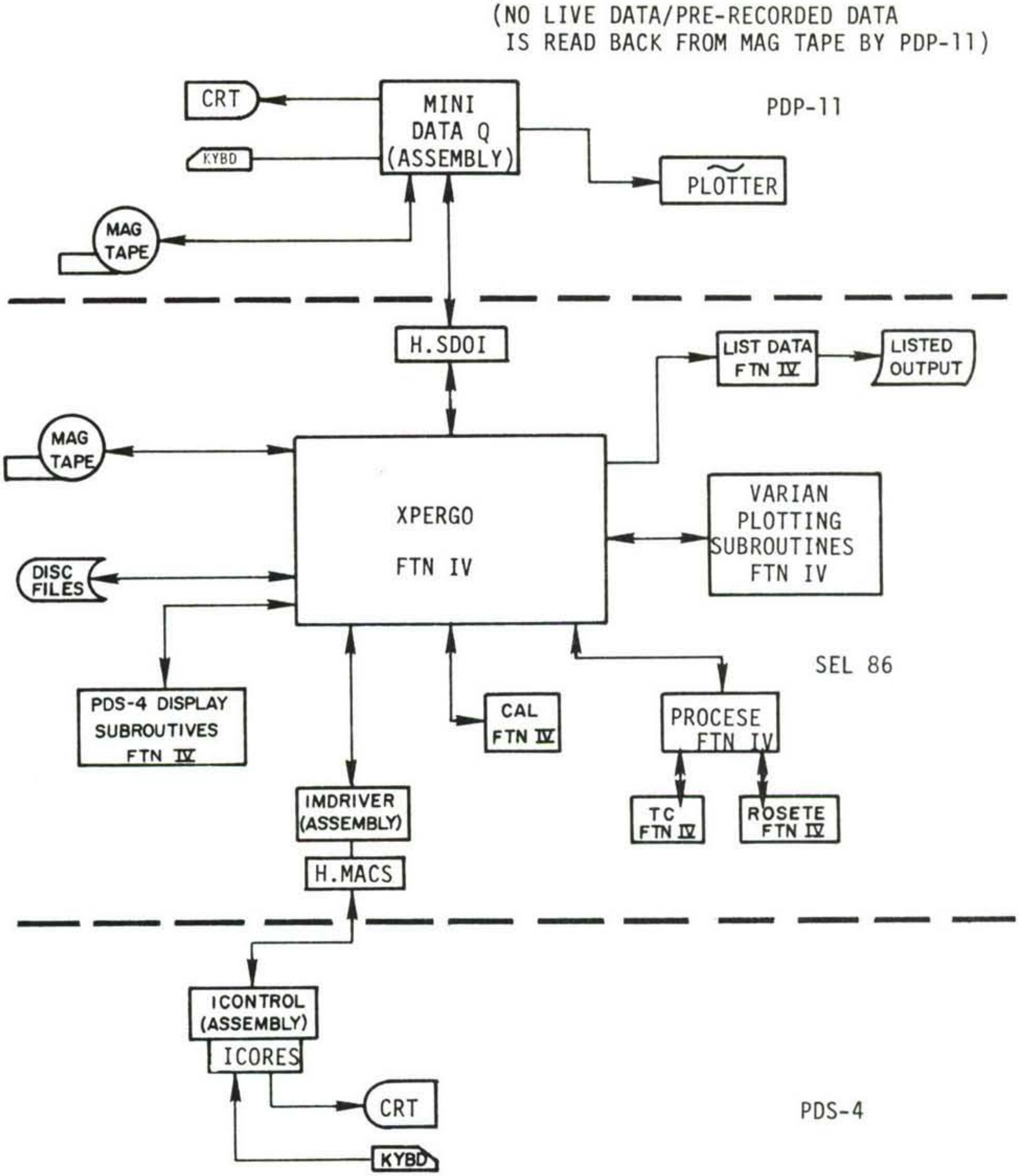

Figure 22. Typical Simulation Network Mode Software Interconnections

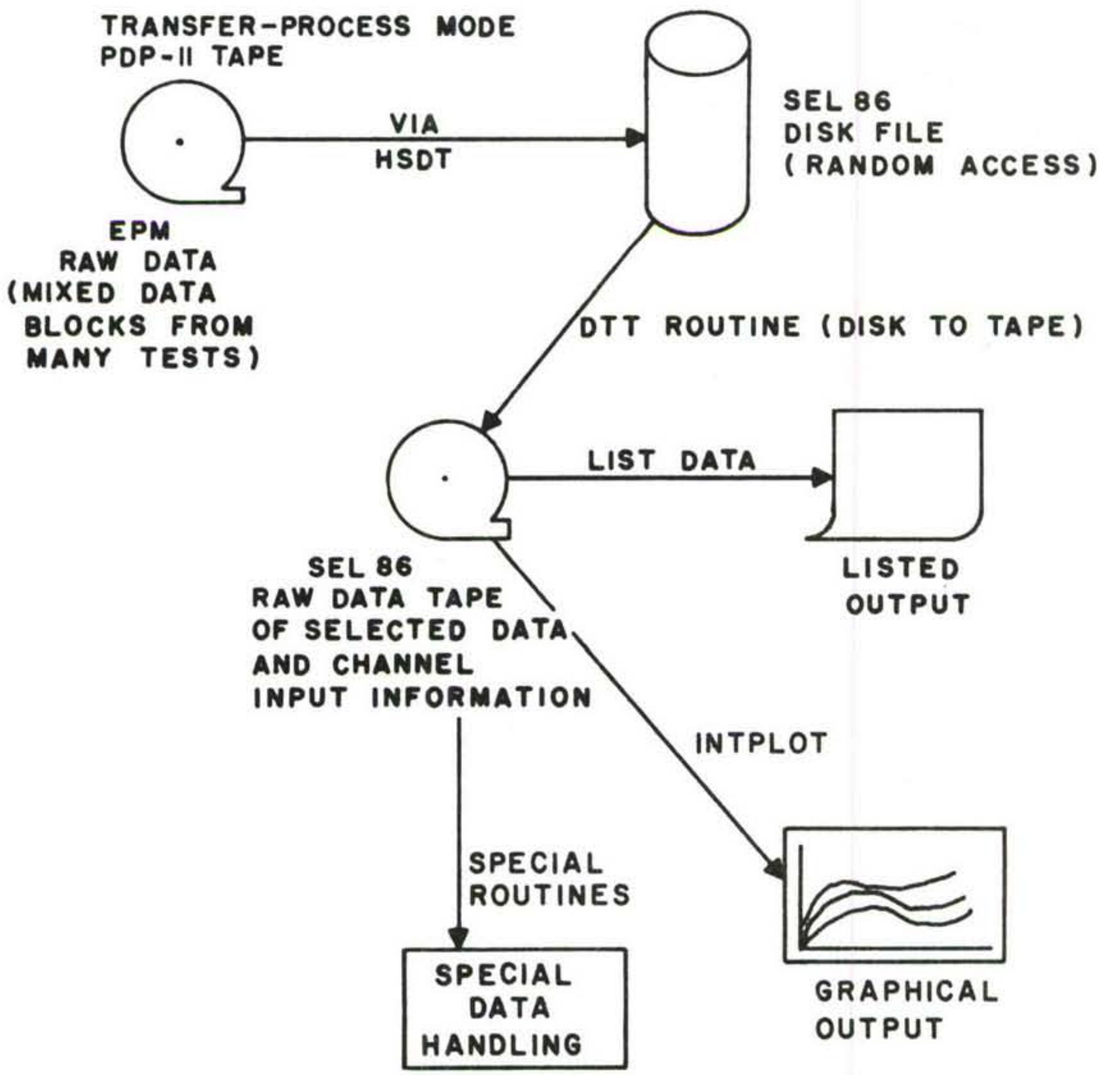

Figure 23. EPM Transfer Mode

3. INDEPENDENT MODE SOFTWARE

a. General Information

Independent mode software is software which runs on one machine and which does not include any on-line communications between machines. It is not intended to imply that the computers are physically disconnected from each other when in independent mode. Normally the hardware communication channels between machines are available but inactive in independent mode. PDP-11s may be downline loaded with independent mode software from the SEL 86. When this is done they are in network mode until the loading process is completed. They then revert to independent mode using their independent magnetic tape or paper tape systems.

LSI-11s are normally downline loaded from PDP-11s and then operated independently. The software is a subset of PDP-11 software. Figure 24 shows LSI-11 hardware configuration.

b. PDP-11 Eight Program Monitor

The Eight Program Monitor is a software package developed to support concurrent data acquisition monitoring and recording for up to eight small (not exceeding 128 data channels each) test programs by a single PDP-11/40. Figure 25 shows the hardware interconnections for the Eight Program Monitor. Each program supported requires a dedicated multiplexer/analog-digital SDC together with its assigned DMA port and a dedicated CRT terminal. The CRT terminal is located at the test site. All programs share a single magnetic tape transport, consequently once activated all programs using the magnetic tape must be terminated prior to reading the tape.

Test set up and operation is accomplished at the on-site CRT terminal by operator issued directives. The directives provide the capability to enter/review/change identification and calibration data, select on-line transducer equations for each data channel, set sample rate, switch between monitor and record modes, set gains and select information for tabular display on the CRT. Transducer equations programmed are for temperature, load, deflection, strain and linear variable differential transformers. All equations are solved using fixed point

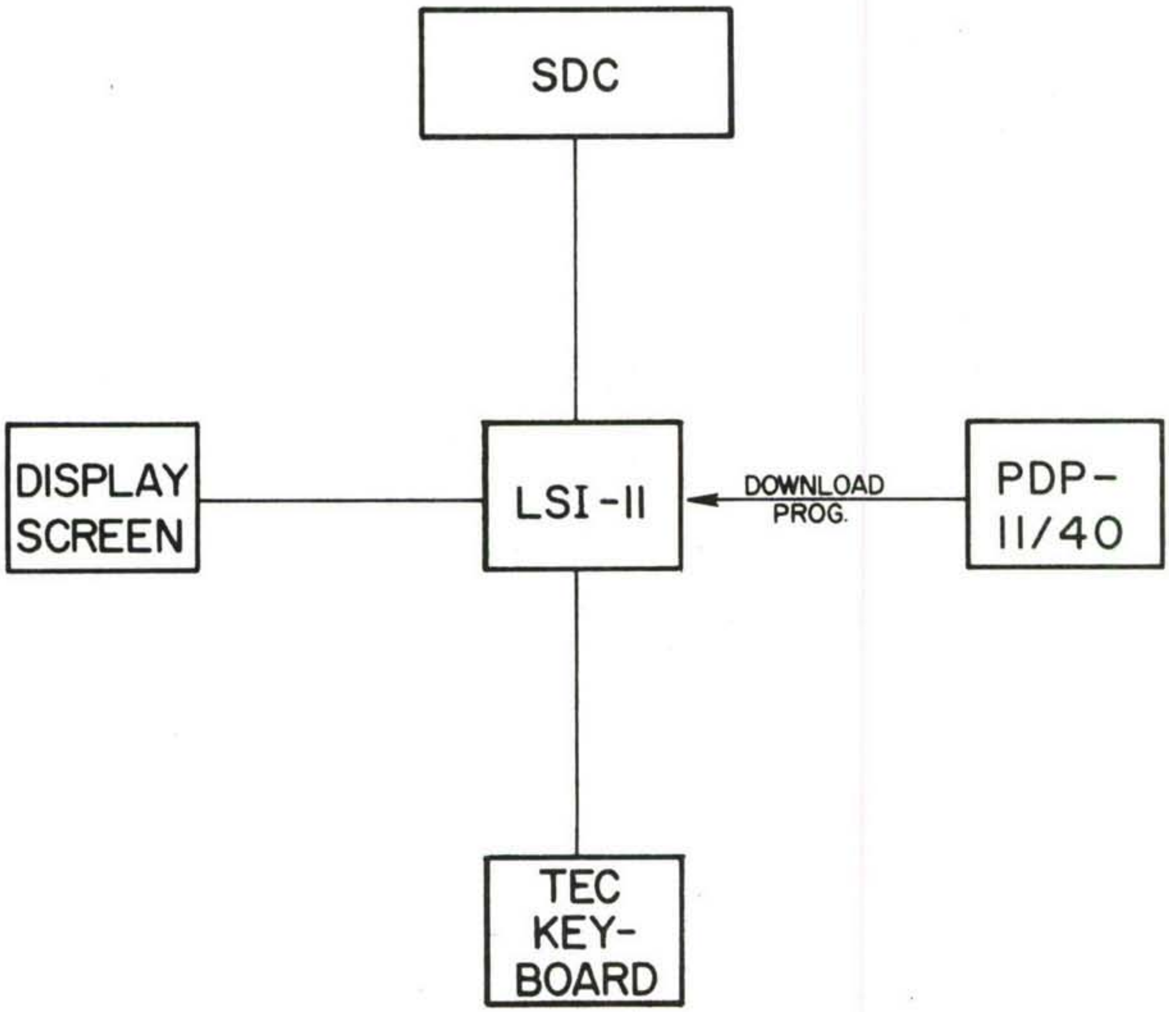

Figure 24. LSI-11 Hardware Configuration

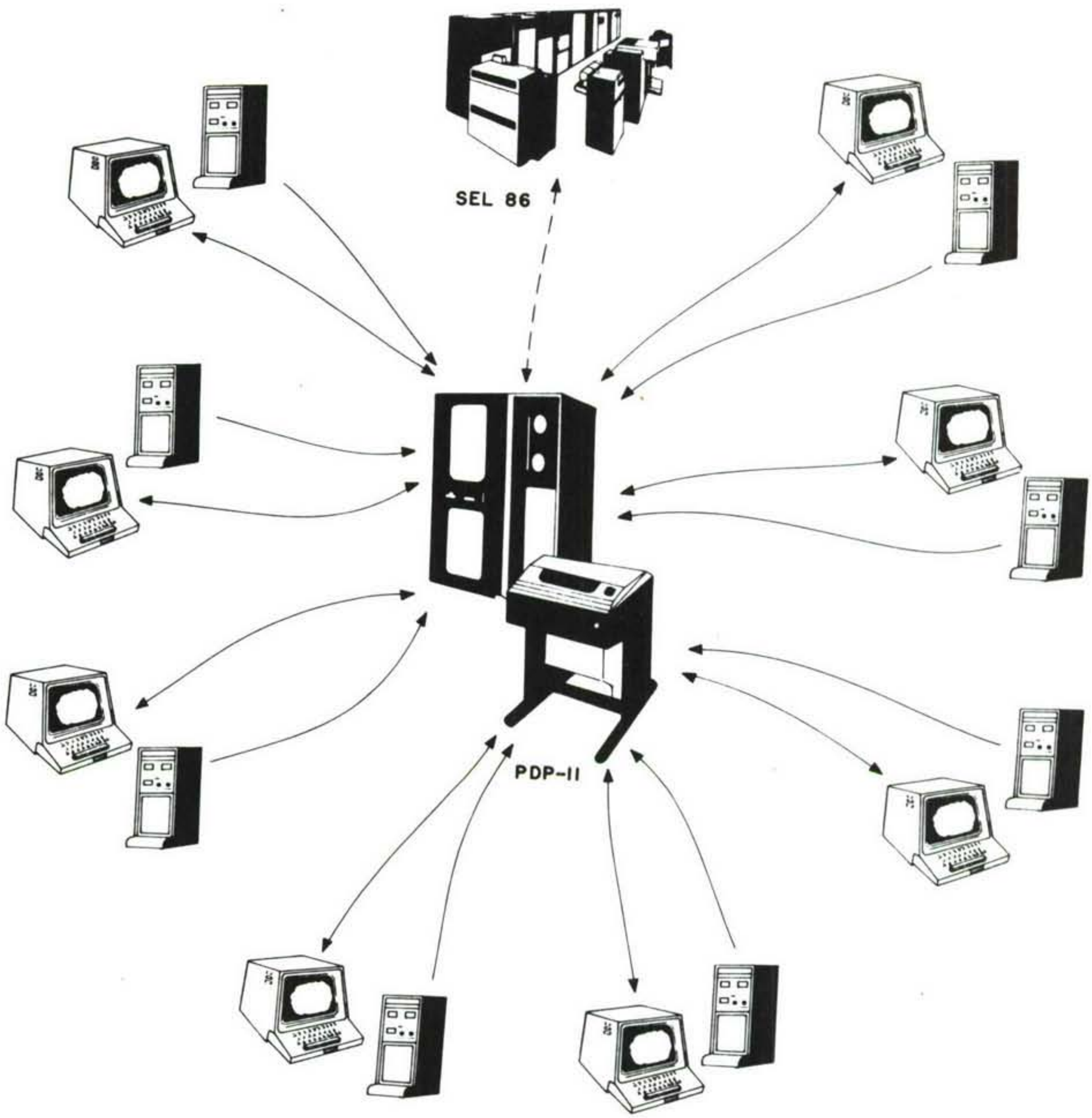

Figure 25. Eight Program Monitor Interconnections

arithmetic. Up to 12 points on up to 11 consecutive channels may be displayed simultaneously on the monitor. Directives can also be issued to link multiple SDCs and terminals together to support larger programs. A special feature of EPM is the peak search and display function. A keyboard directive initiates the function. Very high speed data is acquired for a predetermined number of data points. Then the maximum and minimum value of the selected channel is displayed. The values of the 10 adjacent channels at the time the max/min occurred are also displayed. In this operation, all computation is performed by the PDP-11 and all displays are tabular and presented on the CRT terminals.

In the event of a malfunction the PDP-11 can be physically replaced by another unit (they sit side-by-side in the facility computer room) but a complete restart is required. There is no other fallback or degradation mode.

Figure 26 shows the interconnections and information flow for a single SDC/terminal set. Additional SDC/terminal sets share the same computer. The figure also indicates the transfer of information to the SEL 86 for further processing and preparation of hard copy. This transfer involves reading the raw data tape (PDP-11), transfer of data to the SEL 86 disk. By definition this process is off-line with respect to the specific tests involved but takes place in network mode since communication between the PDP-11 and the SEL 86 is required.

Data from all active tests is interspersed on the PDP-11 tape. It is transferred to the SEL 86 via the High Speed Data channel where it is re-recorded on disk in the same format. Each block of data is identified by its SDC/terminal set number. Processing then proceeds in the SEL 86 on an off-line basis for tabular data and in network mode with one PDP-11 for graphical data via INTPLOT.

c. On-Line Peaks (OL Peaks)

The On-Line Peaks Program was originally written to display on a display screen 16 maximum and minimum load peaks from cyclic data taken from an Instron or MTS machine. It has been modified to operate in

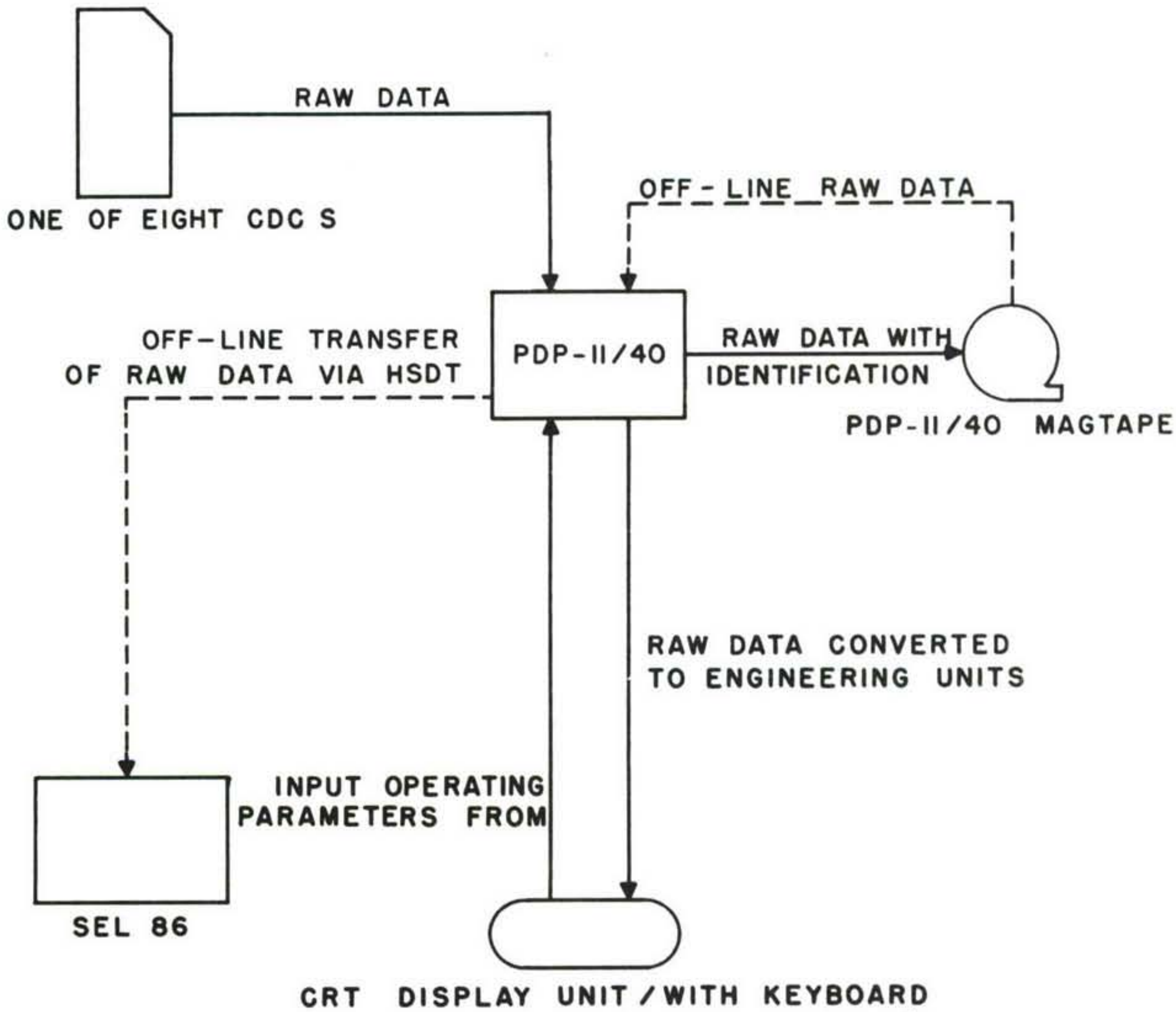

Figure 26. EPM Record/Monitor Mode

several modes. Each mode must be selected each time before a display occurs.

Mode A will display 16 maximum and 16 minimum load peaks.

Mode B will display 16 holding loads.

Mode F will re-initialize program for a restart.

Mode E will display zero and shunt calibrations and a load cell correction factor for up to eight selected data channels.

Mode C will display 15 load peaks with 15 corresponding load program points at those peaks and the mean and standard deviation computed from these peaks and program points.

Mode D will display 1 load peak along with up to 31 load points occurring immediately before/after the peak value.

Modes A, B and C can also be selected in the Constant Update Mode. This allows these displays to be updated without a mode reselection.

d. SEL 86 Off-Line Test Data Processing

This processing takes place in the post-test environment and is used to prepare tabular hard copy data for engineering evaluation and record.

A standard program module handles all normally used test transducer outputs. This module (PROCESE) is the same one used by the SEL 86 for this purpose when operating in network mode. It prepares tabular listings of parameter versus time or test percent load. In addition to this module a second program section is attached to allow certain data handling as dictated by the individual program. Such distinctions may involve strain translations on composites ('COMPROS'), Poisson's ratio determination, etc.

These modules are identical to the processing portions of XPERGO (Network Mode). (The parameters associated with each transducer channel must be loaded into the SEL 86, normally from the card reader. The parameters used in the PDP-11 for on-line processing are not transferred to the SEL 86.)

e. General Computer Support

The SEL 86 and one of the PDP-11s are equipped with a complete set of peripherals. These machines can be used to provide nontest related computational support to the technical staff. The systems are presently configured to provide only batch processing of this class of job.

SECTION VI

SYSTEM OPERATION

1. OVERVIEW

Operation of the various elements of STARNET is largely a function of the distribution of system hardware. Signal conditioning equipment and SDCs are always located at individual test sites in the Structures Test Facility. Some signal conditioning equipment has no operating controls; an example of this is the thermocouples reference system which consists of a thermostatically regulated 150°F temperature oven. The temperature of the oven is periodically measured with calibrated thermometers and adjusted as required, but this is not part of day-to-day operation.

The majority of signal conditioning equipment used in the facility is either Wheatstone bridge or potentiometric bridge equipment. Operator controls on these classes of equipment include excitation voltage adjustments, bridge balance adjustments and switch/relay contact closures for calibration of the excitation supplies.

All facility SDCs are operated during actual testing by PDP-11 minicomputers or LSI-11 microcomputers. However they all have an alternate local mode of operation. The local mode operation provides the capability of selecting each individual channel in the SDC for readout in a digital display (octal format) which is an integral part of each unit. During transducer hookup and checkout the signal conditioning/SDC local mode controls are used to verify transducer/cabling integrity. In pretest situation they are used to check the bridge circuit and to set excitation voltage and balance the bridge circuits. As a matter of policy, bridge outputs are manually balanced to within $\pm$50 microvolts DC unless offsets are required by special operating conditions.

During actual testing no adjustments are made to signal conditioners, and SDCs are returned to computer controlled mode.

All STARNET computing equipment is centrally located in an air conditioned computer room. Peripheral equipment (magnetic tape, disc, punch cards, system consoles etc.) is also located here. This arrangement was chosen to facilitate system operation by one operator and to provide maximum flexibility of operation by allowing interchange (either electrical or physical) of the PDP-11s, LSI-11s and PDS-4s to sustain operation of the highest priority jobs in the event of maintenance problems.

STARNET CRT terminals may be located either at individual test sites, in the computer room or both. This applies to both TEC terminals used on the PDP-11s and to the graphics displays of the PDS-4s.

Limited program operation/control involving a specific test is permitted from the various test sites when terminals are located at these sites. This arrangement is designed to give test personnel necessary access to the system but to prevent them from terminating or interfering with other jobs that are on the system simultaneously.

Voice communication between the computer room and the various test sites is accomplished via two independent intercommunication systems. The first system is a private one for communication involving only operation of the STARNET. The second system is facility wide, that is, it is available to personnel involved in all aspects of test operation.

During large-scale testing, overall operational control is exercised at the individual test site unless precluded by safety considerations. Closed circuit television is used to monitor the computer room and other manned locations away from the test sites and to display video data from these locations to the Project/Instrumentation enginner at the test site. This is a safety measure which is used because locations away from the test site are frequently manned by one person.

2. NETWORK MODE OPERATION

STARNET network mode operation involves man-machine interaction at three classes of physical locations: (a) At each individual test site, (b) In the computer room itself and (c) At the location of each control computer which is to be monitored by Program Validation software.
When operating in network mode, all direct human communication with the PDP-11s and the SEL 86 takes place within the computer room. After a test is started, communication with the system from the test site is via a PDS-4 keyboard.

a. Pretest (Setup) Functions

This is a group of preparatory activities that take place both at the test site and in the computer room.

(1) Test Site

The engineer or technician checks all on-site signal conditioning equipment and prepares it for operation. This includes balancing of all bridge transducer channels using an SDC in local mode as a readout (this also confirms the connection and the SDC channel condition). When all is in readiness, the computer operator is advised and all SDCs are switched to computer controlled mode.

(2) Computer Room

The SEL 86, the PDP-11(s) and the PDS-4(s) must be initialized prior to setup for testing. The initialization procedure assumes that RTM^R is up and running in the SEL 86. If MINIDATAQ is not resident in any PDP-11 that will be used for the data acquisition function, it must be loaded. If Program Validation is involved in the test, the PDP-11 to be used must be loaded with the Validation Software Package. All PDP-11 programs can be downline loaded from the SEL 86 or bootstrapped from magnetic tape. ICONTROL/ICORES must be loaded into a PDS-4. This can be downline loaded from the SEL 86 or bootstrapped from paper tape. When loaded the PDS-4 is ready for operation, no further setup procedure is required.

Setup of the PDP-11 for the data acquisition function is accomplished by keying in answers to three groups of questions posed by the PDP-11 and displayed on the associated TEC terminal screen. (The computer also suggests suitable responses to its questions.) The first group of responses identify the equipment to be used, the second group identifies the date and serial number of the specific test and the third group causes a transducer calibration sequence to be completed.

Setup of the PDP-11 used for the validation function is also accomplished interactively at the terminal. This is not a generalized procedure but is tailored to the requirements of each project.

Setup of the SEL 86 requires loading a directory card into the punched card reader and then activating the relevant copy of XPERGO at the system console (the directory card specifies the operating mode of XPERGO). The computer responds by printing a copy of the list of parameters associated with each transducer channel on the line printer (by reviewing this printout the engineer confirms that the proper parameters have been selected). The machine then issues instructions for setting up data tapes. When the operator completes his response the data acquisition PDP-11 and the SEL 86 are in communication. At this time system control is exercised from the PDP-11 TEC terminal and the system is ready to enter the transducer calibration sequence (the third group of responses at the PDP-11 terminal). The calibration sequence consists of acquiring and recording a zero reading and a positive and negative shunt calibration for each bridge type transducer active on the specific test. The sequence is accomplished interactively at the TEC terminal. The PDP-11 acquires the data and both records it and forwards it to the SEL 86. The SEL 86 responds by identifying that it has accepted and recorded a calibration point. When the three point calibration sequence is completed the SEL 86 printer outputs a copy of all calibration data for verification by the using engineer. Simultaneously system control is transferred to the PDS-4 keyboard where it stays until withdrawn. The acquisition and transfer process performs two functions. It identifies all calibration data and parameter information that will be used to reduce data acquired during testing and it demonstrates successful operation of the connected SDCs and the intercomputer communication channels prior to their time critical use. When this process is completed, real-time test operation is ready to begin.

b. Real-Time Operation

Transfer of control to the PDS-4 keyboard marks the beginning of real-time test operation. This continues until the test is completed or the system is taken off-line. If the system is taken off-line it is normally restarted by returning to a shortened setup in which calibration data is restored from disc instead of being reacquired live.

(1) Test Site

The engineer or technician monitors test progress by observing the PDS-4 Display. He/she has limited system control (for the test) via the PDS-4 Keyboard. He/she can direct the system to start sampling, select different display formats (tabular or graphical in various channel combinations), select skip/record functions, direct hard copy plots to the Varian plotter and a variety of other functions (Table 1). A Varian 3113 plotter can be located at the test for hard copy.

(2) Computer Room

The primary function of the operator during real-time test operation is to monitor the systems and take corrective action if indicated. If a PDP-11 detects a problem it will identify it on its associated TEC display. If the SEL 86 detects a problem it will output it to the operator console. The operator is expected to clear the problem if he/she can. As a precautionary measure he/she monitors the operations of the target tape drive when the test site engineer calls for data to be recorded by the SEL 86 (data is continuously recorded by the PDP-11 but is used only in emergencies). In some classes of tests, baseline deviation data is automatically computed by the system and outputted to the line printer. When this occurs the operator reviews the output and advises the test site engineer. In general, real-time operation as viewed from the computer room is automatic and intervention is required only in case of problems.

(3) Functions of MINIDATAQ (PDP-11 Data ACQ) in Real-Time Operation

(a) Acquires data from up to 512 SDC channels at operator specified data rates (4 SDCs up to 128 channels each).

(b) Performs limited on-line diagnostics of SDC.

(c) Writes data to magnetic tape.

(d) Transmits data to SEL 86.

(e) Monitors SEL 86 Communication channel.

(f) Accepts data from SEL 86 in plotter format.

(g) Controls Varian plotter.

TABLE 1

FREQUENTLY USED IMLAC KEYBOARD DIRECTIVES

(ALL KEYBOARD ENTRIES TERMINATE WITH A CARRIAGE RETURN FOR EXECUTION)

ENTRY	FUNCTION
SK	SKIP MODE: Mode in which program starts, data are available for update, no data are recorded on disk i.e. 100 point file, no baseline comparisons are made
RU	RUN MODE: 100 point file is continuously updated, baseline comparisons are made
HO	HOLD MODE: Suspends data gathering, computer must be in this mode in order to call for IMLAC or VARIAN PLOT
IPXXXX	IMLAC PLOT PORT CHANNEL NUMBER: Displays latest 100 points recorded on channel designated
VPXXXX	VARIAN PLOT PORT CHANNEL NUMBER: Produces Varian hardcopy plot from latest 100 points recorded on channel designated or all points if less than 100 are recorded
CHXXXX	CHANNEL PORT CHANNEL NUMBER: Initiates a continuously updated tabular display of 60 channels (if 60 are available to end of listing) starting with channel designated
WR	WRITE 100 PT FILE: Writes contents of 100 point file onto magnetic tape as permanent record
DLXXXX	DELETE PORT CHANNEL NUMBER: Deletes designated channel from further baseline comparison checking
CU	CANCEL UPDATE: (Type RUn or SKip to return from hold mode and resume data sampling)
BASELINE	(STATIC) DATA SAMPLE
MXXXT	Record Data Only XXX - Step Number T - Data Point Only
MXXXB	Record Data Point and Enter Point into Baseline File XXX - Step Number B - Baseline Point for Designated Channels (Delete Removes Latest Character if Entered Prior to Carriage Return)

(4) Functions of XPERGO (SEL 86) in Real-Time Operation

(a) Accepts raw data from MINIDATAQ (PDP-11).

(b) Writes data to magnetic tape.

(c) Stores a special baseline file on permanent disk file. This file normally consists of the structural response data at selected static load levels when the test structure is new. It is assumed that this represents a baseline response of a structure in perfect condition.

(d) Checks live data at manually or automatically selected times against the baseline file. Outputs deviations of >10% to line printer.

(e) Processes latest data on every channel for possible tabular display on PDS-4.

(f) Processes and stores latest 100 data points on every channel for possible recall and display as graphical data on PDS-4 and/or hard copy on the PDP-11/Varian 3113.

(g) Monitors linearity of data by computing slopes of transducer outputs over 0-50% of limit load range, linearly extrapolating this to 150% of limit load and processing all channels for display that deviate from linearity by more than any specified percentage.

(h) Monitors all data for exceedance of allowables. Process for display (uses actuals for axial strain gages, Von Mises yield criteria for rosettes).

(i) Monitors operation of PDP-11 and PDS-4 communication channels. Aborts if non responsive.

(5) Functions of ICORES/ICONTROL (PDS-4) IN Real-Time Operation

(a) Provides system operational control via keyboard commands which are communicated to XPERGO (SEL 86) for execution.

(b) Provides test site display of commanded data:
-Various tabular formats (up to 60 channels concurrently) of present values, exceedances, etc.
-Plots from 100 point file or real-time (Up to six channels concurrently). Channels may be displayed as cross plots (parameter "x" vs parameter "y") or time plots.

(6) Fall Back

Recovery procedures are provided to attempt to return to operation after system errors/malfunction. Fall back procedures are provided to allow continuation of testing in the event of certain nonrecoverable errors. Continuation under fall back is possible only if temporary reduction or elimination of Real-Time Processing/Monitoring can be tolerated on a specific test run.

(a) Fall Back from PDS-4.

Two fall backs are provided. The second PDS-4 can be brought on-line if it is not in use on a higher priority test, or PDS-4 operation can be terminated and limited control can be transferred to the terminal on the MINIDATAQ PDP-11. When this is done only data sampling, writing to magnetic tape and baseline comparison are accomplished on the SEL 86.

(b) Fall Back from SEL 86.

Since the PDS-4 depends on the SEL 86, loss of the SEL 86 takes both off-line. When this occurs the MINIDATAQ PDP-11 can continue sampling and recording in a stand alone mode. However all real-time processing is halted.

(c) Fall Back from PDP-11.

The PDP-11 must be physically replaced. No on-line fall back operation is possible.

c. Post-Test Operation

(1) Test Site

Control is withdrawn from the PDS-4 keyboard and all test site equipment is secured.

(2) Computer Room

If multiple tests are running real-time operation of the SEL 86 is continued until all have terminated.

Raw data is processed for final hard copy output (if required). Raw data may be read from SEL 86 tape or read from a PDP-11 tape and transferred to the SEL 86. (PDP-11 data tape is normally backup only).

Tabular data is processed on the SEL 86 and outputted to the line printer. Graphical data is processed on the SEL 86/PDP-11/Varian 3113 combination under control if INTPLOT. A Varian 3113 is located in the computer room for this operation.

3. INDEPENDENT MODE OPERATION OF THE SEL 86

The SEL 86 can be used independently for three functions:

(a) Post-test processing

(b) Program development

(c) Nontest connected computational support

When in independent mode the SEL 86 is not directly associated with real-time test support. It is not in communication with any other STARNET element. This operation is carried out in the computer room by the operator - no remote communication of any kind is required.

4. INDEPENDENT MODE OPERATION OF THE PDS-4s

Since the PDS-4s have internal computing capability and input/output capability they can be used on a stand alone basis. The STARNET PDS-4s are not highly configured. Therefore stand alone operation is infrequently used. When it is used it is for program development and debugging.

5. INDEPENDENT MODE OPERATION OF THE MINICOMPUTERS

The minicomputers can, in theory, be used independently to perform the same three functions as the SEL 86. In practice only one of the machines is configured to do this kind of work in a reasonably effective way and it is intended for use as a fall back processor in case the SEL 86 is not available. The principal use of the minicomputers in both network and independent modes is for real-time test support. When used independently for real-time test support the minicomputers are normally operated under control of the Eight Program Monitor (EPM). EPM gives a single PDP-11/40 the capability to support concurrent data acquisition, monitoring and recording on up to 8 test programs (Section V, paragraph 3.b.).

a. Pretest (Setup) Operations Under EPM Control

(1) Computer Room

At the beginning of the operational day the operator determines the number and locations of tests requiring support (this operation occurs only once per week during three-shift operation). A blank tape is mounted on the host PDP-11 tape drive. The PDP-11 is then downline loaded and initialized (alternatively the PDP-11 can be loaded from tape). No further operator intervention is required until the last user logs off the system.

(2) Test Site

The engineer or technician checks all on-site signal conditioning equipment and prepares it for operation the same as in network mode. When all is in readiness the SDC is switched to computer controlled mode. The engineer/technician then goes to the TEC terminal and initiates an identification and calibration sequence. The test is identified by serial number and data by means of keyboard entries. Shunt calibration data for bridge type transducers is then acquired. When both sequences are complete the stored information can be called from memory and displayed on the TEC. When verified it can be written to magnetic tape by another keyboard entry. (The engineer retains system control throughout the test).

The engineer can call for displays of any fixed data or live test data. He/she can also change transducer type and parameters used in converting raw data to engineering units, select sampling rate, write to (or skip) magnetic tape and perform a number of other operations important to test operations. These include partial reinitialization, gain setting, selection of channels (1 to 11 concurrently) for display in real-time, terminate testing, and invoke/cancel special functions such as peak detection. In all, some 50 different directives can be issued from the keyboard.

b. Real-Time Operation

There is no real-time operational requirement in the computer room. The system runs automatically under control of the engineer at the individual connected test sites. At each test site the engineer monitors test progress by observing the TEC display. Since the engineer retains control of the system (for each test) at the TEC keyboard he/she can issue any relevant directives to change the display, start and stop sampling/recording and perform other system functions. The engineer remains in control until he/she keys in a predetermined two letter stop code. At that time he/she can initiate a totally new test or relinquish control.

Engineers at up to eight test sites can perform the same functions concurrently or separately (or any combination). The system is transparent to these multiple users.

c. Post-Test Operation

(1) Test Sites

Stop codes are keyed in to terminate testing. Test site equipment is then secured.

(2) Computer Room

When all active tests have been terminated the computer operator can write an End of File on tape. Then the line to the SEL 86 is activated and data is transferred to the SEL 86 where it is sorted into individual tests and processed.

SECTION VII

REVIEW OF A LARGE-SCALE NETWORK MODE APPLICATION

1. OVERVIEW

The STARNET system was first used successfully on a flight-by-flight fatigue test of an Advanced Metallic Air Vehicle Structure/Wing Carry Through Structure (AMAVS/WCTS) developed on an Air Force Advanced Metallic Structure Advanced Development Program. Two months later it was deployed on another flight-by-flight fatigue program, this one on a complete F-4 model C/D aircraft. First successful use of the system for multiple testing occurred after another one and one half months, when the AMAVS/WCTS and the F-4 tests were operated concurrently for the first time. During the peak testing periods on these two projects, load cycling (and STARNET operation) was performed on a three shift, five-day week basis.

A total of seven computing systems were interconnected to perform the testing (Figure 27). The systems were the SEL 86, three PDP-11s and the PDS-4 Dual Display Graphics System from STARNET and two PDP-11s used to generate analog signals (via Digital to Analog Converters) for operation of analog load controllers.

2. LOAD SPECTRUM

A load program computer was dedicated to each project. The AMAVS/WCTS computer generated program signals on 11 channels to correspond to the load application points on the structure. Three unique flights of 140 cycles each were generated using computer stored information (table lookup). The F-4 computer generated program signals on 30 channels. The F-4 not only had more channels but it required a much more complex spectrum. The spectrum included 730 individual (unique) flights. Each flight included an average of 34 cycles obtained from a matrix of 139 different speeds, altitudes and accelerations on each of the 30 channels.

3. DIVISION OF STARNET FUNCTIONS

a. Data Acquisition for the AMAVS/WCTS

One PDP-11 was dedicated to data acquisition for the AMAVS/WCTS. It controlled the operation of four, 128-channel SDCs for a total connected capacity of 512 channels. This includes 39 loads, 1 pressure,

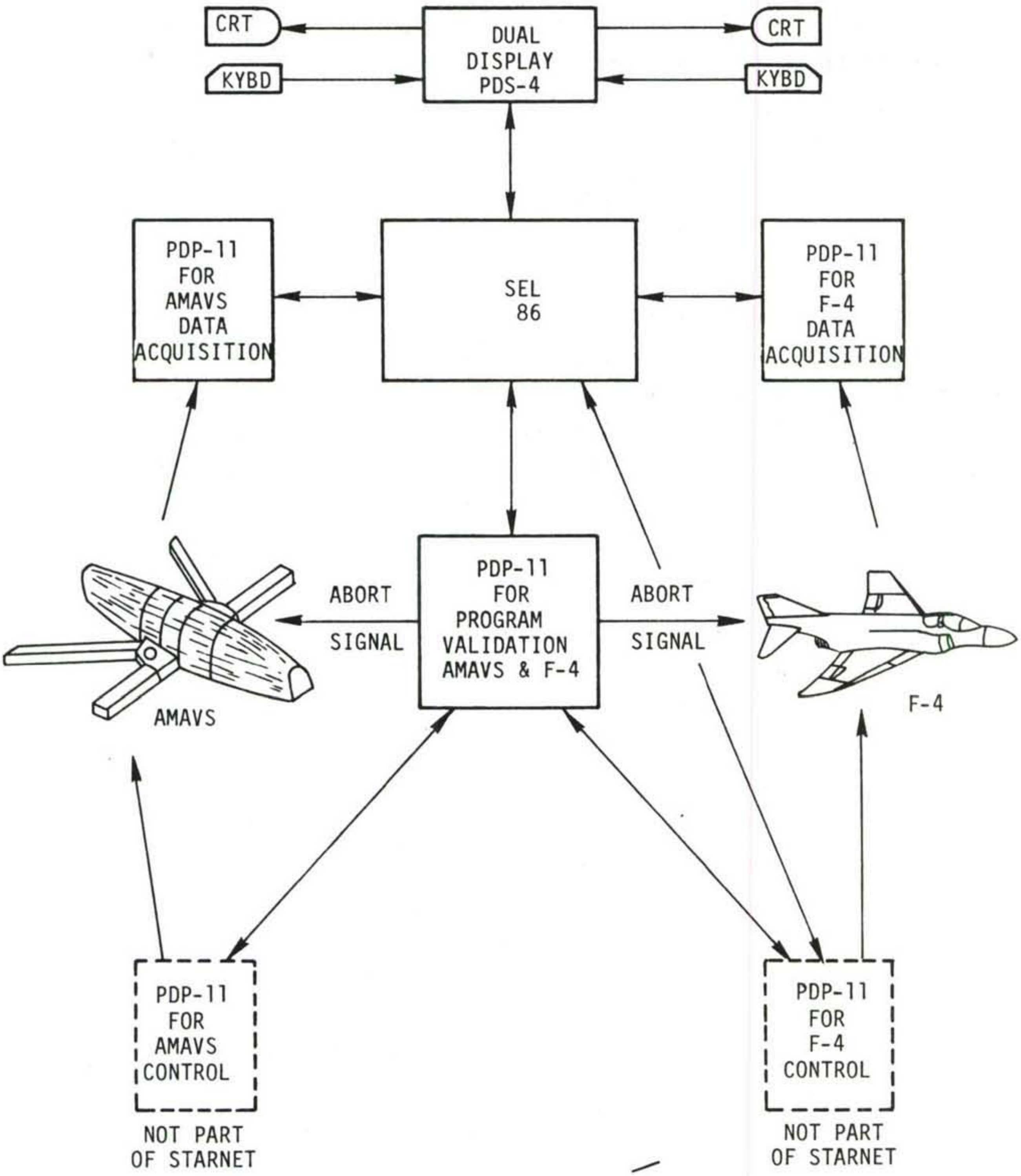

Figure 27. Conceptual Hardware for F-4/AMAVS Testing

46 deflection and 426 strain transducers. MINIDATAQ software was used (reference Section V, paragraph 2b).

b. Data Acquisition for the F-4

One PDP-11 was dedicated to data acquisition on the F-4. It also controlled four, 128-channel SDCs. The channel complement for the F-4 included 50 load, 20 deflection and 403 strain transducers. MINIDATAQ was used on this program also.

c. Load Program Validation

One PDP-11 was used to concurrently perform the program validation functions on the AMAVS/WCTS and the F-4. The AMAVS/WCTS spectrum information was generated from a table. The much more complex F-4 spectrum was stored on disc and read by the program as required. The programs were custom coded for the applications and were independent of each other although they shared the computer and its display terminal. A single SDC was used for the program signals (reference Section V, paragraph 2c).

d. On-Line Data Monitoring, Computation and Recording

The SEL 86 was used to concurrently support the AMAVS/WCTS and F-4 projects. Two independent copies of XPERGO (reference Section V, paragraph 2d) were running in the machine for these tests. The AMAVS/WCTS copy of XPERGO performed the following functions:

(1) Accepted data from the data acquisition PDP-11

(2) Stored raw data on tape

(3) Processed all incoming data into engineering units for display on the PDS-4 as tabular data. (Latest point on each of 512 channels saved.)

(4) Processed all incoming data for display on the PDS-4 as graphical data. (Latest 100 points on each of 512 channels saved.)

(5) Compared data from 148 designated channels with stored baseline data at selected load levels throughout each flight. Advised test engineers if any channel deviated by more than 5% from its baseline value. (The requirement to perform the baseline comparison was established by a signal from the program verification PDP-11 to the SEL 86.)

(6) Automatically outputted transducer outputs as tabular hard copy of selected levels of every 160th flight.

(7) Prepared and outputted transducer outputs as tabular hard copy for other flight levels on a demand basis.

The F-4 copy of XPERGO performed similar functions for the F-4 project. In the F-4 case there were only 100 baseline channels and the requirement to perform baseline comparison was established by a signal from the function program PDP-11 rather than the verification PDP-11.

e. On-Line Display

At the time the AMAVS/WCTS and F-4 software was being prepared there was only one (IMLAC PDS-4) display system in STARNET. However this PDS-4 was a dual display system with two separately addressable displays and keyboards. This system was shared by the two projects. One display/keyboard was dedicated to each project. The PDS-4 processor and communication channel were shared.

4. SUMMARY OF FUNCTION DISTRIBUTION

Within the STARNET system two PDP-11s (the data acquisition minicomputers) were each dedicated to one test program, one PDP-11 (the program validation minicomputer) was shared and the SEL 86 and PDS-4 were shared.

5. SUMMARY OF INTERCOMPUTER COMMUNICATIONS

Each data acquisition PDP-11 communicated only with the SEL 86. The program validation PDP-11 communication with the SEL 86 and both the F-4 and AMAVS/WCTS control PDP-11s. The PDS-4 communicated only with the SEL 86 but supported both the F-4 and AMAVS/WCTS programs. Both load program computers (which are not part of STARNET) communicated with the program validation PDP-11. The F-4 load program computer also communicated with the SEL 86. (This communication was to flag the SEL 86 when baseline comparison was required. In the case of the less complex AMAVS/WCTS test, this information was transferred through the program validation minicomputer). The control computers were each dedicated to their respective projects. The purpose of all these interconnections was to transfer information between the minicomputers that each one needed to perform its programmed tasks. It was not to transfer tasks or portions of tasks back and forth between the minicomputers.

6. PROGRAM RESULTS

Concurrent running continued for approximately 10 months. At that time the AMAVS/WCTS testing program was successfully completed and testing continued on the F-4, which was a much longer program.

SECTION VIII

CONCLUSIONS

The Structures Testing Analysis Real-time NETwork, called STARNET, is thoroughly described in this Technical Report. The STARNET is a highly successful data acquisition and processing system for use in mechanical tests of specimens ranging from coupons to full-scale airframe structures.

APPENDIX A

SYSTEM HARDWARE TABLE

ITEM	NUMBER	REMARKS
SEL 86 Computer	1	32 Bit, 112K Memory, 600 NS Cycle
PDP-11 Computer	4	16 Bit, 24K Memory, 1.1 μS Cycle
LSI-11 Computer	3	16 Bit, 16K Memory, .9 μS Cycle
PDS-4	2	Vector Graphics System with Integral Computer
Analog Data Channels	2000+	Low Level Bipolar Packaged in 18 Signal Data Converters
Thermocouple Conditioner and Channels	600	
½ Bridge Strain Conditioner and Channels	600	
Universal Bridge Conditioner Channels	600	
Deflection Conditioner Channels	200	