THE UNIVERSITY OF WISCONSIN

VAS DATA PROCESSING SYSTEM

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I. Introduction

With the launch of GOES-D in August, 1980 the first VAS instrument will be placed in geosynchronous orbit. A new opportunity for timely observation and analysis of short lived weather phenomena will become available. Full utility of the VAS data will be realized through assimilation with other available satellite and ground based data sources (conventional weather, VISSR, TIROS-N, radar, numerical model outputs). The data collection, analysis, and synthesis will be aimed at generating in near real time as complete and consistent a four dimensional description of the atmospheric state as possible. Achieving the goal of the VAS program, to better understand and predict short lived weather phenomena, will require atmospheric data with a spatial scale fine enough to resolve severe weather activity (tens of kilometers) as well as observations frequent enough to determine rates of change in relevant atmospheric parameters (half hourly).

The Space Science and Engineering Center has designed and is building a data processing system that will satisfy the needs of researchers trying to achieve that goal. This system will be completed by August, 1980. It is an outgrowth of the McIDAS (Man-computer Interactive Data Access System) and, indeed, contains hardware components from that system.

The McIDAS system was created five years ago to cope with the avalanche of satellite and ground based data available to the meteorological community. The design specifications required quality performance in five areas. They are: (1) the system must be quantitative so that available resolution of the data is neither lost nor distorted through acquisition, display, or analysis, (2) the data must be accessible in a timely fashion, (3) the user must be able to isolate the important data in a fast and efficient fashion, (4) the system must be capable of complex analysis on the preferred data upon user command, and (5) the system must be highly flexible in response to changing research requirements and yet it must be able to perform routine data processing tasks related to the measurement of atmospheric parameters. Those design specifications still serve as the measure of performance which the VAS processing subsystem of the McIDAS must aspire to.

This report summarizes the overall system architecture and describes the major hardware subsystems. While the emphasis here is on the hardware description, it is imperative that the reader understand that the software gives the system its capability. Therefore a section giving a brief description of the software has also been added.

II. The VAS Data Processing System Architecture

As identified in our proposal of April, 1977, the VAS system architecture is designed to perform three types of processing activities, (1) data base aquisition/data handling, (2) applications processing, and (3) user communications.

Data base management implies that the system must accept enormous quantities of data from a variety of sources (teletype data, satellite data, radar data, data from an archive ...), preprocess it to intelligible formats, and organize it for easy access. Applications processing refers to the computational capability for specific applications that the system must provide. User communications must be handled by the system in such a way that large volumes of data can be scrutinized rapidly and compacted in small volumes of information with the man interacting efficiently via his keyboard and joystick cursor. All of this must happen in near real time, so that the meteorologist can keep up with the weather. The McIDAS system accomplishes the first two activities with several midicomputers connected together in a wideband communications network; the last activity is performed by microprocessors with local storage interacting with a display system.

Figure 1 shows the UW system which performs these activities. Three GOES antennae receive data from two VISSRs and VAS. Two VHF antennae track TIROS-N and NOAA-6 during passes over Madison, WI. Dial up 4800 baud lines enable acquistion of numerical modelling results from computing faciliies at NCAR and NMC. Dedicated 9600 baud lines connect McIDAS with GSFC and Wallops to allow data set transfer and VAS spacecraft communications respectively. Conventional weather information is received from the FAA 604 line and from dial up links to the Weather Bureau Remote Radar stations. These five antennae and six phone lines give access to the meteorological data.

Three video cassette recorders archive the high volume data from the three GOES. This archival occurs even when the computing facility is down; the recorders stand alone from the central processing units (CPU). One video cassette player performs the playback duties when archived GOES data is requested. Four magnetic tape units archive the remaining data, raw and processed.

A total of six microprocessors accomplish part of the TIROS and GOES data

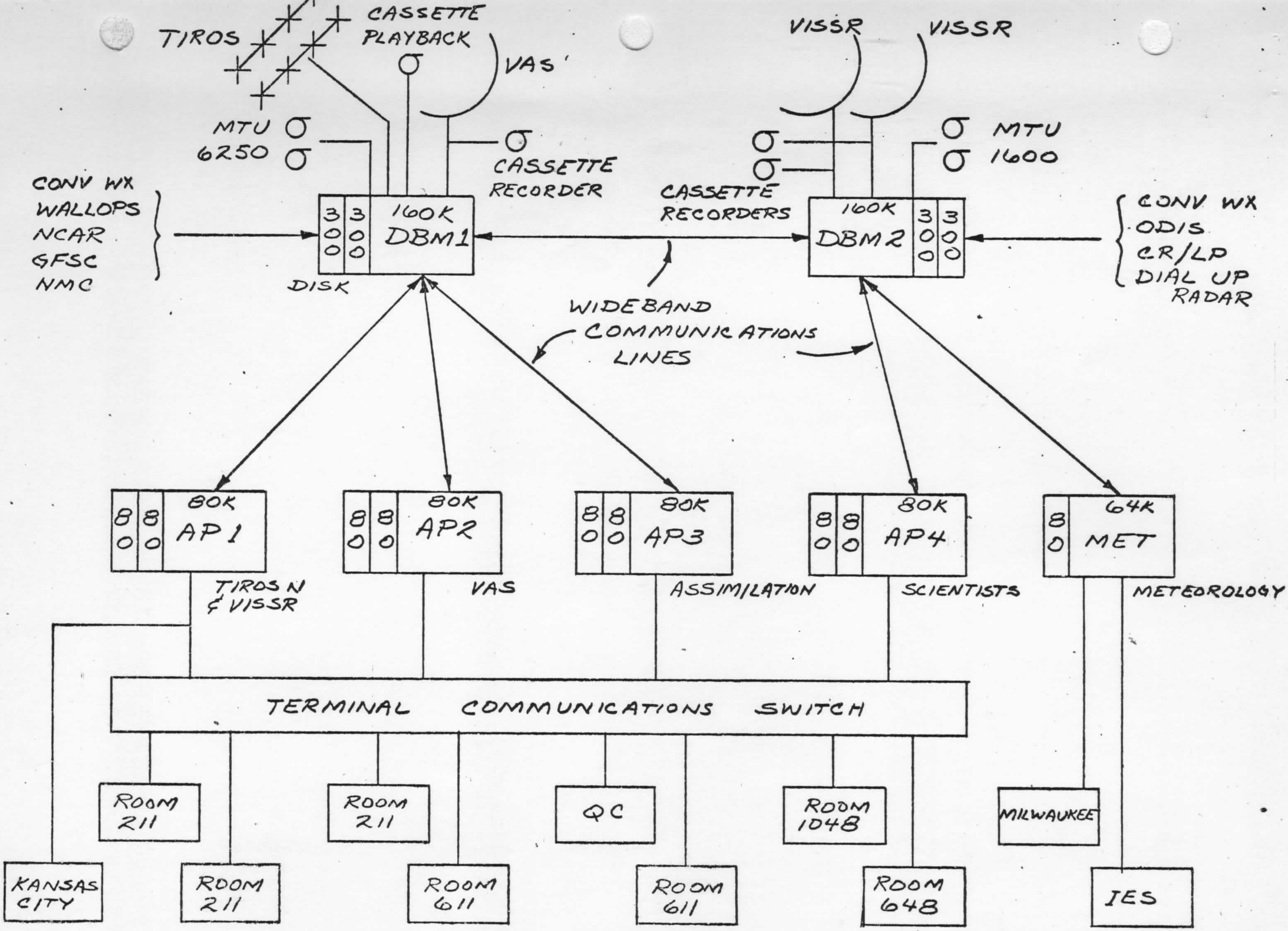


FIGURE .1 McIDAS SYSTEM

preprocessing. The remainder of the preprocessing is completed in the two data base management CPUs. These two data base managers (DBM) with their attached large disk storage space act as the librarian for the rest of the system; the data collection and handling occurs here.

Five CPUs with attached disk storage space perform the applications processing. Three are dedicated to the VAS program for TIROS-N and VISSR data processing, VAS data processing, and mesoscale data set assimilation; the remaining two support other programs within the SSEC, the UW Meteorology department, and the Institute for Environmental Studies (IES). Data sets are transferred back and forth between the applications processors (AP) and the DBMs via the wideband communications link (WCL). The WCL enables any AP to view the DBMs as a local disk with enormous capacity; it performs rapid transfer of large volumes of data.

Ten user terminals provide the mechanism for man interaction with the data; an eleventh terminal allows the system operator to exercise image quality control. User communication from any local user terminal with a selected AP can be accomplished for scheduled times through the Terminal Communications Switch. Remote user terminals at NESS, Kansas City and UW, Milwaukee communicate with a fixed AP via 9600 baud phone lines. The user terminals can display images, overlay graphics, display alphanumeric results, and enable interaction with the data through the keyboard and joystick.

This data processing facility will support the UW VAS Demonstration.

III. The Receiving Systems

A) The VAS Receiving System

The GOES receiving system captures the signal, deciphers the bit stream, and feeds digital radiance values to the data base management system. Three GOES antennae will point at the east and west VISSRs and at VAS. A description of the VAS receiving system follows: the VISSR systems are similar. The VAS antenna consists of a 24 foot dish and feed point receiving electronics that perform the signal reception, amplification, and downconversion of the 1.75 Mbps stretched VAS data. It is located on the sixteenth floor roof of the SSEC building. On the sixth floor in the McIDAS facility room, the PSK demodulator decodes the serial bit stream and feeds it into the bit synchronizer, which in turn provides the data and data clock for the frame synchronizer. The frame synchronizer detects PN sequence and sync words, derandomizes the data bits, and generates sector ID, boundary, and frame code. The data is now ready for distribution to the video cassette archive and the VAS data preprocessor (VDP). Figure 2 summarizes this part of the VAS data chain.

The VDP averages the VAS dwell sounding multiple scans for signal to noise enhancement. It consists of four parts. They are the control microprocessor, the buffer memory, the data acquisition and vector averager, and the DMA link to the host computer. The control microprocessor, an Intel 8086 16 bit microcomputer, orchestrates the preprocessing. The buffer memory, 64 Kbytes of RAM, holds the partial averages generated during the dwell sounding signal to noise enhancement. The vector averaging card accomplishes the scan line averaging on the fly by taking (1/N) x (new data) + (1 - 1/N) x (previous

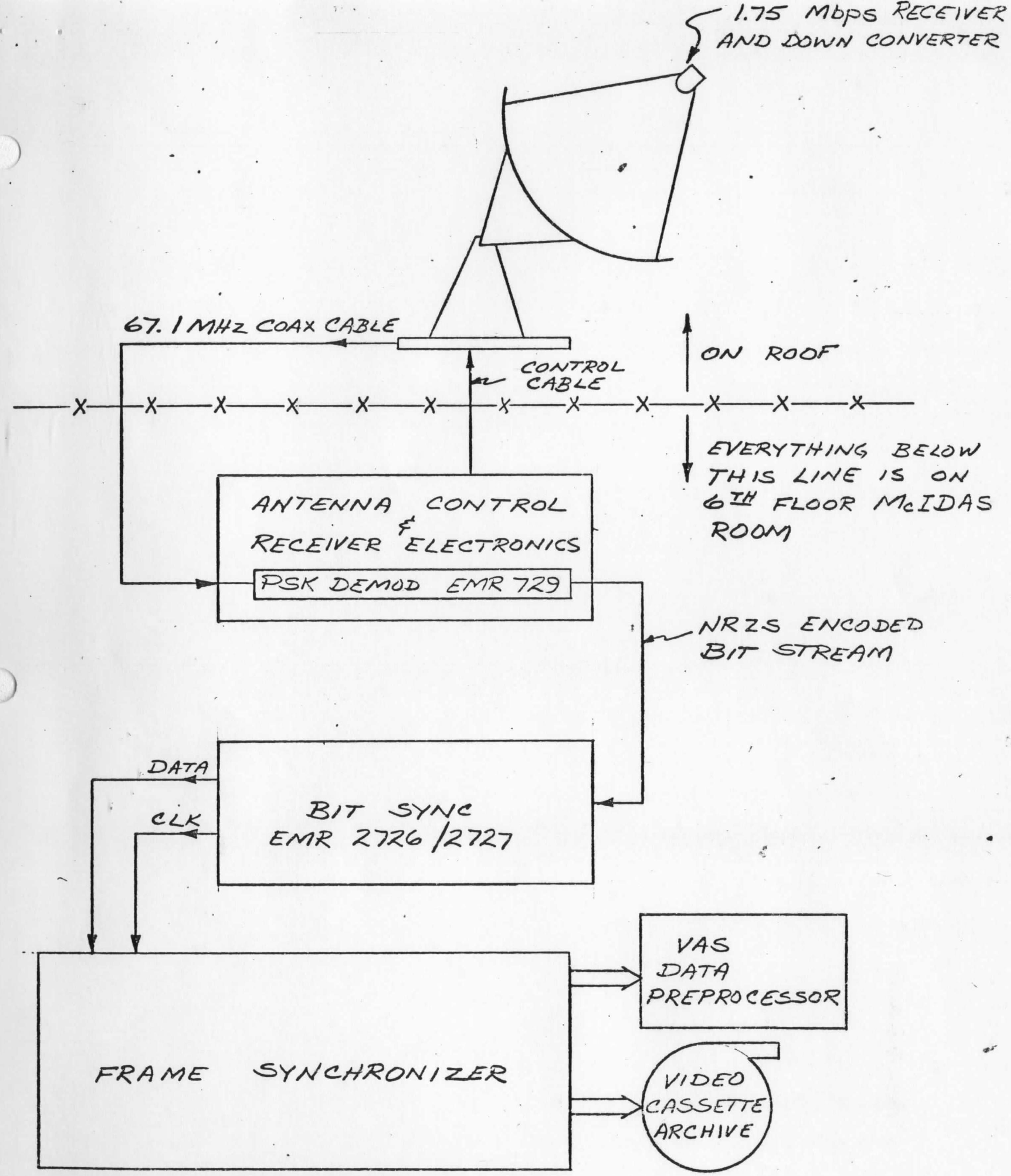


FIGURE 2
VAS RECEIVING SYSTEM

average). Figure 3 shows a schematic drawing of this. The DMA link performs the data transfer to the host computer. For VAS multispectral imaging no averaging is required, so the VDP feeds the data into the host computer directly.

B) The TIROS Receiving System

The TIROS-N data acquisition system allows direct readout and preprocessing of TIROS-N (and NOAA-6) satellite sounding data. Two VHF antennae located on the roof of the SSEC building receive, in real time, the Direct Sounder Broadcast signal while the polar orbiting satellite is within line of sight of Madison, WI. These antennae are controlled by the antenna control microprocessor which contains updated orbit information and sends out azimuth and elevation data to the antenna position controller to point the antennae toward the satellite as it moves through the sky. The main microprocessor is programmed to ingest, collect, and archive the incoming data. These preprocessed data are transmitted directly to the McIDAS facility room to be stored on disk with other contemporary data. Archival is accomplished by a 9-track magnetic tape unit controlled by the main microprocessor. Figure 4 is a block diagram of the hardware configuration.

C) The Radar Receiving System

The FM radar system receives the radar echo signals from National Weather Service stations and creates digitized images suitable for use on McIDAS (see Figure 5). An auto-dialer is used to call the desired station, equipped with a Weather Bureau Remote Radar transmitter. Once dialing is complete, the ingest hardware proceeds to digitize the incoming signal. The images are digitized to

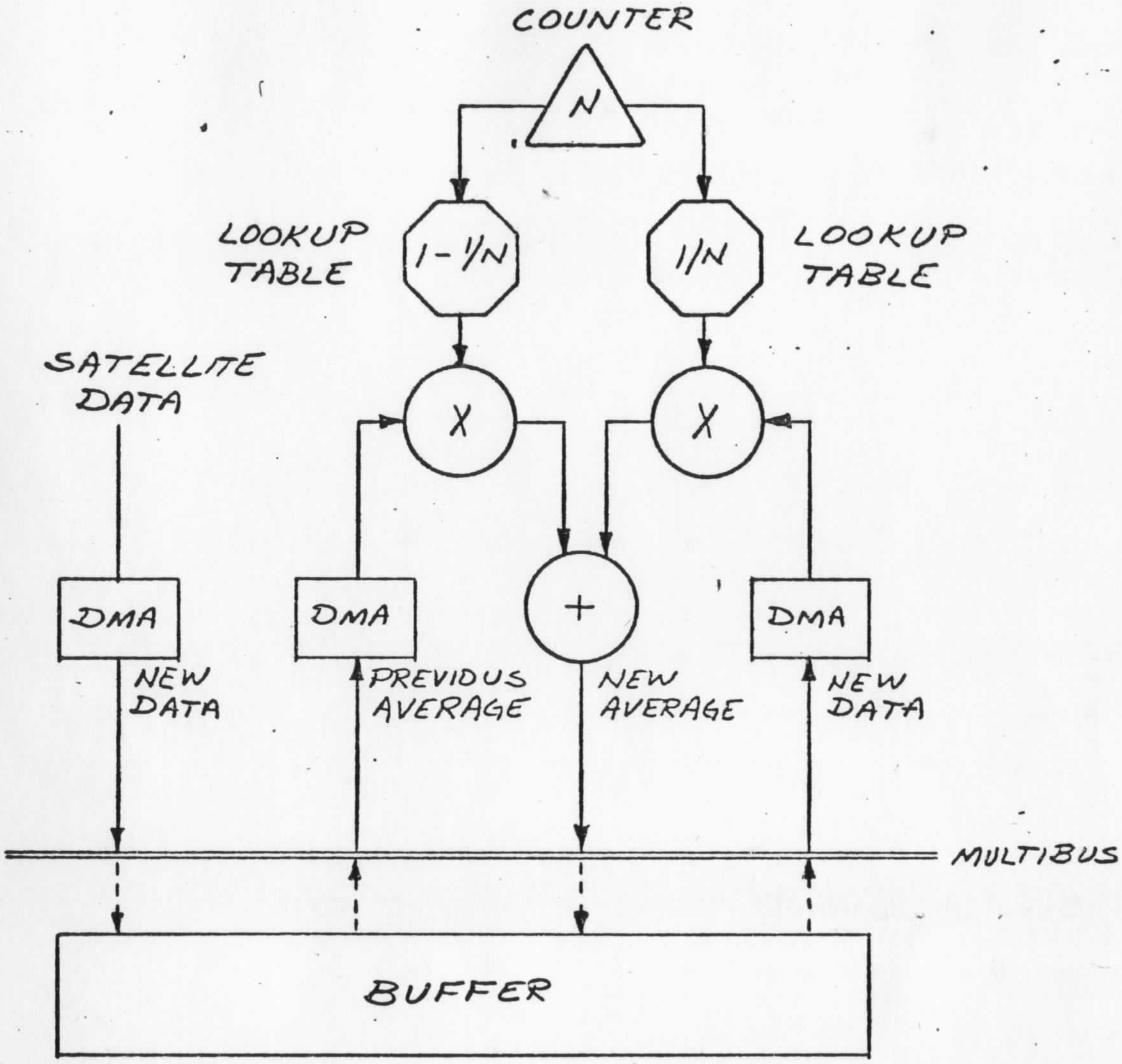


FIGURE 3 VDP DATA FLOW

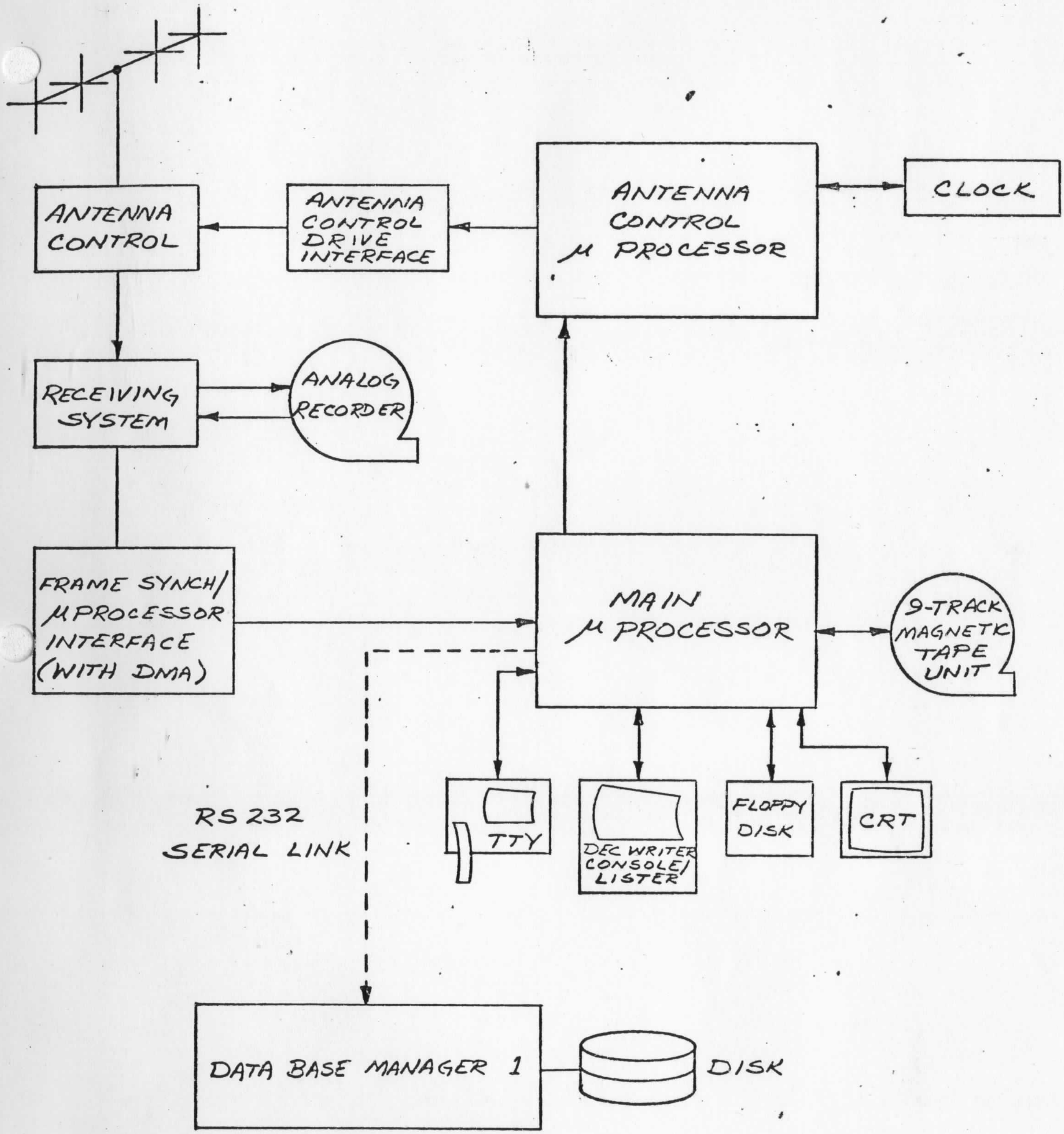


FIGURE 4 TIROS-N RECEIVING SYSTEM

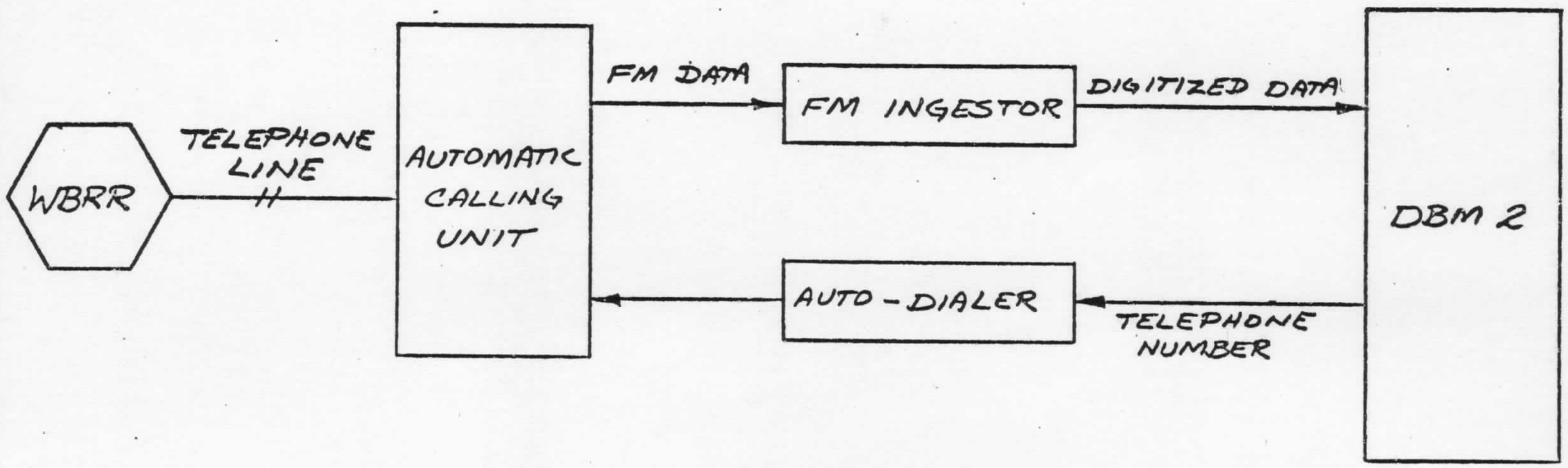


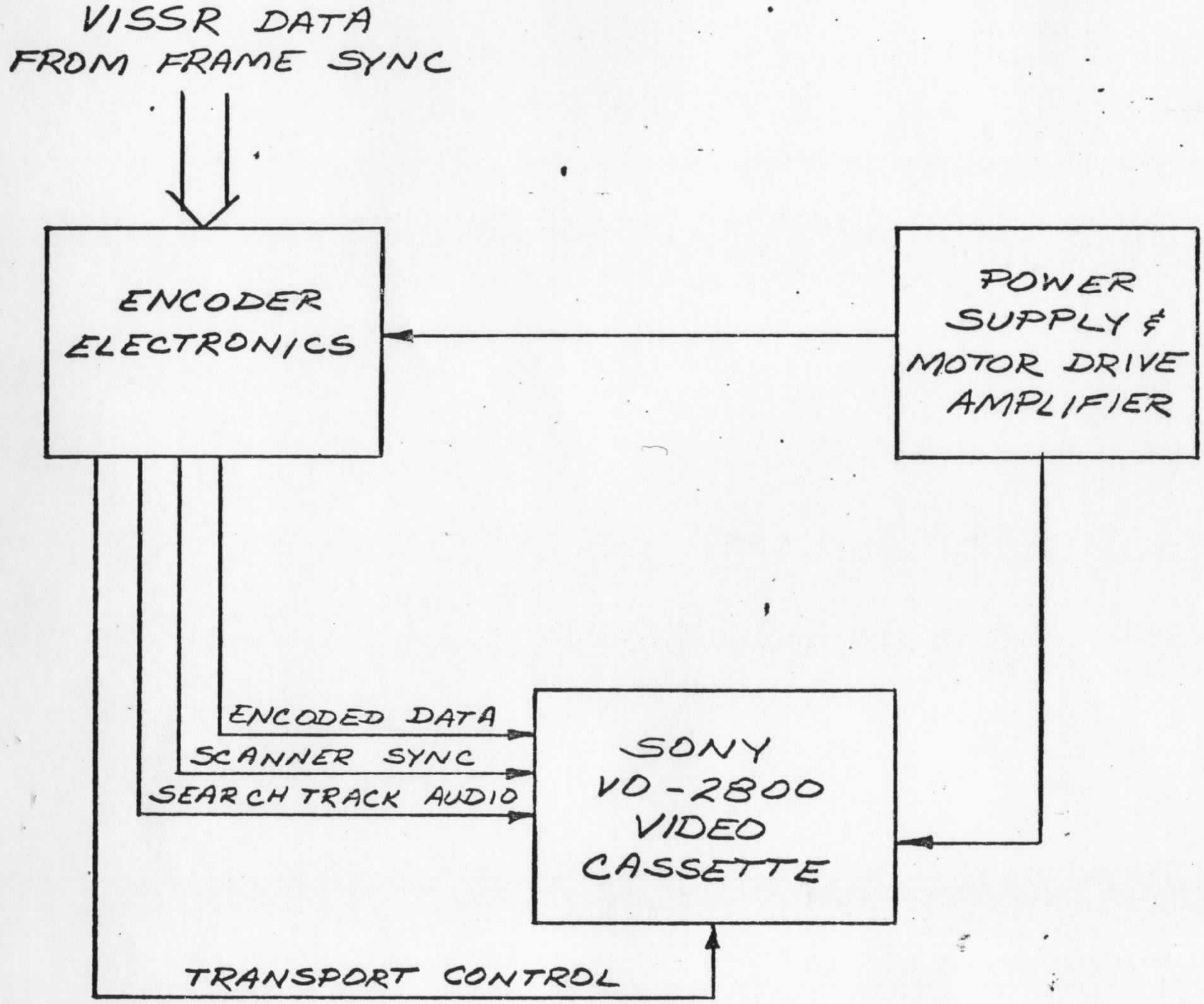
FIGURE 5 THE FM RADAR INGEST SYSTEM

64 brightness levels and are about 600 pixels wide by 800 lines long. Determination of whether the digitized data is actually the radar signal or some other signal (e.g. busy, ringing) is accomplished in the software.

IV. The Videocassette Archive

The videocassette archive system was developed at SSEC to record high-speed data from the GOES series of satellites. The VISSR data from GOES are received at a rate of 1.7472 MBS and are continuous for 18 minutes. This amount of data, representing full hemispheric coverage, uses 200 megabytes of disk. VAS data volumes will be comparable. The use of an adapted video recorder is particularly advantageous since video recorders have high bandwidths and long recording times.

The actual recording system consists of a record unit and a playback unit, thereby allowing simultaneous recording and playback of GOES data. The record unit (Figure 6) consists of a modified SONY VO-2800 recorder and an associated electronics drawer. The recorder can record modes A, AA, and B of a GOES spacecraft as well as data transcribing off a prerecorded GOES data cassette. Data format is the stretched VISSR bit stream from either a frame sync or directly from a S/DB. Correct data mode is automatically selected by the electronics drawer. The recorder transport is controlled by the satellite signal. Presence of sector start pulses places the recorder in the record mode by threading the tape. The unit waits in pause mode until reception of frame code, indicating actual picture transmission; then the pinch roller engages and data is recorded on tape. Absence of frame code disengages the pinch roller,



ARCHIVE RECORDER
HARDWARE CONFIGURATION
FIGURE 6

while absence of sector start pulses causes the tape to be unthreaded, thereby preventing excessive tape wear between pictures.

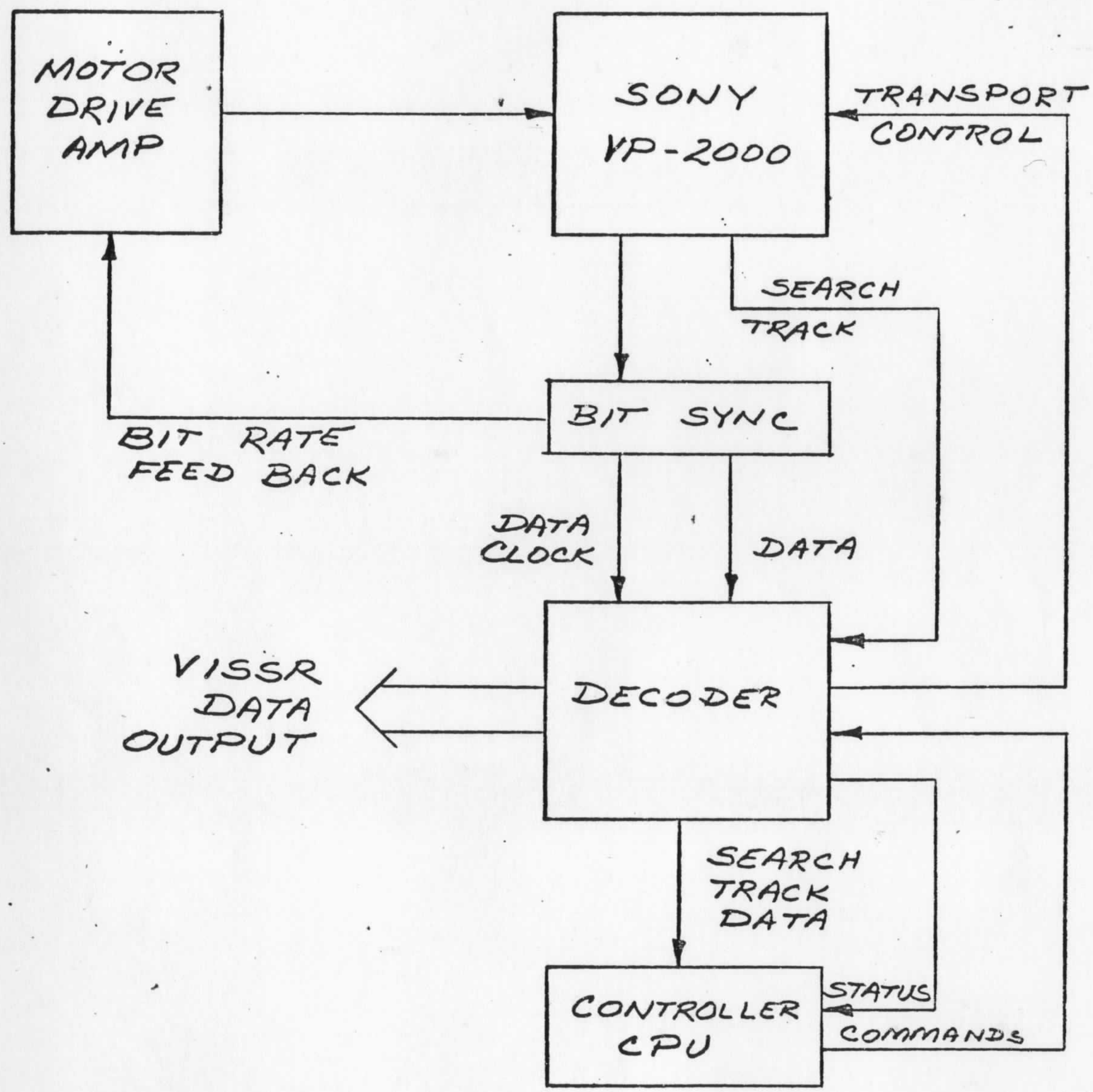
A search track is also recorded on an audio track as a means to facilitate location of a particular data segment. For a GOES picture, the satellite identifier, scan number, julian day, hour, and minute adequately describe any data segment. These data words are separated from the IR documentation and recorded as an amplitude modulated tone on an audio track.

The playback unit consists of a SONY VP-2000, a bit sync, and an associated electronics drawer (Figure 7). The player reconstructs the GOES data to the same format as stretched VISSR. The player can be used manually or it can be controlled with a computer via a standard 300 baud RS-232 asynchronous line. ASCII control characters are used for the transport functions. Transport status is sent back via the same line. In addition, the search track is decoded and transformed into a 1200 baud RS-232 asynchronous line. In this way automated control is possible.

Eleven full disc (IR + visible) images can be stored on a standard 60 minute cassette, while the newer 75 minute cassettes allow up to 14 images per cassette.

V. Data Base Management

The McIDAS facility will include two Harris /6 midicomputers with 1200 Mbytes attached disk storage configured as Data Base Managers (DBM). The VAS



ARCHIVE PLAYER
HARDWARE CONFIGURATION
FIGURE 7

Demonstration will require two DBMs for increased capacity and extra reliability. As seen in Figure 1, the DBMs occupy the central nodes of the system computer network and provide a common input/output resource to the rest of the network. Specifically the DBMs: (1) ingest data from two VISSRs (DBM2), ingest and reformat data from VAS (DBM1), store data from TIROS-N and NOAA-6 (DBM1), receive and record conventional weather data from the FAA 604 line (both DBMs), dial up and ingest Weather Bureau Remote Radar (WBRR) images (DBM 2); (2) communicate with computer facilities at NMC, NCAR, GSFC, and Wallops Island; (3) access data stored on nine track tapes, videocassettes, and large disc drives; and (4) handle messages and satisfy data requests from the rest of the system.

Because these are all I/O intensive tasks, the performance of the DBMs depends mainly on the bandwidth and size of their memories. The bandwidth of the Harris /6 is 55 Mbits/sec which is adequate to meet the combined peak I/O transfer rates required of each DBM. The memory size is critical in reducing the overhead associated with I/O requests, and for the Harris /6 it goes up to .75 Mbytes which is sufficient to allow handling of all DBM tasks simultaneously. The Harris /6 CPU provides rapid input/output and convenient multitasking capabilities, a matured and efficient disk management operating system, and a 24 bit word length which provides adequate memory address capacity and efficient handling of data in eight-bit or twelve-bit words.

The DBMs (and APs) in the McIDAS system share a common hardware configuration. The functional distinction between the CPUs is solely in software and peripheral attachments. Figure 8 provides a detailed block diagram of DBM2. Primary power for all equipment in the system is regulated and scrubbed of voltage transients by a Sola line conditioner. The DBMs will be supplied with about 160 kilowords

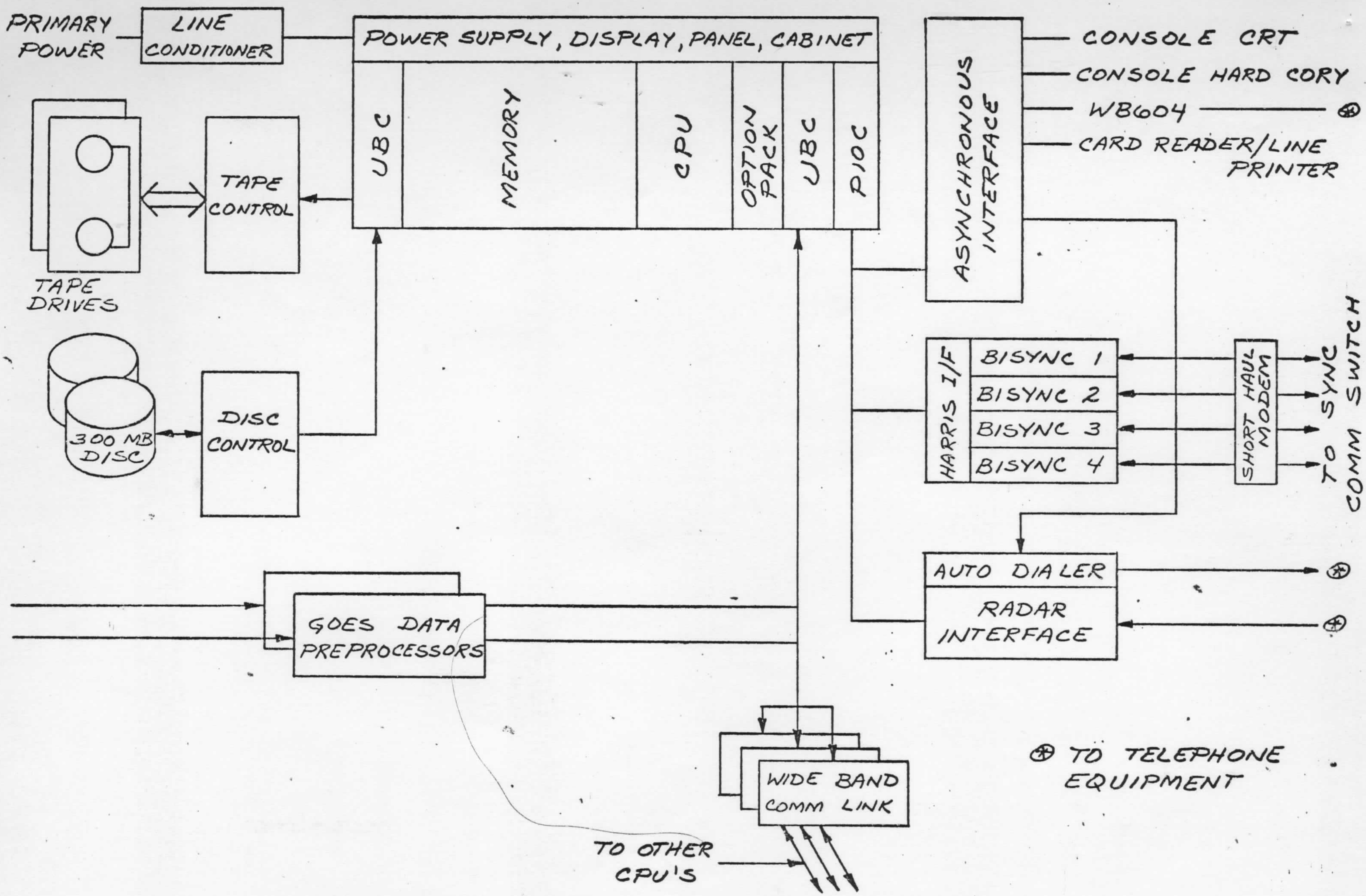
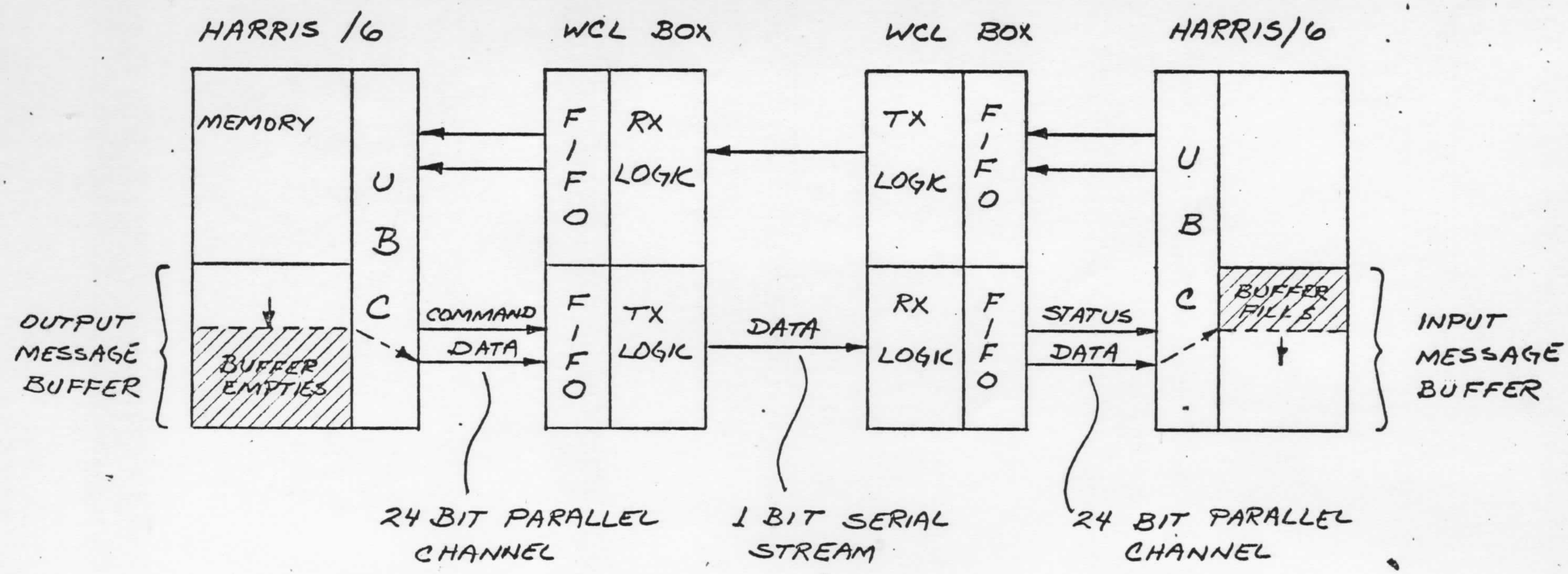


FIGURE 8 DETAILED CPU CONFIGURATION (DBM2 OF McIDAS SYSTEM)

of 24 bit memory with error correcting codes, a complete option pack of program restrict, halt and address trap, an interval timer and a programmers panel. Input/output to the Harris /6 is accomplished with the Universal Block Controller for DMA-ing out large records and with a Programmed Input/Output Controller for handling key-ins and single byte transfers (more will be said about this later). Online storage is done with two 300 Mbyte disks. Offline storage and program saves are done on 800/1600 BPI tension arm tape drives (later on they will be done on 6250 BPI tape units).

The Asynchronous Interface provides asynchronous low speed communications. Devices connected to the interface are the console CRT and hardcopy error logger, the WB604 conventional data broadcast line, local card reader/line printer lines and the dialer portion of the radar interface.

Since the DBMs are the focal point of all data transfers, the communications from one CPU to another has been designed for efficiency and speed. This wideband communications link (WCL) functions in isocronous format on bit serial lines and is capable of handling data rates up to 10 Mbits/sec. The direct connection to each CPU is accomplished through a Universal Block Controller (a Harris Corporation DMA board), which accomodates block moves and asynchronous program input/output (i.e. status, command, and data information). Block moves require CPU overhead at the start and finish of a transfer only, thus allowing efficient large volume moves. The vital hardware element in this transfer is the WCL box, which has been designed and built at SSEC. Figure 9 depicts the functioning WCL. The WCL box has two bidirectional interfaces, the 24 bit parallel interface to the UBC and a serial data and clock interface to another WCL box. A pair of fifos (first in first out memories) serve to buffer bursts



RX IS SERIAL TO PARALLEL

TX IS PARALLEL TO SERIAL

FIGURE 9 THE WIDEBAND COMMUNICATIONS LINK in data traffic, either while sending or receiving. Sixteen bits of check sum are automatically generated, transmitted, received, and verified for each data transfer bounded by two command words. Finally, a direct command word to status word link between the two CPUs is provided to facilitate high level protocol interaction.

VI. Applications Processing

The McIDAS facility will have five Harris /6 midicomputers configured as Applications Processors (AP). These Applications Processors will perform the large arithmetic processing tasks necessary for extracting useful meteorological parameters from the collected raw data. Each AP has a local memory of 80 kilo words of 24 bits, floating point hardware, and 160 Mbytes of disk storage. Local disk storage will accomodate applications software and requested data sets (transferred from the DBMs). Each AP will run in a time sharing mode, thus being able to serve as many users as conditions warrant.

Each AP will be primarily assigned to one major processing task. The VAS APs will focus individually on (1) extracting TIROS-N sounding and VISSR wind fields, (2) producing VAS temperature and moisture fields and determining time rate of changes in those fields, and (3) assimilating all available meteorological data into data sets depicting the atmospheric state on the mesoscale.

VII. The McIDAS User Terminal

The user terminal is the critcal link between the man and the computer in the McIDAS system. The user terminal concept at SSEC has evolved over several years and has the goal of delivering the most effective interaction between the computers and the users.

All user terminals are functionally similar; they consist of a set of input and output devices under the control of a microprocessor. Input devices are the user keyboard (which enables interaction with the monitor, terminal diagnostics, and the host CPU) and the joysticks (which control cursor position and size or image colors). Output devices include the image display (on which color and/or graphics overlays are enabled by the video control), the colorizer (which enables application of various black and white or color transformations to the image), the CRT (which provides alphanumeric readout for operations or diagnostic testing), and the line printer (which delivers hard copy output).

The user terminal hardware consists of the electronics necessary to interface to a CPU, a data storage device capable of holding one or more frames of imagery and repeating output at video rates to refresh the display, and the several devices enabling operator interaction.

Figure 10 shows the user terminal configuration. The control microprocessor is an Intel 8080A in an SBC 80/10A with SBC 104 memory and I/O expansion. Necessary TV timing signals are generated by the TV timing board and are distributed to the cursor generator, colorizer, and the refresh subsystems. Both analog disk recorder and solid state memory units have been used for video

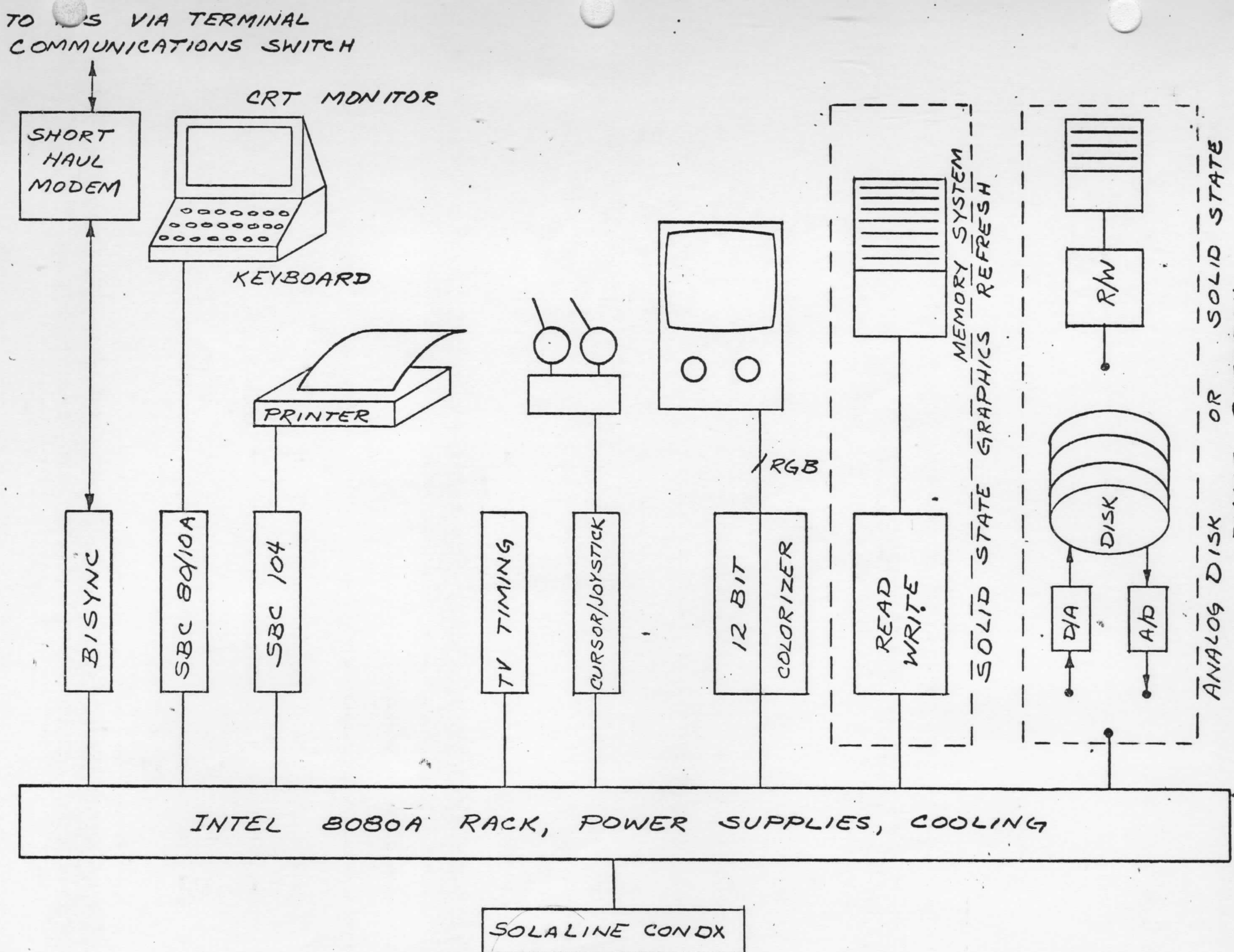


FIGURE 10 USER TERMINAL FUNCTION DIAGRAM

image storage and display refresh. The analog disk refresh provides a large number of data frames (about 260), but it suffers some loss of fidelity in the amplitude information. The solid state refresh provides full digital data fidelity, the capability to access stored images in random order, and the writing of graphics into the refresh memory at a high rate of speed. However the cost per frame of image data is much higher for available solid state devices than for the analog disk (6 frames of solid state refresh is roughly equivalent to 600 frames of analog disk refresh). Each pair of images has an associated graphics frame with up to 3 different colored lines. Full correlated enhancement in pseudo-color is accomplished with the 12 bit enhancement option to the colorizer board. Images from either the analog disk refresh or the solid state refresh are enhanced and colored by the identical process. Since the colorizer-enhancer is a digital process, its effects are fully reproducible. The 12 bit version of the colorizer electronics allows combination of two 6-bit images by any algorithm which is a function of the amplitude of the picture elements of the two individual images; that is to say, that a new image can be generated by multiplying image A by image B, by subtracting them, or by using any other linear or non-linear algorithm. This capability is expected to be useful for doing multi-spectral analysis.

The cursor can be moved about the screen by the operator with no apparent time lag using one of the joysticks. The cursor can be a dot, a cross, or a rectangle -- the dimensions of which can be determined at will by the operator.

The link between terminal and computer is flexible. The rate of communication can be from a modest 9600 baud to a 614 Kbaud serial link. The format down this link is designed to allow for easy expansion by specification of new destination codes. This flexibility is enhanced by the use of a microprocessor to orchestrate the terminal activities.

VIII. Ground Communication with GSFC and Wallops

Communication between the VAS processing system at Wisconsin, the VAS system at GSFC, and the S/DB at Wallops will be accomplished via a 9600 baud full duplex synchronous line using the ADCCP (Advanced Data Communications Control Procedures) protocol. Two identical communications interface units will be operating between SSEC's DBMs and the remote CPUs (i.e. one to the SD/B and one to GSFC). Figure 11 shows a block diagram of such a unit.

All control is via an Intel 8080A microprocessor. Two hardware-software communications submodules are employed in each unit. One module controls communications to and from the remote site via modem using a subset of the ADCCP protocol, the other module controls communications to and from SSEC's DBM using a subset of the Bisync protocol.

ADCCP I/O is accomplished under DMA (Direct Memory Access) control using an Intel 8273 SDLC/HDLC protocol controller chip. This device provides bit level and checksum procedures identical to ADCCP with speeds up to 60 Kbaud. Up to 8 input and 8 output buffers may be stored in the 16k RAM, with maximum buffer size being 1k bytes. Bisync I/O is accomplished using a SSEC developed psuedo Bisync transceiver board. This board contains two 1k biported RAM buffers allowing 8080 "ping ponging" between the board's transmitter and receiver. Although Bisync is a half duplex protocol, no speed degradation will occur at

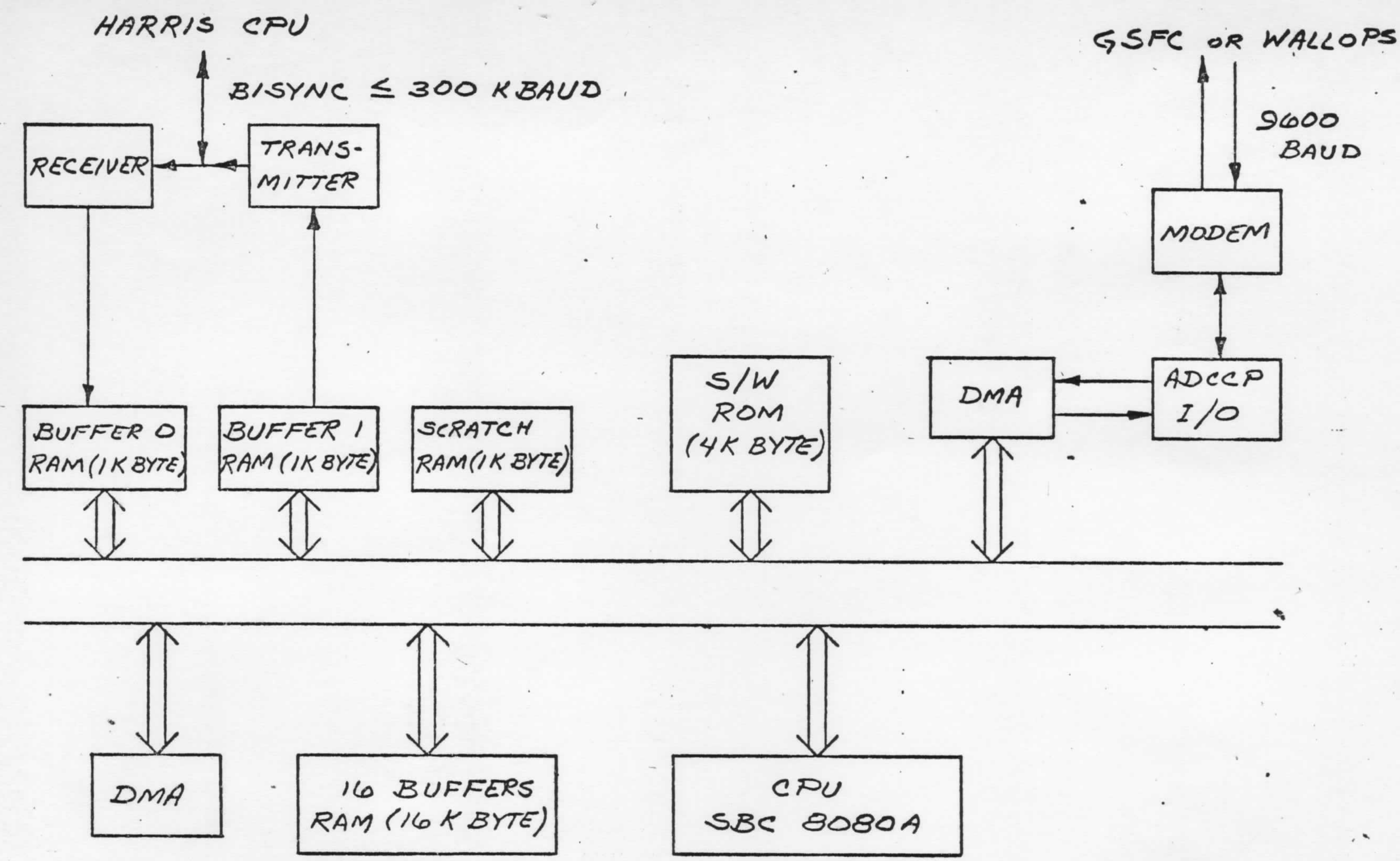


FIGURE 11 ADDCP COMMUNICATIONS UNIT

the ADCCP end because the Bisync module can be driven at up to 600 Kbaud.

Buffer transfers between the ADCCP and Bisync modules will be via DMA memory to memory transfers with the 8080 doing protocol control modifications. 8080 software is stored in 4k ROM and 1k RAM is provided for 8080 scratch pad memory.

IX. The McIDAS Software

While this report summarizes the hardware components of the VAS subsystem of the McIDAS, it must be emphasized that the largest part of this system is software. Therefore a brief summary of the operations and applications software follows.

The McIDAS software consists of approximately 400 applications modules and a flexible operator command structure (operating in a slightly modified Harris Disk Management System). The DMS operating system is almost ideally suited to the kind of data processing which McIDAS is designed to perform. It provides rapid input/output to the digital disks where all of the modules are normally stored, and it provides an efficient multitasking capability which allows the system to ingest satellite, teletype, radar, or other data at the same time that it supports data requests from one or more users independently with little or no apparent conflict. Applications software modules are kept small, so that a minimum amount of computer core is occupied by operating programs, and a maximum amount is available for data.

A) Operating Software

The operating, housekeeping, and applications software resident in the computers normally occupies approximately 25,000 words of core space, although this number may vary for special applications. The command language available to the operator has been designed to exploit the modularity of the applications software so as to provide maximum flexibility to the operator in assembling modules to meet his specialized data processing needs. With some exceptions, the operator is free to assemble modules in any order he desires to move, modify, analyze, or display data. The command structure allows the operator to assemble and designate macro commands (a series of lower order commands) in order to improve the efficiency of repetitive processing procedures. The operator command system has been designed to provide the complexity necessary for truly interactive processing, but to avoid being difficult or complicated.

Operation of the McIDAS control software is shown diagrammatically in Figure 12. Operator input, whether by joystick or keyboard, is through the communications module. The operator's instructions are accumulated in a task message queue which are processed by the task dispatcher to call up the chain of applications programs required to accomplish the operator's wishes. The operator also controls all of the visual effects of the display through the video control module.

B) Applications Software

The applications software consists of many task oriented modules. Much of the VAS program will be occupied with the generation of more modules to take

McIDAS CONTROL SOFTWARE

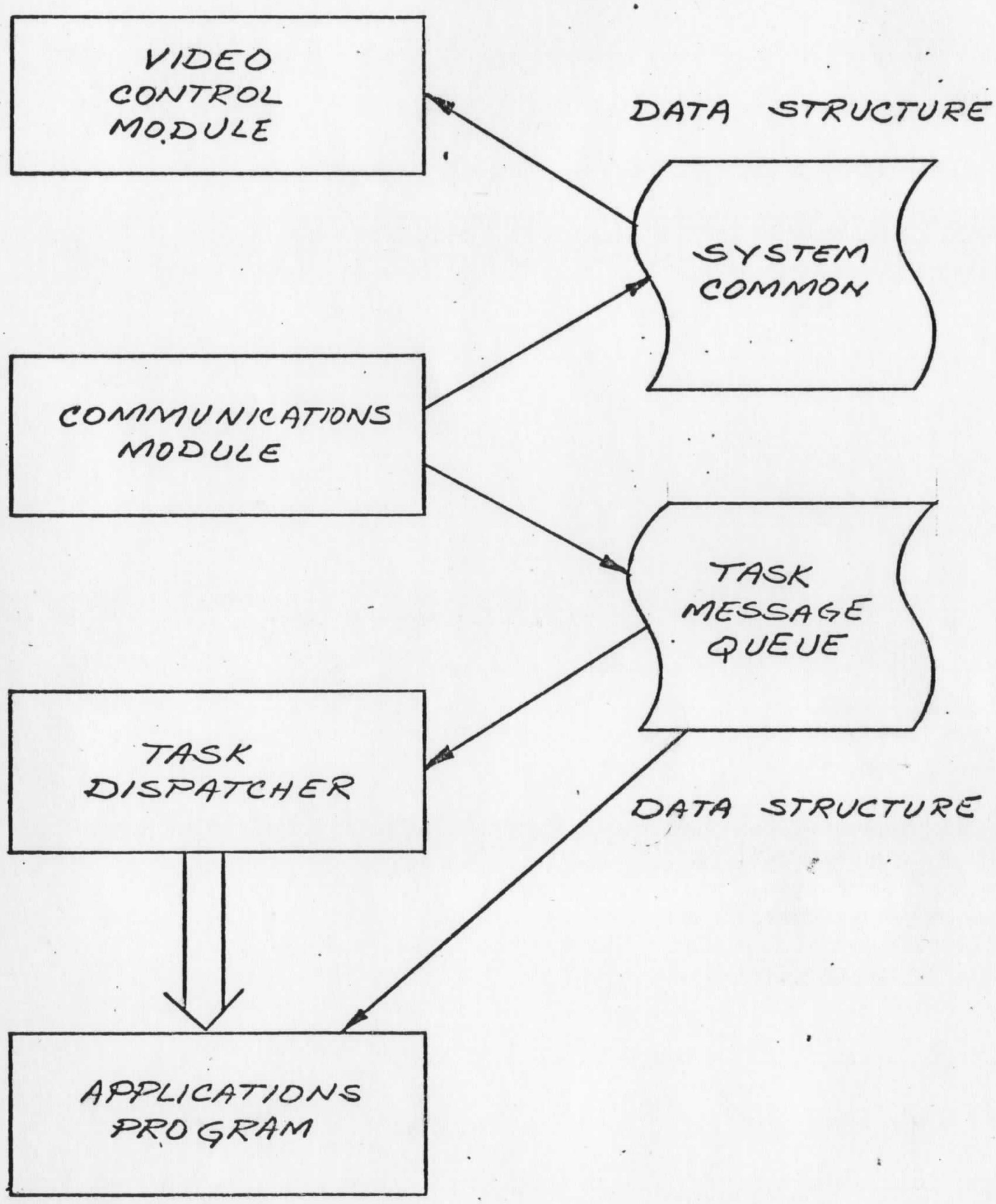


FIGURE 12

advantage of the unique VAS capabilities. A brief summary of some of the already existing modules follows.

Real time image ingest modules enable the entry into the system of two dimensional data arrays such as satellite images, radar scans, and facsimile charts. These are recorded on digital disks, tapes, or display refresh memories through the image management modules. Image management also keeps track of the locations and descriptions of all images under system control.

The exact latitude and longitude of each picture element is determined by the image navigation process. A basic module in the image navigation group provides the capability to transform coordinates from satellite image line and pixel to latitude and longitude or the inverse. In addition to normal image navigation functions, this module is also used to relate computer-generated graphics or other information arrays, so that information from different sources can be overlaid accurately. For example, geographical or political boundaries, user supplied maps, isopleths of meteorological parameters, geological data, etc., can be overlaid on satellite images.

The group of modules called "WINDCO" is used to determine the displacement of image elements measured from a series of images. The modules were developed and are used principally to determine cloud motions, but also have been used to track gravity waves, storm systems, squall lines, radar echoes, and other meteorological phenomena.

Conventional weather information is brought into the system, decoded, and stored in parameter/time files by the weather data ingest and management group of modules. The weather data analysis group includes a fairly large number of modules to compute streamlines, equivalent potential temperature, vorticity, divergence, advection, stretch and shear deformations, and many other derived parameters which are then converted into graphics form and displayed on the video screen.. The graphics modules can produce line drawings or character plots of any of the basic or derived parameters, including upper air soundings, cross sections, advection plots, and many others. The graphics modules can also generate filled area images, as well as line drawings, and can write alphanumerics in several styles and sizes wherever desired on the image. An associated set of modules provides the capability to color or enhance images or graphics, to move or rotate image elements, to provide scintillation, shading, crosshatching, or other special effects in the displayed image.

A growing group of TIROS modules allows the operator to manipulate the available visible, infrared, and microwave data. Vertical temperature and moisture profiles can be generated at 100 km resolution over a selected region automatically and then manually edited for consistency. Geopotential heights (or thickness) and thermal winds (or gradient or geostrophic winds) from analyzed temperature data can be compared against each other to check for meteorological consistency. Intercomparisons with radiosonde temperature profiles and cloud tracked winds are facilitated through remapping of data to polar orbiting or geostationary reference frames.

Most of the VAS software modules will be outgrowths of the existing applications software modules, modified to allow the determination of time rate of change of relevant meteorological parameters.

X. Conclusion

The described VAS hardware and software system will be functioning by the summer of 1980, in preparation for the launch of the first VAS instrument. The VAS ground processing system will be a part of the larger McIDAS. It is a flexible system; it can accomodate adjustments dictated by extensive testing of VAS processing techniques (many of which will be developed only after work with inflight VAS data), and it is capable of expansion to more DBMs, APs, and UTs.

This processing facility will satisfy the requirements suggested in our proposal of April, 1977, which states that the VAS system must

1) provide a test facility for evaluation of in orbit VAS performance,

2) serve as a research facility for the development of techniques for mesoscale analysis, synthesis, and prediction,

3) provide an archive of all data during the demonstration period, and

4) serve as an operational prototype which can be adapted by NOAA to provide operational VAS support.