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JOHN F. KENNEDY
SPACE CENTER

THE KSC
TELEVISION DATA DISPLAY SYSTEM
(TDDS)

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JOHN F. KENNEDY SPACE CENTER

THE KSC

TELEVISION DATA DISPLAY SYSTEM

(TDDS)

DIRECTOR, INFORMATION SYSTEMS

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DEFINITIONS OF ACRONYMS AND ABBREVIATIONS

ADP	Automatic Data Processing
ALDS	Apollo Launch Data Systems
CIF	Central Instrumentation Facility (at KSC)
CRT	Cathode Ray Tube
GECOS III	GE 635 Operating System
GESEC	Real Time Module for Operating System
ETR	Eastern Test Range (U. S. Air Force)
GE	General Electric Company (As used in this document refers to computers manufactured by General Electric. These computers are now maintained by HISI (Honeywell Information Systems Incorporated)).
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center (Greenbelt, Maryland)
I/O	Input/Output
IP	Impact Predictor
kb/s	kilobits per second
KSC	Kennedy Space Center
LCC	Launch Control Center (at KSC)
LIEF	Launch Information Exchange Facility

MCC	Mission Control Center (at MSC)
MSC	Manned Spacecraft Center (Houston, Texas)
MSFC	Marshall Space Flight Center (Huntsville, Alabama)
MSFN	Manned Space Flight Network
NASA	National Aeronautics and Space Administration
PAM	Pulse Amplitude Modulation
PDM	Pulse Duration Modulation
PCM	Pulse Code Modulation
pps	pulses per second
RT	Real Time
RTCF	Real-Time Computer Facility (at ETR)
RTIOC	Real-Time Input-Output Controller
TDDS	Television Data Display System
TV	Television

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SECTION I

INTRODUCTION

This document briefly describes the Television Data Display System (TDDS) at Kennedy Space Center (KSC) which displays computer processed data derived from space vehicle launch and prelaunch tests. It is not intended to completely describe or specify the major KSC systems which are integrated to form the TDDS. This document is intended only to familiarize one with the general system capabilities and technical features. Simplifications are made in some instances to enable a better understanding of the principles involved. For example, the GE-635 computers do not only operate as part of the system described herein, but they are also used to process normal ADP and scientific workload in the non-real-time mode of operation. To simplify the explanation of the system, these other capabilities and modes of operation are excluded from the general discussion and included in the Appendix of this document.

The unique design features incorporated in the TDDS allow significant flexibility of the system to support new and changing program requirements. This adaptability is also discussed in Section 7 of this document.

SECTION 2

BACKGROUND

The Television Data Display System at KSC was developed because of the stringent data requirements, both in complexity and number of measurements, associated with the testing and launching of space vehicles used in our space programs. Figure 1 depicts the growth in real-time data processing and display requirements at KSC. In 1957, the Redstone missile had a total of 116 telemetered measurements. People physically monitored the measured parameters during checkout and launch by observing lights, meter indications, and strip chart recordings. The necessary post-test analysis of the strip charts was done by using calibration overlays in conjunction with calibration curves for the conversion of recorded data to engineering units. This manual process was slow, and considerable time elapsed before engineering changes could be made based on the analysis of recorded data. The relatively small number of telemetered measurements associated with checkout of the Redstone missile and others like the Pershing, made the manual process feasible. However, on the other end of the scale, the Saturn vehicles have many more telemetered measurements, with the Saturn V requiring at one time approximately 3200 measurements. The automation of data processing and display functions became mandatory to successfully evaluate this large number of measurements and to permit checkout and launch of such a complex system within a reasonable time frame.

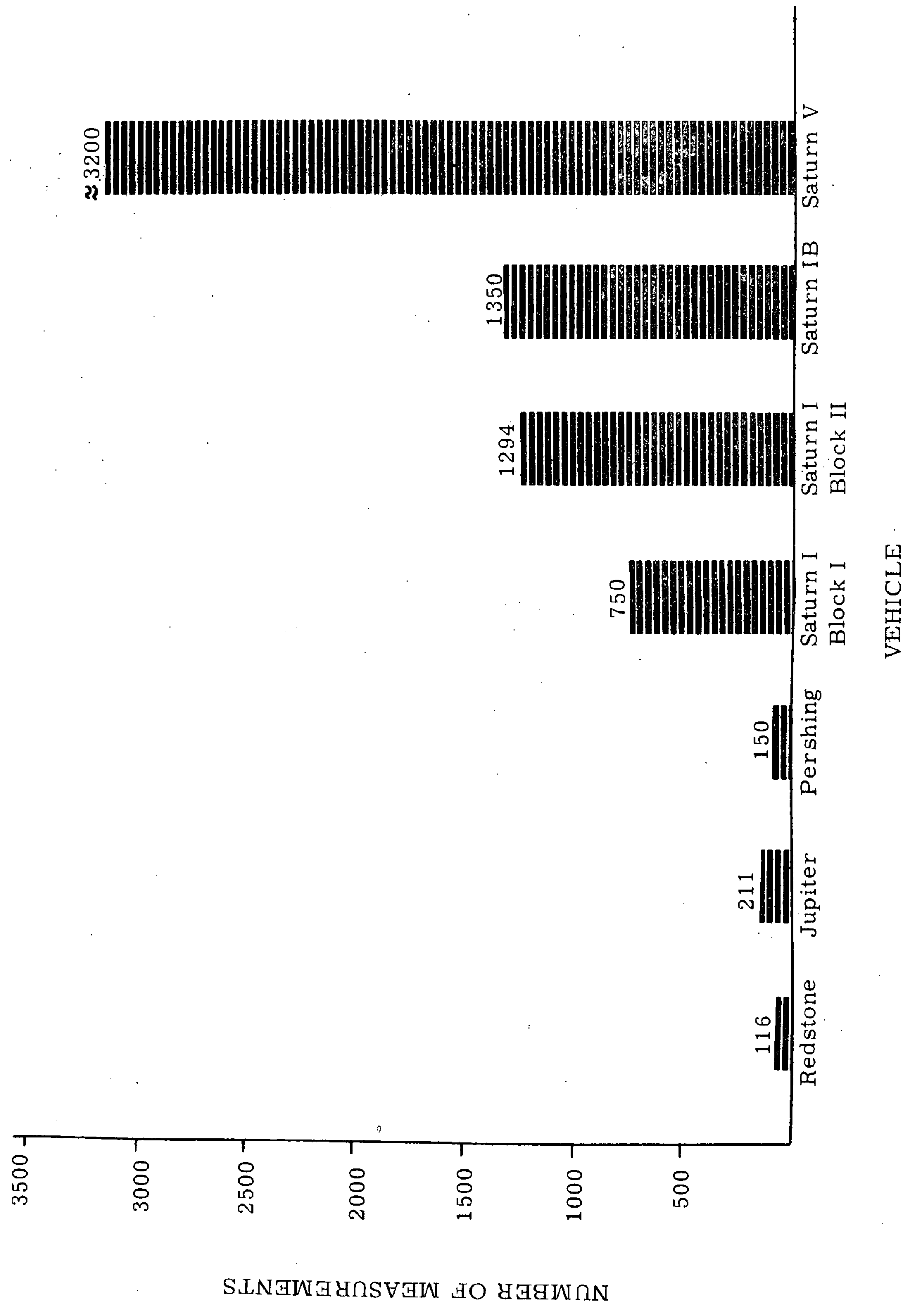

Figure 1. Number of Telemetered Measurements Associated with Space Vehicles

SECTION 3

OPERATIONAL USE

During space vehicle prelaunch tests and the actual launch, selected telemetry, tracking, flight television, and environmental information are processed and displayed in real time. This displayed information is used by engineers and scientists to evaluate the performance of the system under test.

A major application of the TDDS is vehicle systems performance monitoring during the many hours of major prelaunch tests. To assist in the detection and evaluation of malfunctions, data are displayed and limit checks are made on measured data to detect deviations from expected performance. When deviations beyond tolerable limits do occur in one or more measurements, these measurements may be flagged and presented on displays in real time at critical locations in the test control loop.

The major subsystems of the TDDS are physically located in the Central Instrumentation Facility (CIF) in the KSC industrial area. Information may be requested and displayed at consoles at the Launch Control Center 39 (LCC), Central Instrumentation Facility (CIF), and the Centaur Blockhouse. Figure 2 is a map of the KSC area showing the relative locations of these building. Figure 3, 4, and 5, respectively are photographs of display equipment in the Launch Control Center 39, Centaur Blockhouse, and the CIF Data Display Station, Room 327.

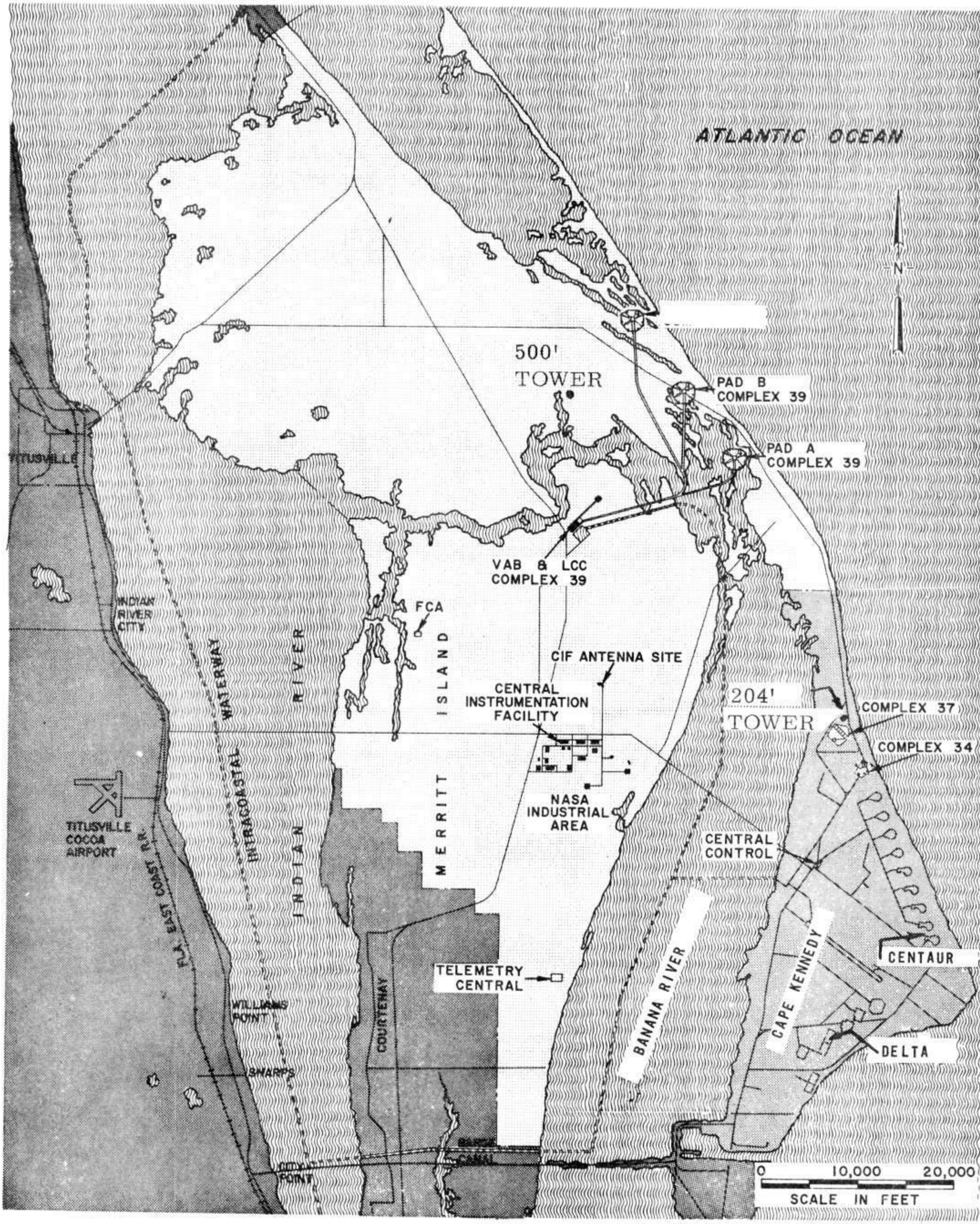

Figure 2. Map Showing the KSC Industrial Area and Complexes

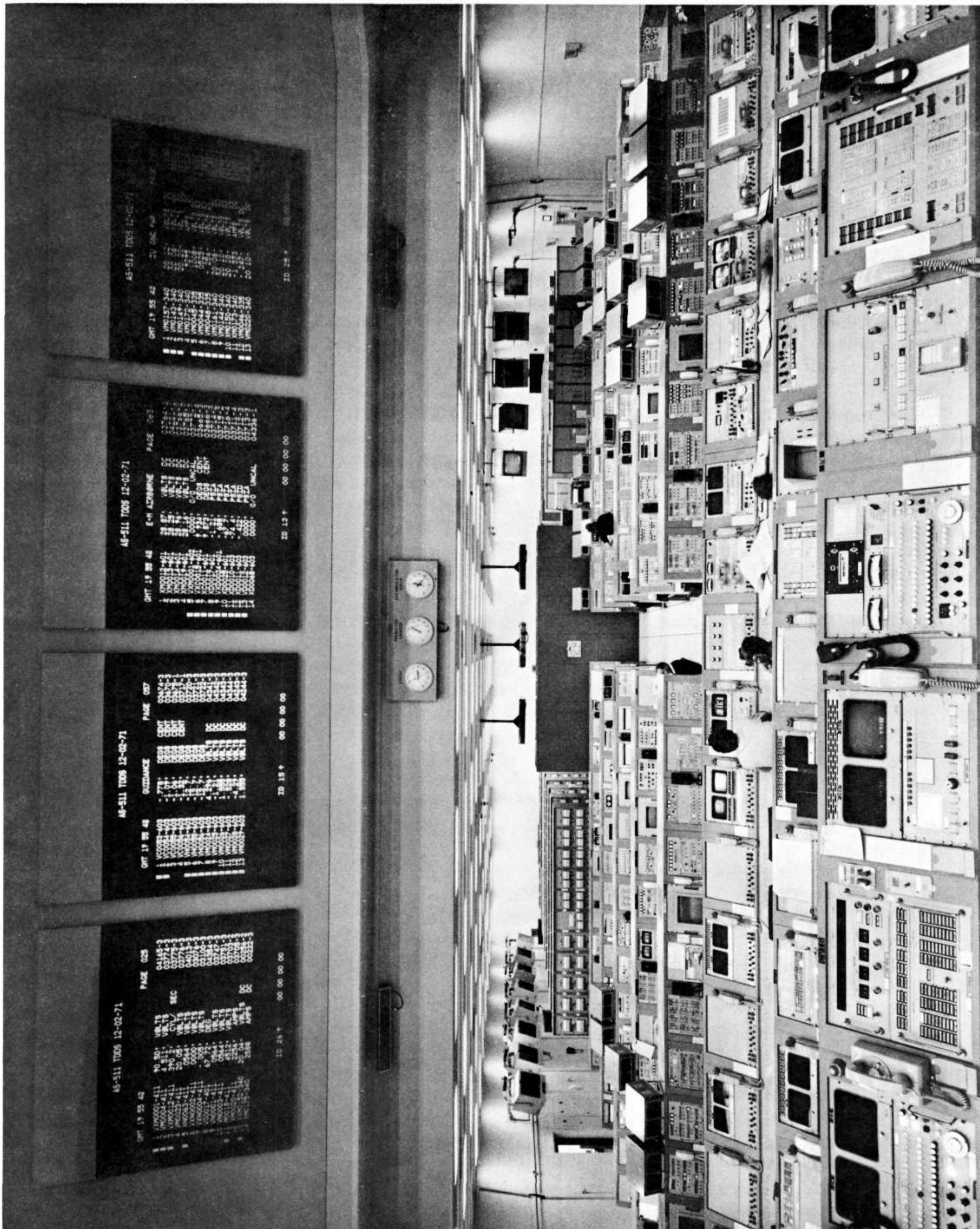

Figure 3. Launch Control Center 39

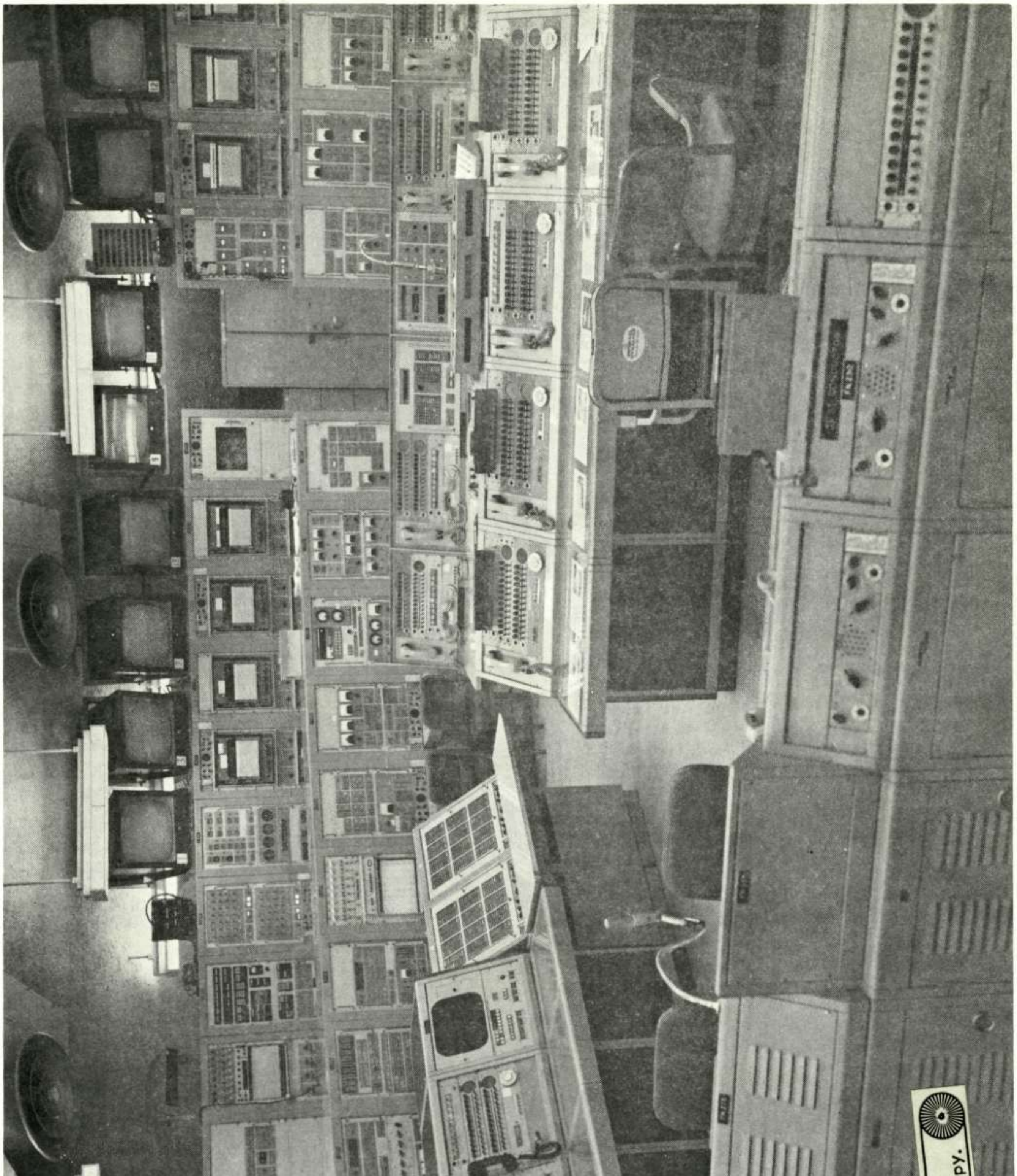

Figure 4. Photograph of the Centaur Blockhouse Display

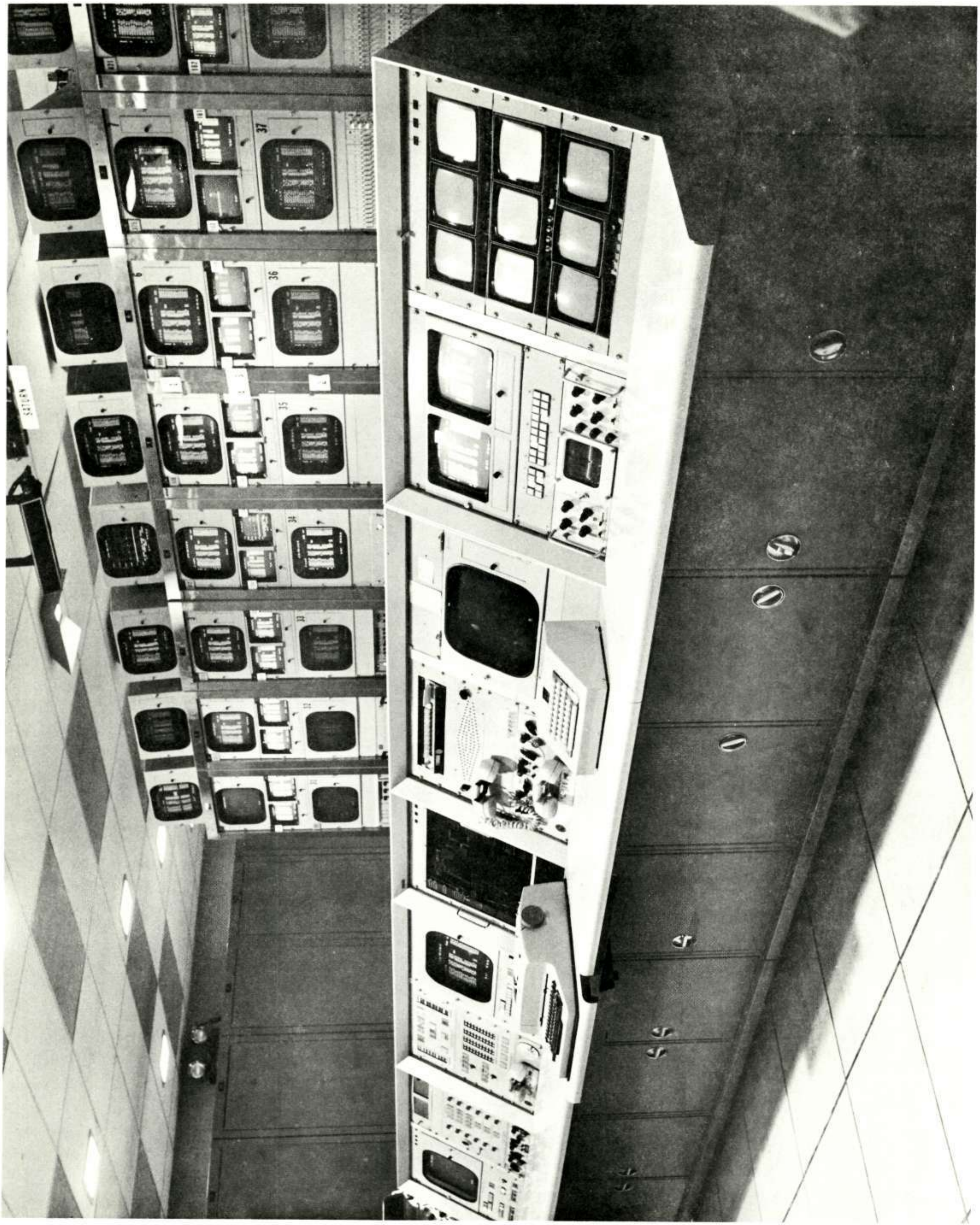

Figure 5. CIF Data Display Station-Room 327

SECTION 4

SYSTEM DESCRIPTION

4.1 System Functions

Figure 6 is a simplified block diagram showing the major components of the TDDS. For the purpose of simplification, the system is composed of three major subsystems; (a) the Data Core subsystem; (b) the computer subsystem; and (c) the display subsystem.

The primary functions performed by each subsystem are as follows:

a. Data Core Subsystem

Decommutates, synchronizes and converts data from various telemetry systems to common digital format and time base.

b. Computer Subsystem

1. Performs data analysis (limit checking).
2. Prints real-time engineering unit data.
3. Interprets data display requests.
4. Processes and formats display data.
5. Performs real-time simultaneous operational computations (e.g., guidance data reduction vehicle bending moments).
6. Mass storage and retrieval of historical data.
7. Records data on magnetic tape.

c. Display Subsystem

1. Generates display requests.

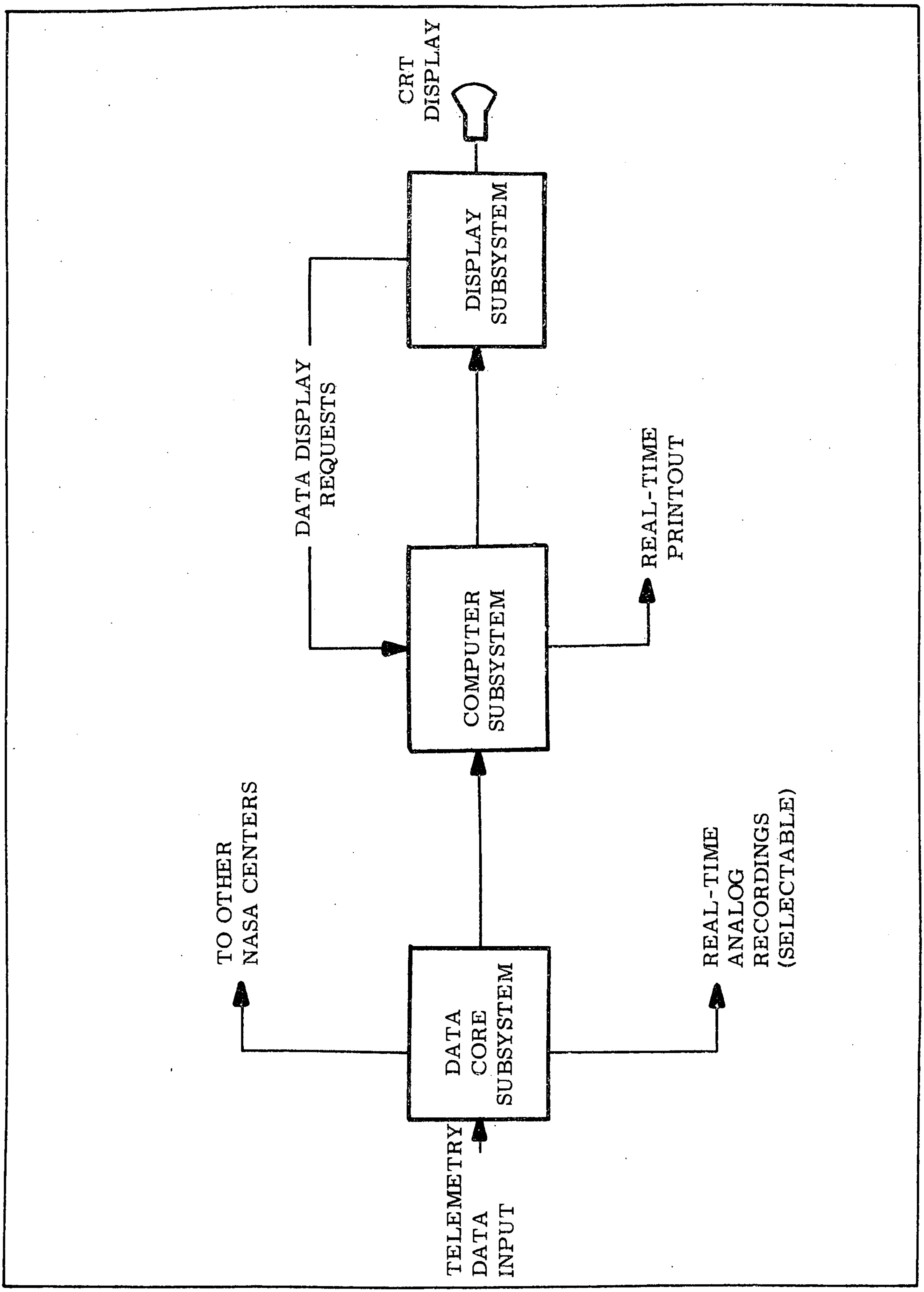

Figure 6. Simplified Television Data Display System

2. Interprets processed computer words.

3. Generates display characters.

4. Converts digital data to standard 525-line TV signals.

5. Refreshes pictures at the rate of 30 frames per second.

6. Generates background signals.

7. Distributes video data.

Each of these subsystems will be discussed in detail in the following paragraphs, however, they will be discussed in the order of the Display Subsystem first and then the Data Core Subsystem and Computer Subsystem. Since the display output is what the observer sees as the final product, it seems logical to describe the Display Subsystem first, and then to describe the others in terms of how they function in the overall system to support the operation of the Display Subsystem.

4.2 Data Display Subsystem

Figure 7 is a simplified block diagram of the overall KSC display system. It uses a standard commercial 525-line closed-circuit television format to distribute real-time data to large screen displays and conventional TV monitors. Types of data displayed are telemetry measurements processed by the GE-635 computer, radar information for trajectory plots, weather information, TV from on-board and pad cameras, nominal trajectory profiles, and other existing data required for mission analysis.

Only that portion of the display system concerned with the GE-635 computer processed data is discussed in the main body of this document.

Figure 8 is a simplified block diagram showing that portion of the display system used to display GE-635 computer processed data. Requests are made for the display of selected data from any of the 40 independent data request panels located at the various monitoring stations. As a result of the request and by means of the request transmitter and request receiver, a four 36-bit digital word request message is generated and entered into the GE-635 computer. After this message has been interpreted by the computer and the selected data has been processed, a 36-bit digital word appears at the computer output for each character to be displayed. This output word contains column and line position, character, character size, and identification

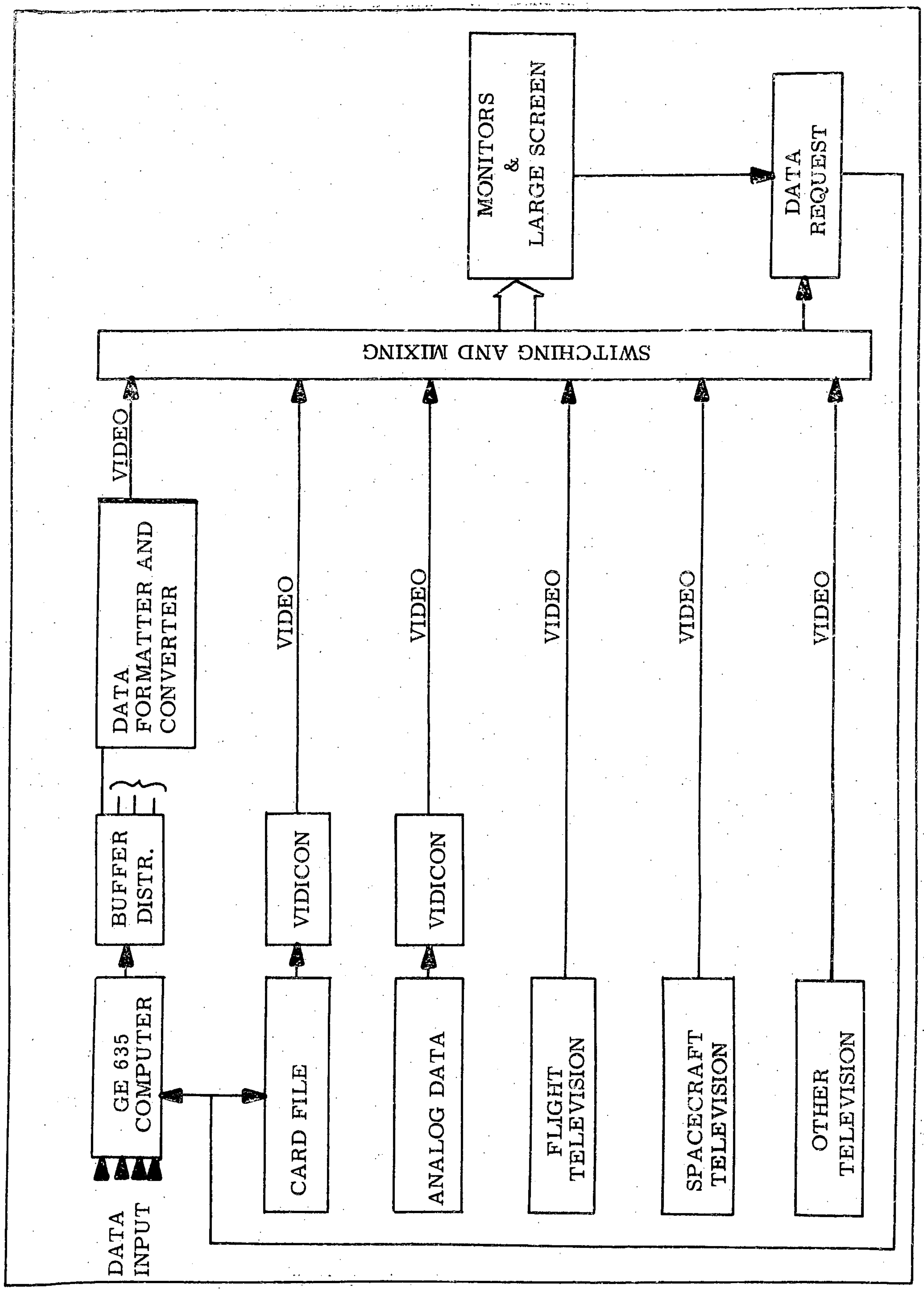

Figure 7. Block Diagram of Television Data Display System

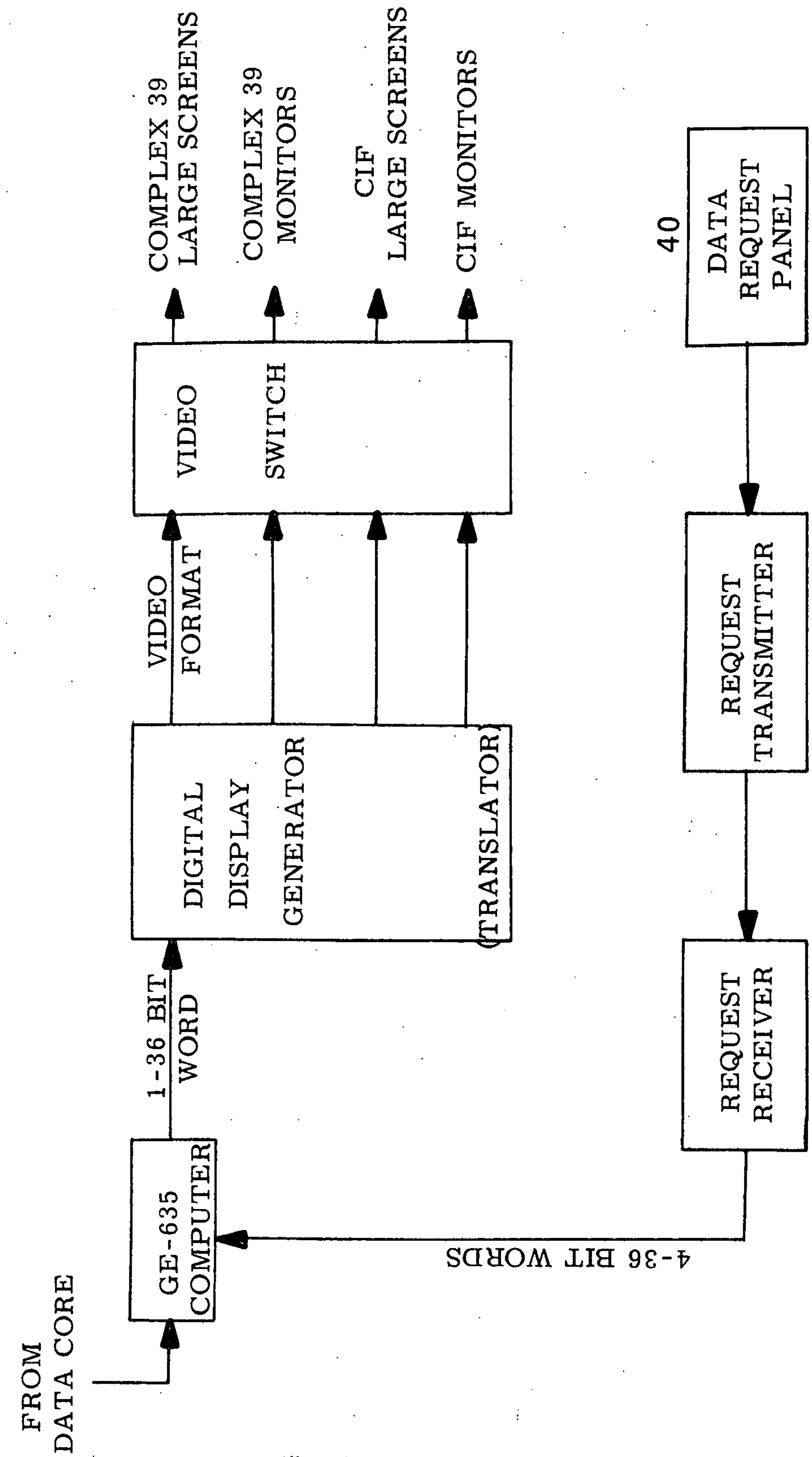

Figure 8. Data Display Subsystem

information in a format that is recognized by the digital display translator. It is then entered into the translator that consists of logic, memory (core and drum), timing and synchronization, vector and character generators, control circuitry and shift registers. In the translator, computer output data are converted to alphanumeric symbols and graphic data and stored in digital form. By means of shift registers loaded from storage, digital data are then converted to the television standard 525-line video format. To reduce the computer time required in generating these data displays, a magnetic storage drum is used to refresh the video display (between data updates) at the rate of 30 frames per second. Each display subsystem has 10 independent output video channels. There are four display subsystems at KSC, thereby serving a total of 40 independent display activities.

Figure 9 shows a typical single CRT display monitoring station. A dual CRT presentation is shown in Figure 10. By means of switches on the data display request panel any of 40 video channels may be selected independently and information displayed on the CRT monitors or large screens. The "dual-up" controls on the left of the data display request panel permit the selection and display of any of the computer processed telemetry measurements. Each character displayed is formed in a 32x32-bit dot matrix and the character size

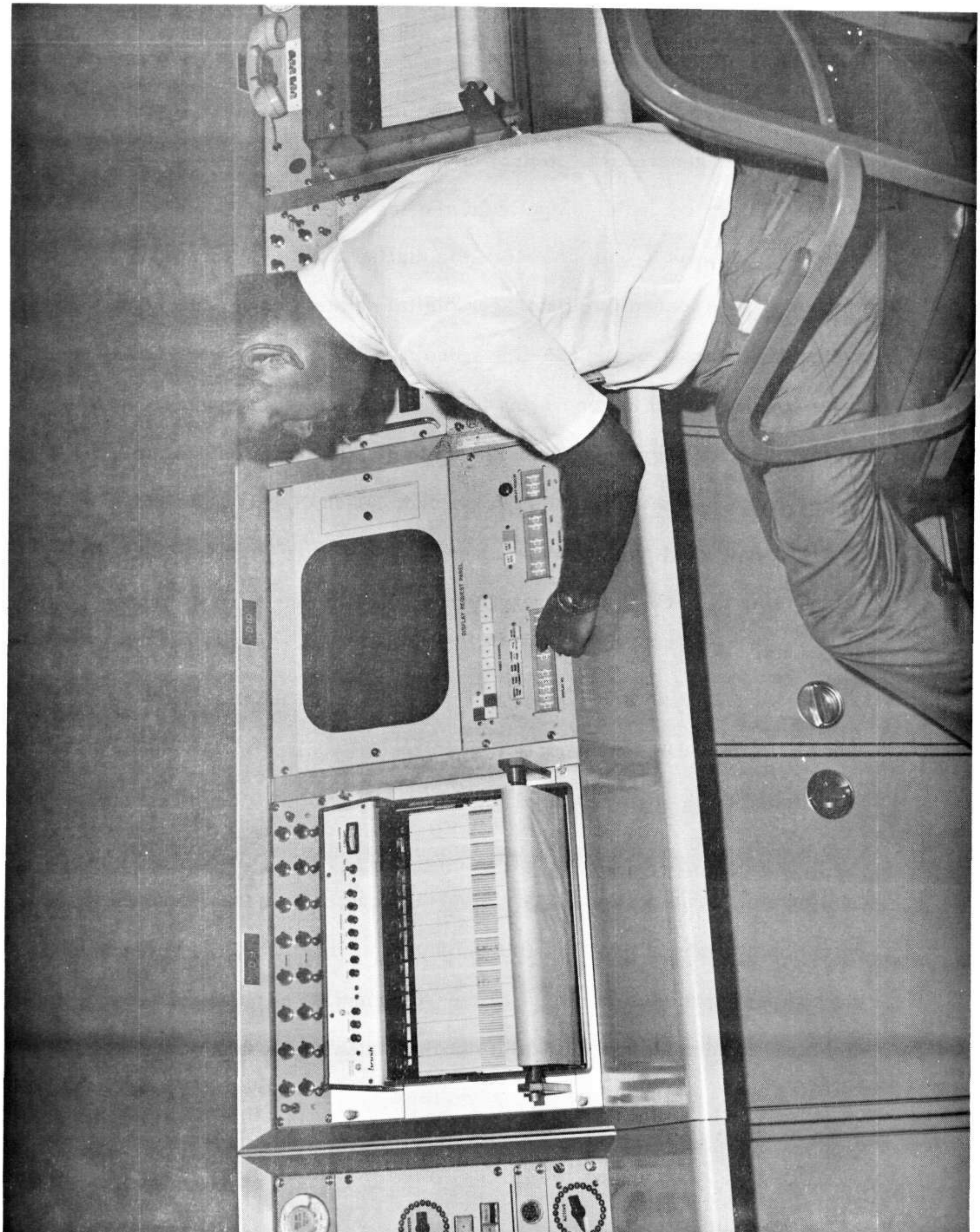

Figure 9. Data Request and CRT Display Console

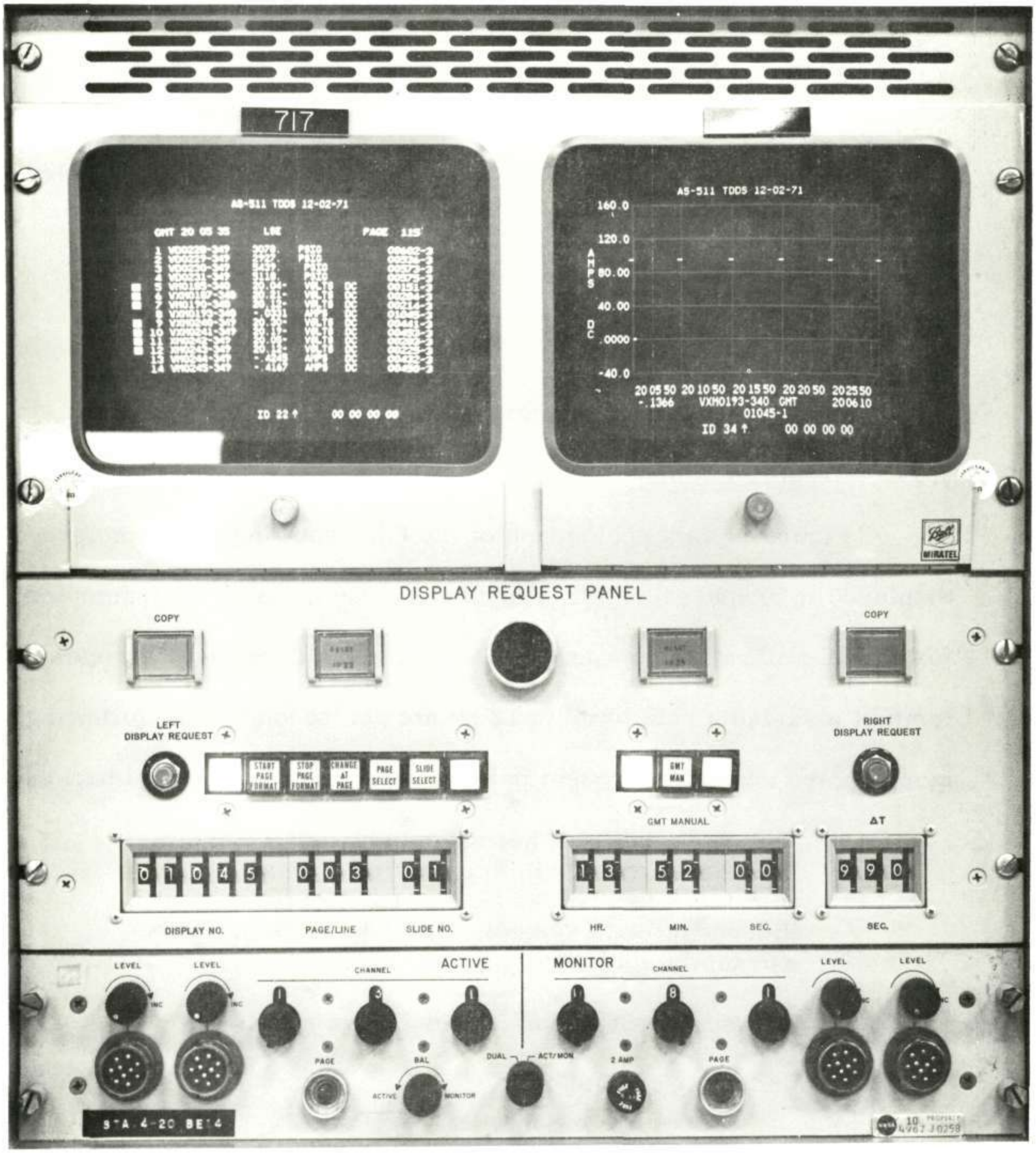

Figure 10. Dual CRT Presentation

is variable within this matrix. Characters are positioned on the CRT by specifying the coordinates of a matrix of 1024 columns and 480 horizontal lines.

Data requested for display by the console operator can be presented on the CRT in any of several formats. The following are available:

1. Graphic Format
2. Page Format
3. Event Matrix Format

4.2.1 Graphic Format

Figure 11 is a photograph of the CRT showing a parameter displayed in graphic format. Any one of 4000 measured parameters for which calibration data are available can be displayed in graphic form at a variable rate of up to 12 points per second. The following symbols are used to represent points plotted against the grid background:

+	Indicates data has been properly updated and the measurement is within specified limits
◇	Redundant data symbol, i.e., data has not been currently updated
-	Measurement is outside the limits specified
I	Indicates invalid data
C	Vehicle containing that measurement is called out for calibration

Limits applied to the graphed parameter are placed at each vertical grid line.

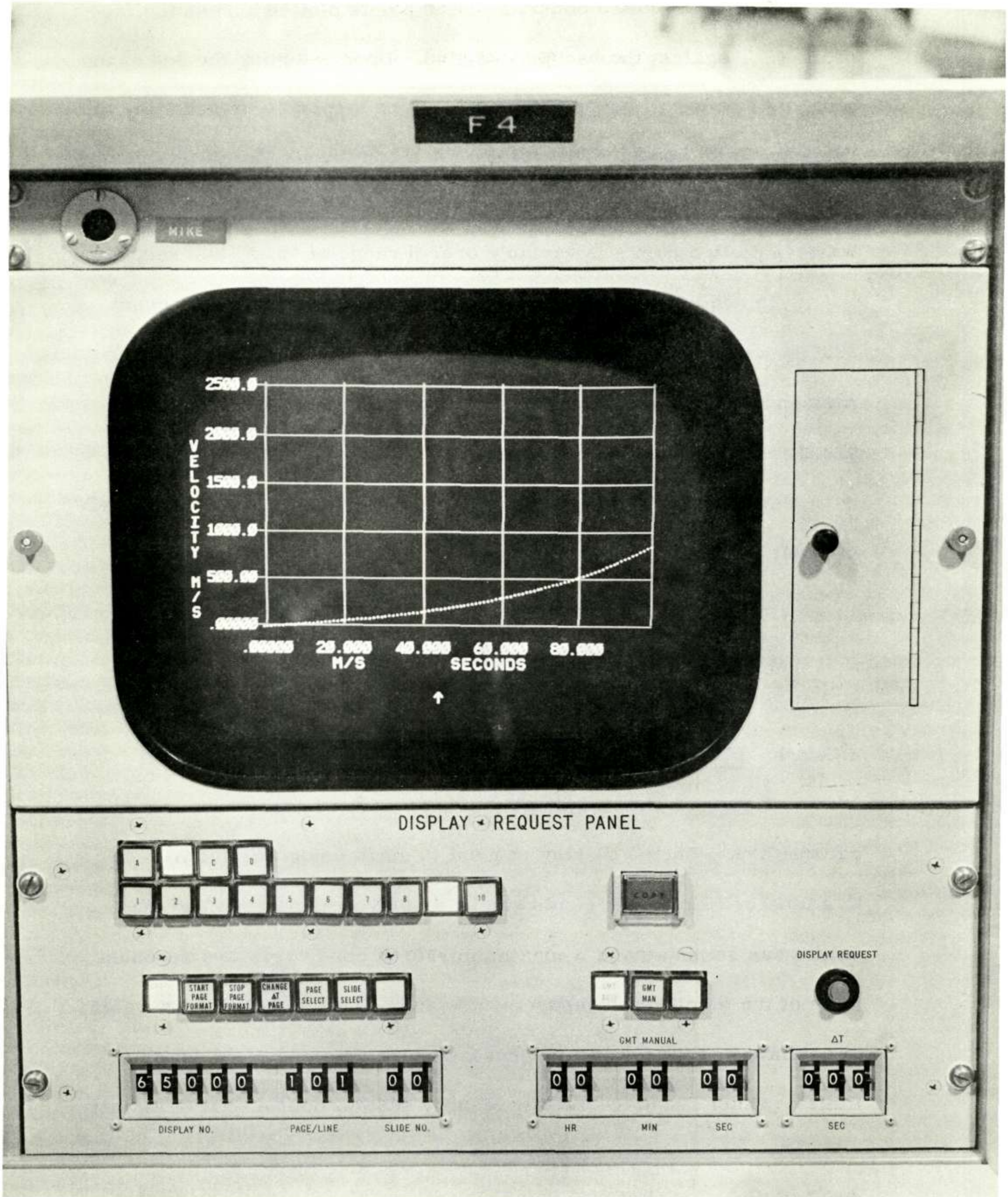

Figure 11. CRT Display of Analog Measurement

The data plotted consists of 150 points plotted across the face of the CRT against the background grid. Upon reaching the end of the grid, data acquired beyond this time can be displayed by selecting the "Shifting Grid" mode. This allows for a continuous plot of the measured parameter for as long a period as desired. The time increments between plotted points is variable over a range of 10 to 1000 seconds.

In addition to the display of real-time data, the most recent 3000 seconds of historical data can be retrieved from mass storage files and displayed.

4.2.2 Page Format

Alphanumeric display of requested parameters can be presented in several ways:

1. Predefined page
2. Operator-defined page, and
3. Out-of-limit check set page.

4.2.2.1 Predefined Page

Figure 12 shows a display of a predefined page of measured parameters. When a display request is made using this format, up to a total of 16 measurements can be displayed as a group and their values can be updated at a maximum rate of once every two seconds. Each of the displayed measurements can be flagged with a + or - sign to indicate when the measurement falls outside a specified set of limits. Other flags are used to identify special operational situations.

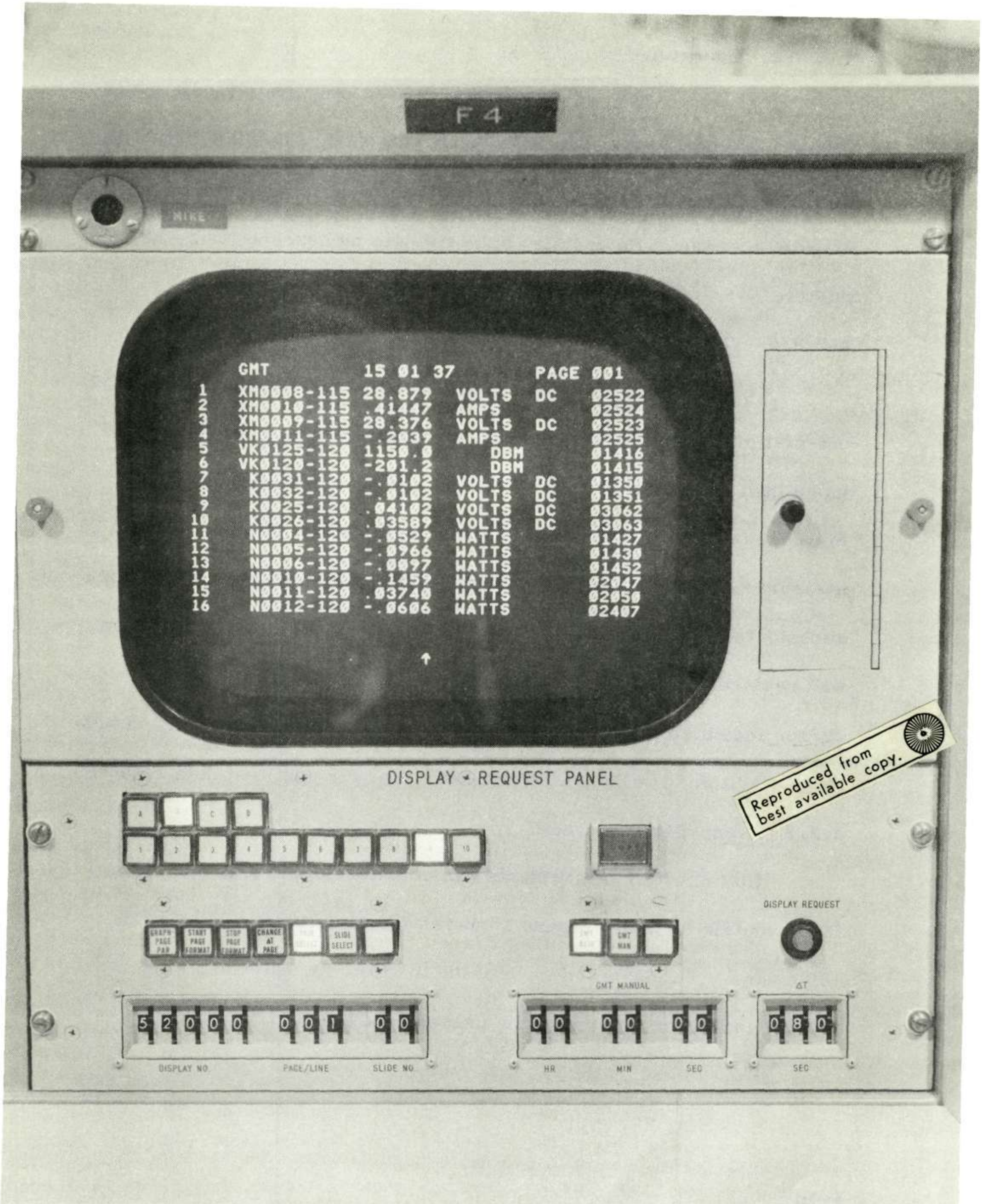

Figure 12. CRT Display of Analog Measurements in Page Format

4.2.2.2 Operator-Defined Page

The form of the operator-defined page is essentially the same as the predefined page except that up to 16 measurements can be called up individually and assembled as a page in the order desired by the console operator. He can also add or delete measurements as he desires.

4.2.2.3 Out-of-Limit-Check Set Page

This is a display of a predefined list of measurements on which out-of-limit conditions processing is performed on a group basis. If more than 16 measurements are in the group, each full page of 16 measurements will be stored for dynamic history. The most recent 15 measurements with out-of-limit conditions will be presented. As measurements in this group fall out of limits, the most current condition will replace the older condition on the CRT. A blank line rolling cursor indicates the most recent entry on the current page. All out-of-limit conditions are logged on magnetic tape for post test data reduction.

4.2.3 Event Matrix Format

Up to 2000 measurements can be selected and displayed in a 10x10 matrix format. Figure 13 shows the simultaneous display of 100 events. The status of each of the discrete measurements is symbolized in the display by the presence of either a "0" or a "1".

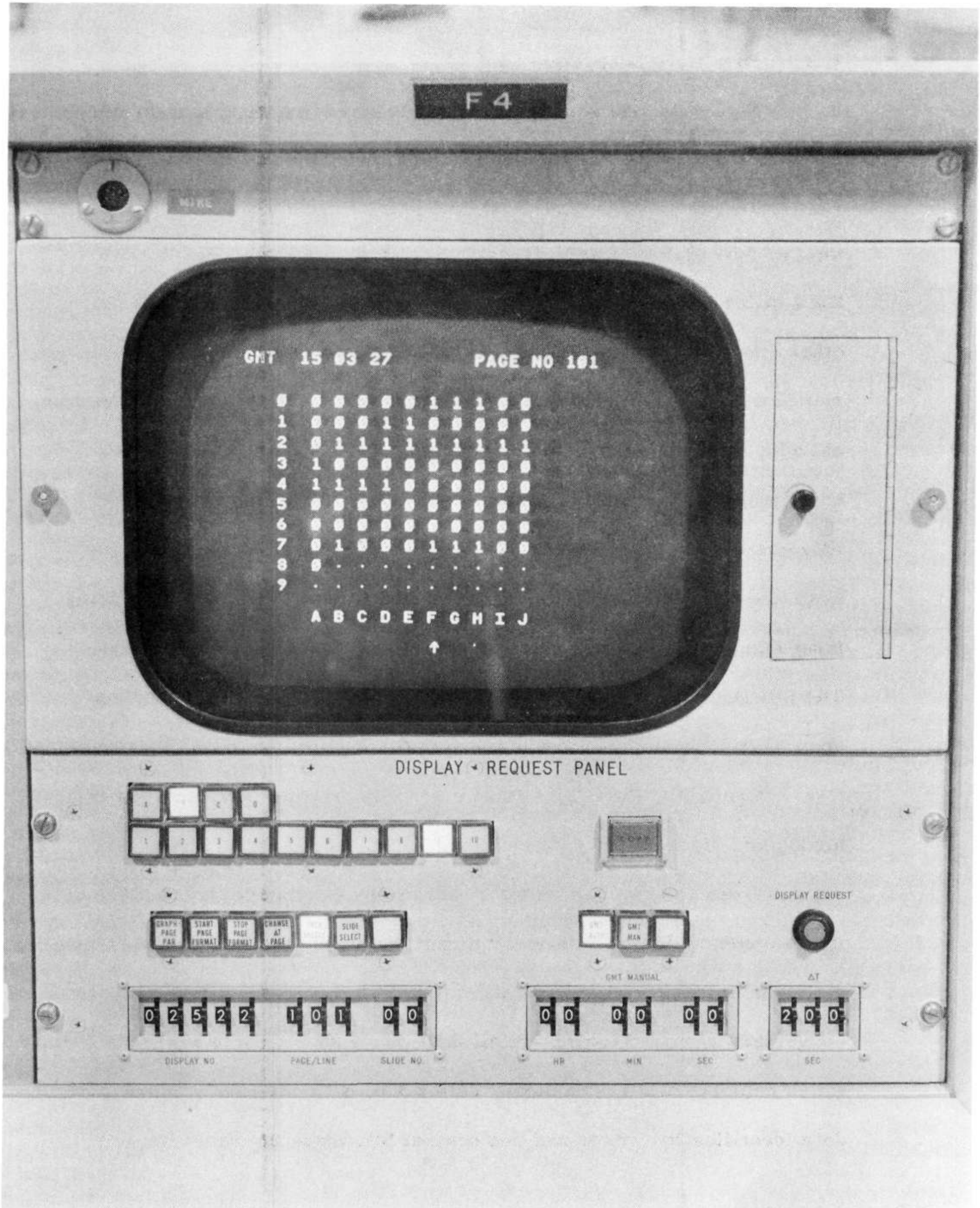

Figure 13. CRT Display of 10 X 10 Matrix of Descrete Measurements

4.3 Data Core Subsystem

Figure 14 is a photograph of the telemetry ground station and Data Core hardware. Figure 15 is a simplified block diagram of the Data Core subsystem. There are two pair of ground stations, for a total of four stations, each of which is based upon Data Core hardware. Each of the two stations making up a pair is virtually identical to the other, the operating philosophy being one of providing two redundant systems for a given support requirement when appropriate. Each station, called a "module", can simultaneously process (a) seven PCM links containing multilevel subcommutation, (b) two PCM links containing only one level of commutation, (c) twelve PAM or PDM links, (d) one GMT and one Countdown Timing input, and (e) up to two hundred analog input signals from FM subcarrier discriminators and other sources. The full Data Core capability is 7500-8000 measurements, depending upon multiple addressing requirements for supercommutated measurements.

Basically, Data Core is an electronic system that receives various analog and digital input data including PCM, PDM, PAM, and analog signals from a number of asynchronous sources and processes these data into a common digital format for direct use by high-speed digital computers, data transmission equipment, and quick-look data display devices. Data converters are used to convert all data into a 26-bit common digital format which consists of a 12-bit binary data word, a 13-bit binary address or data identification word, and one control bit, these 26-bit words are

Figure 14. Telemetry Ground Station - Including Data Core

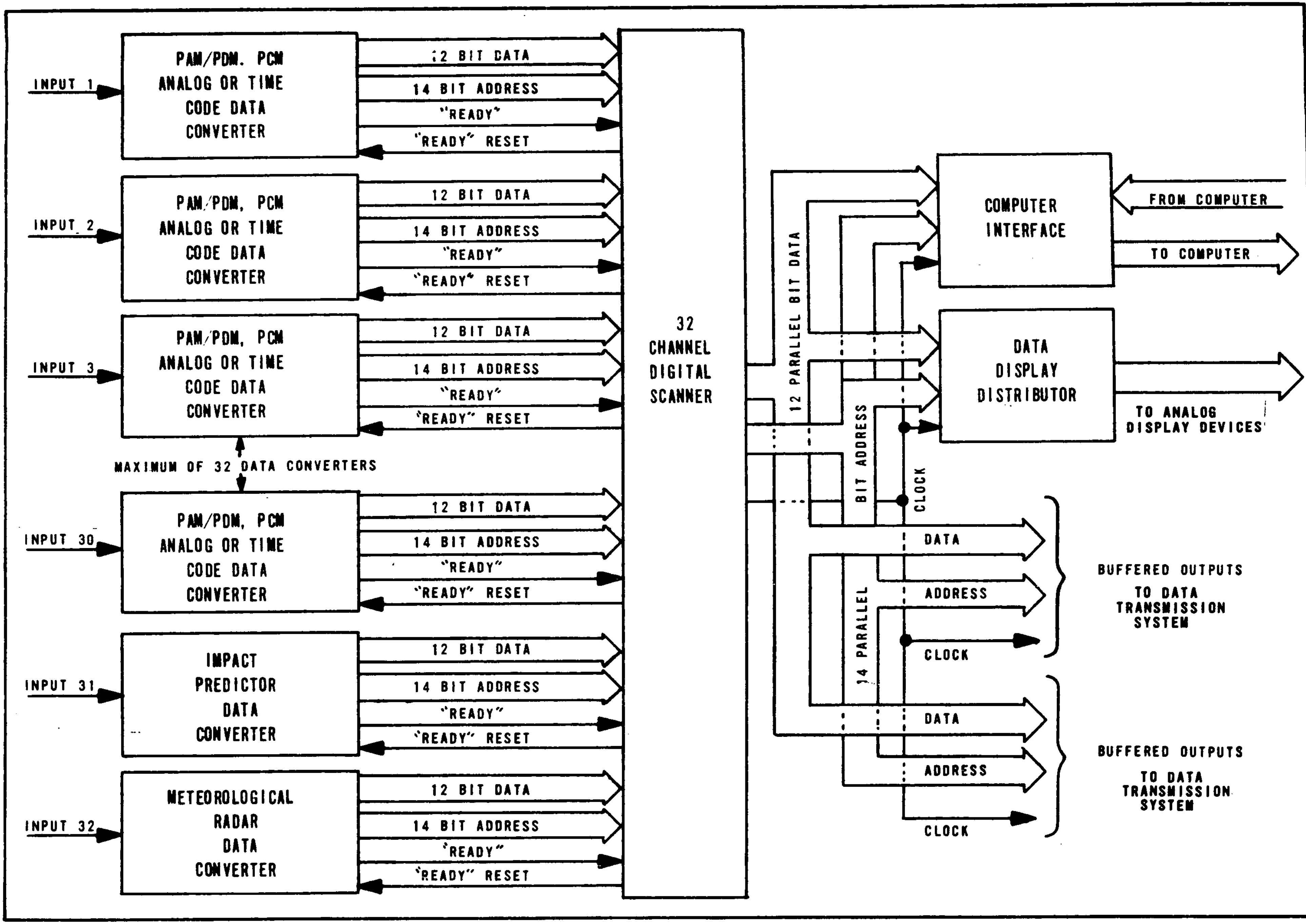

Figure 15. Data Core Subsystem Block Diagram

presented to a scanner or digital multiplexer along with a ready signal which signifies when data are available at a particular input. After the words are transferred through the scanner they are transmitted out in parallel to (a) the digital-to-analog conversion system, (b) the GE-635 computer interface and (c) two data selection and transmission systems.

The digital-to-analog system splits the 26-bit word into three parts. The 13-bit address portion is used to "look-up" a disposition instruction for the 12-bit data word portion. This instruction routes the data word to a specific digital-to-analog converter. The control bit portion of the 26-bit word is not used in the digital-to-analog conversion system. The analog outputs of the digital-to-analog converters may then drive various analog display devices. The available devices include Brush direct-write strip chart recorders (128 channels in each of two stations) and CES oscillograph recorders (160 channels in each of two stations).

Associated with the digital-to-analog system is a bilevel decommutation system having the capability of making available up to thirty-two event words for display on strip chart event recorders (100 channels in each of two stations).

The computer interface consists of three separate memories. The first is a 16, 384-word memory in which data words are stored. The storage location is specified by the address portion of the 26-bit word. The control bit is used to determine whether the data are stored in the upper or lower field of the memory to provide a "double buffer" feature. This "double buffering" allows computer access to the previous data cycle while a new data cycle is being updated in memory. The other two memories are used to generate interrupt signals to the computer Real Time Input/Output Controller, to store the starting location in memory of each data block for internal housekeeping purposes, and to store the GMT time tags associated with the end of each cycle of input data.

The 26-bit words from the scanner are also available to two real - time selection and transmission systems. These are the Launch Information Exchange Facility (LIEF) and Apollo Launch Data System (ALDS). The LIEF system interface equipment prepares and transmits data to Marshall Space Flight Center (MSFC), Huntsville, at the rate of 40.8 kb/s. The data request messages from Huntsville to KSC are at the rate of 2.4 kb/s. The 40.8 kb/s data are further processed by computers at MSFC and are used to drive plotters, meters, status displays, and CRT plots at that Center. The ALDS selects, processes, and formats data using two SDS 930 computers at the CIF and transmits information to MSC (Houston) at the rate of 40.8 kb/s, where it is further processed and used to drive real-time display equipment at the Mission Control Center (MCC).

In two of the stations, the scanner outputs are available to the Data Bus System. The Data Bus is a system by which all of the data available in the Data Core scanner may be reformatted into a 7 megabit per second serial PCM stream, remoted to the user site over a wideband

"TV grade" transmission line, and decommutated at the user site to drive user displays. The 26-bit Data Core output words are present in the Data Bus output, so that each data word is uniquely identified by its 13-bit address tag.

A scanner output is also available to the Data Compaction System. The Data Compaction System is a programmable device which can monitor pre-selected data words, detect changes in value over a pre-selected tolerance, and insert back into the scanner flag words with certain dedicated address tags. These flag words and address tags are full 26-bit Data Core words which are then available to the GE-635 computers. These flag words transmit information to the GE-635 processor software as to which, and how many, data words have changed their value by sufficient magnitude to represent new data values to be processed. This compaction system can be used with any station to reduce the amount of reduction time devoted to non-changing, redundant data values.

4.4 Computer Subsystem

The computer subsystem of the overall TDDS consists of two GE-635 computers. Figure 16 is a photograph of the equipment. These computers are also used for general-purpose scientific, time and sharing, and other non-real-time data processing applications, but only the real-time operational support and real-time display applications of these computers will be covered here. The additional modes of operation are briefly discussed in the appendix to this document. Figure 17 shows the relation of the computer subsystem to the Data Core and display subsystems. The symmetrical dual configuration of computers and all other subsystems makes possible the support of simultaneous tests as well as a backup capability through the cross-switching arrangement shown in the illustration.

For the purpose of our explanation here, the bottom half of Figure 17 is not considered part of the TDDS. That equipment is used to acquire, select, and format data from Data Core for transmission to MSFC, GSFC, and MSC where it is further processed for display at those facilities.

In real-time operation, the computer processes telemetry information received from Data Core, formats it, and outputs the processed information to the display subsystem in response to display request messages. The computer also converts processed data into

Figure 16. GE-635 Computer Subsystem

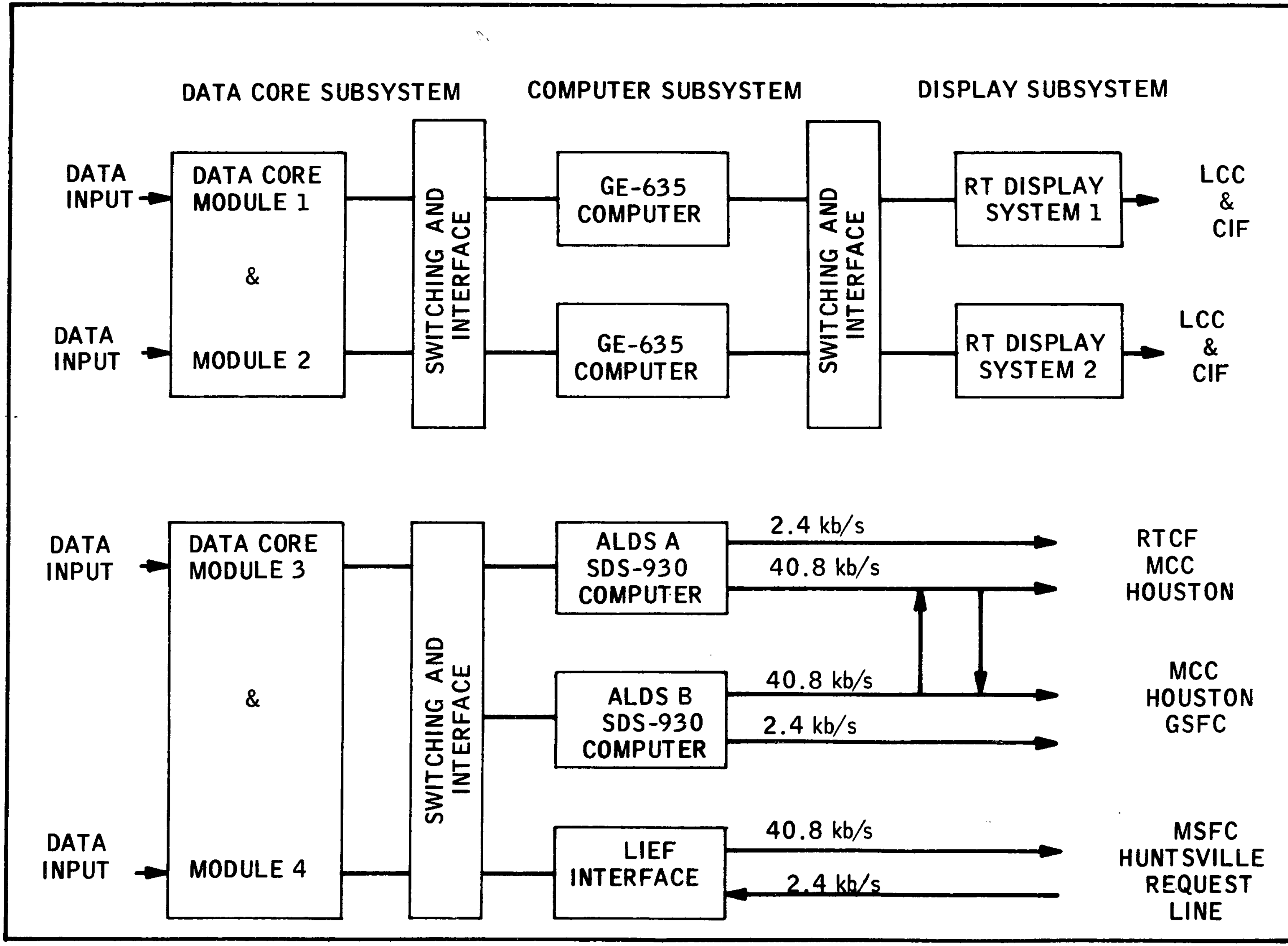

Figure 17. Television Data Display System
(The upper half of this figure constitutes the System described in this document)

engineering units and provides real-time print-outs and magnetic tape recordings. Simultaneously with these computations other real-time operational support is performed, such as computing guidance parameters and vehicle bending moments.

SECTION 5

COMPUTER PROGRAMS

The current operating system for the GE-635 computer is GECOS III. A special executive module GSEC becomes part of this operating system for the real time mode of operation. Subservient to GSEC is the "Saturn Mission Program," which directs the activity of the TDDS. The mission program is designed to capture up to 32 data blocks of information from Data Core; however, the total number of measurements must not exceed 5000. The program can accept display requests for X-Y plots, event matrix, operator defined page and predefined page formats. Data received from Data Core are examined by the Saturn Mission Program's Out-of-Limits Condition Module, and out-of-limits conditions can be made available for display in any of the formats described in this document. Out-of-Limits Conditions processing are determined by comparing the data with predefined pairs of limits assigned to each measurement. If no limits are specified for a measurement, one pair of limits is assigned near the lower and upper limits of the instrument involved. All out-of-limit conditions, defined by the limit pairs, are logged on magnetic tape for use in post test data reduction.

The Saturn Mission Program can capture data and update it at the maximum rate of 12 samples per second. This data can also be recorded on magnetic tape with optional rates of 1, 2, 4, or 12 times per second.

Disk files are used as mass storage devices to store measurement histories. The program has the capability to retrieve up to 3000 seconds of historical data from mass storage and process it for display at the monitoring stations when requested.

All systems programs are stored in disk files and on magnetic drums. These programs are available for use upon demand.

SECTION 6

COMPUTER HARDWARE

Figure 18 shows the equipment configuration for the GE-635 computer subsystem. The GE-635 is a third-generation, general-purpose, large scale digital computer with multiprocessing and multi-programming capabilities. Each GE-635 consists of 224 thousand 36-bit words with one-microsecond core memory, a processor, an I/O Controller (IOC) which services the consoles, card readers and punches, magnetic tapes, drums, and disk files. Each computer has two 4.7 million character drums for the storage of systems programs and use as scratch memory. Each computer has five 15 million character disk files; 16 tape handlers; one real-time input-output controller (RTIOC), and two interface adapters.

RTIOC is the basic computer module which acts as a real-time interface to the external systems, such as, Data Core and display subsystems.

The actual interface between the Data Core subsystem and the RTIOC is provided by the Data Core adapter. The Data Core adapter provides signal line interfacing, a 12-bit character-to-computer-word assembly, Data Core to computer synchronization, and memory addressing for the computer and Data Core. The nominal data rate for the interface is 36 thousand 12-bit characters per second. The peak data rate

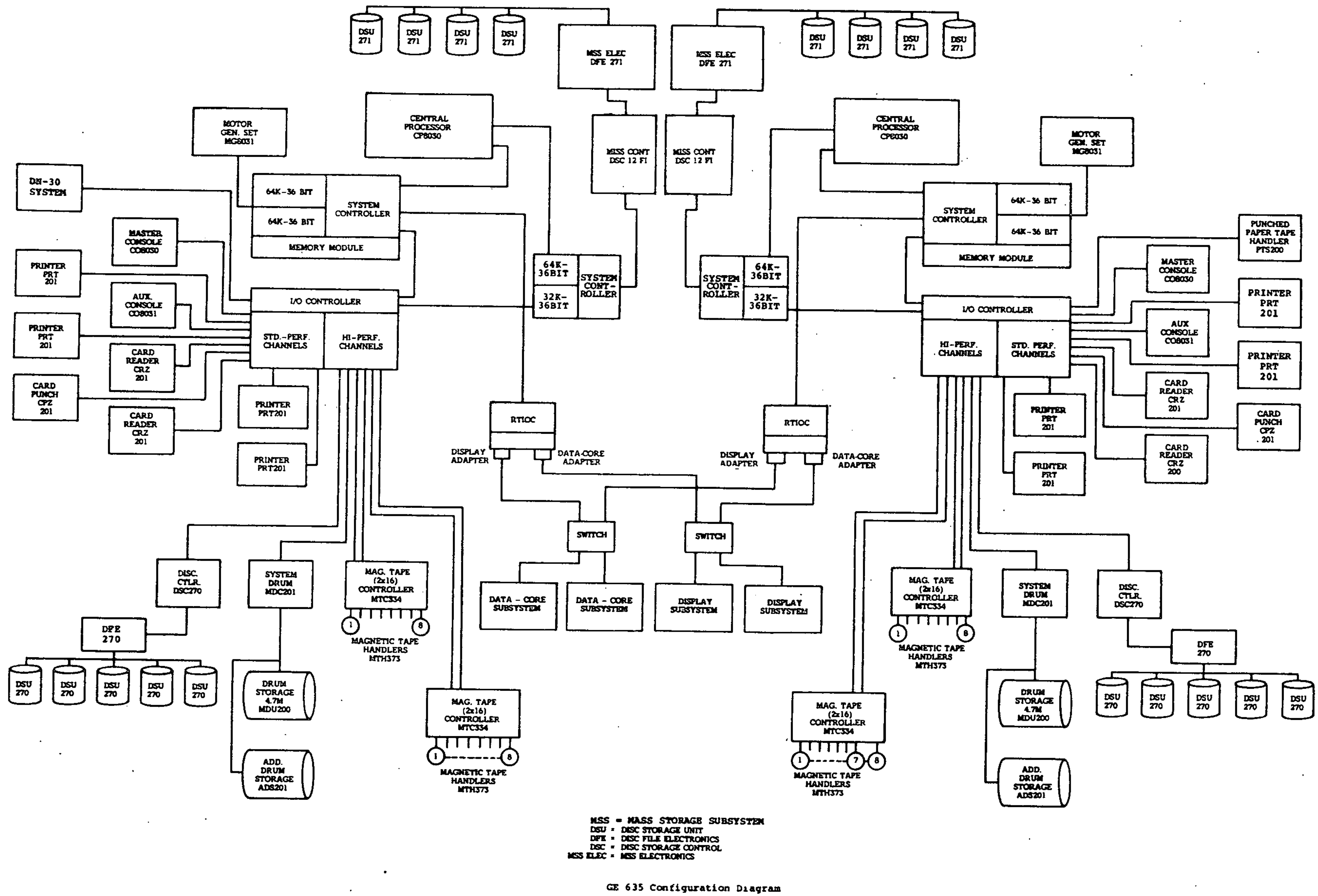

Figure 18. GE-635 Computer Subsystem Configuration

is reduced from 250,000 to 83,333 transfers per second when 12-bit characters are packed into a 36-bit word assembly register.

The interface between the real-time display subsystem and the computer's RTIOC is provided by the display-adapter. This display adapter provides signal line interfacing, display request message formatting, display data message formatting, and interface synchronization between the data display subsystem and the computing subsystem. The peak data rate from the data display subsystem to the computing subsystem and from the computing subsystem to the data display subsystem will not exceed 150 thousand 36-bit words per second. Two RTIOC channels are required to service the data display subsystem. One channel handles the data requests from the display units. These requests include the following basic information: (a) the identification of the unit requesting the display; (b) the time period of desired measurements, and (c) the desired measurements. The second channel transfers the display information from the computing subsystem to the display bus, which includes the following: character, position, size, and display unit. The two channels operate asynchronously, and display requests do not interfere with the data being transmitted to the display bus. Display requests may be stacked up and serviced in a predetermined priority which is under program control.

SECTION 7

ADAPTABILITY

The TDDS has been used to support prelaunch tests and launches of the Saturn IB, Saturn V, Gemini, Centaur, and Delta vehicles. The system possesses an inherent capability to support future programs such as experiments checkout and checkout of the space shuttle.

The design philosophy and high degree of flexibility built into the system made it possible to support these space programs with only changes in computer programs and essentially no hardware modifications, except for the graceful growth of the system by the addition of standard units. The Data Core and display subsystems are also programmable and can be adapted easily to new and changing requirements.

System flexibility is enhanced by the multiprogramming feature of the GE-635 computers which can operate with a multitude of independent programs. With the existing computer configuration, the system has operated successfully in the multiprogramming mode with seventeen independent programs.

The display subsystem is basically a digital system with the digital output being converted to standard TV 525-line video format. This feature allows flexibility in the distribution of the display signals with low cost hardware and yet has the inherent advantages of a digital system.

The standardizing of the Data Core output to a 26-bit word format eliminates computer and display system hardware interface problems when new test requirements arise or as existing requirements are changed. In a broad sense, the TDDS is hardware independent of the system under test.

APPENDIX

The basic document shows how the Display, Data Core, and Computer subsystems are integrated to form the TDDS. Emphasis was placed on the application of the GE-635 computers for this purpose. This Appendix is included to show applications other than the real-time display mode covered in the basic document.

Playback Mode

During real-time tests and launches, telemetry video data are recorded on magnetic tape. When it is desired to reconstruct an actual mission or test for evaluation purposes or to provide training for operators, the tape can be played back into Data Core and then data displayed as if the actual mission was again taking place.

Real-Time and Batch Mode

The GE-635 systems, with their multiprogramming capabilities, can provide the necessary computations for the TDDS and perform ordinary batch type data processing concurrently.

Batch Mode

When operating in this mode, the computers process scientific and administrative type work. The system operates in a multiprogramming environment and it can be considered to be a general-purpose computer.

Time-Sharing Mode

The GE-635 computers in conjunction with the Datanet 30 service remote time-sharing terminals located throughout the Kennedy Space Center. Time sharing can be performed alone or with any of the other modes described above.

Summary of Applications

A brief description of the type of work performed on the GE-635 computers is summarized below:

Prelaunch

Acquisition Angles for Tracking System
Safety Curve Plotting
Coordinate Transformation
Compute Doppler Frequencies
Compute Wind Shear
Acoustical Computations

Real Time

Capture Meteorological Data
Special ETR IP Data
Vehicle Telemetry Data
Guidance Data
Preflight Simulation
Data Communications
Compute Display Parameters
Prelaunch Checkout (Booster & Spacecraft)

Quick Look

Telemetry - (Engineering Units - 4020 Plots)
Reduce Computer Guidance Data
Calculate Weather Data
Orbital Elements
IP Data
Ground & Environmental Reduction
Format Engineering Units for Transmittal to MSFC (LIEF)

Commercial

General ADP
Management Information Retrieval

Time Sharing

General Computing Support to all organizational elements of KSC

Display Subsystem

In the basic document, only the display of computer processed data was emphasized and covered in detail. The display subsystem also has the capability of selecting and displaying analog and event data on strip charts. This analog system can be programmed to select and group measurements for display on strip recorders located in the CIF.