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NASA-CR-167637

2. A FUNCTIONAL VIDEO-BASED ANTHROPOMETRIC MEASURING SYSTEM

3. By: J. H. Nixon
J. P. Cater

Final Report
for
5 Contract NAS9-16158
7. SwRI Project 16-6141

Prepared for

NASA Lyndon B. Johnson Space Center
Houston, TX 77058

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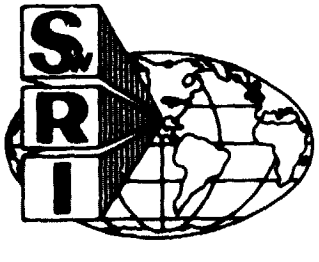

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I. INTRODUCTION

A. Purpose of the Program

The purpose of this program was to design, construct, and test a high-speed anthropometric measurement system using the Selcom Selspot motion tracking instrument for visual data acquisition. A three-dimensional scanning system was created which collects video, audio, and performance data on a single standard video cassette recorder. Recording rates of 1 megabit per second for periods of up to two hours are possible with the system design.

B. Video Anthropometric Measurements

1. Background

This is SwRI's third NASA contract dealing with the subject of video anthropometric measurements. The contracts have progressed in a logical sequence of development from an original single-camera two-dimensional system developed under NASA Contract NAS9-15038. This system used a single camera to automatically perform measurements on human link angle flexibility ranges, normally measured with mechanical goniometers or protractor-like devices. The success of the initial two-dimensional video measurement system prompted the second research contract, NAS9-15568, which developed a three-television camera video anthropometric system. The three-dimensional data acquisition system which was supplied to NASA at the termination of that contract, uses a microprocessor-based video data collection system in conjunction with off-line computer processing to provide automated measurements of body segment position, force, velocity, and acceleration. The configuration for the three-television camera system is shown in

Figure 1. The total components required for acquisition of data are the three cameras, the anthropometric measurement system, and the video monitor. Measurement of positional data occurs in the video image by temporal dissection of the video frame. The measured two-dimensional coordinate data from each camera is formatted by the internal microprocessor in the anthropometric measurement system (AMS) and simultaneously recorded on a small internal micro-cassette. The data is also sent via RS-232 to an on-line computer for post-processing of data.

At the conclusion of a test, the on-line computer is tasked to compute the range of motion sphere and generate intersecting parallel horizontal planes. An example of the type of output data generated by the Fortran program utilized in this test is shown in Figure 2.

The current stage of evolution in automatic three-dimensional anthropometric measurement systems is the prototype system described herein. The system developed under the subject contract utilizes a high-speed off-the-shelf motion analysis system for collecting optical information. The use of a Selcom "Selspot" system for data acquisition was a contractual requirement based upon its unique performance parameters and commercial off-the-shelf availability. Interfaced to the Selspot system is the SwRI developed Video Recording Adapter (VRA). This prototype recording system is the first of its kind and represents a landmark in anthropometric data recording. The combined systems give the anthropometrist a portable measurement tool with performance capabilities, which were previously nonexistent.

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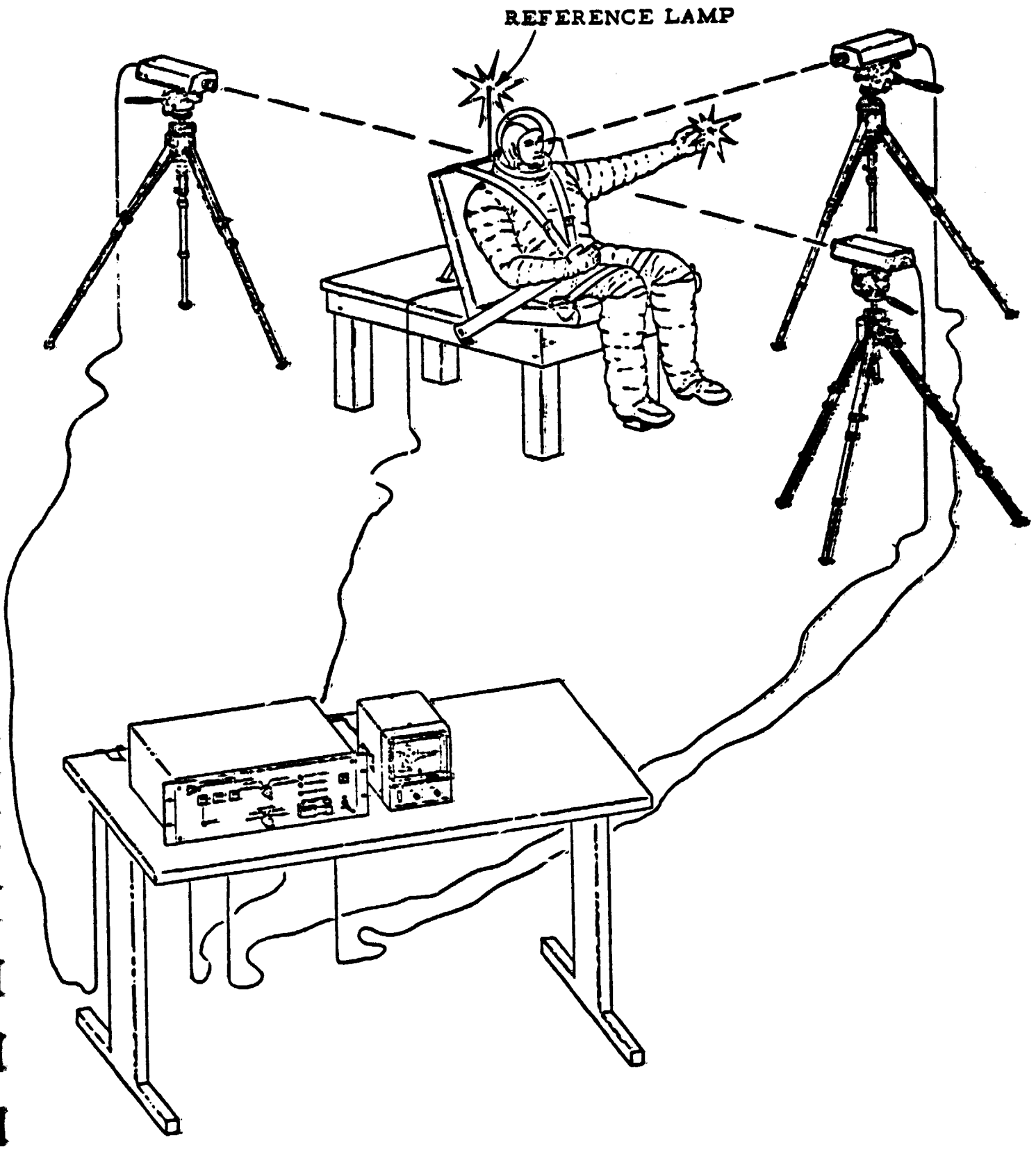

Figure 1. THREE-DIMENSIONAL ANTHROPOMETRIC MEASUREMENT SYSTEM

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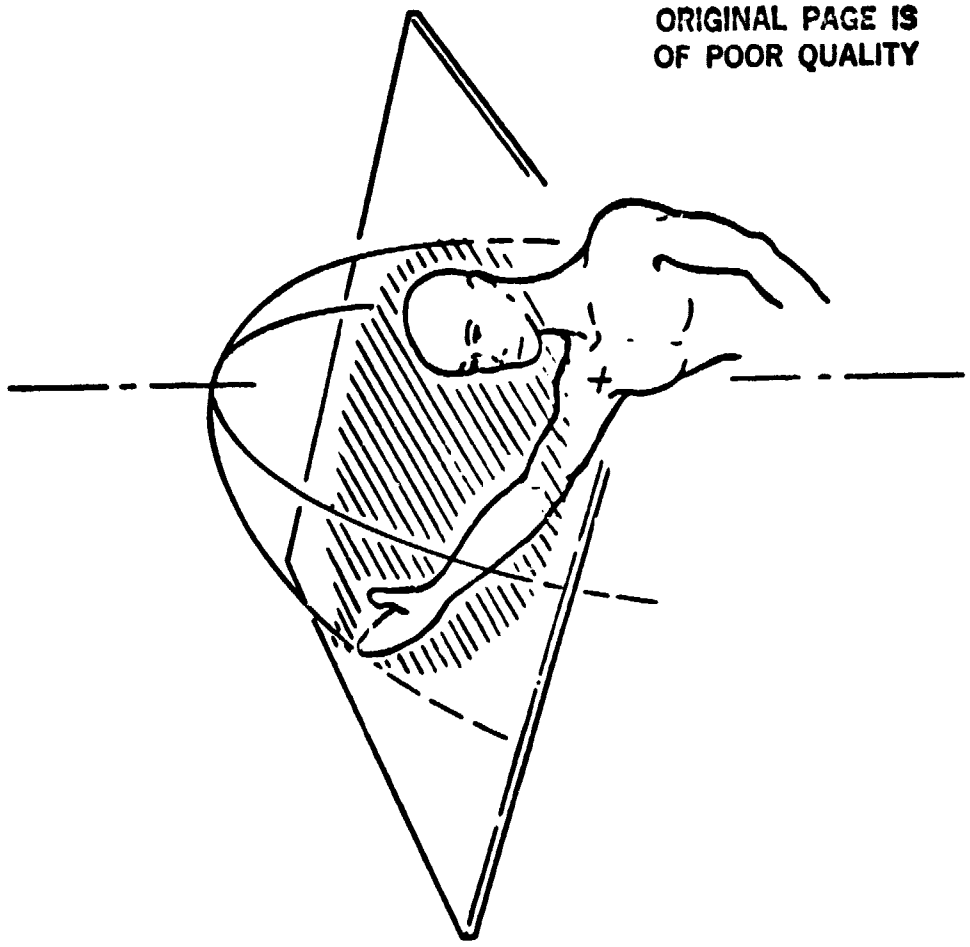

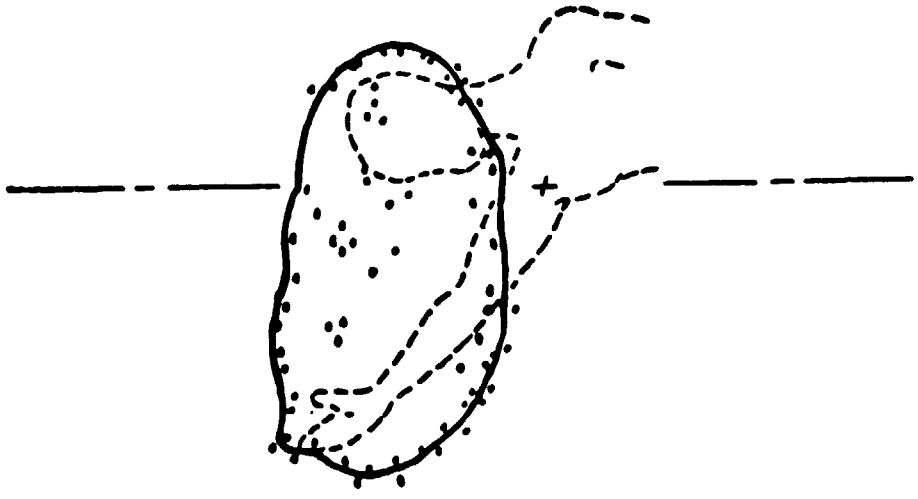

Figure 2. INTERSECTING PLANE SHAPE

2. The Video Recording Adapter System

The Video Recording Adapter (VRA) was developed by SwRI as part of the subject program for the purpose of recording and retrieving anthropometric data using a standard video cassette tape recorder. Positional data from up to 30 light emitting diodes is measured and digitized using the Selcom Selspot instrument with an accuracy of 1 part in 1024. The Selspot system controls the time division multiplexing among LEDs and, through the use of four special purpose cameras, measures the relative position of the LEDs with respect to each camera. This coordinate information is then digitized and made available to the VRA through ports on the front panel of the Selspot instrument.

The VRA system, shown in Figure 3 with the Selspot equipment, converts the digital data from the Selspot instrument to a format which is compatible with its internal microprocessor bus. This data along with digitized data from an analog input channel (Cybex force data), and experiment logging information such as elapsed time, experiment title, etc., are then encoded and stored on video tape. The composite video data is also available for transfer over a standard general purpose interface bus (IEEE-488 Standard) to a large computer for analysis. This system provides great flexibility, allowing either direct on-line computer analysis or archiving of large amounts of anthropometric data on standard video cassettes.

The VRA provides the operator with a mode for verification of the recorded video cassette, allowing him to check the recorded data integrity and insure that the events were recorded properly. In the verification mode, as the video tape is played back,

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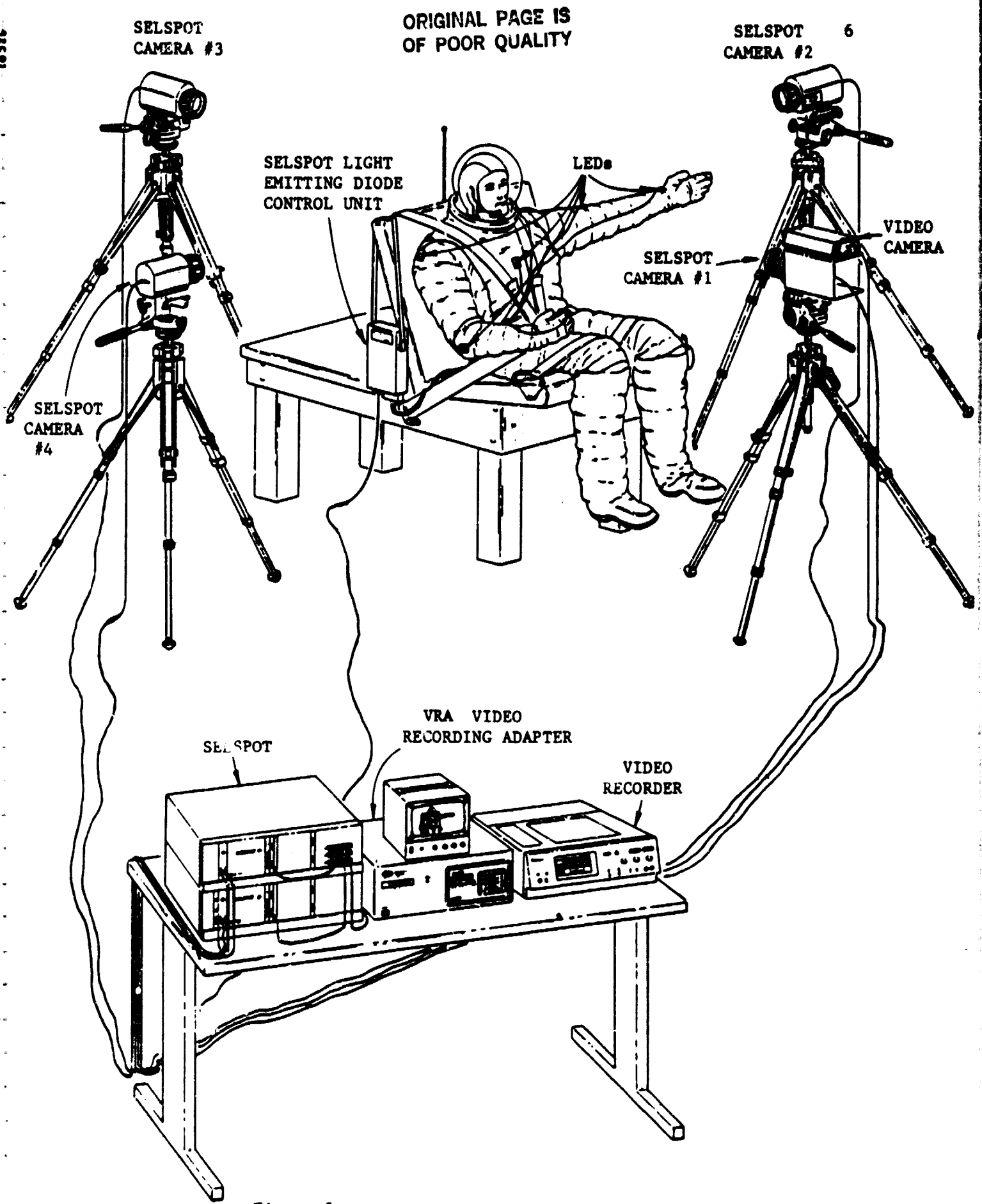

Figure 3. ANTHROPOMETRIC MEASUREMENT SYSTEM SETUP

anthropometric data and experiment parameters are retrieved from the video signal. From this data, information such as the start time, date of the experiment, elapsed time into the experiment, and title of the test are obtained and decoded. The decoded information is then superimposed on the prerecorded television picture of the experiment.

The VRA also has the capability of verifying any of the recorded LEDs by superimposing a cursor on the television display over the selected LED. The three-dimensional coordinates of the selected LED are also computed and displayed as a numeric overlay on the visual scene.

During playback, video tape data recovery and transfer to the computer is accomplished by the VRA. The PLAYBACK TO GPIB mode decodes the prerecorded data on the video cassette and transfers this data over the general purpose interface bus (GPIB) to any computer with an appropriate interface and driving software. In the event that the GPIB data transfer rate overflows the remote computer's input capability, a data overflow indicator on the front panel of the VRA indicates the condition.

Before experiment data can be recorded, the optical iris of each of the four Selspot cameras must be adjusted for camera-to-average LED distance and the particular experiment ambient illumination. An ALIGNMENT mode provides verification that all the cameras can "see" the desired LEDs and a capability for aligning the television camera with Selspot camera No. 1. This mode graphically displays the over-range or under-range status of all the cameras for each LED. It also provides an overlay cursor for LED #1 on the television picture as seen by Selspot camera No. 1.

The VRA has an internal realtime clock with power-off date and timekeeping capability. The time-of-day clock can be displayed or set using the front panel keyboard on the VRA, or through the use of an external RS-232 port on the rear panel of the VRA. The baud rate on the external RS-232 serial port can be set using the front panel keyboard on the VRA. The baud rate is selectable from 110 to 9600 baud.

II. EXECUTIVE SUMMARY

A. Dual Microprocessor Video Recording Adapter System

The system design of the 4-camera photo-electric anthropometric system, shown in Figure 3, is quite complex because of the required high speed operation. Using two R6502 microprocessors (the same used in the previous NASA contracts), the video recording system interfaces to a custom Selspot optical data acquisition system and records the digitized positional data of up to 30 light-emitting diodes along with a composite video image of the experimental tests. The development of the video recording adapter (VRA) was prerequisite to the anthropometric measuring system integration and test. Therefore, the task 1 goal was to design, fabricate and test a microprocessor based control unit for recording GPIB data onto standard video tape cassettes and replaying the data as with a standard digital tape recorder. The second phase of the contract (or task 2) centered on the integration of the VRA with a custom 4-camera Selspot optical data acquisition system. This task of the contract produced an expanded version of the original recording system with the ability to record not only GPIB data, but also a complex array of positional parameters and target identifications from a high speed optical data acquisition system. In addition to the recording capability, the expanded VRA contains the capability of direct real-time GPIB interfacing, the playback of positional data to the GPIB, the recording of calibration positional information, and the real-time three-dimensional positional calculation and display of prerecorded data.

In order to accomplish the tasks set forth in the contract under

real-time conditions, the system was designed with dual microprocessors which share memory in a multiprocessing mode. To handle the one megabit per second recording rate required in the video recorder, one microprocessor operates at a clock rate of 2 megahertz while the second operates at one megahertz. The effective cycle times for the two microprocessors are 500 nanoseconds and 1 microsecond respectively.

Whereas in the previous contract, a single internal microprocessor commanded the acquisition of optical information from the three-camera video system, the optically measured positional information from the Selspot system is transferred into the VRA internal memory with the first microprocessor and then recorded on the video tape immediately following the vertical synch interval via the second high speed microprocessor.

The functions of the video recording adapter during experiment data acquisition are as follows:

(1) The microprocessor pair synchronizes with the data train from the Selspot's system and converts the positional and target information for subsequent video storage.

(2) The system remotely controls the activation of the record and playback controls on the video tape recorder, thus preventing operator error in the selection of operating modes.

(3) The VRA provides an alignment mode which allows the operator to adjust the iris of each of the 4 photo-electric cameras for proper data collection. It also provides a method of aligning the single

video camera with the appropriate data collection camera for off-line data verification.

(4) The video recording adapter digitizes the Cybex dynamometer force measurement, displays the normalized value of force in pounds on the front panel, and simultaneously records the information imbedded into the digital positional information.

(5) The dual microprocessors allow the selection of variable recording data rates based upon the number of target LEDs selected for data acquisition. This feature allows the user to select a compromise between the number of targets recorded and the ultimate speed of data acquisition.

(6) The video recording adapter provides appropriate operator interaction to either the front panel alphanumeric keyboard or an external RS-232 terminal or computer port for remote activation of all internal functions.

(7) On data playback, the microprocessor system provides operator verification of calibration and data acquisition by giving the operator numerical and graphical indications of the positions of the desired targets. This feature also allows the system to be used as a standalone three-dimensional optical data acquisition system. In addition to the real-time playback application, the video recorder can be placed in the variable speed playback mode and the data examined either frame by frame, or at an exagerated high speed rate.

B. Video Recorder Modifications

The video cassette recorder utilized with the video recorder adapter is a standard commercially available half-inch video cassette recorder (VCR). In addition to the video recording channel, the recorder offers dual audio channels for recording up to 2 channels of audio commentary or simultaneous stereo audio channels.

There have been no internal modifications made to the VCR in order to work with the video recording adapter. The only modification made to the recorder system was the addition of a cable connector on the remote control cable so that the recording adapter could automatically select the proper recording or playback mode during operation.

The VCR which is a standard Panasonic MV-6000 uses VHS video cassettes which may be purchased in any local video store. Current availability for recording length is one hour and two hours. The recorder is completely solenoid controlled, thus preventing loss of data through operator error.

C. Selspot Interface Module

The Selspot system (manufactured by Selcom in Sweden) is a custom four-camera opto-electronic positional measurement instrument. The system was purchased with a standard TTL interface rather than a specific computer compatible port. In order to correctly interface the Selspot system with the video recording adapter, an electronic interface unit was constructed and mounted directly within the Selspot measuring system.

The purpose of the video recording adapter interface (VRAI) is to synchronize the output of the Selspot system with the video recording

rate of the VRA. In addition to data synchronization, there is also signal buffering provided to allow a connecting cable length of up to three feet. Although the VRAI does not contain a microprocessor, the internal operation of the interface is highly dependent on the data collection microprocessor within the VRA. The VRAI has been designed to interface only with the video recording adapter and will not be compatible with any other computer system. Although other computer interface units can be purchased from Selspot, the VRAI is custom designed for recording positional digital information on video tape.

D. Test Fixture Construction

As with the previous three-dimensional system, this unit requires a positional and dimensional calibration before data acquisition begins. SwRI's experience in video anthropometry has shown that a simple three-dimensional "cube" can provide adequate calibration for dimensional data. The calibration fixture supplied with the current unit employs alligator clips to hold the first four numeric order light-emitting diodes in the Selspot target array. This calibration fixture shown in Figure 4 should be placed at the center line of the four orthogonal cameras during the calibration mode execution. Operator interaction (other than the simple calibration setup) is supplemented by the intelligence within the microprocessor system. The development of this calibration test fixture provides for very simple experiment setup and ease of calibration data acquisition.

E. System Software Development

The internal software which has been developed for the video recording adapter operation is quite extensive and complex. A manual including the source code listing of the operating software is

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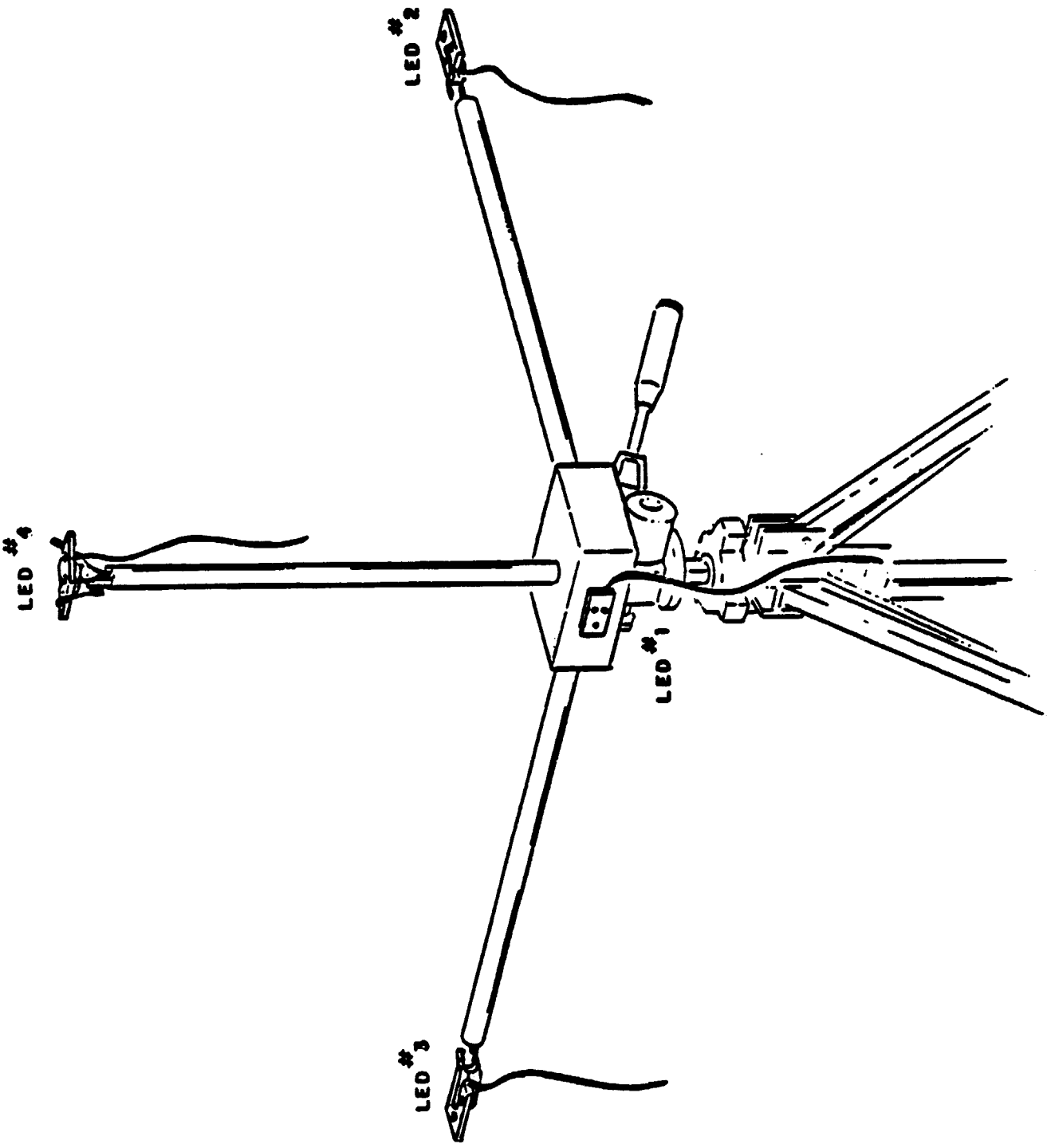

Figure 4. CALIBRATION TEST FIXTURE

submitted under a separate cover entitled DRD #OM-123T. This listing provides a comprehensive documented listing of the internal software used within the optical recording system.

F. HPIB (GPIB) Service Software Development

In order to test the HPIB interface characteristics of the video recording adapter, SwRI designed and developed a Hewlett Packard Interface Bus service program for the HP9825 desktop computer. The software listing of this program which has been demonstrated to NASA technical representatives is included with the contract deliverables. It may be used as a guideline for implementing further data collection programs on mainframe computers utilizing the HPIB interface bus.

III. TECHNICAL DISCUSSION

A. Hardware Design and Implementation

The main function of the video recording adapter is the storage and retrieval of anthropometric data using a video tape recorder. Other features include verification of prerecorded data, IEEE-488 data I/O and various recording and data playback configurations.
The block diagram in Figure 5 shows the various components of the video recording adapter and anthropometric measuring system.

1. The Selspot Instrument

The Selspot instrumentation is comprised of a control unit, four special photoelectric cameras, up to 30 Light Emitting Diodes (LEDs) and a special LED sequencer as shown in Figure 6. The functions of the Selspot system are the time-sequenced multiplexing of the LEDs and conversion of the electrical signals from the four data cameras into positional information about the LEDs.

Each camera contains a photo sensitive surface upon which the experiment image is focused. An infrared filter allows only the wave length of light emitted by the sequenced LEDs to be focused on the sensitive area. This assures that ambient light has minimal effect on system accuracy. By measuring the vector currents in the photo sensitive wafer caused by the LEDs, and properly scaling these values, the position of each LED being viewed can be determined. This coordinate information is digitized and then output in a parallel bit/ serial word form through connectors on the front panel of the Selspot main unit.

The method used by the Selspot instrument to monitor the position of more than one LED is called time division multiplexing:

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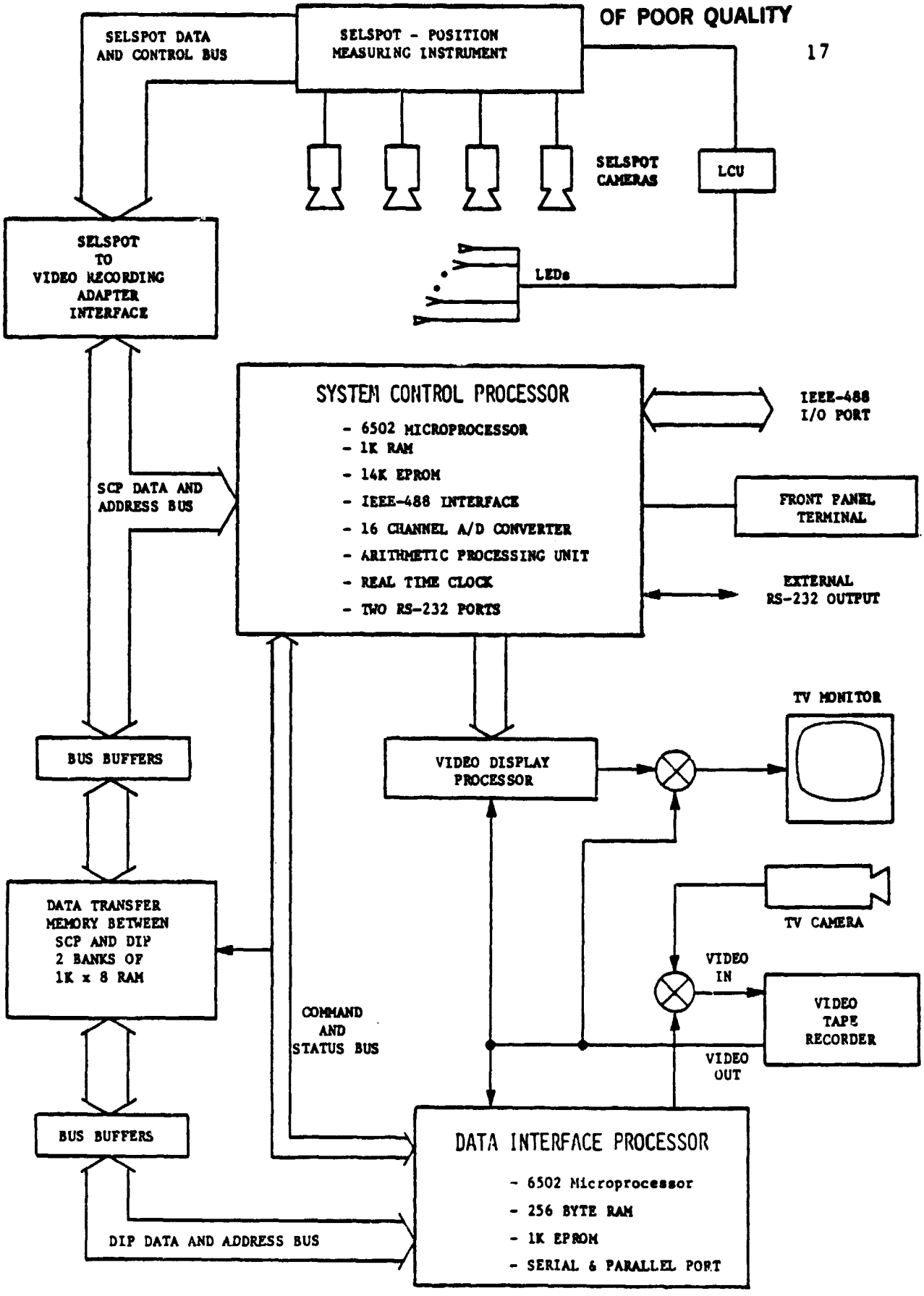

Figure 5

THE VRA SYSTEM BLOCK DIAGRAM

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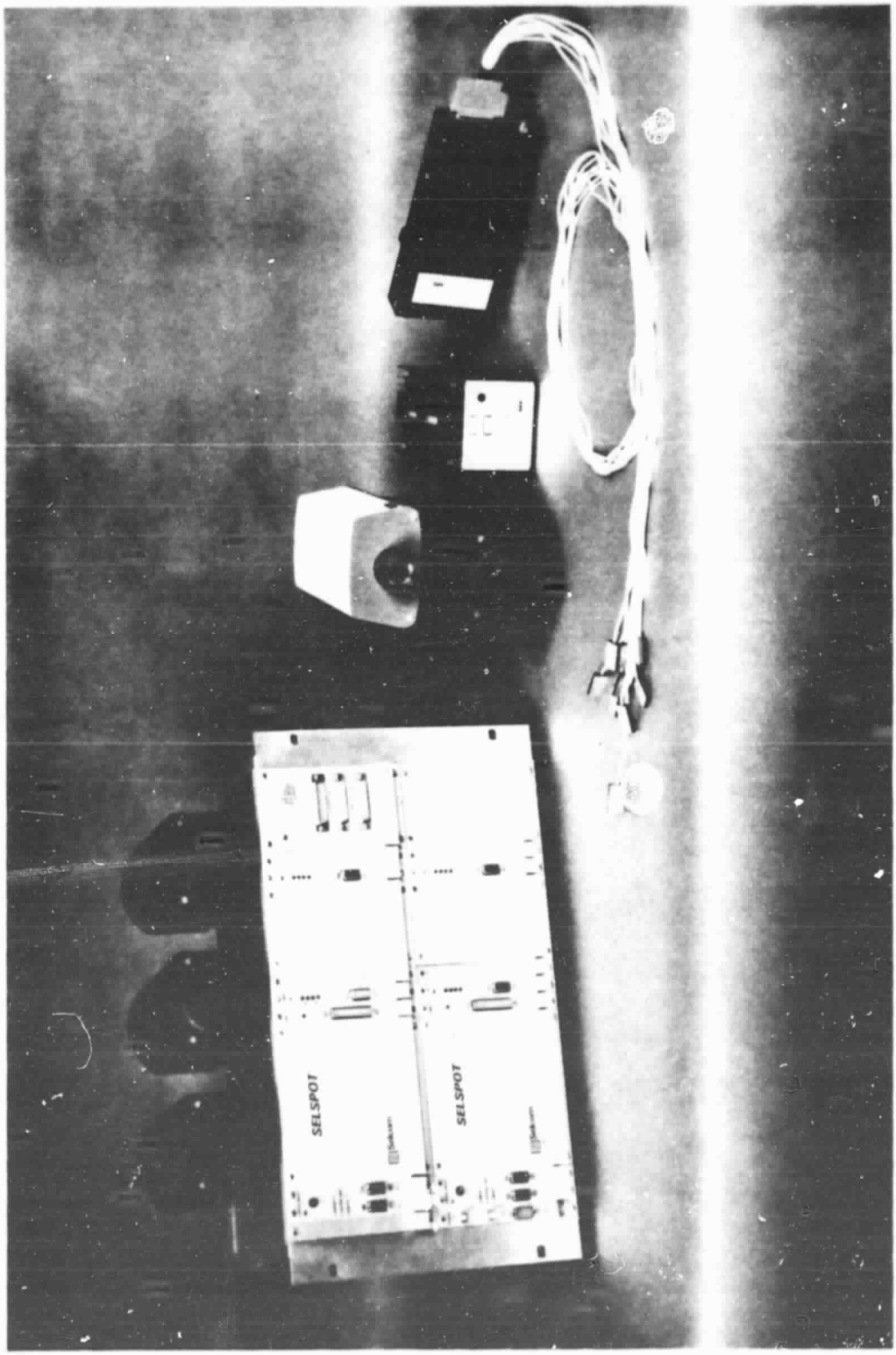

Figure 6
SELSPOT INSTRUMENTATION

The Selspot sequentially illuminates up to 30 LEDs, each LED being turned on for 1/30 of the time. The time required to sequence through all 30 LEDs is 3.2 milliseconds, allowing a maximum sampling rate of 312 samples per second.

A control line from the LED control unit to the Selspot initiates the position measuring process. Upon activation of the control line, the Selspot waits until LED #1 is sequenced before outputting any LED coordinate information. This operation can delay the measuring process more than 3 milliseconds if the control line is activated shortly after LED #1 is sequenced. The hardware and software designs in the video recording adapter have been optimized to compensate for these probable delays.

2. Video Recording Adapter Interface

The video recording adapter interface (VRAI) is a hardware interface designed to buffer and format data from the Selspot unit into an 8-bit format which can be readily transferred over the system control processor's data bus. Data from the Selspot unit is output 24 bits at a time, with 4 groups of 24 bits comprising the position information for one LED. This data is transferred to the VRAI memory. After the preselected number of LEDs have been sequenced and measured, the busy bit of the VRAI's status register goes HI. This indicates that the buffer memory can now be accessed by the system control processor. Also included in the status register is the four bit Selspot counter. This counter is latched each time a command to collect Selspot data is given. The counter is incremented each time the Selspot completes one sequence of the LEDs (every 3.2 milliseconds). The format of the data in the buffer memory is given in Figure 7.

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DATA FROM VIDEO
RECORDING ADAPTER INTERFACE

ADDRESS OF SCP ADDRESS BUS				
$5XX0	CAM 1X MSB			
$5XX1			CAM 3X LSB	CAM 1X LSB
$5XX2	CAM 3X, MSB			
$5XX3	COMMAND/STATUS REG.			
$5XX4	CAM 2X, MSB			
$5XX5			CAM 4X LSB	CAM 2X LSB
$5XX6	CAM 4X, MSB			
$5XX7	COMMAND/STATUS REG.			
$5XX8	CAM 1Y, MSB			
$5XX9	STATUS 3 HI LO	STATUS 1 HI LO	CAM 2 LSB	CAM 1 LSB
$5XXA	CAM 3Y, MSB			
$5XXB	COMMAND/STATUS REG.			
$5XXC	CAM 2Y, MSB			
$5XXD	STATUS 4 HI LO	STATUS 2 HI LO	CAM 4X LSB	CAM 2Y LSB
$5XXE	CAM 4Y, MSB			
$5XXF	COMMAND/STATUS REG.			

XX - LED INDEX
$00-$1D

COMMAND/STATUS REGISTER
OF VRAI

COMMAND REGISTER
(WRITE ONLY)

D7							D0
O	X	X	X	X	X	O	O

XXXXX - NUMBER OF LEDS TO MEASURE

STATUS REGISTER
(READ ONLY)

BUSY		SELSPOT COUNTER

Figure 7

VRAI DATA FORMAT

3. Video Recording Adapter

a. System Control Processor

The system control processor (SCP) shown in Figure 8 is the controller for the video recording adapter. The heart of the SCP is a 6502 microprocessor. It is responsible for all input/output and operator prompting, processing and formatting of anthropometric data, timekeeping, and general control of data recording and playback functions. The SCP peripheral hardware consists of 14K bytes of EPROM, 1K bytes of RAM for variable storage and the processor stack, an IEEE-488 bus (HPIB) interface, a 16 channel A/D converter, an arithmetic processing unit, a real time clock with battery backup, and two RS-232 ports.

The 14 Kbytes of EPROM contain the operating system software required for the operation of the VRA. The entire operating system is written in 6502 assembly language code which makes its operation and execution very efficient. A description of the software operation is given in the Software Implementation section of this report.

The IEEE-488 bus interface is used to transfer data to and from a host computer system. This particular bus was selected because of its ability to handle data at high rates since large amounts of anthropometric data must be recorded on video tape. This provides for large amounts of data transfer at a relatively high data rate. During playback, the data must be transferred at a rate at least that of the recorded rate.

The 16 channel A/D converter is used to digitize the analog output of the Cybex dynamometer. The digitized value is

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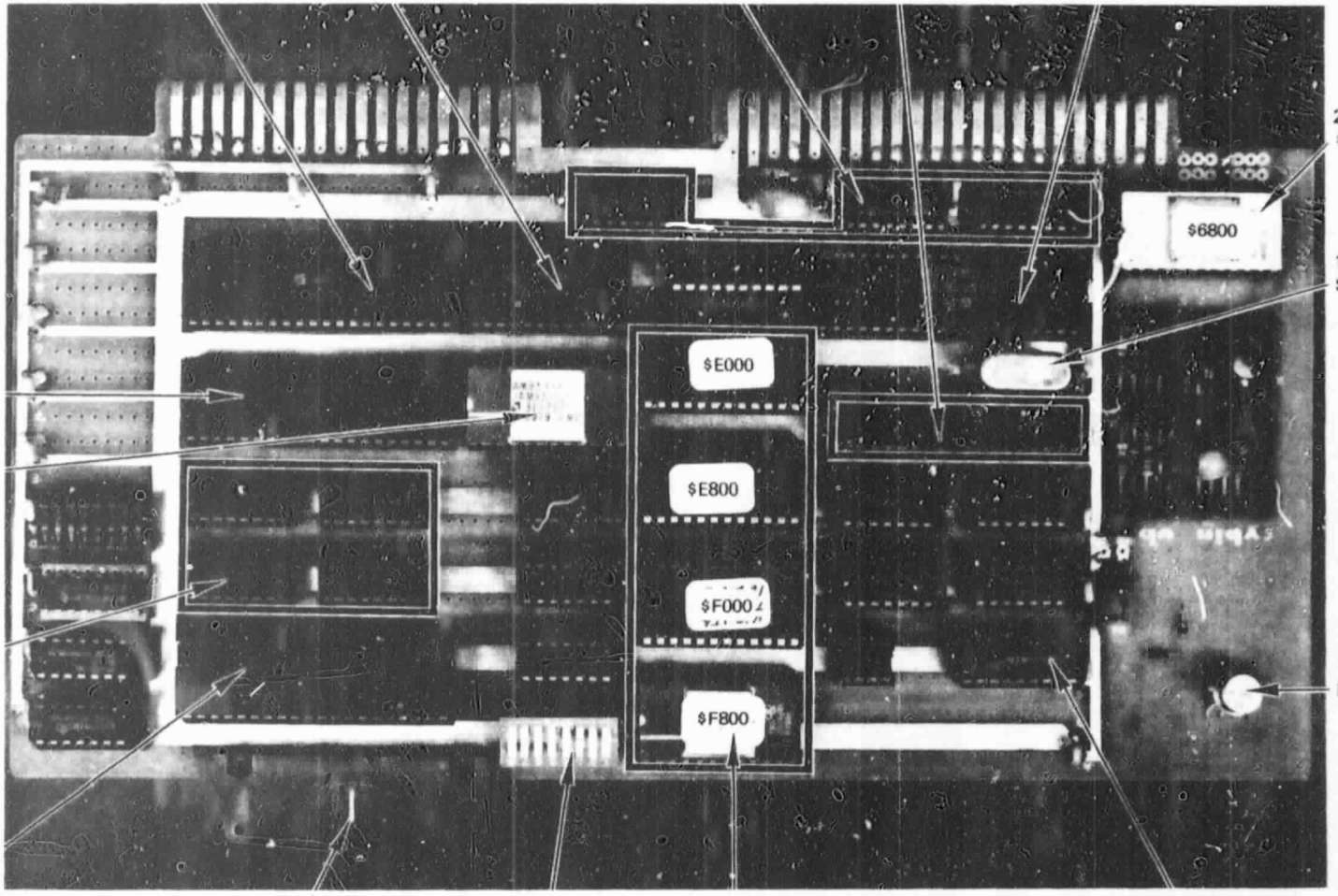

Figure 8

SYSTEM CONTROL PROCESSOR, BOARD #1

encoded and stored with the anthropometric data on video tape. The Cybex analog channel is sampled once every 16.6 milliseconds, corresponding to one data frame. The remaining 15 analog input channels are available for future expansion.

The primary purpose of the arithmetic processing unit (APU) is to aid in the computation of LED coordinate information during the data verification process. The APU is also utilized in calculating various operating parameters in the data recording and recovery process. The particular arithmetic processor used in this unit is the Advanced Micro Devices 9511A. It is capable of performing fixed and floating point arithmetic and a variety of transcendental and trigonometic functions. The incorporation of this device greatly enhances the processing abilities of the VRA.

The real time clock (RTC) with battery backup is used to mark the start time of a data recording process. A real time clock module, the MSM5832, manufactured by OKI Semiconductor is used to keep track of the time of day and the date, even when power is not applied. The use of the RTC frees the operator of frequent clock setting and reduces the errors in documenting the start time of a particular data recording.

Two RS-232 standard serial interfaces are used in communication between the VRA and operator. One of the serial ports is used to communicate with the front panel terminal. The Burr-Brown panel terminal makes the VRA portable and reduces the amount of external hardware necessary for operation. A second RS-232 interface is provided on the rear panel of the VRA. It may be connected to an external printer/terminal and used to communicate with the VRA. Both

serial ports utilize a 6551 asynchronous communications interface adapter manufactured by Rockwell Co. The 6551 offers software configuration of the communication baud rate, enabling selection, via the front panel, of the rear panels serial port baud rate.

b. Video Display Processor

The primary function of the video display processor (VDP) is to enable the overlay of text and graphic characters on the television monitor. This feature is utilized in the alignment and verification procedures in displaying LED and Selspot camera status and in the display of various parameters about a data recording. The device used to perform this task is a video display processor chip, the TMS 9918, manufactured by Texas Instruments. It utilizes 16 Kbytes of dynamic RAM as a display buffer to hold the characters and graphics displayed on the television monitor. The VDP is controlled by the SCP which has access to the VDP through two memory address locations. It is through these two locations that the SCP accesses the seven configuration registers of the VDP and the display memory of the VDP. A picture of the circuit board containing the VDP is shown in Figure 9.

c. Data Interface Processor

The data interface processor (DIP) shown in Figure 10 functions as the bidirectional interface between digital data in the VRA memory and video tape stored data. This data encoding and decoding process is the main feature which sets this system apart from other anthropometric measuring systems. The DIP provides the capability for storing large quantities (up to 2 hours) of digital data using only a standard video tape recorder. This data can later be retrieved from the tape and converted to its original format.

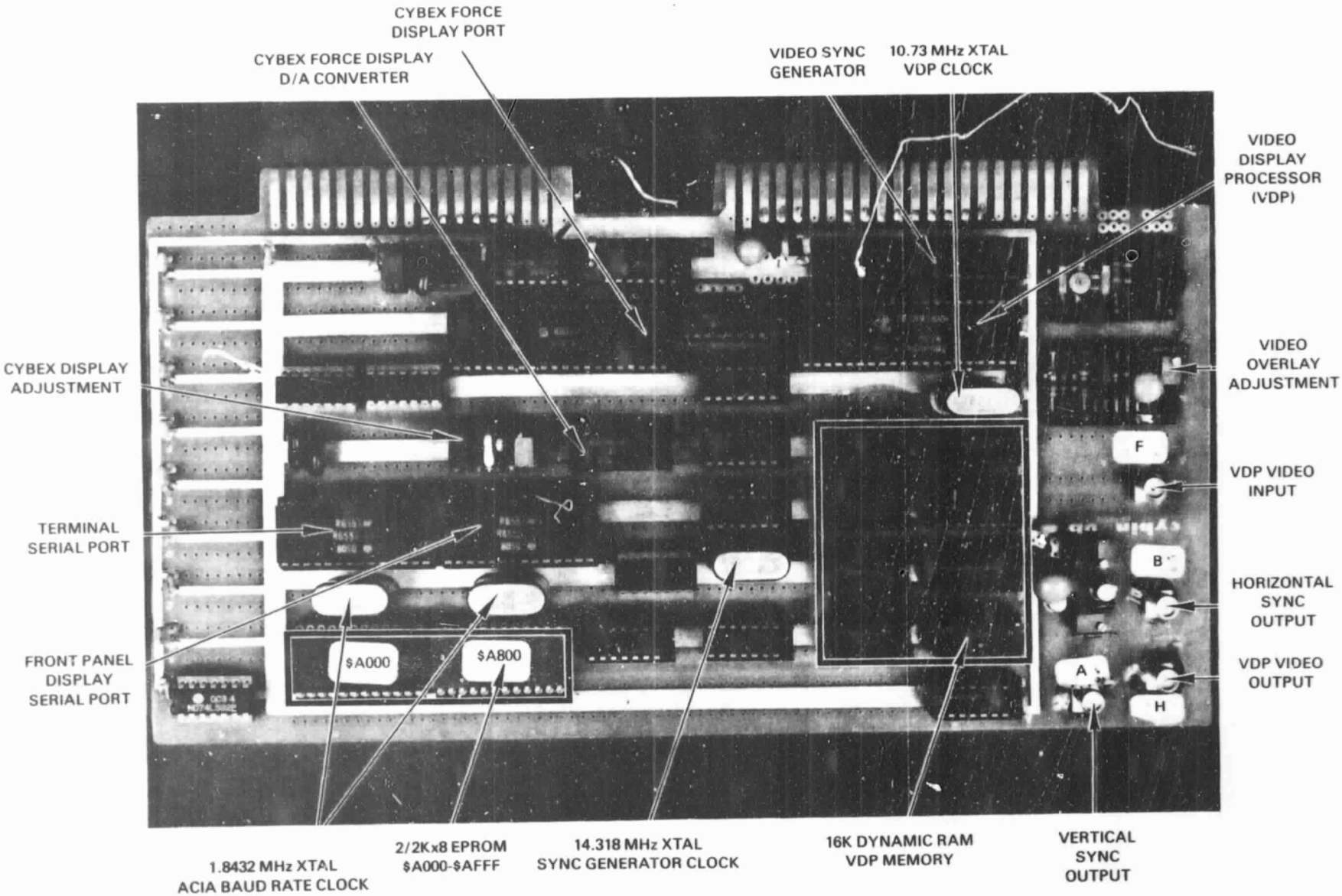

Figure 9

VIDEO DISPLAY PROCESSOR, BOARD #2

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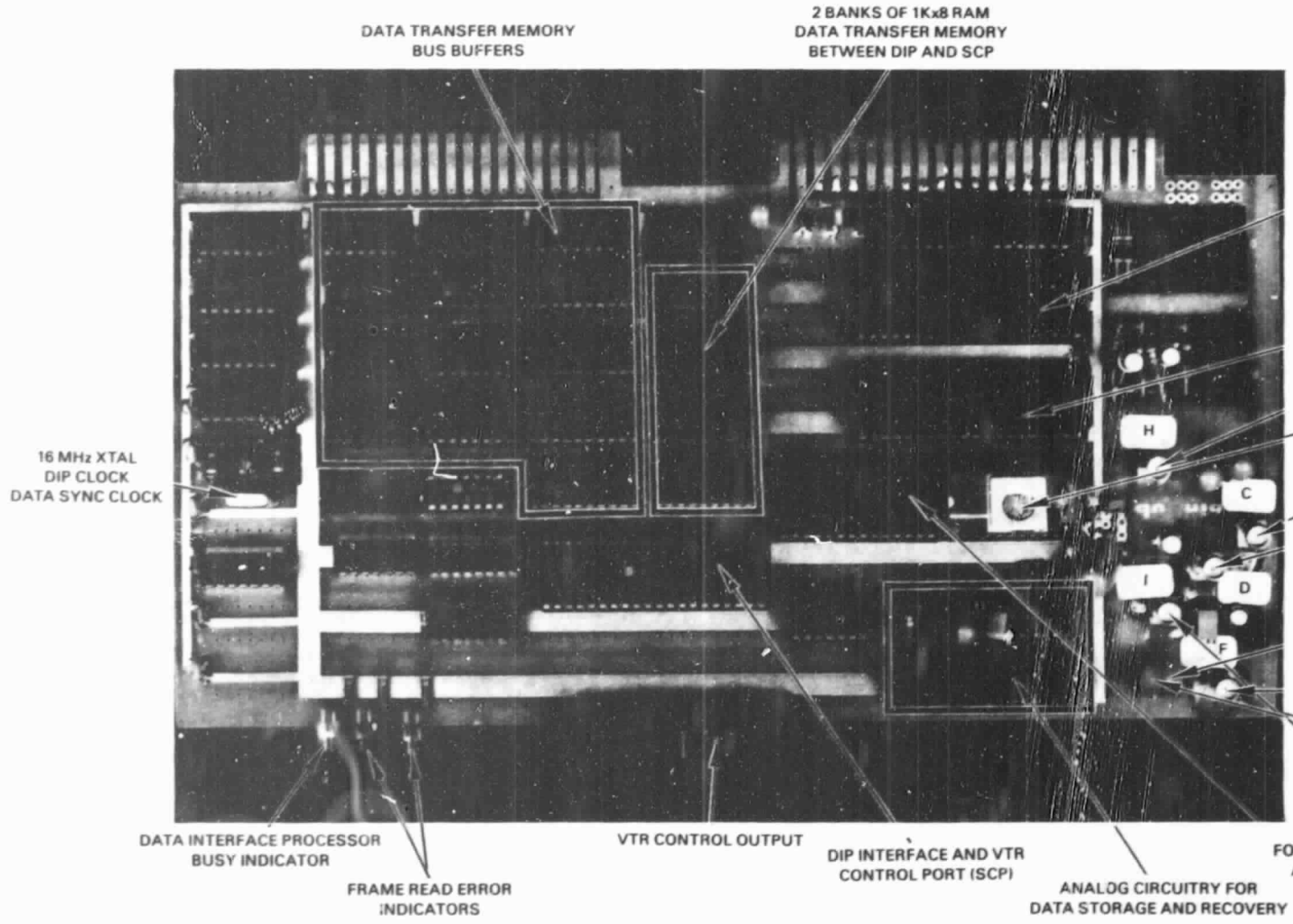

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Figure 10

DATA INTERFACE PROCESSOR, BOARD #3

The DIP is controlled by a 6502 microprocessor which has its own memory and support hardware separate from the SCP. It does, however, share 2 banks of memory, each containing 1K bytes of RAM, with the SCP. This memory serves as a means of transferring data from the SCP to the DIP for recording on video tape and a means of transferring retrieved data from a video tape to the SCP. A command and status bus exists between the two processors allowing the SCP to instruct the DIP on what function to perform. There are five commands which the SCP can pass to the DIP. The commands are: IDLE, RECORD MEMORY BANK 1, RECORD MEMORY BANK 2, PLAYBACK DATA TO MEMORY BANK 1 and PLAYBACK DATA TO MEMORY BANK 2.

The IDLE command instructs the DIP to wait for an instruction. The RECORD MEMORY BANK 1 and 2 commands instruct the DIP to encode and record the data stored in the given memory bank. The bus structure between the memory banks is designed to allow the DIP access to one of the memory banks while the SCP is transferring data to the other memory bank 2. Both processors cannot access the same bank of memory simultaneously, however. The PLAYBACK DATA TO BANK 1 and 2 commands instruct the DIP to decode data from a previously recorded video tape and store the data in memory bank 1 or 2. The SCP can be accessing data in one of the memory banks at the same time data is being loaded into the other bank by the DIP.

The DIP is also responsible for illuminating the front panel FRAME OVERFLOW lamp. As the DIP receives commands to fill the data transfer memory banks, it also checks for a data overflow condition. This condition occurs when data recorded on the video tape is not read by the DIP. It may be created by two faults. The first

fault turns on the FRAME OVERFLOW lamp if the DIP has not received an instruction to read a new block of data in a 50 millisecond period. Since a new frame of data passes by every 16.6 milliseconds, this will alert the operator after approximately 3 frames of data have been lost. The second fault checks information embedded in the recorded anthropometric data set. The particular piece of data checked is a data frame counter which is incremented by one each time a frame of data is recorded. Upon playback, the DIP checks if this counter changes by more than one since the last frame was retrieved. If it has, the processor assumes data overflow has occurred and lights the overflow indicator.

d. The Data Recording Process

The VRA utilizes the wide bandwidth recording capabilities of a video tape recorder to store large amounts of encoded digital anthropometric data. Also recorded is a portion of the video camera's view of the anthropometric experiment.

The DIP, which performs the encoding and storage of the digital data, utilizes a programmable communications interface (PCI), type 2651 manufactured by Signetics Corp. to convert the 8 bit words of data into a serial data stream. The data stream is encoded using analog circuitry to "look like" video picture information. The DIP monitors the vertical and horizontal sync of the video signal and synchronizes the output of the PCI with it. The storage process always begins at the top portion of the picture, immediately after the vertical sync pulse has occurred. This practice maintains synchronization of the recorded information and allows resynchronization and decoding during the playback process.

After the DIP has detected the vertical sync pulse, it delays 2 horizontal lines and then encodes two horizontal lines of "white" level. This is used to set the automatic threshold circuitry of the data decoder during data playback. The DIP delays another 2 lines and then records 3 redundant bytes of data. These bytes contain the number of horizontal lines of data which are to be recorded in this video field. Each byte has the alternate bits inverted, so that on data playback, the number of bytes to be retrieved can be determined even if data integrity is poor. Following the three alternating bytes, a delay of one horizontal line is inserted to allow processing of the number-of-line bytes upon playback.

After the calculation delay, data to be recorded is sequentially read from the data transfer memory by the DIP and 4 bytes of data are encoded on each horizontal line at a rate of 1 megabit/second. At the completion of data transferral, the video signal from the TV camera replaces the encoded data signal and becomes the remainder of the video field.

e. The Data Retrieval Process

During playback of the recorded signal, the encoded digital data is decoded and transferred to the SCP for further processing by the DIP and associated circuitry. Upon acceptance of a PLAYBACK DATA TO MEMORY command from the SCP, the DIP monitors the video signal from the VTR for a vertical sync pulse in order to synchronize itself with the recording process. It then delays 5 horizontal lines to allow the "white signal" to set the threshold of the data stripping circuitry. After the threshold of the analog circuitry is set, the circuit is ready to decode data from the video

signal. When the 8th horizontal line is played, the digital data is stripped from the video signal and conditioned such that the PCI can accept it. After the 3 bytes containing information on the number of horizontal data lines are read, the DIP determines whether valid data exists. If no valid data exists, a flag is set in the bank of memory used to transfer data and the FRAME READ ERROR indicators are illuminated on board #3.

If valid data is present, then the specified number of horizontal lines are decoded, and data is decoded and stored in the data transfer memory between the SCP and DIP.

B. Data Acquisition and Recording

This section describes the process of anthropometric data acquisition from the Selspot system to the encoding and storage of the data on video tape.

The timing diagrams of Figure 11 shows the state of various control signals throughout the data acquisition and recording process. The Selspot channel sync is a signal output from the Selspot main unit. The channel sync is high while LEDs 1 thru 14 are on and low during the illumination of LEDs 15-30. The rising edge of the channel sync is used to increment the Selspot cycle counter as detailed in the section describing the VRAI. The VRAI BUSY AND SELSPOT CONTROL is used to indicate when the VRAI is busy collecting data from the Selspot main unit and controls and data acquisition mode of the Selspot. A low state indicates the busy condition and sets the Selspot in the data collection mode. The DATA INTERFACE PROCESSOR BUSY signal is a status signal from the DIP to the SCP. This control line is part of the command and status bus between the two processors.

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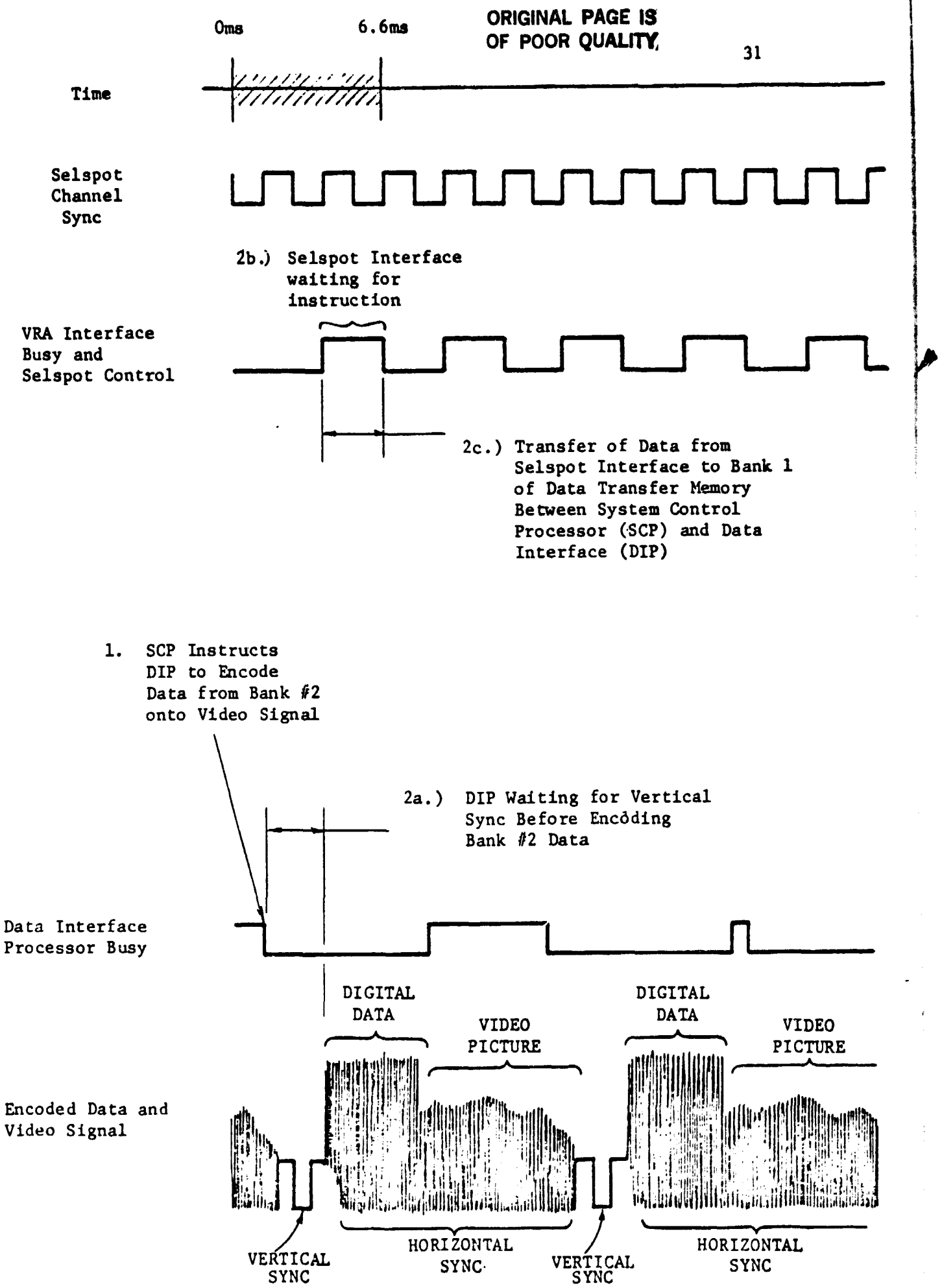

Figure 11
VRA SYSTEM TIMING

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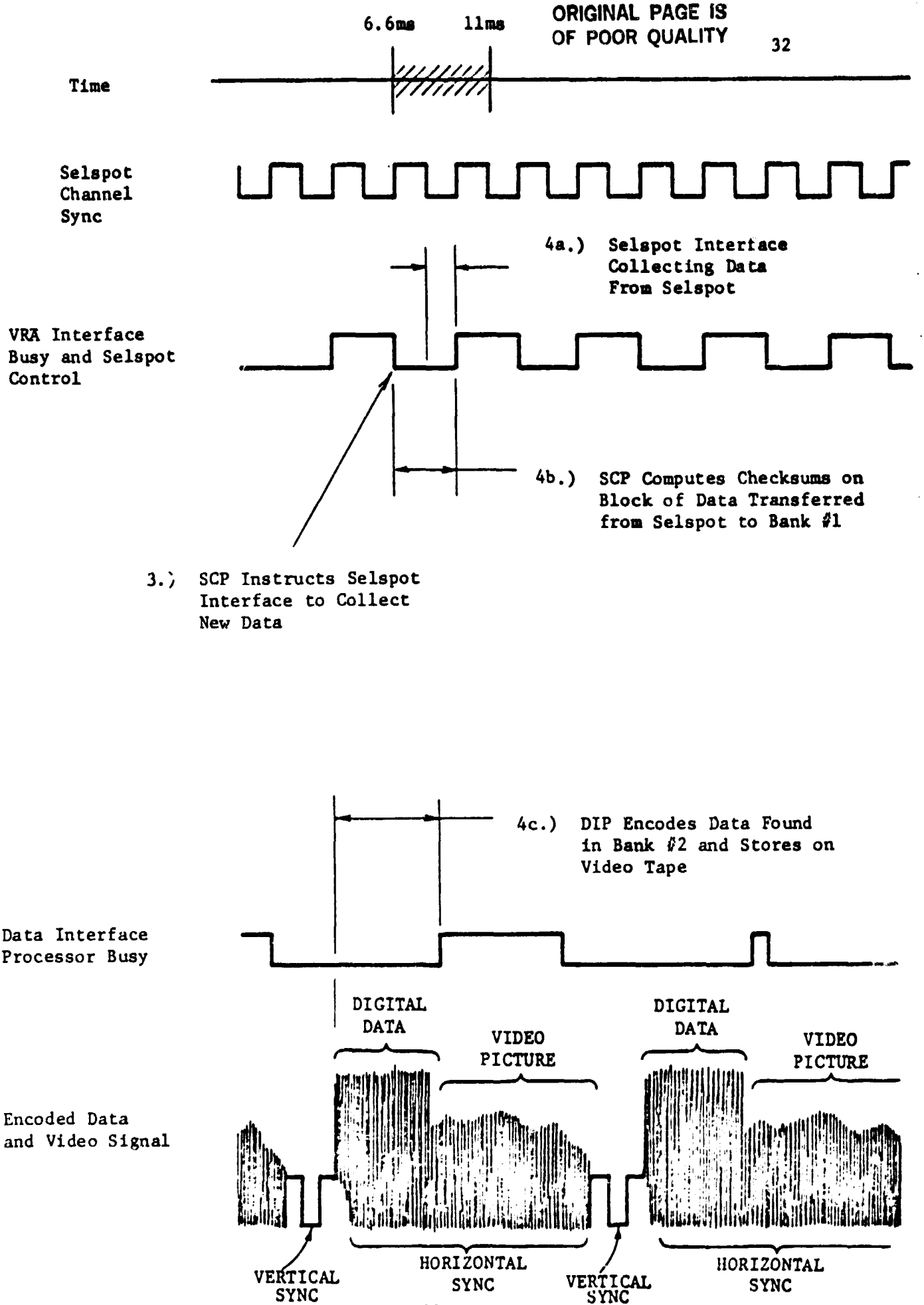

Figure 11

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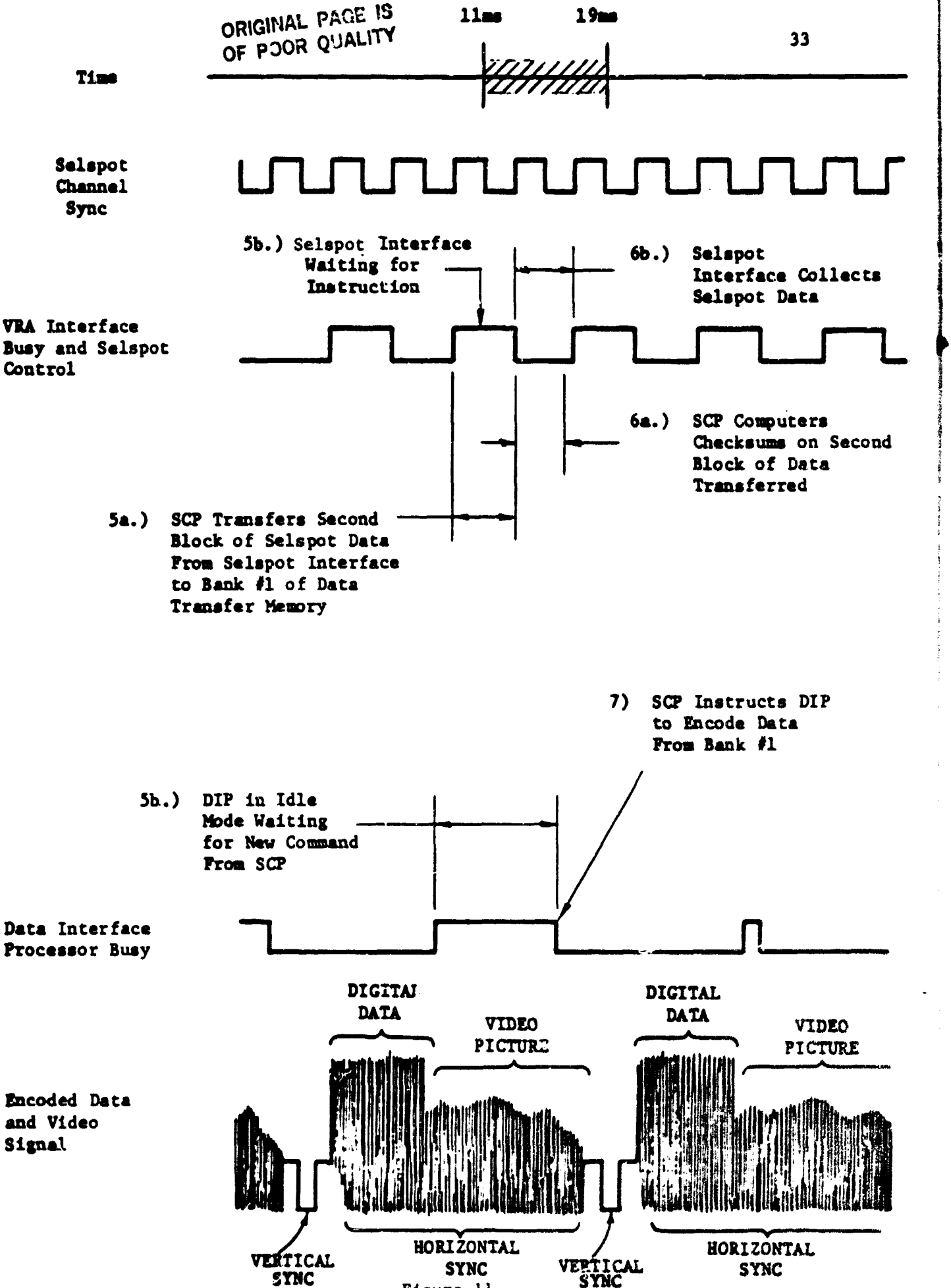


Figure 11
VRA SYSTEM TIMING (CONT)

It is used to indicate when the DIP is busy recording data or retrieving data from video tape. A low level on this line indicates the busy condition and illuminates the DATA INTERFACE BUSY indicator on circuit board #3. The encoded data and video signal is a representation of the video input to the video tape recorder. It depicts the various components of the video signal, the encoded digital data and a portion of the TV picture signal, and the vertical and horizontal synch pulses.

The first step in the recording process is the issuance of a command from the SCP to the DIP instructing the DIP to encode and record data present in memory bank #2 of the data transfer memory. References to Figure 11 are provided in the following discussions. Upon receipt of this command the DIP indicates it is busy and waits for the vertical sync (2a) before beginning the data storage process. After issuing the command to record data in memory bank #2, the SCP waits for the VRAI to complete the acceptance of data from the Selspot. When the VRAI busy line goes HI, the SCP begins to transfer data from the interface to memory bank #1 of the data transfer memory (2c).

After the data transfer is complete, (3) in Figure 12 shows the SCP instructing the VRAI to collect a new set of anthropometric data from the Selspot unit. The VRAI does not begin to accept data from the Selspot, however, until LED #1 is sequenced. After the VRAI accepts the command, the SCP begins to compute checksums (or error detection codes) for the data transferred from the Selspot interface (4b).

Simultaneous with the procedures, the DIP begins its storage of data in memory bank #2. At one point, three operations are occurring

simultaneously: the Selspot interface is collecting data (4a), the SCP is computing checksums on collected data (4b), and the DIP is storing processed and formatted data on video tape (4c).

After the VRAI completes collection of data from the Selspot, the SCP transfers a second sampling of data to memory bank #1 as shown in Figure 11 (5a). Upon completion of the data transfer, the SCP computes checksums on this new set of data (6a) and then instructs the DIP to record bank #1 on video tape (7).

The process is repeated until the SCP is instructed by the operator to terminate data collection.

C. Data Retrieval and GPIB Output

The data retrieval process involves the recovery of recorded data from video tape and the transfer of the data over the General Purpose Interface Bus (GPIB). The data transfer process is executed by a command entry from the front panel or external RS-232 port. Upon command acceptance, the VRA configures the GPIB interface as selected by the configuration switch located on circuit board #1. If the GPIB is configured in the talk only mode, the VRA immediately begins the data playback process. If the addressable mode is selected, however, the VRA awaits the receipt of its address from the GPIB controller before beginning data playback. When the data playback process is executed, the SCP instructs the DIP to load one of the data transfer memory banks with a frame of recovered data. (A frame of data is the amount of data stored on one video field.) After a frame of data has been recovered, the SCP instructs the DIP to load the alternate memory bank with the next frame of data. The SCP then begins the transfer of data from the memory bank over the GPIB. When this transfer is

complete, the SCP instructs the DIP to load data into the empty memory bank and then begins the transfer of data from the alternate data transfer memory. This process continues until the VRA is unaddressed by the GPIB, or a system reset is executed.

Each data frame is made up of several data blocks. The first block in each frame is the header block. The header block contains information such as the start time of the recording, the elapsed time of the recording, the digitized output of the Cybex dynamometer, the number of LEDs sampled, the number of samples in the data frame, and one sequential character of the experiment header title entered by the operator at the beginning of the experiment. The experiment header title is reconstructed by using the elapsed time frame counter as an index to locate the position of the header character in the header. A diagram of the header block is shown in Figure 12. The subsequent blocks of data in a frame are called data blocks. Each data block contains information about the position of a particular LED as seen by the four Selspot imaging cameras.

Also included in the data block is the mode byte. This byte indicates in which of the three modes the VRA is operating and the I.D. number of the LED which this data block is describing. The Selspot counter byte contains the value of the Selspot cycle counter when data was last taken. However, the counter contents is only valid when associated with LED number 1.* A description of the data block, and the mode and cycle counter bytes are given in Figures 13 and 14.

*Note: Although the LEDs are entered as numbers 1 through 32, the computer addresses them as I.D. number 0 through 31. Thus LED number 1 has an I.D. of 0.

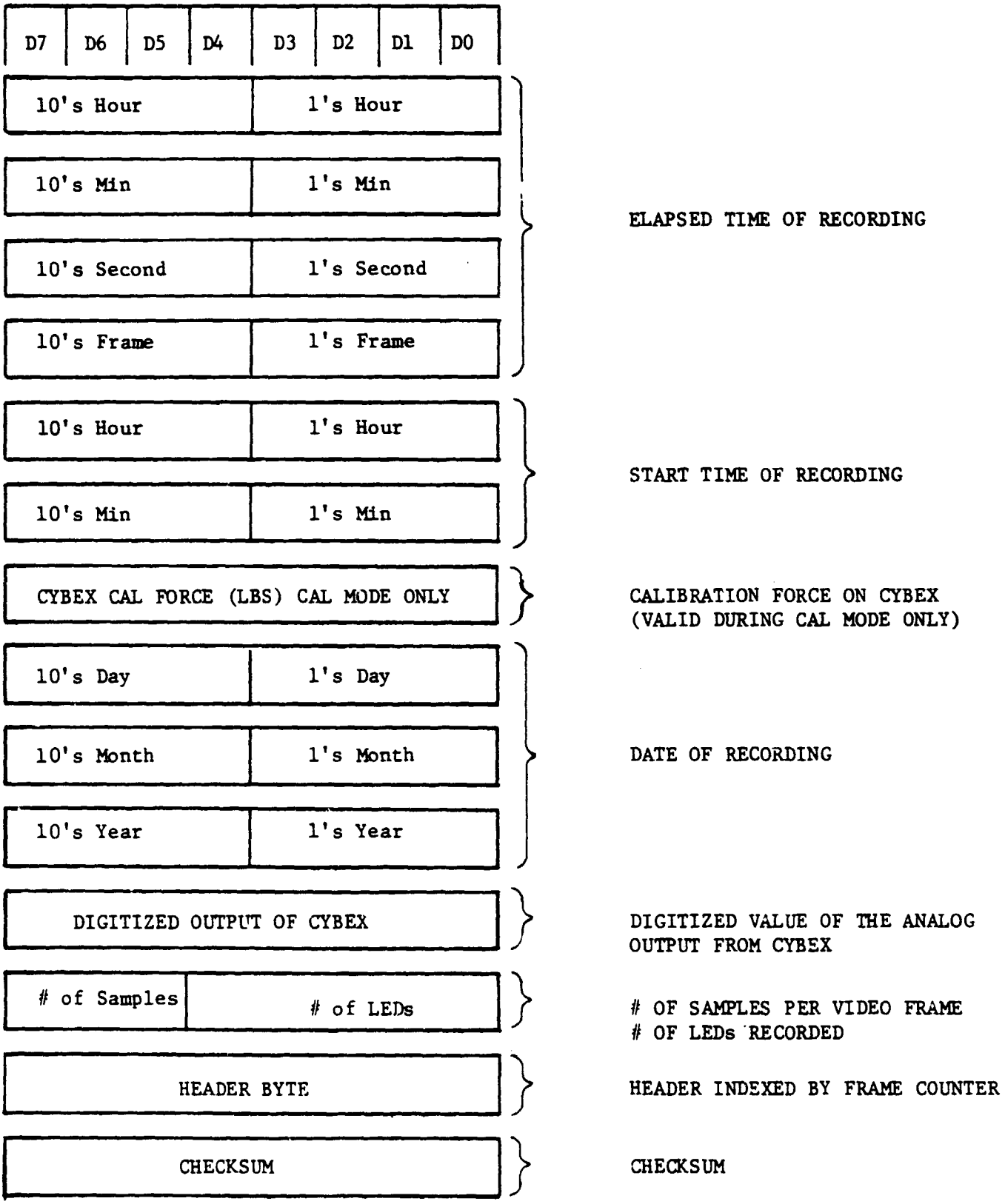


Figure 12

FORMAT OF HEADER BLOCK

DATA FORMAT

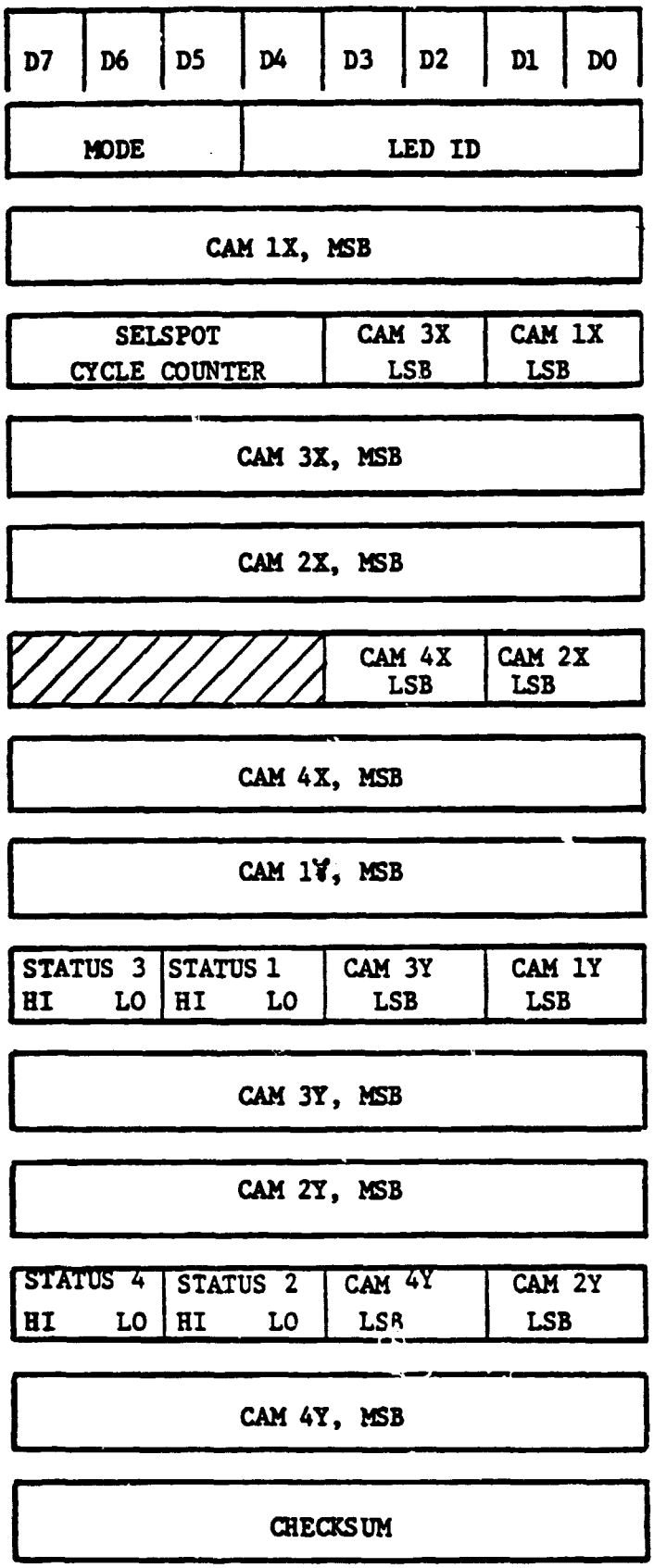
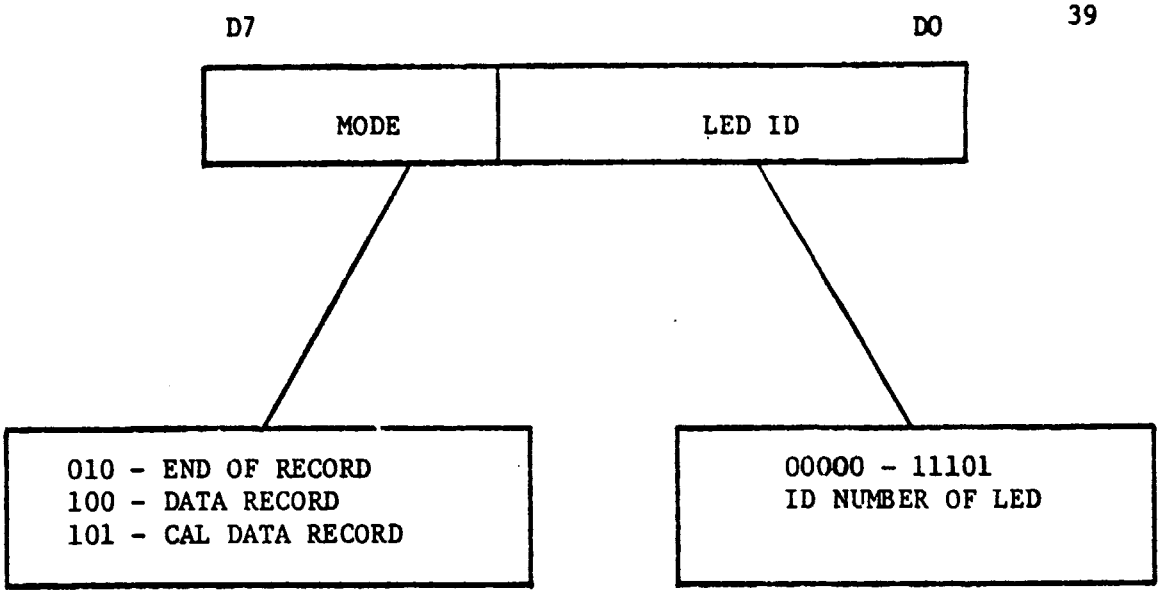


Figure 13

FORMAT OF ONE DATA BLOCK



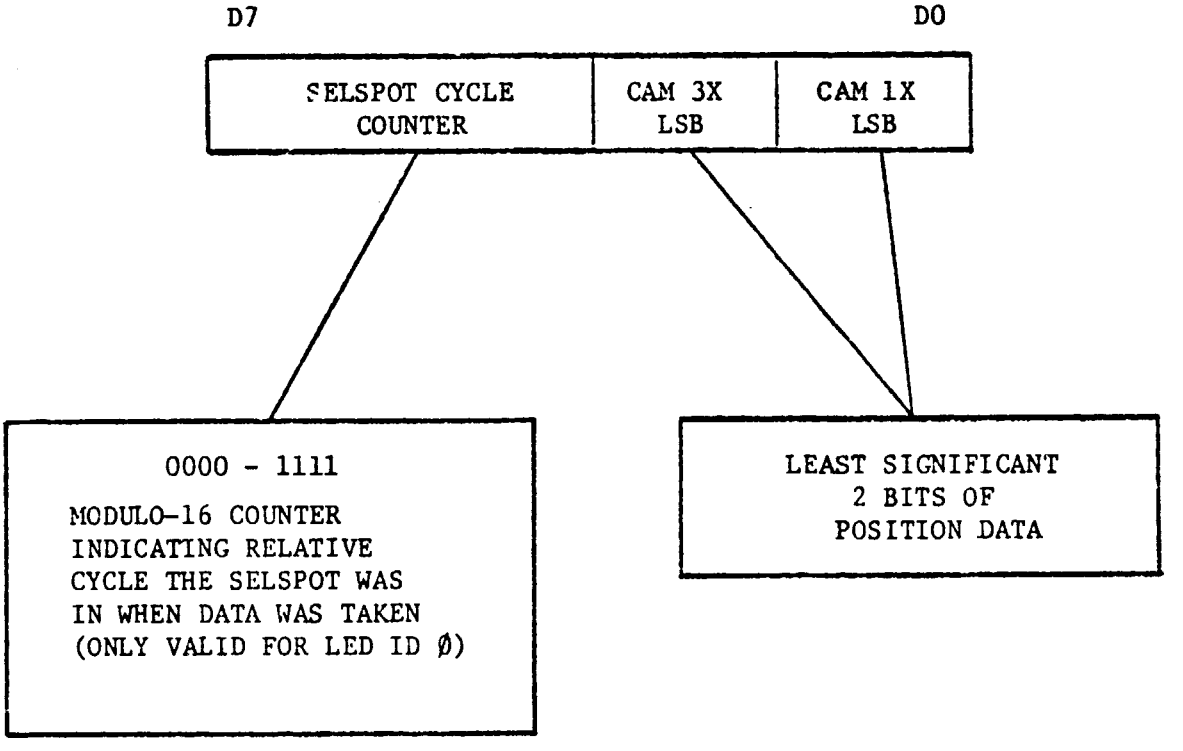


Figure 14

MODE & COUNTER BYTE CONTENTS

D. Software Implementation

The software package in the VRA is written in 6502 machine language code using a modular software design philosophy to create a flexible and maintainable system. The modular design concept involves the use of subroutines or modules to perform a particular function. These subroutines are then linked together through a main line program. The flow chart of the main line program for the VRA SCP is given in Figure 15. A source code listing for the software in the VRA is given in Document No DRD No. OM-123T, "Software Listings for a Video-based Anthropometric Measuring System".

A software design aid included in the VRA is a software debug monitor. This terminal interface monitor referred to as "TIM" gives the designer the ability to inspect and modify the microprocessor's memory or internal registers and accumulator. The software monitor can be executed by entering a C^{c} over the rear panel RS-232 port. When the monitor mode is entered, the VRA will respond with:

```
* AB7B  30  AB  FF 10  FF
```

This is a hexidecimal display of the registers within the microprocessor. The CPU registers are displayed in this order: program counter, status register, accumulator, X register, Y register and stack pointer. The registers are displayed anytime an "R" is entered from the RS-232 port or a software break point is encountered. To alter the contents of the registers, type "R" and ":", then type the new hexadecimal values for the registers. Typing spaces in place of a hexadecimal entry leaves the old value intact. After the register values have been entered, the modification does not take effect until a "G" is typed.

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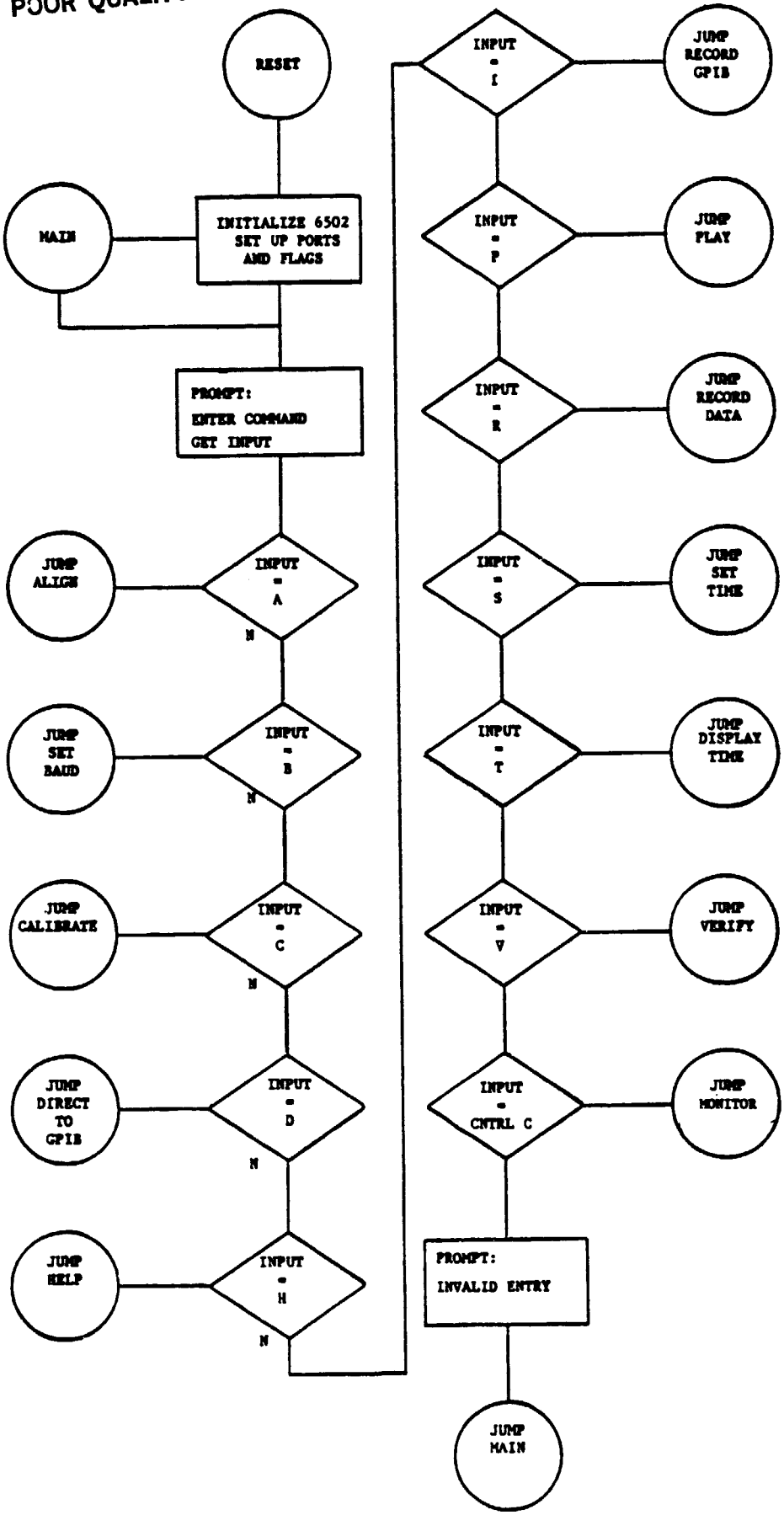

Figure 15
VRA SYSTEM CONTROL PROCESSOR FLOW CHART

Memory can be inspected by typing an "M" and the hexadecimal address of the memory location. Doing so will display the first eight locations from the entered address. Below is an example of examining memory location $F000:

M F000	4C 2A F0 4C B6 F0 4C D4
Entered by Operator	Displayed by Computer

The displayed memory locations can be modified by typing a colon and then the modifying data.

To return the VRA to the command acceptance mode, enter a A^C or press the RESET key on the front panel.

IV. OPERATING PROCEDURES

A. System Configuration

The SwRI developed video recording adapter system configuration is shown in Figure 16. The equipment in this figure consists of the electronic data acquisition system pictured in the foreground of Figure 16, the photo-imaging system and light-emitting diode target assembly in place on the suited astronaut. The data collection and recording system shown in the foreground of this figure is also shown in Figure 17. The rack-mount unit on the left of this photograph is the Selspot four-camera control system with the video recorder interface adapter (VRAI) in the upper right hand corner slot. The cable leading from the VRAI to the video recording adapter in the center of the photograph carries data from the Selspot to the recording system. The monitor sitting on top the video recording adapter is not furnished with this equipment but may be replaced by any standard video monitor. The video display function is to monitor the alignment of the visual recording camera. Finally, at the right of Figure 17 is a commercial quality video cassette recorder used to record both data and visual images during the experimental data acquisition. In addition to the capability for the visual and data recording, this recorder has a pair of audio channels which are unused by the data recording system. Both of these channels may be used to form either a stereo audio capability or independent synchronized audio recording. The video tape recorder (with the associated remote control which may also be used with the system when not under VRA control) is shown in Figure 18.

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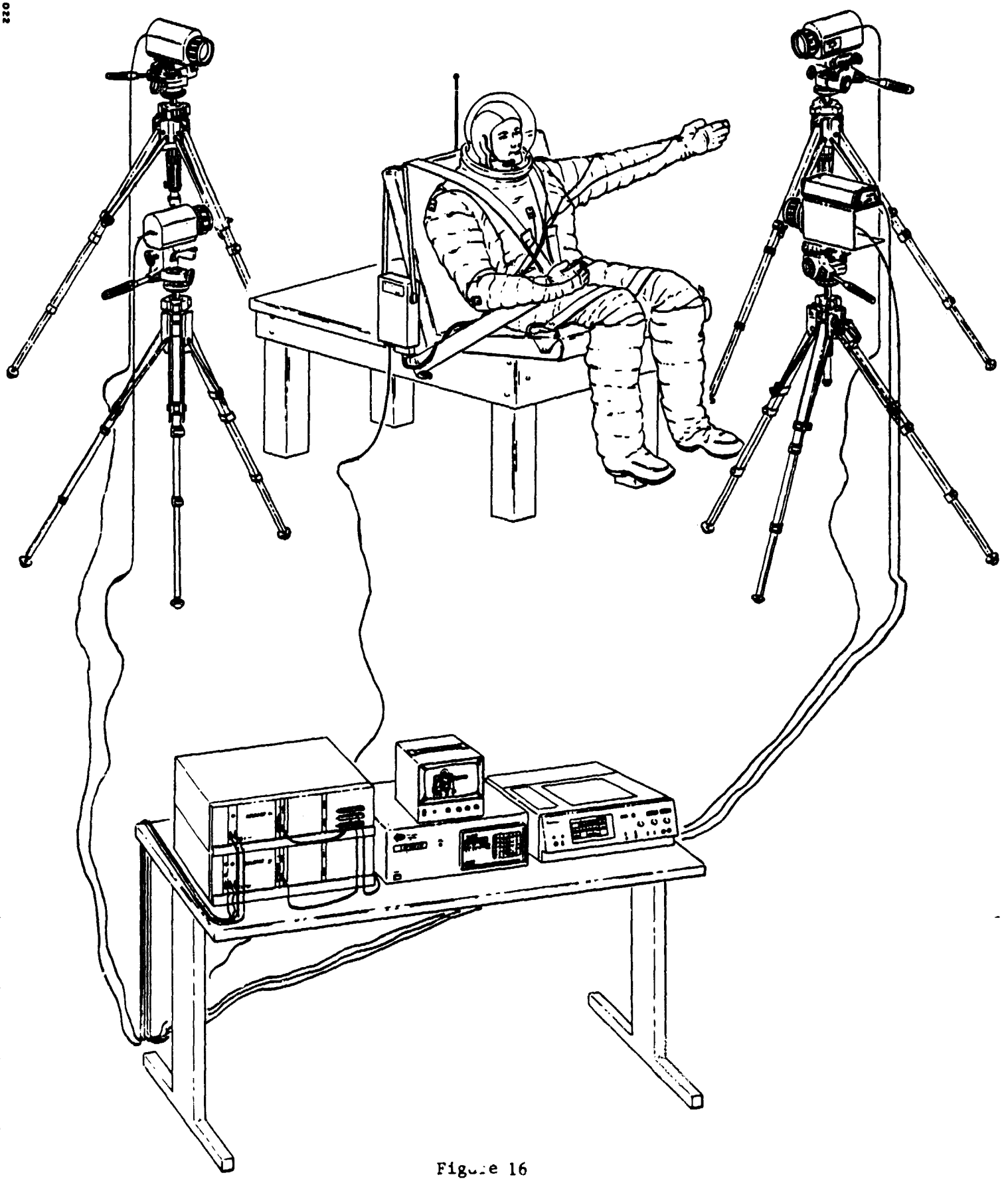

Figure 16

THE VRA SYSTEM BY SwRI

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Figure 17
DATA COLLECTION AND RECORDING SYSTEM

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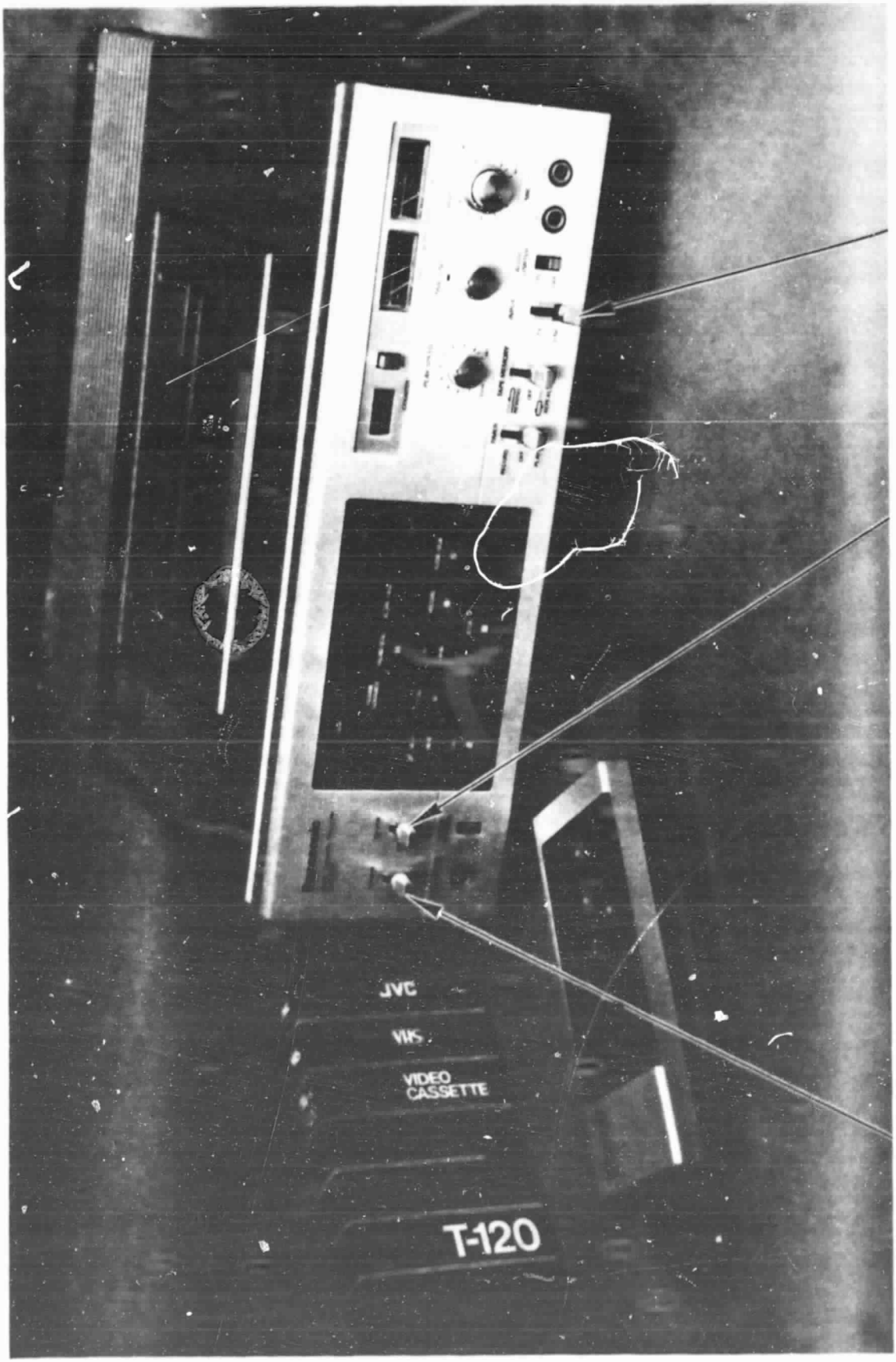

INPUT SWITCH

TV/VTR SELECT
SWITCH

POWER
SWITCH

Figure 18
VIDEO TAPE RECORDER

The video recording adapter which forms the heart of the data acquisition system is shown in Figure 19. Indicators point to the functions of the various controls on the front panel of the VRA. The rear of the video recording adapter contains the various connections for the Selspot and video recorder with other connections for the TV camera, TV monitor, and computer GPIB output. These various connections to the peripheral equipments are shown in Figure 20. The Selspot system with its associated connections to both the cameras and the VRA is shown in Figure 21.

The interconnection of the various components of the video anthroposetric system is shown in the wiring configuration diagram (Figure 22). The wiring locations for each block follow the wire names listed for that particular component. The choice of specific Selspot cameras for connection to the Selspot system is somewhat immaterial with the exception of placement. In all cases, the video camera must be aligned colinearly with Selspot camera #1. Then cameras 2, 3 and 4 proceed in an counterclockwise direction around the subject from that point. Other equipment which may be connected into the system is shown in the Table 1. This list contains the equipments that may be used during the experimental data acquisition. In addition, this table lists the equipments which are supplied with the delivered hardware and those equipments which must be sponsor supplied.

B. Operating Modes

The Video Recording Adapter (VRA) is a dual-microprocessor based Selspot to video tape adapter system. The entire operation of the VRA is under software control and is therefore extremely flexible. Upon power up, the VRA enters a command acceptance mode. This is indicated

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Figure 19
FRONT PANEL OF VIDEO RECORDING ADAPTER

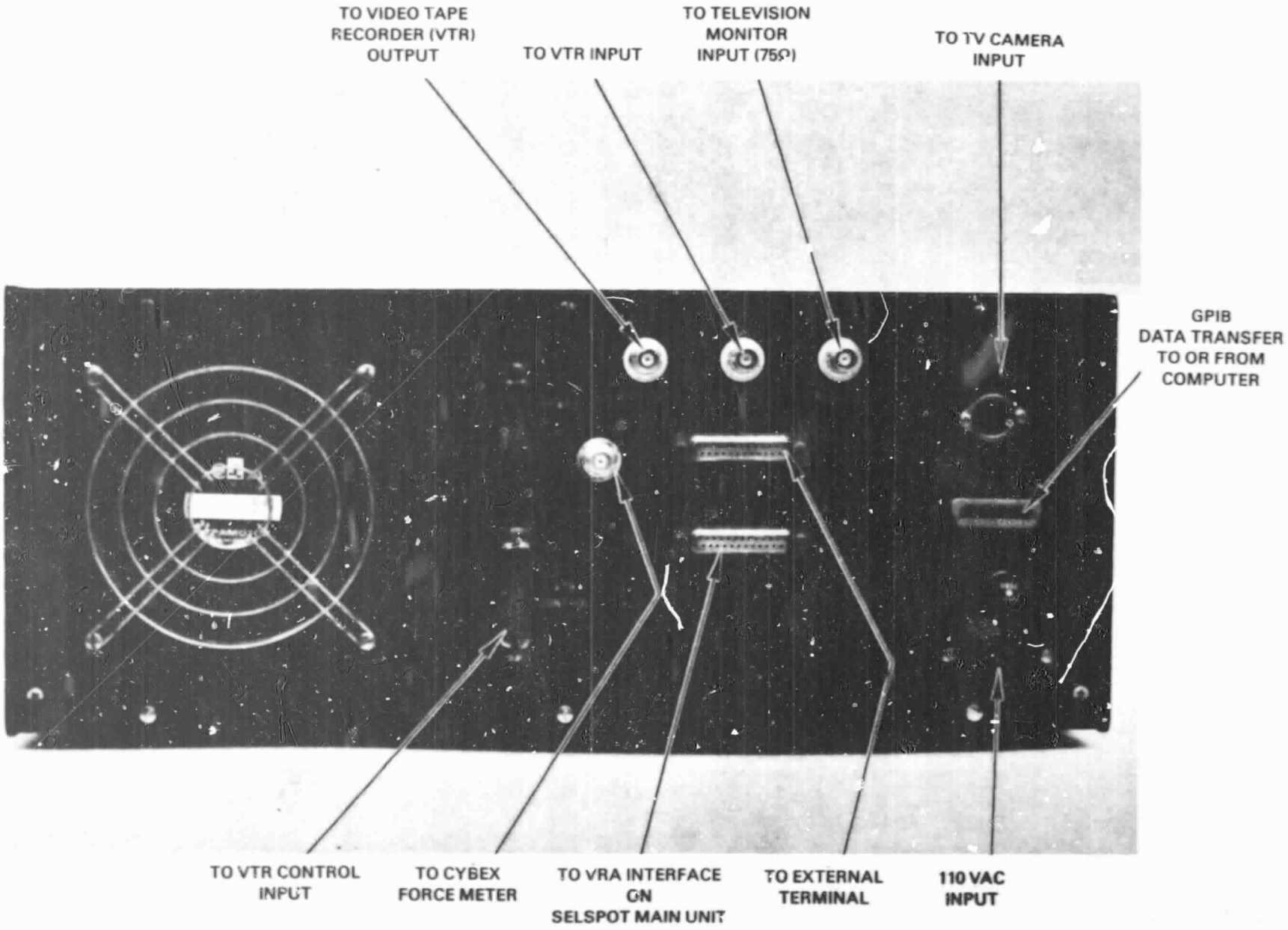

Figure 20
REAR PANEL OF VIDEO RECORDING ADAPTER

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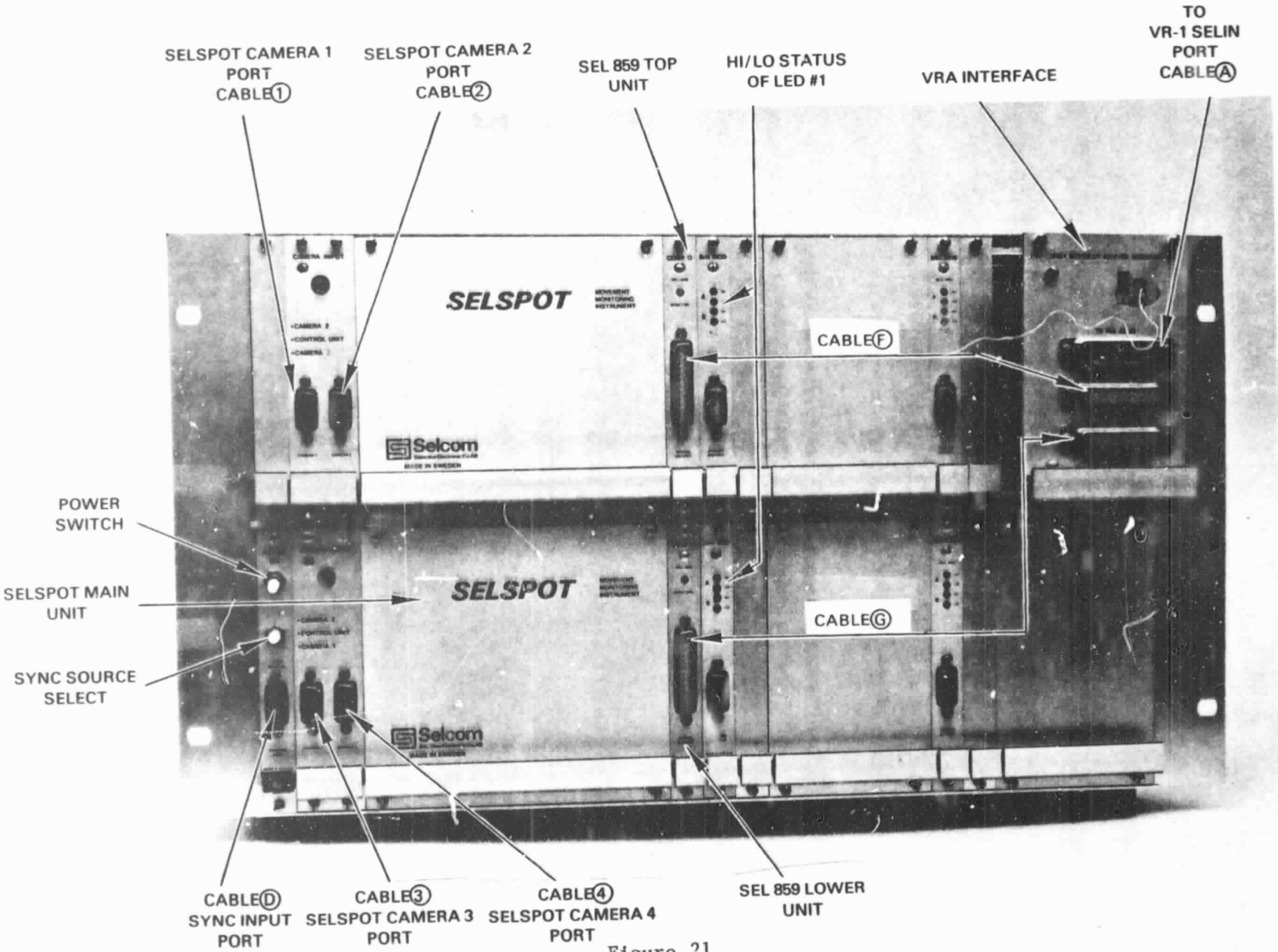

Figure 21
SELSPOT MAIN UNIT

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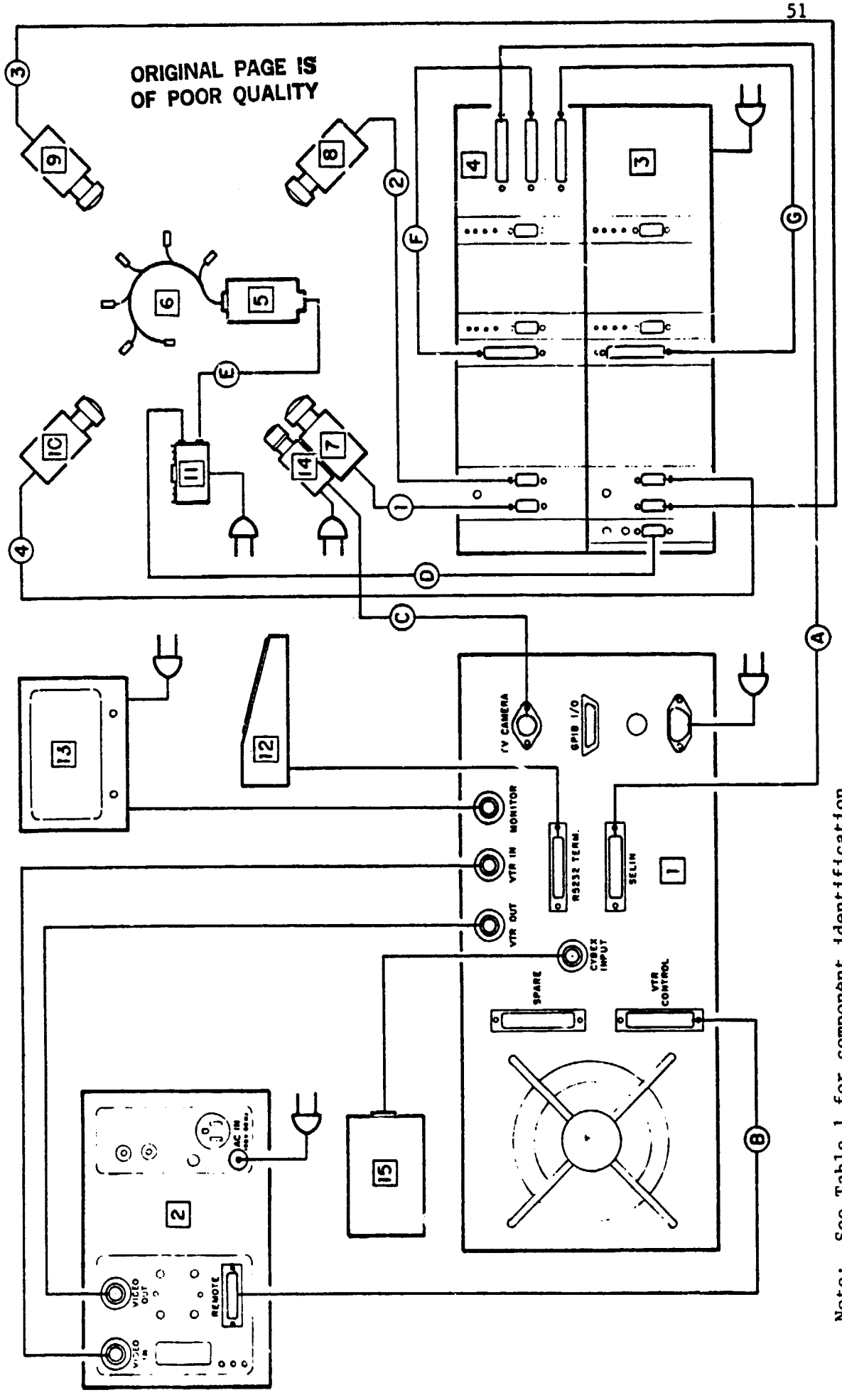

Figure 22

VIDEO ANTHROPOMETRIC WIRING DIAGRAM

Note: See Table 1 for component identification.

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NE - Non Essential

NS - Not Supplied

Table 1
VRA System Equipment List

Equipment Code	Equipment Description
1	Video Recording Adapter (VR-1)
2	Video Tape Recorder (VTR)
3	Selspot Main Unit
4	Video Recording Adapter Interface (VRAI)
5	LED Control Unit (LCU)
6	LED Cluster
7 8 9 10	Selspot Cameras 1,2,3,4
11	Remote LED Power Supply
12	Terminal (NE, NS)
13	TV Monitor (NE, NS)
14	TV Camera (NE, NS)
15	CYBEX Force Meter (NS)

Cable Code	Cable Function
A	VR-1 to Selspot Interface
B	VR-1 to VCR Remote Input
C	VR-1 to TV Camera
D	SYNC Cable
E	Remote LED Power Supply to LED Control Unit
F G	SEL 859 to VRA Interface
1 2 3 4	Selspot Main Unit to Cameras

by the prompt ENTER COMMAND as seen on the front panel display. The same prompt is output over the rear panel RS-232 input/output port at 9600 baud. While the VRA is in the command acceptance mode, it continuously checks for a character sent from the front panel or over the rear panel serial port. After receipt of a character from either port followed by a carriage return, the Video Recording Adapter's SCP compares the received character with the valid command characters as shown in the flow chart, Figure 23. When the input is found to be a valid command, it is executed as described in the following discussions. If a valid command is not input, an INVALID ENTRY prompt is momentarily displayed and the system is ready to accept another command.

During command execution, it is often necessary for the operator to respond to various prompts. If, while responding to a prompt, the operator depresses an incorrect key, the capability to edit the erroneous character is available. The VRA has the capability to edit characters in a line by typing a H^C or back space character. This causes the last character entered to be erased. The front panel keyboard does not require this feature since it has its own internal editing mode and does not send any information to the VRA until the ENTER key is pressed.

Aborting a process is possible by entering a A^C from the front panel keyboard or real panel RS-232 port. After receiving the A^C, the VRA returns to the command acceptance mode.

1. The Set Baud Rate Mode (B)

The BAUD RATE SET mode is executed by entering a "B" from the front panel or RS-232 port. This mode allows the selection of

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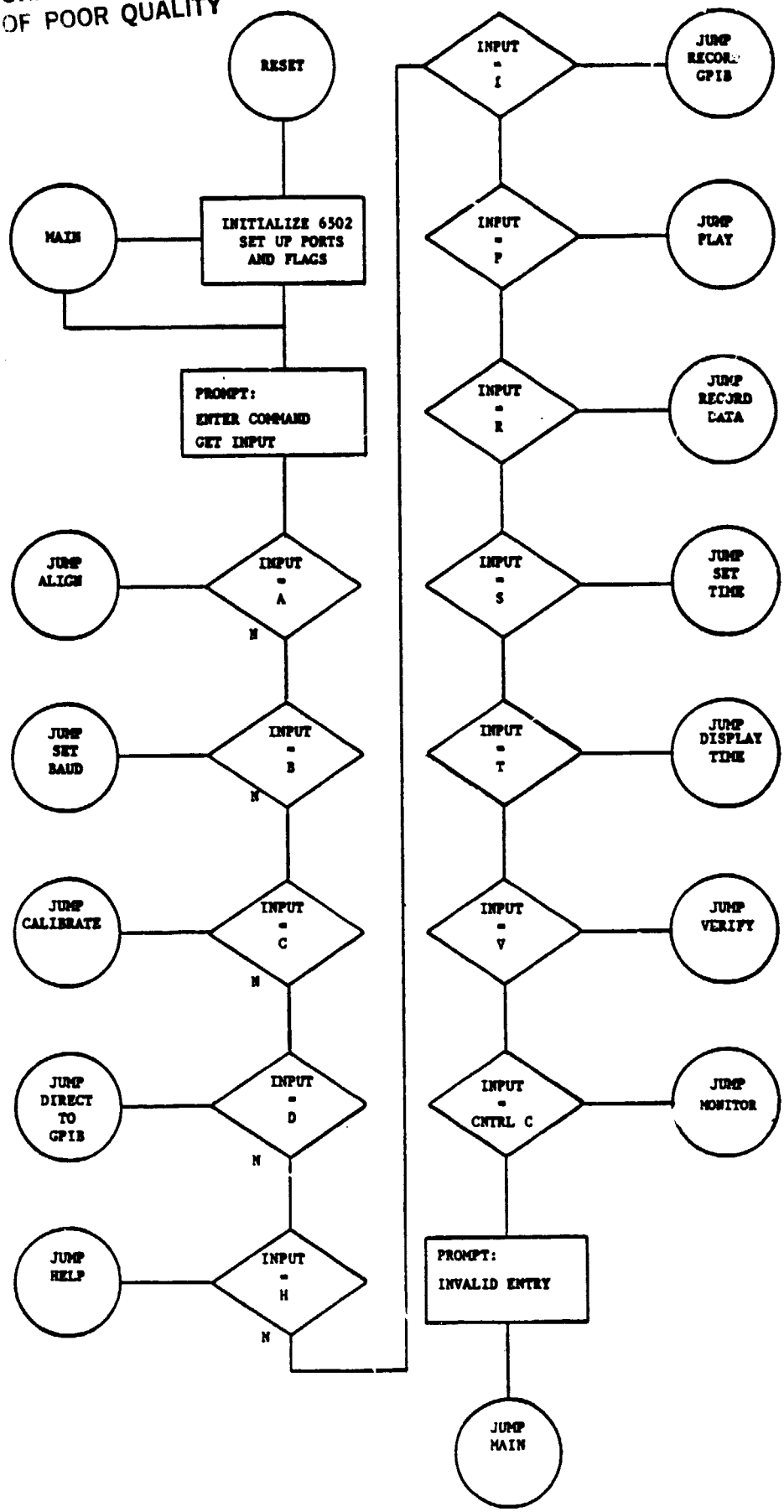

Figure 23
VRA SYSTEM CONTROL PROCESSOR FLOW CHART

baud rates ranging from 110 baud to 9600 baud for the external serial terminal. When this command is executed, the available rates are sequenced on the front panel display, each remaining for 1.5 seconds. The available selections are 110, 300, 2400 and 9600 baud. After the operator selects the desired baud rate, the processor checks to see if the entry is valid. If so, then the serial RS-232 data rate is set to that rate. If an incorrect entry is made, then the INVALID ENTRY prompt is displayed and another attempt can be made to set the baud rate.

2. The Help Command (H)

The HELP mode can be invoked by entering the character "H" from the front panel keyboard or external terminal. Upon execution, the various command characters are displayed along with a brief description of each function. When viewed on the external terminal, this information is displayed as 13 rows of command characters and title descriptors. On the front panel display, however, this information must be sequentially displayed since there is only one row of 16 characters viewable at one time. Each character and title are displayed for 1.5 seconds before the next prompt is displayed.

3. Time Display Command (T)

The TIME DISPLAY mode is entered by entering a "T" from the front panel or rear panel RS-232 port. When this command is executed, the time of the real time clock is read and displayed on the front panel display for 5 seconds; and output over the serial port. The format for the time display is HOURS: MINUTES DAY MONTH YEAR where the month is displayed as a 3 alpha character abbreviation and the hours are in 24 hour format. The internal real time clock is battery

operated and should require infrequent setting.

4. Set Time Command (S)

The real time clock can be set by executing the "S" command. This allows setting of the microprocessor real time clock in the event that its timekeeping function is disrupted by events such as a circuit board removal or discharged batteries. The first entry expected by the microprocessor is the day, followed by the month and year; as indicated by the prompts, ENTER: DAY/MON/YR. Leading zeros must be included in the entry. For example, 5 January 1982 would be entered as 05/01/82, carriage return. After the date has been entered, entry of the time is requested by the prompt ENTER: HRS MIN. The hours are entered in 24 hour format. A space between the hours and minutes is required. After the time is entered, the time and date are displayed for 5 seconds and the system returns to the command acceptance mode.

5. The Alignment Mode (A)

The ALIGNMENT mode is entered by typing an "A" followed by a carriage return from either the front panel keyboard or an external RS-232 terminal. The function of the alignment mode is threefold. The first function aids in adjusting the lens aperture of the four Selspot cameras. The aperture of each camera must be adjusted by the operator to allow the proper amount of light from the LEDs being measured. This adjustment is aided by the graphical display on the VRA TV monitor of the LEDs overrange or out-of-range status. An example of the alignment display format is given in Figure 24. In this figure, there are 30 columns of status information for each of the four Selspot cameras. Each row represents a particular Selspot camera and each column represents the status of a particular LED. LED

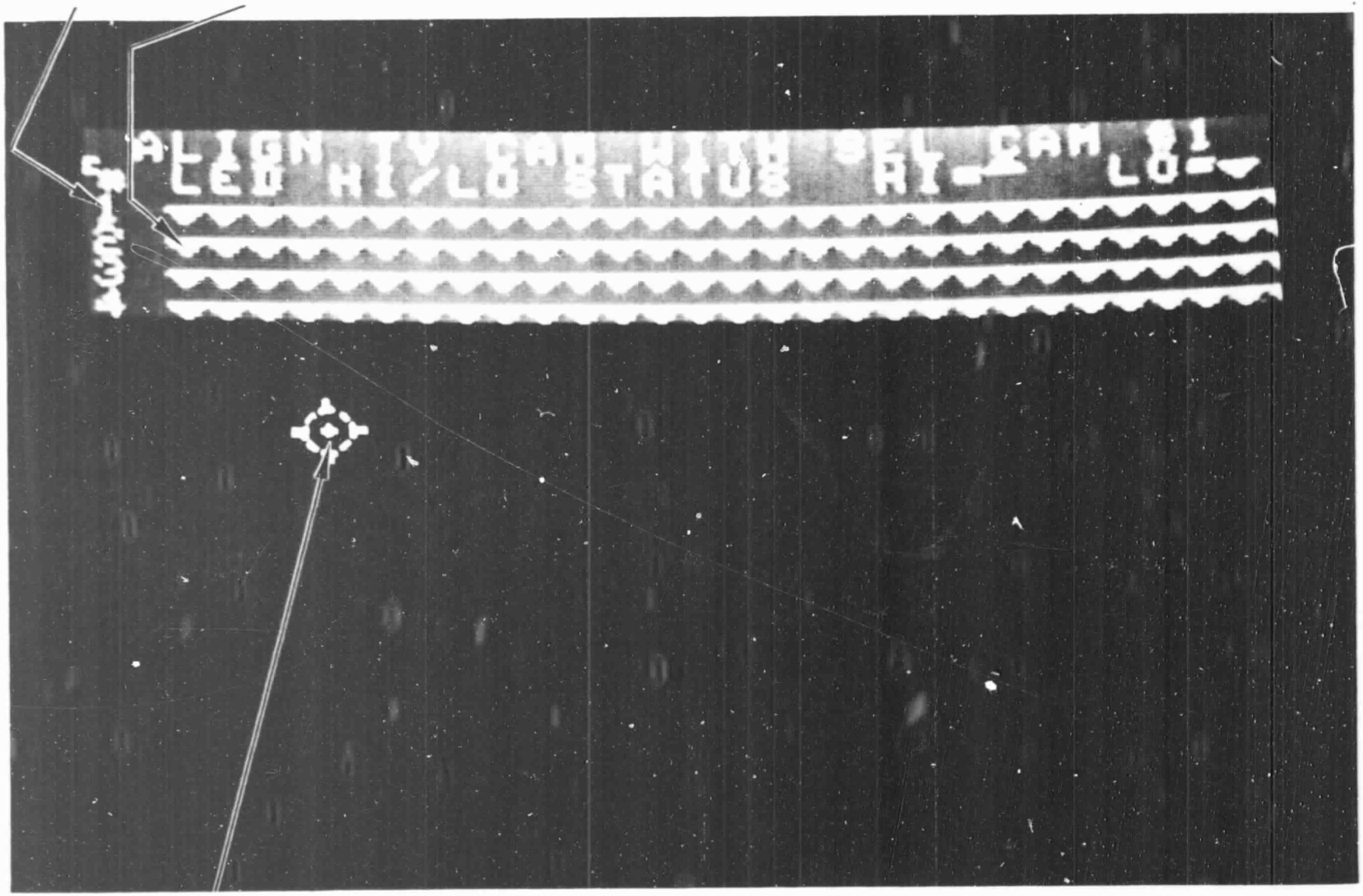

Figure 24

ALIGNMENT MODE DISPLAY

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number one status is located at the leftmost column.

The second function of the alignment mode informs the operator if all the LEDs being used in a particular experiment are "visible" to the Selspot cameras. It is quite possible that during a subject's preparation for an experiment, one or more of the LEDs could be inadvertently hidden or disoriented from the camera view. A quick inspection of the status display will reveal a down arrow for the hidden LED.

The third function of the alignment mode aids the operator in the alignment of the TV camera with Selspot camera number one. This alignment is necessary so that graphical LED data can later be correlated with the recorded television picture. As noted in Figure 24, a cursor is displayed on the television monitor which should overlay LED #1, if the TV camera and Selspot camera are in proper alignment. If the cursor is not overlaying LED #1, then the TV camera should be moved until the two coincide. This adjustment is important since it will affect the ability to correlate prerecorded data with the associated television picture. After satisfactory alignment has been made, the mode may be exited by entering a "Q" in response to the prompt ENTER Q TO STOP.

6. The Calibration Data Record Mode (C)

The purpose of this mode is to collect and record calibration data which the VRA uses to initialize calibration constants for future data analysis and verification processes. During the execution of this mode, a calibration fixture placed into position by the operator with four LEDs attached; referred to as the calibration cube, will be viewed by the four Selspot cameras as seen

in Figure 25. Before calibration the operator should mount the calibration weight on the Cybex force meter. The Cybex output will be measured and recorded automatically during calibration. Upon entering the calibration mode, the system will respond with the prompt: CYBEX FORCE (LB), requesting the operator to enter the force of the calibration weight. The prompt ENTER G TO START will then be displayed. The system will wait until a "G" is entered before recording data. During the calibration recording process, only 4 LEDs are recorded. The recording rate is always 60 samples per second and the header is preinitialized to CAL DATA. After sufficient calibration data is taken, the calibration recording process may be terminated by entering "Q" on the keyboard.

7. The Data Record Mode (R)

The purpose of this mode is: (1) to collect anthropometric data from selected LEDs using the Selspot position measuring system, (2) to encode the data into a format acceptable to the VRA data bus and (3) to store the data along with information about the experiment on a standard video tape recorder. Positional data on selected LEDs are collected by four Selspot photoelectric cameras. The number of LEDs monitored and the frequency at which they are sampled are selected by the operator via the front panel keyboard or external terminal. A table of the available sample rates corresponding to the number of LEDs selected for recording is given in Table 2. Since there are several sampling rate selections available, the front panel display sequences through the various rates, displaying each selection for 1.5 seconds before the next is displayed. After the operator enters the number of LEDs and sampling rate, the system responds with

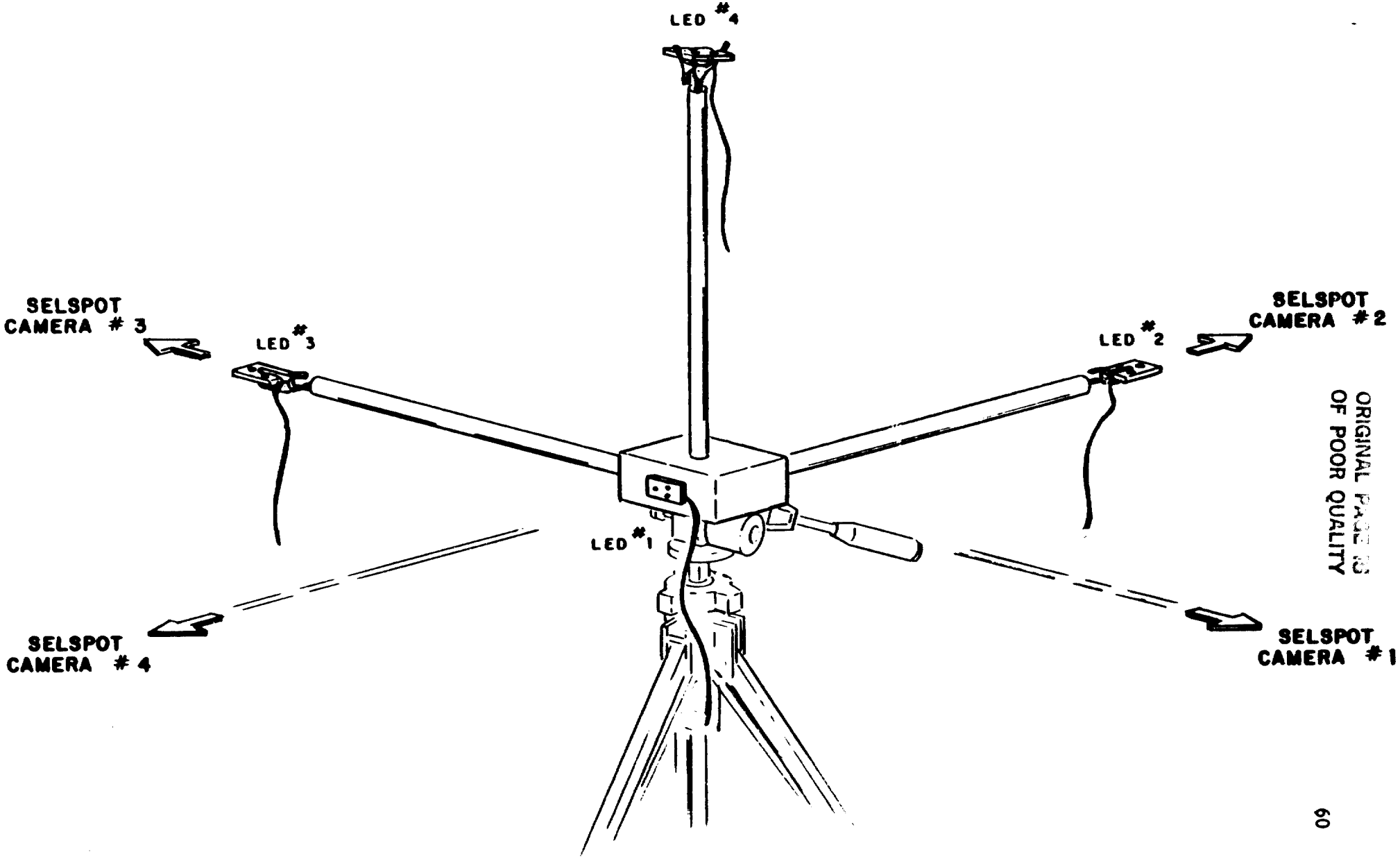

Figure 25
CALIBRATION FIXTURE ALIGNMENT

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Table 2

Recording Rate Selection

Number of LEDs selected (for Recording)	Available Sampling Rates (Samples/Second)
1-4	300, 240, 180, 120, 60
5-7	240, 180, 120, 60
8-10	180, 120, 60
11-20	120, 60
21-30	60

the ENTER HEADER prompt. The unit is now awaiting the entry of up to a 60 character header. This operator entry is optional, and will be automatically filled with blank spaces if no entry is made. However, the entry of some information should be made to aid in future identification of the record. If an incorrect entry is made using the external RS-232 terminal, the character may be erased by a H^C and retyped. After the header is entered, the video recording adapter will respond with ENTER G TO START. The system is now awaiting the entry of a "G" from either the front panel or terminal. The receipt of a "G" from the front panel or external terminal initiates the recording process. Immediately after receipt of the "G" command, the processor starts the video tape recorder and places it in the record mode. The operator is then told how to stop the recording process by the prompt: ENTER Q TO STOP. A second leader is placed on the tape prior to recording. After the six second delay, the data collection and recording process begins.

The events that take place during the recording process are: (1) collection and formating of Selspot position data, (2) error detection code calculation, (3) digitization of the Cybex force meter voltage, (4) elapsed timekeeping, and (5) the encoding and storage of the formatted data. During the recording process, the recorded image is a composite of video and digital data with digital data masking the top portion of the picture. As more LEDs are recorded or the sampling rate is increased, the data will grow to cover the picture. A technical discussion of the recording process is given in the Theory of Operation portion of this report.

When the operator desires to terminate data acquisition, he enters a "Q" and the VRA records an end of record indication for 1.5

seconds. After this is recorded, the processor allows a delay of 3 seconds for tape leader, stops the video tape recorder, and then returns the system to the command acceptance mode.

8. Data Verify Mode (V)

The purpose of the data verify mode is the verification of recorded data integrity and to insure that desired information was recorded properly using the VRA internal microprocessors and graphic display capabilities. To initiate execution of the verify mode a "V" is entered from the front panel keyboard through the rear panel RS-232 port. In order to calculate and display meaningful information about the data being verified, it is necessary to initialize the VRA with calibration data. A video tape of the calibration measurement is loaded into the video tape recorder and the VRA is given the verify command. The response returned by the VRA is the prompt: CAM-CTR DIS (CM), requesting the distance from the Selspot cameras to the origin of the calibration cube. After this entry, the VRA requests the length of the calibration cubes sides by the prompt: CAL CUBE SIZE. Immediately after the cubes size is entered, the VRA starts the playback of the video tape. After the calibration portion of the tape is read, the system is ready to verify experimental data.

During the data verification process, parameters of the data are overlayed on the data/picture composite being displayed on the video monitor. The information displayed include, the time and date the recording was made, the elapsed time into the test, header information, sampling rate of the LEDs, and the number of LEDs monitored. Simultaneous with the display of this information, the VRA display prompts for the entry of an LED Identification number. The

entered LED will be verified by a cursor overlayed on the television display which follows the LED. The spatial coordinates of the LED are calculated in reference to LED #1 and displayed on the monitor. An example of the display format is given in Figure 26. If another LED is desired, an "N" is typed from the input device and the VRA requests the entry of the new LED identification number. If an LED is requested which was not recorded, the VRA responds with INVALID ENTRY and waits for another selection. The verification process is halted by typing a "Q" which returns the VRA to the command acceptance mode.

9. Direct to GPIB command (D)

The DIRECT TO GPIB command is selected by entering a "D" from the front panel keyboard or external terminal. This mode allows the direct transfer of Selspot position data over the GPIB without recording the data on video tape. The operating mode of the GPIB bus may be selected by a switch internal to the VRA. Upon execution of this command, the operator should select the number of LEDs to monitor. After this selection has been made, the system enters the GPIB control mode. A hardware reset is required to return to the command acceptance mode.

10. Playback to GPIB command (P)

The purpose of this mode is to decode data previously stored on the video tape recorder and transfer the decoded data over the GPIB to a host computer for analysis. The equipment necessary for downloading of data are the VRA and video tape recorder. This is an advantage when portability is needed and access to a computer may be limited.

The PLAYBACK TO GPIB command is executed by entering a "P" from the front panel keyboard or rear panel RS-232 port. The VRA

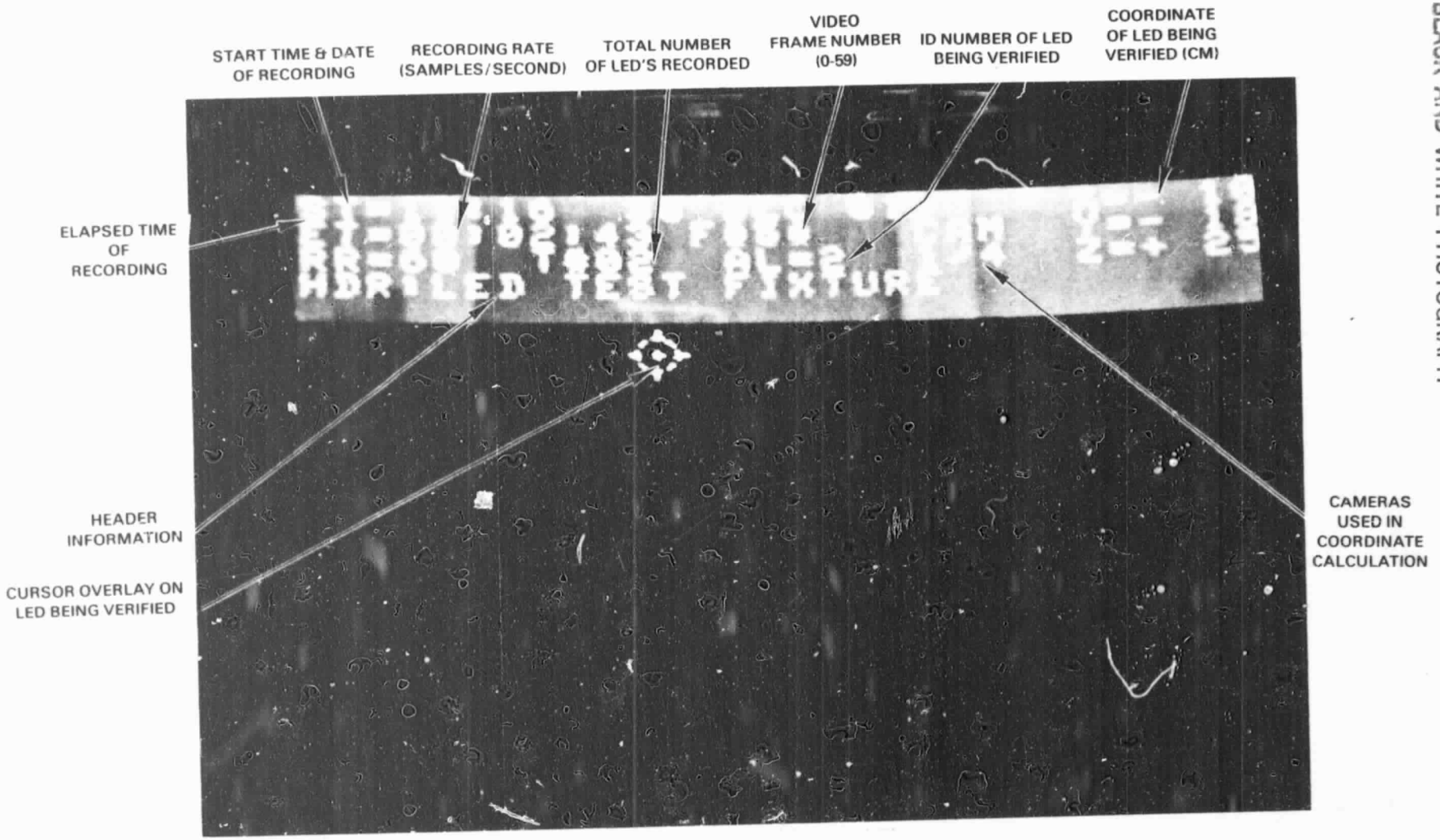

Figure 26
VERIFY MODE DISPLAY

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responds to this command with the prompt: GPIB CONTROL. The operating mode of the video recording adapter GPIB interface is selected by a switch internal to the VRA. The GPIB interface can operate in either the addressable or talk only mode, allowing flexibility in data transfer methods. The addressable mode is useful when two or more devices are connected to the GPIB simultaneously. Each device using the GPIB interface will only communicate over the interface when it is specifically addressed by the GPIB controller. When the VRA address is received, the video tape recorder is automatically placed in the playback mode and data transfer begins. Data transfer continues until the VRA is unaddressed or disabled as a talker.

The talk only mode is used when no controller exists on the GPIB to address the VRA. Data transfer begins immediately when this mode is selected.

11. GPIB Record Mode (I)

The GPIB RECORD mode is executed by typing an "I" and carriage return from the front panel keyboard or external terminal. The function of the mode is to record data received over the GPIB using the mass storage capabilities of the VRA. When this mode is entered, the prompt GPIB CONTROL is displayed on the VRA front panel display and to the external terminal. The processor is now incapable of responding to any keyboard entries with the excepting of the hardware reset located on the front panel. The hardware reset will return the system to the command acceptance mode and initialize the baud rate of the RS-232 port to 9600 baud.

Before GPIB data recording can begin, the microprocessor must determine what operating mode is required for the GPIB interface

hardware. The two possible operating modes are the addressable mode and listen only mode. Mode selection is made using the dip switch on board #1 as shown in Figure 27.

a. Addressed Operation

When the addressable mode is selected for GPIB operation and the GPIB record mode is executed, the system will prompt with GPIB CONTROL and wait for its address to be sent over the GPIB. When the GPIB interface receives its address as a listener, the VRA will turn on the video tape recorder, delay five seconds to allow a leader of tape, and begin accepting data over the GPIB. The received data is buffered, encoded and then recorded on video tape. When the GPIB interface is unaddressed or placed in the unlisten mode, the video tape recorder is automatically stopped and the interface again waits for its address and a listen command. This process will continue indefinitely until a hardware reset is executed.

b. Listen Only Operation

When the listen only mode is selected and the GPIB command is executed, the system indicates it is under GPIB CONTROL and immediately begins accepting data from the interface bus. The received data is buffered, encoded and then stored on video tape. The VRA cannot be disabled from the GPIB bus by any command from the GPIB. A hardware reset is the only method of returning the system to the command acceptance mode.

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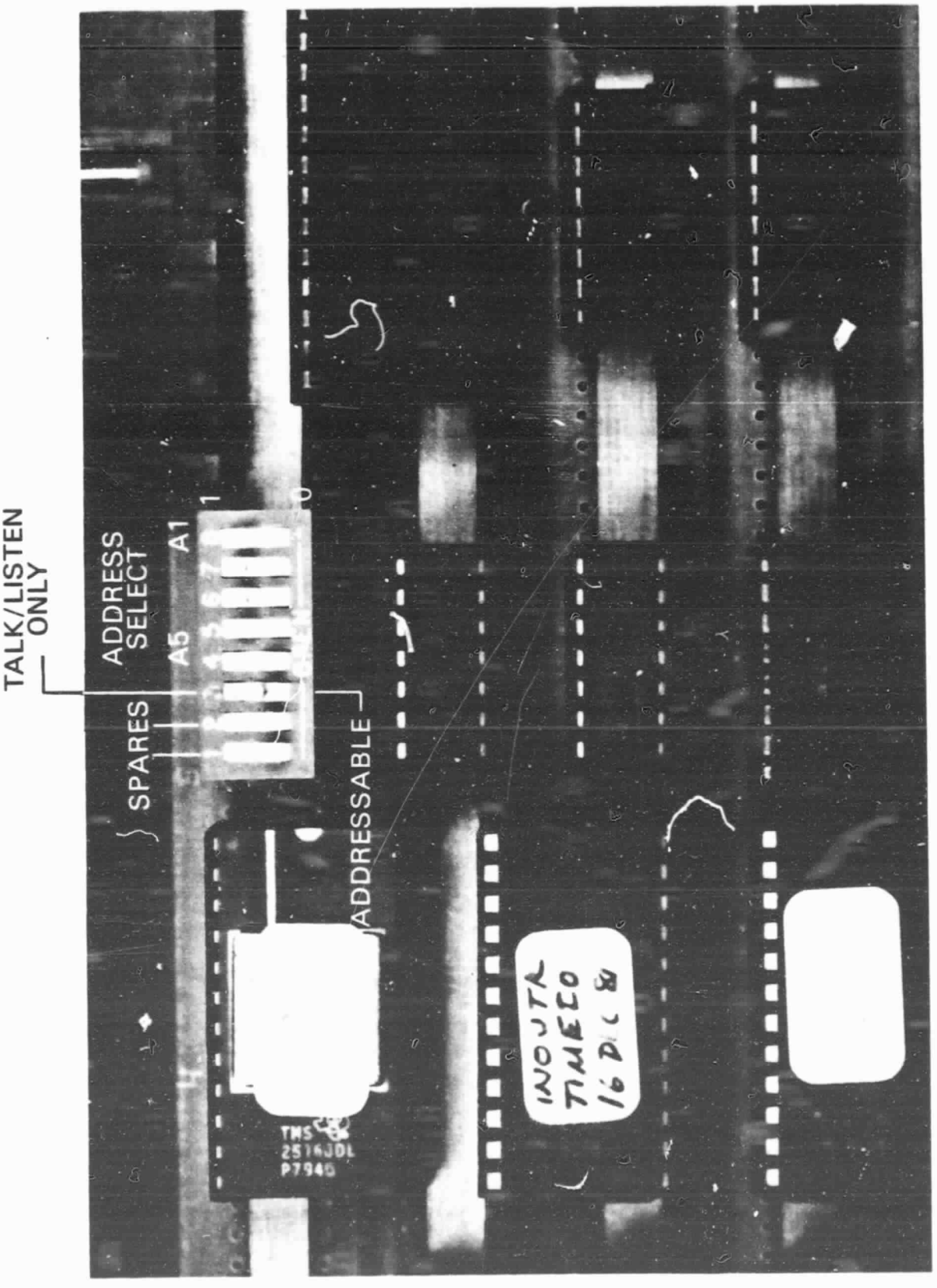

Figure 27
GPIB MODE AND ADDRESS SELECT

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Simultaneous Video and Digital Data Recording

The concept of acquiring visual and digital anthropometric data simultaneously for storage on long term recording systems appears to have considerable applications ranging from anthropometry to automobile barrier collision documentation. A uniquely significant feature of the SwRI video recording system is that while the system records a visual image of the test or experiment in progress, it simultaneously superimposes digital data at a recording rate of up to 30,000 bytes of data per second. Thus, if a 2-hour test is performed and recorded, the system will have stored not only 2 hours of visual test verification, but also approximately 2.2×10^8 bytes of digital information.

2. System Limitations

The experimental technique of storing digitized data imbedded within a video frame has proven successful. However, several changes in the original recording concept have occurred which will occasionally require up to almost one-half of the total picture viewing area for data storage. The two limitations found are:

(1) The desired recording bite rate of three to four megabits per second was unattainable using available off-the-shelf components. This limitation, combined with the high bit-error-rates encountered at recording rates over a megabit per second, forced a final digital recording rate of 1 megabit per second.

(2) The second condition which changed the recording concept from the original proposal was requested by technical representatives at NASA. The original concept was to select (prior to recording) the two data cameras to be used for eventual data playback and positional computations. Instead, SwRI was requested to record 4 cameras constantly for sake of data redundancy, thus increasing the ultimate data storage requirements by two.

3. System Operation and Accuracy

The difficulties encountered in interfacing the Selspot to the video recorder were of such complexity that the system testing and evaluation was abbreviated to comply with the contractual expenditure limitations. However, limited testing illustrated that system operation and accuracy was certainly adequate for the prototype video system. The errors which were encountered are displayed in Table 3. They may be generated by either the Selspot data acquisition system or possibly the three-dimensional software within the VRA. The values of X, Y and Z in centimeters which are reported in this table were calculated using the VERIFY routine on a calibration type fixture experiment. The numbers, which show an error of up to 2.5 centimeters, are based upon a camera to center spacing of three meters. Thus the field of view of each camera being approximately 1.5 meters or 150 centimeters causes the direct error to be somewhat less than three percent of full scale. Further testing across the field of view of each camera will yield more reliable and higher confidence accuracy figures.

Table 3

VRA Data Record and Verify Mode Test Results

CAMERAS USED BY VRA	MEASURED AND CALCULATED COORDINATES USING VRA			ERROR IN COORDINATE VALUE (cm)		
	X	Y	Z	X	Y	Z
1 and 2	-10	-17,-16	25,26	1	2.5	2.5
2 and 3	-10	-17,-16	22,23,24	1	2.5	0
3 and 4	-10	-17,-18	22,23	1	1.5	.5
4 and 1	-10	-19,-18	25	1	.5	2

TABLE 3

VRA DATA RECORD AND VERIFY MODE TEST RESULTS

B. Recommendations

1. NASA System Evaluation

The complexity of the video recording adapter system with its eleven operating modes will require considerable evaluation time and rigorous system operation to determine any possible operational oversights or operating bugs. It is recommended that considerable time be spent exercising all of the possible modes of operation as described in the operating manual. Deficiencies can then be identified and possible corrective action pursued.

2. Zero G Adaptability

The system is highly portable, and therefore, a possible future application of the system will be measurement of gravity free anthropometric observations. To accomplish the zero G test, the system may be modified and converted for flight use, or as an alternative, the cameras and light emitting target system may be converted for underwater use in the immersion facility.

3. Synchronization Improvement

Although the data storage technique has proved satisfactory and a relatively low bit error rate has been achieved, there has been some difficulty in synchronizing the video recording adapter circuitry with that of the Selspot output registers. The difficulty existing here is one of synchronizing two circuits together having different clock periods. The difficulty should be solved with the addition of a slight circuit modification to the Selspot video recording adapter interface unit. This will insure that both the Selspot control units will synchronize simultaneously with the video recording adapter, thus preventing the loss or permutation of data frames.