Final Report
The U.S. Air Force Contract FO 8650-83-M-0156
for a
Study of the Meteorological Interactive Data
Display Needs of the Cape Canaveral Forecast Facility

A REPORT

from the space science and engineering center
the university of wisconsin-madison
madison, wisconsin

Final Report
The U.S. Air Force Contract FO 8650-83-M-0156
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Study of the Meteorological Interactive Data Display Needs of the Cape Canaveral Forecast Facility

by

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I. INTRODUCTION

Detachment 11, 2nd Weather Squadron, is tasked to provide meteorological, environmental and aerospace support to the Eastern Space and Missile Center (ESMC), the National Aeronautics and Space Administration (NASA), and the DOD Manager for Space Shuttle Support Operations. They provide this support to the Cape Canaveral Air Force Station (CCAFS), to Patrick Air Force Base (PAFB), the Kennedy Space Center (KSC), and the Eastern Test Range (ETR) primarily through the Cape Canaveral Forecast Facility (CCFF).

The CCFF is a 24-hour a day forecasting and observing operation for normal facility and airfield support; in addition, it provides specialized forecasts for all space and missile launches, diffusion predictions for toxic fuel operations and weather services for recovery forces, instrumented aircraft and the range instrumented ships. It is an integrated facility in the sense that the data sources which are required for its mission are either terminated in the facility or the products produced by the observing and computing facilities are delivered here. It is not an integrated facility in the sense that these data sources and products can be effectively displayed, merged and manipulated to produce a fully integrated mission product; the burden for this merging, manipulating and integrating still falls to the mental processes of the duty forecaster.

The problems of integrating data sources and producing mission support products which use all of the available data in an internally consistent manner have become more acute to the forecasters of Det 11 in the Space Shuttle era. The environmental sensitivities of the Shuttle have increased the temporal and geographic preciseness with which many meteorological variables must be forecast. The need to accomplish this support in a routine, non labor-intensive manner will be even greater when Shuttle recovery operations begin at PAFB, and when the Shuttle schedule becomes more routine and frequent.

It is to specifically address these data integration problems that the Space Science and Engineering Center (SSEC) proposed and the ESMC funded a study to recommend an interactive computer system. This interactive system would be used by ESMC to integrate the data from the many special meteorological data collection systems used to support the ESMC mission; it would also provide interactive access to these data through a high quality video and graphics display terminal or terminals.

This study recommends the acquisition of a Meteorological Interactive Data Display System (MIDDS) to better support the CCFF mission. This MIDDS should consist of an IBM 4341 computer with appropriate peripherials and terminals in support of a variant of the Man-computer Interactive Data Access System (McIDAS) software. Such a system will provide almost immediate integration of the data sources available to the CCFF into a single data base where the various types of data can be melded and displayed together for forecaster use. It also provides growth for new data sources and for a significant increase in the applications which the forecasters and users of the system are expected to make after they become more familiar with the power and versatility of the system.

II. BACKGROUND

A. Study History and Methodology

In February 1983, Captains Mert Forsythe and Art Thomas of Det 11 and Mr. Rich Wesenberg of NASA/KSC visited SSEC to discuss the data access problems at ESMC and to become familiar with the McIDAS. At this meeting and as verified by subsequent discussions and conversations, it became clear that a study was needed to clarify ESMC's meteorological data processing needs and to suggest the most appropriate solution. SSEC therefore prepared and submitted a proposal for same.

The timeframe for this study was very short; ESMC desired the study to be completed and the report to be produced in final form within two months after funding the effort. Therefore, SSEC immediately dispatched a team of five individuals (Dr. Frederick R. Mosher, scientist and study manager; Mr. John M. Benson, computer systems analyst and architect; Mr. Joseph P. Rueden, computer specialist; Mr. Ronald P. Steiner, systems engineer; and Dr. Robert J. Fox, Executive Director of SSEC) to PAFB and the CCFF. This team spent three days on station researching the data sources, the mission of Det 11 and how it was being accomplished within the existing CCFF configuration, the physical facilities and the planned modifications thereto, and the desires for a more efficient and integrated system for mission support on the part of those responsible for the management and effective mission accomplishment of Det 11.

During their visit, the team met with these individuals, who were most generous with their time and helpful with their information and insight into the CCFF data integration problem, and without whose help this study could not have been accomplished.

Mr. Rich Bailey	ETR/RSL
Mr. Jim Collins	PanAm/PAPWZ
Mr. Orville Daniel	PanAm/PAPWZ
Major John Erickson	Det 11, 2WS
Mr. Cy Golub	ETR/RSL
Major Donald Green	Det 11, 2WS
Mr. Holly Johnson	PanAm/PAPWZ
Mr. Rick Kulow	PanAm/PAPWZ
Mr. Tom Linder	unknown
Mr. Dick Serra	PanAm/PAET
Mr. Joe Sloan	ESMC/WE
MSgt Albert Smedley	Det 11, 2WS
Captain Art Thomas	Det 11, 2WS
Ms. Nancy Tingler	ETR/PL

After their return to Madison, the team, assisted by Mr. J. T. Young and other SSEC specialists, spent the remainder of the time in requirements analysis and the architecture design of the MIDDS.

B. Relevant SSEC Experience

SSEC has been actively working in the field of interactive meteorological computer technology for the past 15 years. The Man-computer Interactive Data Access System (McIDAS) is the evolutionary result of this research; it is a system which began its existence as a tool to derive cloud motion vectors from geosynchronous meteorological satellite data. Early in its existence, the McIDAS was used exclusively for research within SSEC, but as the system has developed and matured, there have been several adaptations of the McIDAS to the more operationally oriented environments.

Operationally oriented McIDAS-based systems within the federal government are being used daily to support the National Hurricane Center (NHC), the National Severe Storms Forecast Center (NSSFC) and the Marshall Space Flight Center (MSFC). A description of the current McIDAS as implemented at SSEC is contained in Appendix 1, and should be viewed as a departure point for design of the potential MIDDS. Also attached as Appendix 2 are three reports created during the evolution of the Centralized Storm Identification System (CSIS) for the NSSFC; these reports will give the reader the viewpoint of the user during the evolution of the CSIS to the specific configuration desired by the users. These reports are considered to be particularly applicable because they represent a view of the system independent of SSEC, and because the meteorology being supported is very similar to the mission of Det 11.

C. Study Assumptions and Limitations

While this was a relative unconstrained look at the data management and forecasting problems of Det 11, there are certain explicit or implied assumptions, constraints and biases which bear on the conclusions and recommendations, and these are stated here so that the reader does not have to search for them.

1. The system design was not constrained by financial considerations, other than to be practical and not gild the lily; however, the Phase 1 design was driven by a $500K financial limitation, with the design goal being to get as much capability as possible in Phase 1 without sacrificing the ability to later expand into the full system should more funds become available.

2. Security and possible classification constraints were not considered.

3. Equipment and antenna sitings were recommended on the best advise of the people interviewed, and were made without an actual RFI site survey. An RFI survey must be made before any actual implementation in begun.

4. Expansion capability was included in the computer system design commensurate with SSEC's experience with other similar system implementations, and is sufficient to include all known Det 11 requirements plus provide years of normal growth.

5. The telecommunications recommended are all standard commercial communications and were assumed to be readily available on CCAFS. Right-of-way and access for telecommunications were not explicitly investigated and

accommodation was assumed.

6. SSEC's experience has primarily been with systems of a McIDAS lineage, and therefore the discussions and recommendations herein are biased by that fact. SSEC does not claim to have exhaustively surveyed all possible interactive system architectures in designing MIDDS, nor to have selected the optimal one. We do claim, however, to have recommended a design which will efficiently fulfill the governments needs, whose concept has been proven in an operational environment, and which provides a vast amount of proven interactive meteorological software at no expense to the government.

D. The CCFF Mode of Operation and Data Sources

Det 11 has produced an excellent document which very completely describes the current state of weather support and instrumentation at ESMC. This 47 page document, ESMC Pamphlet 105-1, Meteorological Handbook, was heavily used by the study team throughout the course of this study. In recognition of the completeness of this pamphlet, we have elected to include herein only the sketchiest outline of the mode of operation and data sources available at the CCFF; interested readers are referred to ESMCP 105-1 for more information.

The range of support required of the CCFF forecaster varies greatly from normal base weather station operations to the extensive support needed for manned missile launches. The support for the latter involves collecting special data of importance to mission safety, monitoring of the weather as launch approaches, preparing briefings, as well as preparing special forecasts with pin-point accuracy in both time and space. Since many unique weather factors effect missile launch and recovery operations, special observing systems have been developed.

The operational support provided to the Space Shuttle missions are by far the most demanding of the many launch activities Det 11 handles. Currently, three forecasters are on duty during shuttle launch operations, the Shuttle Briefing Officer, the Mission Forecaster, and the Duty forecaster. A support team of six Observers and specialists man the CCFF prior to launch. Each of the six are handling one or more data collection/display units. These units are distributed around a large room. For example, one observer is monitoring the radar and evaluating echoes, another is posting maps and teletype data and operating the satellite display, an atmospheric electricity specialist is monitoring the field mill data, and another is communicating with a pilot on a weather reconnaissance mission. Yet another specialist is run the Blast Accessment system and monitoring the predictions. This means that the mission support officer must move physically from one display to the next and mentally overlay, transpose, stack, change projection, remap and do all of those other functions which are needed to properly grasp a situation when it is presented from many different types of displays and formats. Thus, much of the forecaster's time is spent in accessing and assimilating data rather than in preparing the actual forecast. In the normal operation, this is relatively satisfactory; however, in times of increased operational stress, the only solution which Det 11 has is to apply more people to the problem, which severely complicates data access by disrupting the forecaster's normal access patterns, and increases the internal coordination between individuals so that a consistent product in presented to the customer.

And that meteorological data which they need are collected and made available to the CCFF in a variety of ways. Data which are directly available to the CCFF are usually directly displayed on CRTs or in some hard-copy form for use by the forecaster. All computer processed data available to the CCFF are processed in the ESMC Range Safety Operations Control Data Corporation Cyber 740. Most of these data are input to the Cyber 740 through a locally developed outboard ingester called the Automated Range Meteorological System (ARMS). The ARMS polls selected meteorological devices on a cyclic basis and makes these data available to the Cyber 740 as desired. Cyber 740 data or products are available to the CCFF as displays on Tektronix 4025A or 4051 terminals or as hardcopy made from these terminal display.

There are 11 types of data available to the CCFF which bear on this study. These are:

1. Lightning Location and Protection (LLP). There are three sensors in this lightning detection system. Their data are collected in a lightning position analyzer, which analyzes the sensor data and determines cloud to ground lightning stroke location and intensity. The output of this analyzer is currently available in the CCFF as a graph on an x-y plotter.

2. Launch Pad Lightning Warning System (LPLWS). This system consists of 34 electric field mills whose output is transmitted via modem links to the ARMS for input to the Cyber 740. Twenty nine of these field mills have digital outputs for the ARMS, while the remaining five are digitized after transmission and prior to ARMS processing. These analog units are scheduled to be converted to digital transmission in the near future. Data from the individual field mills in LPLWS can be displayed on strip charts in the CCFF, or, more commonly, the output of the mills is available from the Cyber 740 as printed individual values or collectively as a contoured field on a Tektronics graphics display.

3. Weather Information Network Display System (WINDS). Sixteen instrumented meteorological towers comprise this system. The data from the meteorological sensors on these towers are all transmitted digitally via modem links to the ARMS and hence to the Cyber 740. Processed data are printed in tabular form or may be displayed in the CCFF on an alpha-numeric CRT.

4. A. D. Little Flash Counter. This device is another type of electrostatic field measurement device which is largely been replaced by the LPLWS. Although its output is available in the CCFF on a chart recorder, it is rarely used and is not considered worth including in an integrated data base.

5. Radar Data. The CCFF currently has a remote display capability from the FPS-77 radar located at CCAFS; however, this unit is in the process of being replaced with a new WSR-74 specially modified for C-band and for high density binning. The new unit will also be located at CCAFS, with a real time remote display furnished to the CCFF via wide band communications line.

The CCFF also has a dial-up communications capability at 2,400 bits per second which they use most frequently to access the National Weather Service (NWS) WSR-74 (S-band) radar at Daytona Beach. These remote data are displayed at the CCFF on an Enterprise radar to television color converter.

6. Radiosonde and Rocketsonde Data. These data, from both Cape Canaveral and from downrange launches, are input in raw telemetry form via punched paper tape to a NOVA computer system for data reduction. They can then be transmitted via digital link at 2,400 bits per second in ASCII format to the Cyber 740 for further processing or distribution via a dial-up communications line.

7. Facsimile. The NWS NAFAX facsimile circuit provides hard-copy facsimile charts on an Aldyn facsimile recorder which are used for wall mounted display.

8. Conventional (teletype) Data. The military CONUS Meteorological Data System (COMEDS) query-response teletype service plus the NWS Service A are available in printed form, as well as an ETR Communication Center pony circuit which carries some downrange data. These data are torn and filed in printed form.

9. Satellite Data. The National Earth Satellite, Data and Information Service (NESDIS) GOES-TAP data are received via communication line and processed into hard-copy via a Harris Corporation laserfax. These data are then wall mounted for display.

10. Model Output. Two models are executed on the Cyber 740 for CCFF forecasters, with the model output being presented to the CCFF via CRT display on Tektronic terminals. The models are the Blast and the PanAm diffusion models.

11. Jimsphere. Radar data from tracking the Jimsphere are input to the Cyber 740 as a 2,400 bit per second digital data stream. The data are reduced to high resolution wind information in the Cyber.

12. Manual observations. Special observations from personnel on chase planes and helicopters are available, as are observations at critical points such as the shuttle runway on re-entry. The observations are handwritten into a teleautograph.

In addition, there are several proposed or desired data sources which may be available to the CCFF by or shortly after the MIDDS implementation. Of the known additions, none are expected to impact the MIDDS design in any significant way other than to require that the MIDDS incorporate adequate expansion capability. The data sources considered are:

1. Additional towers which may be added to the WINDS.

2. Additional sensors which may be added to the LLP system.

3. A Portable Automatic Mesoscale System (PAMS) with as many as 27 sites which is being considered. This system is a mesoscale meteorological

sensing system developed by the National Center for Atmospheric Research, and consists of the sensing systems which are deployed geographically and a central data collection and reduction "box" which serves as the single output for the PAMS.

In this vast sea of data, the forecaster must quickly make decisions and disseminate the most important information and effect on the forecast. In the past extraordinary effort on the part of the Det 11 personnel and the specialists has managed to get the job done. But two changes in the Shuttle program will have a devastating effect on the support provided. First the mission frequency will be increasing significantly over the next year. This means that the extraordinary efforts of the past must become ordinary efforts, and because of the increased frequency critical weather decisions will occur more often. Second, the primary mission recovery site will be at the Cape. The net result is a major shuttle support activity about every two weeks at the CCFF in 1984.

A Meteorological Interactive Data Display System such as the one described below could have a major impact on the ability to continue to provide full support to the various ESMC missions and with a higher quality product as well.

III. METEOROLOGICAL INTERACTIVE DATA DISPLAY SYSTEM CONSIDERATIONS

The CCFF provides 24-hour forecasting support for KSC and CCAFS. To support its mission, the CCFF uses a variety of sophisticated pieces of equipment including radar, instrumented towers, atmospheric electricity and lightning detection systems, upper air measurement systems, satellite images, computer services, and a closed circuit television briefing system. During critical weather situations the forecaster has difficulty mentally assimulating all the rapidly changing weather data in addition to carrying out his briefing responsibilities. The Cape Canaveral region presents many forecast problems because of the local influences and interactions between the sea breeze, existing air-mass thunderstorms, outflow boundries, and larger scale weather system.

A MIDDS system which can quickly and easily bring all of the observational data together is vitally needed at the CCFF. The major goal of this system is to provide a means of integrating all the observational data and assisting the forecaster in his forecast and briefing responsibilities through integrated data base management and display. The presentation and interpretation of meteorological data using the system should reduce the time needed to evaluate weather situations and increase the forecaster's confidence in his decisions. Using a high quality video and graphics display terminal, the forecaster should be able to view data from multiple sources on the single display, view these data in time sequences under his control, and interactively interrogate other data for additional information.

A. Implementation Concept

The implementation concept of the MIDDS is determined by mission needs, budget constraints, and requirements for operational redundancy. The mission needs demand a state of the art interactive system ingesting a multiple number of data sources and using an integrated data base management and display technology.

The initial funding available for MIDDS is much less than needed. This necessitates a phased implementation, and we recommend three phases. The first phase should consist of a basic stand alone system consisting of a single embedded computer and a single forecaster workstation. The system should interface to the local data acquisition systems and support the operational mission of the CCFF. This initial system would not be fully operational in that it will lack redundancy and will require that some processing be done on other computers at the CCAFS. The initial system will provide a proof of concept by supporting most of the CCFF mission. In order to minimize costs, the initial system should lean heavily upon the existing McIDAS architecture with only limited modifications to accomodate the local data sources.

The second phase should consist of a gradual increase in the system capabilities being tailored to meet the specific needs of the CCFF. These should consist of transferring models and analysis procedures currently on the CCAFS Cyber 740 computer onto the embedded MIDDS computer, ingesting all of the local data sources directly into the MIDDS, acquiring a local reception capability for satellite image data, and adding additional workstations.

The third phase would consist of procuring the redundancy necessary for a reliable system. At the end of the second phase the MIDDS should be fully supporting the missions of the CCFF, but would not have the redundancy necessary for operational reliability. The third phase provides the hardware and procedures necessary to have the system certified for fully operational use.

B. System Configuration

The MIDDS would consist of a data collection subsystem, an embedded computer, and various workstations. The basic system configuration would be modular so that longer term needs of providing computational redundancy, data interfacing independence, and additional workstations can be accomplished using the phased implementation described previously. The following is an analysis of the factors influencing the design of the system configuration. The data input requirements will be analyzed and recommendations made. The CPU utilization will be analyzed, various CPU options will be discussed and recommendations will be made. Finally, the workstation requirements will be discussed.

1. Data

Section II.B. described the meteorological data currently used to support the CCFF operations. As part of the site survey, we investigated means of incorporating the various data sources into the MIDDS. Considerations were given to ease of initial implementation, operational redundancy, and to the eventual goal of the CCFF becoming a fully self-contained operation, wholly independent of other computer systems. The following are our recommendations for each of the data inputs required by the MIDDS.

a. Local Meteorological Data

Local meteorological data are obtained from the WINDS by the ARMS and input into the Cyber 740. The ARMS interrogates each of the instrumented towers and the electric field mills every 750 milliseconds, buffers the data and then inputs the data into the Cyber 740 via a Cyber channel interface. At the present time the ARMS buffer represents a potential single point failure in that there is no back up unit and no spare unit. As part of the eventual operational system the ARMS buffer needs to be replaced with a system having adequate redundancy.

After lengthy discussions with the CCFF and Pan Am support personnel, several serial steps are recommended for the local meteorological data inputs. A 4800 bps asynchronous (a synchronous link is not suggested due to Cyber limitations) link should be established between the Cyber 740 and the MIDDS. This link should be configured on the Cyber to act as a print-only connection. Using a printer type protocol allows the link to be brought up and tested independently of equipment delivery schedules. It also eliminates any security considerations because the MIDDS would not be able to interrogate the Cyber in any fashion. The Cyber currently supports 4800 bps asynchronous links, as does the proposed IBM embedded computer in the MIDDS. The data to be passed over the link will include the averaged meteorological data and any gridded products. The observational data will be sent from the Cyber to the MIDDS at a frequency consistent with the forecaster display needs (typically between one to five minutes).

In addition to the link from the Cyber, the MIDDS should have a spare 4800 bps port to faciliate the development of an ARMS replacement. This development effort could proceed independently of the MIDDS implementation. Once this ARMS buffer replacement is working, the CCFF could in theory become independent of the Cyber 740. The processing algorithms currently in the 740 could be transferred into the embedded computer in the MIDDS by the Pan Am personnel. Hence we strongly recommend that the CCFF give a high priority to the development of a replacement for the ARMS buffer. We further recommend that the current system of the ARMS, Cyber and Tektronix displays be maintained until the MIDDS has full operational redundancy. By operating the current system in parallel with the MIDDS, full redundancy of critical services can be maintained.

The local weather data network may be expanded in the future to include 27 PAMS. The PAMS data would be collected by its own organic concentrator before input to the MIDDS, and thus would require only a single low speed port on the MIDDS.

b. Atmospheric Electric Fields

Atmospheric electric fields are monitored by 34 electric field mills in the LPLWS. The digital electric field mill data is collected in the ARMS buffer and processed in the Cyber. Electric field products available in the CCFF include listings of electric field strength at each mill, contours of the electric fields computed within the clouds, the calculated locations of the source of lightning and analog strip charts of field mill outputs. The data at the sensors are digitized at ten samples per second. These data are normally averaged into one minute means, although during the lightning source calculations, the program on the Cyber uses the 1/10 second data.

The collection, processing and display of the electric field data are very similar to that of the local meteorological data. They both use the ARMS buffer and the Cyber 740. They both have similar data rates. We recommend that the electric field data use the same links as the local meteorological data. Initially the averaged field strengths and grids of fields would be transmitted from the Cyber to the MIDDS for display on the same asynchronous link as the local meteorological data. When the ARMS buffer is redesigned, the electric field mill data would be part of that design. Likewise, the electric field processing algorithms currently on the Cyber 740 could be installed on the MIDDS at the convenience of the Pan Am support personnel.

c. Cloud to Ground Lightning Location Data

Cloud to ground lightning strokes are monitored by a system manufactured by the Lightning Location and Protection, Inc. (LLP). The system has several direction finder (DF) antennas which communicate with a central position analyzer (PA). The PA has a microcomputer which discriminates against all lightning strokes except cloud to ground and then computes the location and strength of the lightning stroke. The PA has an asynchronous output port which provides a message of time and location of each ground strike. These data are well suited for direct input into the MIDDS. Data from LLP equipment have previously been ingested into the McIDAS. Programs which could be used by MIDDS are available which allow ingestion, storage, and display of LLP data in conjunction with satellite, radar, and conventional data.

Other lightning information at the CCFF is currently provided by an A.D. Little Flash Counter. This system provides strip chart displays of lightning activity as a function of range from the antenna. The system does not provide directional information. It provides range information on the strength of the received signal, although no range correction is made for lightning strokes of differing intensity. The system duplicates functions currently being done better by the LLP and the LPLWS systems. The forecasters make little use of the A. D. Little Flash Counter. Hence we recommend that the A.D. Little system not be interfaced to the MIDDS.

d. Upper Air Observations

Upper air observations are available from a variety of sources. Radiosonde data from conventional weather sources are currently obtained from teletype circuits connected to NWS and COMEDS lines. These upper air data are available from the FAA 604 teletype circuit in addition to hourly surface observations, forecasts, and other weather observations. The 604 circuit has been used at a number of installations, such as CSIS, and has been demonstrated to provide timely access to these data. Considerable software exists for ingesting, storing, and displaying these 604 data. We recommend that MIDDS be connected to the FAA 604 circuit for access to conventional weather data.

The CCFF also receives special upper air sounding reports from a variety of local launch sources. Radiosonde and Windsonde balloon releases as well as meteorological rocket launches are made in support of launch operations. They transmit data in the 1660-1700 MHz band to the Meteorological Sounding System (MSS) which provides automatic tracking and real time data reduction with an embedded NOVA minicomputer. Current operations involve transmission of the data to the Cyber, quality control of the printouts of the radiosonde ascent by the CCFF personnel and then release of the radiosonde data to outside users. We recommend that an asynchronous link be established between the MSS minicomputer and the MIDDS. We recommend that a port on the MIDDS be designated for use by the outside users requiring access to this radiosonde data.

In addition to upper air soundings supported by the MSS, Jimsphere balloon releases are made and tracked by radar to give high resolution wind measurements. The data currently are transmitted from the radar site to the Cyber on a 2400 bps line, where it is then processed and released to outside users. We recommend that initially the processed data be transferred from the Cyber to the MIDDS over the proposed 4800 bps link described in a previous section. We also recommend that a port on the MIDDS be reserved for eventual direct ingestion of these data.

e. Satellite Image Data

The CCFF currently receives GOES imagery every 30 minutes on a laserfax recorder via GOES-TAP analog communication line from the Miami Satellite Field Service Station (SFSS). There is only one communication line, and since each image takes 30 minutes to transmit, either a visible or an infrared image is available every half hour, but not both. While the CCFF can receive full disk pictures, they routinely request higher resolution sectors in the Florida geographical region. Multiple resolution sectors are not provided because of the single communication line. The GOES-TAP data is not intended for quantitative analysis, although the SFSS sometimes provides enhancements of the infrared images which allow crude temperature determination. The CCFF currently can loop the GOES images using a borrowed frame storage device, although this capability is not considered to be a permanent facility. Because of delays involved with data recording and playback, the GOES-TAP data are generally available 40 minutes after the start of an image.

Several methods were considered for bringing GOES data into the MIDDS. These were evaluated for data quality, data timeliness, ability to integrate with the other data sources, and costs. The methods evaluated were

1. a direct GOES satellite reception capability,
2. GOES-TAP,
3. commercial GOES data services, and
4. a remote connection to an existing GOES receiving system.

The most desirable system is a direct GOES satellite reception facility. Direct reception allows local control of ingested areas, a data base which allows quantitative calculations such as cloud heights, access to navigation parameters, and the highest possible resolution. It would consist of a 15 foot stationary antenna, associated electronics (down converter, receiver, PSK demod, two bit synchronizers and a frame synchronizer) and an interface into the MIDDS computer. The antenna and electronics are available commercially. The interface for an IBM computer has been built by SSEC. The direct GOES reception allows timely data access (approximately one minute after the desired scene has been scanned by the satellite sensor), multiple simultaneous resolutions, concurrent visible and infrared data, and is ideally suited for integration with other data sets because all the information required for geographic mapping is contained in embedded documentation. Software for ingestion and display of these data is already available. The only problems associated with a direct reception station are potential radio interference with radiosonde releases and the high initial cost of the ground station. The GOES frequency is 1680 MHz, which is overlapped by the radiosonde transmitters which operate in the 1660-1700 MHz band. It is possible to tune the radiosonde's transmitter to either end of its range such that interference does not occur, and this procedure may have to be incorporated into the normal Det 11 mode of operation if mutual interference is to be avoided.

The GOES-TAP data suffers from poor quality (because of its analog nature), lack of timeliness, lack of embedded navigation data required for computer overlays of other products, and lack of simultaneous visible and infrared images. There currently is no hardware interface available for ingestion of GOES-TAP data into an IBM computer such as is being considered for the MIDDS. The design and fabrication of such a GOES-TAP interface is comparable in price to the purchase of the hardware for a direct GOES reception station.

Because of the limitations of GOES-TAP data, several commercial sources (ESDI, WSI, and Kavouras) have developed GOES product distributions based on a TV weather show user community. These products are not intended for the general forecast user. Some (such as ESDI) modify the data to have bit levels corresponding to land, water, grids, and clouds. The products are available on a dial-up basis. None of these vendors currently provide any direct access to the full range of raw satellite data or calibrated data needed for any quantitative analysis.

Several locations provide remote connections to an existing GOES receiving system. Colorado State University has provided the PROFS program remote access to GOES data via a microwave link. SSEC provides a data base management service which includes remote access to GOES data via dedicated 9600 bps communication lines. MSFC and NSSFC have programs with SSEC which require transfer of GOES image data to a remote computer. Transfer of the full eight bit resolution data requires about seven minutes per TV sized image; visible and infrared data are available with sequential transmissions, as are multiple resolutions and different geographic regions. The SSEC system operates continuously, but is only staffed 16 hours per day during the normal work week.

We recommend that the MIDDS have its own GOES receiving station. The direct data are full resolution and cover the full earth disk versus the previously described GOES-TAP limitations. Equally important to the operational forecaster is the real time availability of the direct data. If cost considerations preclude direct GOES reception for the initial system, we recommend that MIDDS be interfaced to SSEC via a dedicated 9600 bps communications line for remote access to GOES data. This remote access would provide all of the benefits of direct reception except for a slight time delay. We recommend that the GOES-TAP data not be interfaced to MIDDS, but should be kept as a separate back-up data source until MIDDS becomes fully operational.

f. Radar

The CCFF currently obtains radar data from several sources. The local FPS-77 radar will be replaced this year with an Enterprise WSR-74 specially modified for C-band and high density binning. The Daytona Beach radar is accessed via a telephone line and an Enterprise remote radar to television color converter. Other radars in Flordia equipped with Enterprise remote transmitters are occasionally dialed up.

The radar interface presents a formidable problem. Several options have been explored, although no single option is the obvious solution. Options examined include

1. building a custom interface to the Enterprise radars,
2. using a Kavouras, Inc. radar remote transmitter and modified receiver,
3. using a digital interface developed by the Radar Weather Observatory at McGill University which operates the radar in a volumetric mode, and
4. using the RRWDS radar interface developed by ElectroDynamics for the FAA weather radar remote displays.

The Enterprise WSR-74 has an inherent data rate of about one million bits per second output from the Digital Video Integrator and Processor (DVIP). The format of the data is a nonstandard asynchronous format consisting of 26 bit words (of which the first and last bits are synchronizing start and stop bits and the remaining 24 bits consist of three eight bit reflectivity values). The inherent bin size is 0.25 n.mi. with a radial transmission (requires remapping for CRT display). The antenna rotates normally at six rpm so that a complete PPI scan takes 10 seconds. The remote Enterprise displays have a similar 26 bit format, but the data is averaged and sampled down to reduce bandwidth to 2400 bits per second. The high resolution data are not available on remote displays.

In order to access the Enterprise radar data directly into the MIDDS, custom designed interfaces would be necessary for both the high speed high resolution data and for the low speed remote data. The low speed data would require designing a box which converts the 26 bit asynchronous data into 24 bit synchronous data. The data could then be input directly into the MIDDS communications controller. The high speed data would require a special interface directly into the channel of the MIDDS computer. This interface would need to convert the 26 bits to 24 bits, buffer the data, and then input the data into the channel interface. Neither custom interface is very desirable. The low speed interface would cost \$20-40K while the high speed interface would cost \$40-80K.

Kavouras, Inc. makes a commercial product called "RADAC" which allows remote access to most of the weather radars in the country. The data transmitted are three bit rainfall rates at four different ranges (60, 120, 180, 240 n.mi.). The image resolution is 256 x 240 with a rastor scan format. The different range images are transmitted in a cyclic fashion. The time between successive images at the same range is approximately three minutes (scenes with many echoes take longer to transmit). A receiver modifed by Kavouras has been successfully interfaced to the CSIS computer. Kavouras has indicated a willingness to install at no cost a transmitter on the Enterprise radar at the CCFF provided that they can have commercial access to the data. They have also expressed a willingness to sell the transmitter outright if commercial access is not possible. They are investigating the feasibility of accessing the high resolution data, and costs associated with building a modified receiver for the computer interface. The CSIS receiver cost $18.2K, and a similar cost would be expected for a MIDDS receiver. Two receivers would be required (one for the local radar and one for the Daytona and other remote radars).

The volumetric radar option encompasses not only the MIDDS computer interface, but also expands the number of products available from the radar system. The Radar Weather Observatory headed by Dr. Geoff Austin at McGill University has developed a digital radar system which drives the antenna in a volumetric scan mode, captures the volume scan data with a microprocessor, computes products and then provides remote access to microprocessor displays. Standard products computed from the volumetric data base include CAPPI scans (scans with constant height above the surface), RHI scans requested by the forecaster, automatic tracking of precipitation cells, extrapolated forecast images of precipitation, and point forecasts of rainfall start, stop times and intensity. The volume scan sequence takes approximately five minutes. The system provides a low speed interface which could easily be interfaced to MIDDS. The system has been installed on a number of Canadian radars as well as several foreign radars (including a recent installation in Mexico on a WSR-74). The basic system would cost approximately $40-50K. This system would supply the needed interface to the local radar, but another system, such as a Kavouras receiver, would be needed for the remote radars.

The Radar Remote Weather Display System (RRWDS) is being built by ElectroDynamics for the FAA for radar displays at the Air Route Traffic Control Centers. The system interfaces to the MTI video or Log Video signals. The video signal is digitized by a DVIP into a 1/2 n.mi by 1 degree image in the 100 n.mi range and a 1 n.mi by 1 degree image on the 200 n.mi range. The three bit data are transmitted on a 2400 bps line using an SDLC format. The transmitted data are in a radial format. A receiver converts the radial format into a rastor 512 x 512 format and provides overhead functions dealing with maps, etc. RRWDS transmitters are being put on all NWS and FAA weather radars with a phased installation schedule. The transmitter costs about $20K as does the receiver (the receiver may not be necessary. It might be possible to interface the SDLC signal directly into the embedded MIDDS computer). We have had no experience with interfacing to an RRWDS system and thus it is difficult to judge interface costs.

Investigations into the radar interface continue. No decision is possible yet as to the most desirable interface.

2. Computer Requirements

The embedded computer in the MIDDS has to perform several different functions. They include:

1. Data input and reformatting
2. Scheduled products
3. Demand products from the forecaster's key-ins
4. Program development and batch computing

The data ingestion loading is independent of the number of users on the system or the number of products generated. The system will have to bear the full load of the data ingestion from the very beginning of system operation. The computer needs to have the input capabilities to accommodate all the data sources listed in the previous section. It also needs the CPU and disk resources to ingest, preprocess, and store the needed data. The data ingestion and related tasks can consume a significant part of the total CPU resources. The size of CPU needed is directly related to the percentage of the CPU which can be dedicated to these input tasks.

Scheduled products include updates of displays of observed conditions and model runs (such as the BLAST and diffusion models). While scheduled products are not absolutely required, it has been found to be extremely useful in short-range forecasting, as the forecaster does not have to be put off his stride while waiting for the system to respond to his request. However, in extremes, a scheduled product can even slow down the availability of another scheduled product as opposed to the time needed to display it as a demand product. A balance is necessary to schedule the displays which have a high probability of being used, but not so many so as to bog the system down preparing products which will never be used. Tuning the system to the right balance between demand and scheduled products must be tried and retried until a compromise is reached. When compromise is no longer tolerable, it is time to buy your way out with a system upgrade.

The response time to demand product commands is dependent on the machine size and loading. It is the only category which increases as the number of terminals increases. The system loading is dependent on the types and frequency of demand requests.

The CPU family being considered for the MIDDS is the IBM 4300 series. There are four basic systems available, each having several variations available as to processor speed and memory size. The 4331 is the baby of the family. While it probably could do the specified initial implementation, it would soon need a major hardware upgrade and as such it is not considered adequate for the MIDDS. The 4341 is the computer currently used at SSEC on the McIDAS. It has external communications and disk controllers. It has been available for a number of years and has been a popular computer so that it is easily obtainable from the used computer market. The 4361 is a new product announcement available beginning in 1984. It generally has performance in the lower range of the 4341 class, but does not require external controllers so that it is somewhat cheaper. The 4381 is also a new product announcement and is considerably more powerful than a 4341. It is much larger and considerably more expensive than is required for the MIDDS. Within each class of computer there is a range of performance available and a range of memory size available. Memory size is designated by letters K, L, M, N, and P corresponding to 2, 4, 8, 12 and 16 megabytes of memory. Speed of the CPU is related to the number assigned to the model. For instance on the 4341 the CPUs are designated as 9, 10, 1, 11, 2, 12 with relative performance of .6, .85, 1, 1.25, 1.6, and 1.85 respectively. Appendix 3 is an information sheet on the 4341.

a. Input Data Loading

The input data can be divided into low speed and high speed interfaces. High speed interfaces are the Pronet local area network for the terminal(s), the GOES satellite interface, the disks and the tape drive. Low speed interfaces include data ports, programmers terminals and operators terminals. Table 1 lists the initial and known future data port requirements. Not all of the future data sources have been specified as to rates and formats. The table shows that the system needs to be able to handle an aggregate bandwidth of 55.2 K bits. A worse case situation would have 11 asynchronous input ports with a bandwidth of 36 K bits. A worse case for the synchronous ports would be 5 ports with a band width of 34.8 K bits.

Table 1

MIDDS Low Speed Data Inputs

quantity	rate (bits per second)	type	use
1	4800	async	Cyber 740 communications link
1	1200	async	LLP lightning data
1	1200	async	604 conventional data
1	4800	async	MSS NOVA communications link
1	1200?	async?	(future) PAM network
1	1200	async	(future) outside users
1	2400	?	(future) link to Jimsphere radar
1	9600	sync	link to SSEC for GOES data
1	9600?	?	Enterprise Radar
1	2400	async	Daytona Radar
1	2400	async	dial up Radar
1	4800	?	(future) ARMS interface
1	9600	sync	(future) remote terminal
13	55,200 total bandwidth		

18,000 bps async
19,200 bps sync
18,000 bps unspecified types

While the exact system loading of the input data is difficult to accurately assess, some estimate is possible based on the experience with the SSEC 4341-L2 system which has similar inputs. The 4341-K9 (the smallest 4341) would require about 35% of the machine for input data handling. A 4341-L1 would require about 21%, while a 4361-K4 would require about 25% of the machine for input data handling.

The high speed inputs such as the GOES-ingestor and the Pronet interface for the terminal have high data volumes, but low system impacts, because the programs do not have to touch the bytes individually as the programs for the low speed data do. Memory is the only significant system resource consumed by these high speed inputs.

b. Scheduled Products

The number of scheduled products is difficult to size because of uncertainties in the way the MIDDS will ultimately be used. Our experience with CSIS indicates that a large number of products might be prepared in advance. Approximately 50% of the application programs run on CSIS are scheduled products. As the forecasters became aware of the potentials of the system, the demand for products previously unobtainable grew until the system reached capacity. A similar phenomona is expected with the MIDDS.

The following is an analysis of the scheduled products currently available at the CCFF. This will be used as a baseline for computer loading of the MIDDS. The actual computer loading of programs currently running on the Cyber 740 is difficult to access. While we were able to obtain program size and wall clock running time for some of the current programs, we were not able to obtain bench marks of actual CPU utilization. The Cyber 740 is a highly multi-tasked computer so that wall clock running time is of limited use without knowing the mix of other tasks on the computer. Hence the following are our best estimates of CPU usage.

The recommended IBM4341 is a multi-tasked computer and can actively support ten or more programs simultaneously. The following is an analysis of computer wall clock times for various tasks based on McIDAS experience. The system can support multiple programs simultaneously, so for the purposes of this analysis there ae 600 wall clock minutes per hour available for programs.

The GOES sends data every 30 minutes except during severe weather when a new image is sent every 15 minutes. The forecaster will most likely require an automatically updated image loop of the local region and of the large scale view. Each set has a visible and infrared image. The load time of each image is approximately 30 seconds. Hence each terminal will require TV load programs active about 2 minutes every 30 minutes. When the ultimate system is operational with three terminals and a briefing display, the system will have TV load programs active 16 minutes each hour.

The radar data will probably be routinely required every 15 minutes except during active weather when data would be required every 5 minutes. The radar data needs to be displayed in its original projection and in a remapped form compatable with the satellite data. Hence radar programs would be active 8 minutes per terminal per hour (30 sec * 12 images/hour + 1 min * 2 remaps/hour) or a total of 32 minutes per hour for a fully configured system.

The ARMS data will initially be processed and averaged by the Cyber so that this data processing load on the MIDDS will be limited to accepting averaged data from the Cyber communication link. Eventually this task will either be done in a dedicated microprocessor on the redesigned ARMS or on the MIDDS computer. It currently is a 140 K octal (49 K decimal) word (60 bit words) program on the Cyber 740. It processes six seconds of data in four seconds of wall time. Of this time about 1/3 is CPU and the other 2/3 is I/O activities. While the Cyber 740 has a CPU which is about three times faster than the IBM 4341, the Cyber has slow I/O as compared to the IBM. Hence as a first approximation the ARMS program can be expected to be active for 40 minutes of each hour.

The WINDS data is averaged every 5 minutes with displays normally presented every 30 minutes except during launch conditions when the 5 minute data will need to be displayed and used with the diffusion model. Assuming 30 seconds for an analysis and display, the winds and diffusion model will be active 6 minutes each hour.

Electric field data is normally presented every 15 minutes, although the forecaster can currently request output intervals between 1 and 60 minutes. The electric field calculation involves matrix maniputations with a 25 x 25 array. An estimate of the analysis and display time needed is 30 seconds of wall clock time making the programs active, 2 minutes each hour in normal conditions and up to 30 minutes each hour under peak conditions. During lightning conditions the FLASH routine is used which locates the source of the lightning activity. Data are evaluated every two seconds to locate areas of rapid field changes, and when an area is located, 1/10 second data is used to determine the time of the strike. Discharge center data is passed to the forecaster every 15 seconds, with a five minute cycle of the whole process. During lightning conditions, it is envisioned the FLASH routines would be resident in memory almost continuously (although not active continuously).

The LLP lightning location data are currently plotted on a hard copy plotter in real time. On the MIDDS the data would be collected and then plotted for a valid time interval. It is presumed that this would happen every five minutes to be consistent with the FLASH cycle time. The plotting would require about 15 seconds, resulting in a program active time of 3 minutes per hour.

The radiosonde and sounding meteorological data is reduced by the NOVA minicomputer, and output to the Cyber for special analysis and data formatting. The CCFF primarily just quality controls the data before it is given to outside users. It is estimated that preparing the QC outputs would require less than one minute per hour of active computer support.

The 4341 can actively support ten or more programs simultaneously. Adding up the active times in the previous paragraphs shows that on an average three programs preparing scheduled products would be active at any given time when the system is fully operational. Hence on an average about 30% of the system would be used to prepare scheduled products currently available at the CCFF in addition to the 21% of the system used for data ingestion, for a total of 51% of the system. The peak loading of system due to conincident scheduled requests will be higher. The peak loading of the system should be between 80-100% of the system, with the peaks lasting as long as one minute.

c. Computer Comparisons

Two different computer systems were definitively considered for the MIDDS. They were the IBM 4341-L1 and the 4361-K4. The configurations considered are listed in Table 2.

Table 2

Option 1

quantity	component	description
1	IBM 4341-L1	CPU
1	3278-2A	operator CRT
1	3880-1	disk controller
1	3705-II	communications controller
1	3274-D21	programming CRT controller
2	3350-A2	600 mb disk (two spindles)
1	3350-B2	600 mb disk (two spindles)
1	3430-A	6250/1600 bpi tape drive
3	3278-2	programming CRTs
1	Feature 1870	block mux channel

Option 2

quantity	component	description
1	4361-K4	CPU
1	3278-2A	operator CRT
1	3340-A2	140 mb disk
2	3344	540 mb disks
1	3430-A	6250/1600 bpi tape drive
3	3278-2	programming CRTs
1	communication adapter	
1	block mux channel	
1	display/printer adapter for 3278s	

The IBM 4341 system is nearly identical to the system currently used by McIDAS. The 4361 system is a new product first available in early 1984. Preliminary costing of the hardware (using third party vendor prices when lower) has the 4361 system costing \$210.9 K and the 4341 system costing \$304.2 K. The 4361 would have to be sent to SSEC for system development efforts before being sent to the CCFF. The SSEC site preparation, installation, deinstallation effort would add about \$20 K to the cost of the 4361 system. System development efforts on the 4361 which have already been done on the 4341 would add approximately \$30 K to the cost of the

4361. The 4361 supports seven low speed communications lines and one high speed line. A data multiplexer box would have to be built to concentrate all the asynchronous lines into the one high speed port. This box would cost approximately $30 K. Hence the cost of the 4361 system would be approximately $291 K as opposed to the $304 K for the 4341.

The two computers have similar CPU speeds. Both have similar memory and speed expansion capabilities. Both have similar disk storage size capabilities, but the 4341 has faster I/O capabilities because of the external disk controller. The 4341 can ingest the full U.S. satellite image at full 1/2 mi. resolution and the globe at the reduced 2 mile resolution. The 4361 would only be able to ingest a Florida sector at full resolution and the globe at reduced resolution. The 4341 can support a large number of low speed I/O ports (exact number depends on the mix of speeds, but can be in the hundreds), while the 4361 can support a limited number (The total bandwidth of lowspeed I/O supported is 64 K bps. The projected MIDDS input data has a total bandwidth of approximatley 55 K bps for the eventual full up system. The 55 K band is a worse case estimate assuming all data lines would be active simultaneously, so the 4361 should be able to handle the MIDDS I/O load). The eventual full up system with redundant hardware would cost about $90 K less with the 4361. However, the 4361 might present delivery problems, as delivery times have extended to the point where the MIDDS delivery could be delayed into the late fall of 1984. The 4341 systems are readily available.

Either computer system would be sufficient for the MIDDS. The 4361 is slightly cheaper, but the 4341 has a larger margin of potential capability, especially in I/O and communications. The 4361 might present delivery problems. After careful consideration, we recommend that MIDDS use to 4341 computer. It is a known factor and presents the least risk to the success of the MIDDS.

3. Terminal Requirements

Two major factors were found to impact the terminal requirements. First, the most important scientific requirement imposed on the forecaster is the rapid, accurate, and detailed short term (0-3 hr) forecast with the most critical forecasts in the 1 to 2 hr time frame. Our experience with NSSFC and other forecasting experiments have shown that at a minimum the last 3 hours of data should be available in the display memory for time sequencing (looping) and extrapolation. For GOES imagery this means, a 6 image sequence of 1 km resolution visible data and a 6 image sequence of infrared data minimum. For longer term (3 to 24 hr) forecasts a larger area must be presented covering the southeastern quarter of the CONUS so the forecaster will be able to monitor weather further "upstream."

The radar data would have a cycle time as rapid as every 5 minutes so a loop of 12 frames would be needed to display the last hour of radar data. The forecaster should have two loops of six frames each for special image sequences (such as remote radars, other satellite sequences, etc.). This makes a requirement for 48 or more image frames.

The graphic loops would be paired to the image data loops. The 12 frame radar loop would be paired with 12 frames of graphics showing electric fields, lightning location positions, geographic boundries, etc. Likewise the two pairs of loops of satellite data would require two six graphic frame loops. A number of static graphic frames are needed for displays of current weather data, derived parameters such as stability, etc. Hence at least 32 graphic frames would be required.

The basic McIDAS terminal has a video display with a graphic overlay, an alphanumeric CRT, a key board, two cursor control joysticks, a data tablet, and a local printer. The video display has a number of image and graphic frames which are stored locally in the terminal for rapid access. Each frame is 480 x 640 pixels of six bit data, while each graphic is 480 x 640 pixels of three bit data. The image and graphic frames have computer loaded lookup tables used for color displays. The image enhancement system can functionally combine two images for display (such as coloring the satellite image where the radar image shows rain). The graphic overlay can be toggled in or out from the keyboard. The images can be formed into loops and looped at up to 15 frames per second. The video monitor is an RGB studio quality display. An NTSC encoder can be added for distribution of standard TV signals. The main varient in the McIDAS terminals is the number of image and graphic frames which is determined by user needs and cost limitations. The terminal will support between 32 and 128 image frame and between 16 and 64 graphic frames.

The second major factor impacting the terminal design is the human interface. It is important that the forecaster be able to control the display and request new analyses, etc. simply and quickly. This means that the forecaster can spend more time considering the meteorology and less on the control of the system. Also training is greatly simplified which is important in an organization with continually changing personnel.

While the McIDAS is inherently a command language oriented system, it does support special user defined function keys, a macro and a command data tablet process oriented language for linking McIDAS commands. The data tablet has been used successfully at the NSSFC to construct a simplified user interface for forecast purposes. Figure 1 shows the portion of the data tablet used by the NSSFC to analysis and display conventional data. The data tablet pen is used to touch a sequence of boxes specifying the display desired followed by touching GO. Other portions of the data tablet were used for commands changing loops, etc. A similar user interface needs to be designed for MIDDS which encompasses the essential services needed by the forecaster.

IV. Implementation Recommendations

The mission of the Cape Canaveral Forecast Facility requires a system which integrates data from local observing systems together with quantitative image data from radar and satellites. The forecasters must make accurate and detailed short term (0-3 hrs.) forecasts in support of critical launch and recovery activities. They require a system which can effectively ingest, merge, manipulate, integrate, and display the required meteorological information quickly and easily. While most of the data

oper	param		time	levl	map	
PLOT	T	THE	NOW	SFC	SAT	
	TD	Q	−1 HR	850	MERCATOR USA	
CONTOUR	PRE	Z	−2 HR	700	MERCATOR CTR	
PRINT	WIN	STR	−3 HR	500	colr DFLT	interval DFLT
	PLT	SPD	−6 HR	400	2	1
LIST	DIV	THW	−12 HR	250	3	2
CLEAR UP PROBLEM	WX	LCL	−24 HR	200	4	4
ERASE	LPT	VOR	−48 HR	TRO	5	5
	SAVE MYP___	ABV	set time change	set level change	6	10
GO	param DIV	param ADV	change off	change off	7	20
					dash on	50
						100

Figure 1. Data tablet command matrix for conventional data.

required for these forecasts is currently available at the CCFF, they are scattered and poorly integrated. The burden of integrating the required information still falls to the mental processes of the duty forecaster.

In the past, extraordinary efforts on the part of the Det 11 personnel have managed to get the job done. However, the increased frequency of the Space Shuttle launches and recoveries at Cape Canaveral necessitate an improved meteorolgical support system. The efficiency of the forecasters needs to be improved. Normal operations are currently manned by one forecaster and one observer. Shuttle launch operations currently are manned by three forcasters and six observers and specialists. Something needs to be done to allow Shuttle forecast operations with a much smaller staff than is currently required. A system which integrates the required data together in a single display is required. This study recommends the acquisition of a Meteorological Interactive Data Display System (MIDDS) to better support Cape Canaveral Forecast Facility.

A. System Recommendations

This study recommends the acquisition of a system based on the Man computer Interactive Data Access System (McIDAS). The McIDAS has a successful track record in support of operational forecasting at the National Severe Storm Forecast Center. The software is already owned by the U. S. Government which represents a substantial cost savings. The McIDAS hardware subsystems are fully designed and debugged, which again represents a significant cost savings in the system integration. Costs would be limited to only the hardware procurement, and to the development of software relating to the unique data sources and operational missions of the Cape Canaveral Forecast Facility.

The study recommends three phases of system implementation. The initial phase would consist of the installation of a single forecaster workstation with supporting equipment. This workstation would be interfaced to local data acquisition systems and support the operational mission of the CCFF. However, this initial system would not be fully operational in that it will lack redundancy and will require some processing be done by other computers at the CCAFS. The initial system will demonstrate the concept of data integration and show its usefulness in the support of the CCFF forecast missions. The second phase should consist of a gradual increase in the system capabilities being tailored to meet the specific needs of the CCFF. These would consist of transferring models and analysis procedures currently on other computers on to the embedded MIDDS computer, ingesting all the local data sources directly into the MIDDS, acquiring a local reception capability for satellite data, adding additional workstations, and tailoring the user interface to the exact needs of the CCFF forecasters. The third phase would provide the hardware and procedures necessary to have the system certified for full operational use.

1. Phase I - Initial System

The initial system should consist of a McIDAS workstation with its assorted support equipment, which would include the embedded IBM 4341 computer equipment. Because of space and air conditioning constraints the workstation would be remoted from the computer equipment within the CCFF building. The computer would interface to the various data sources, and process the displays required to support the forecaster.

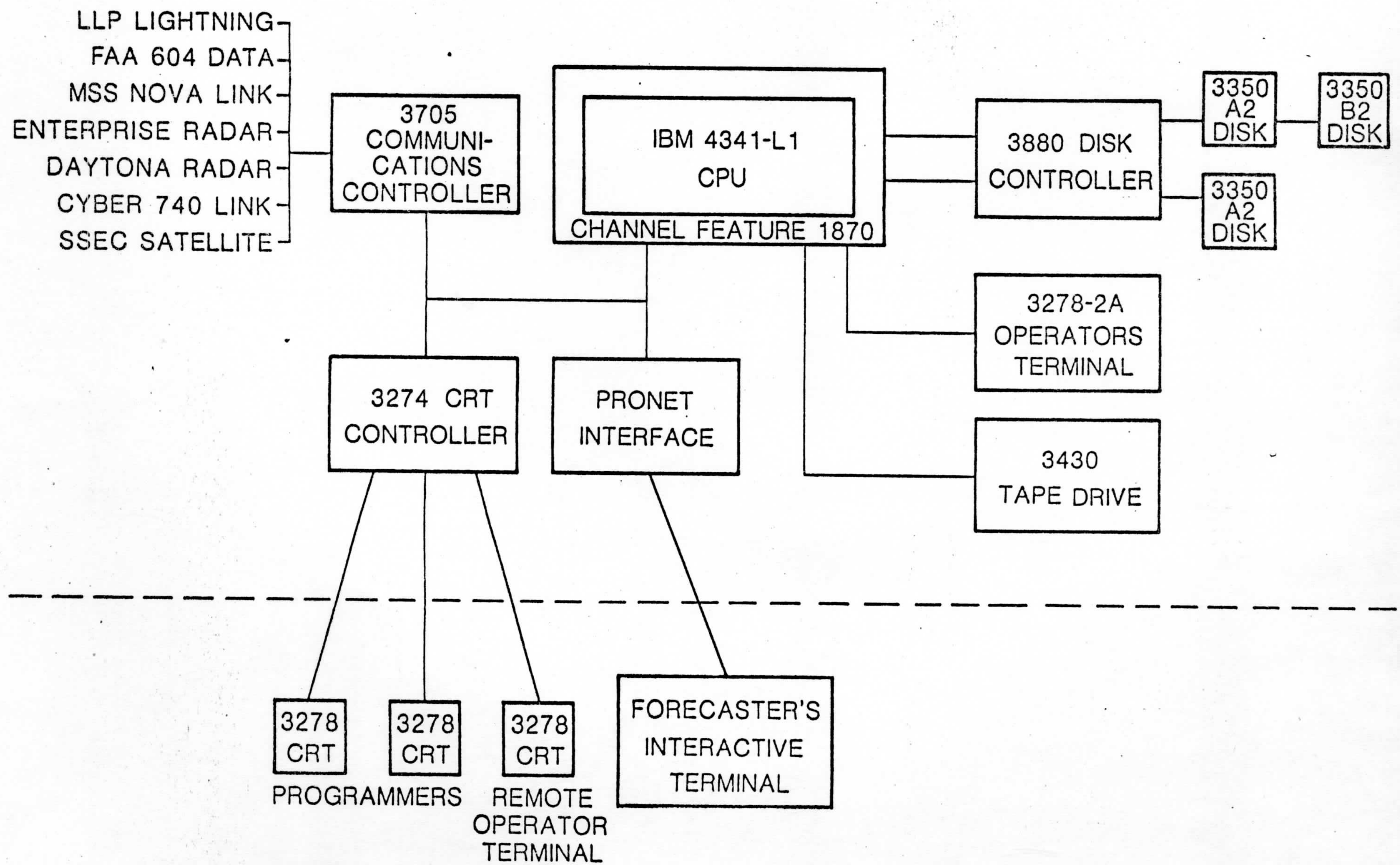
a. Workstation

The basic workstation would consist of an interactive terminal built by SSEC. The terminal is composed of a video display with graphic overlay, an alphanumeric CRT, a keyboard, cursor position control joysticks, a command data tablet, a local printer, a NTSC encoder for interfacing the workstation display with the Cape Canaveral video briefing system, and a single rack of support electronics for interfacing. The video display should have 64 image frames and 32 graphic overlays. This allows multiple loops of radar, satellite visible, and infrared images at various resolutions. Two channels of the image data can be functionally combined, such as the visible satellite image being colored where radar echos are occurring. The graphics allow concurrent or separate overlays of observations and analyses of winds, electric fields, lightning, etc. on top of the image data. The image data is presented as six bit data (64 gray scales) while the graphics are presented as three bits (7 simultaneous colors). The images have color enhancement tables allowing false coloring of images under user or computer control as well as function combinations of two images. The graphics also have color enhancement tables allowing user controlled colors for the graphics. The keyboard is used for general command inputs. The command data tablet are used for specialized process oriented commands. The joysticks are used to manipulate a cursor on the video monitor. Alpha-numeric outputs from the system can be displayed on the CRT or on the local printer. The NTSC encoder is used to convert the RGB television studio type signal into the NTSC signal format used in the briefing television network. The various components of the terminal are modules and can be placed according to the user's desires.

The terminal can be connected directly to a local embedded computer or to a remote McIDAS computer over a DDS phone link. We recommend that as soon as the basic workstation is built, it be installed at the CCFF and be connected to the McIDAS computer at the Space Science and Engineering Center. This would allow familiarization training to take place prior to the delivery of the entire first phase system.

b. Embedded computer

This study recommends using an IBM 4341 computer to support the functions of the forecasters interactive workstation. Figure 2 shows the recommended Phase I configuration. The IBM 4341 computer is available with various memory size and CPU speed configurations. The recommended 4341-L1 is an intermediate sized computer with four megabytes of real memory and 16 megabytes of virtual memory. The computer is upgradable in both speed and memory which will be discussed in the section on Phase II implementation. The channel feature 1870 is an option which allows six channel inputs into the system, rather than the standard three. Five of these channels will be required for the initial installation, with the sixth eventually being used for the satellite image ingestion.



PHASE I INITIAL INSTALLATION

figure 2

Two of the channels would be connected to the IBM 3880 disk controller which in turn would be connected to three IBM 3350 disk drives. Each disk has a capacity of 640 megabytes of data divided between two spindles. The recommended initial system would have 1920 megabytes divided between six spindles. For performance reasons, different functions would be divided between different spindles. One would be for the operating system, one for program source and object code storage, one for computer spooling and paging files, one for McIDAS data files, and two for areas of radar and satellite images (enough for over 1500 TV sized images).

Another channel would be connected to an IBM 3430 tape drive. This is a 6250/1600 bpi tape drive. Its main use would be for system saves and installation, maintenance, and storage and retrieval of historic data sets used for training purposes.

The operator's control terminal would be an IBM 3278-2A CRT. It is used for system diagnostics and control functions. Being that the computer will be remoted from the manned area of the CCFF, a remote operator's terminal would be needed in the staffed areas of the CCFF.

Combined together on the fifth channel would be the communications controller, the CRT controller, and the ProNET interface for the forcaster's terminals. The IBM 3274 CRT controller is used to support interactive IBM 3278 programmer CRTs and the remote operator's terminal. Initially two programmer terminals are rcommended for the use by Pan Am personnel working on conversion of programs currently on the Cyber 740. The ProNET interface is a high speed network interface to the forecasters' terminals. It is a 10 Mbit/sec ring network with nodes at the IBM channel interface and at the terminals. The ProNET/IBM channel interface is built by SSEC and allows up to eight ProNET nodes to be treated as separate logical I/O subchannels. This allows up to eight local forecaster terminal to be connected to the ProNET ring at the CCFF. Remote terminals would be connected via the 3705 communications controller.

The IBM 3705 communications controller would be used to interface to low speed data inputs. Initially these would consist of interfaces to the FAA 604 teletype circuit for conventional surface and upper air observations; the Cyber 740 link for local electric field, wind, and model output data; the LLP lightning location data; the MSS NOVA link for local radiosonde data; the local Enterprise radar data; the remote Daytona radar data; and the remote GOES satellite data from SSEC.

The computer is to be located on the third floor of the Range Control Center Building. Figure 3 shows the tentative room layout. The equipment layout is arranged with considerations for future expansion of the computer hardware in latter phases of the project. The operator's CRT will sit on top of the computer, which will be located near the door for ease of access.

c. Data Inputs

This study recommends that a communication link be established between the Cyber 740 and the MIDDS for input of the local meteorological data

REVISIONS			
LTR.	DESCRIPTION	DATE	APPROVED

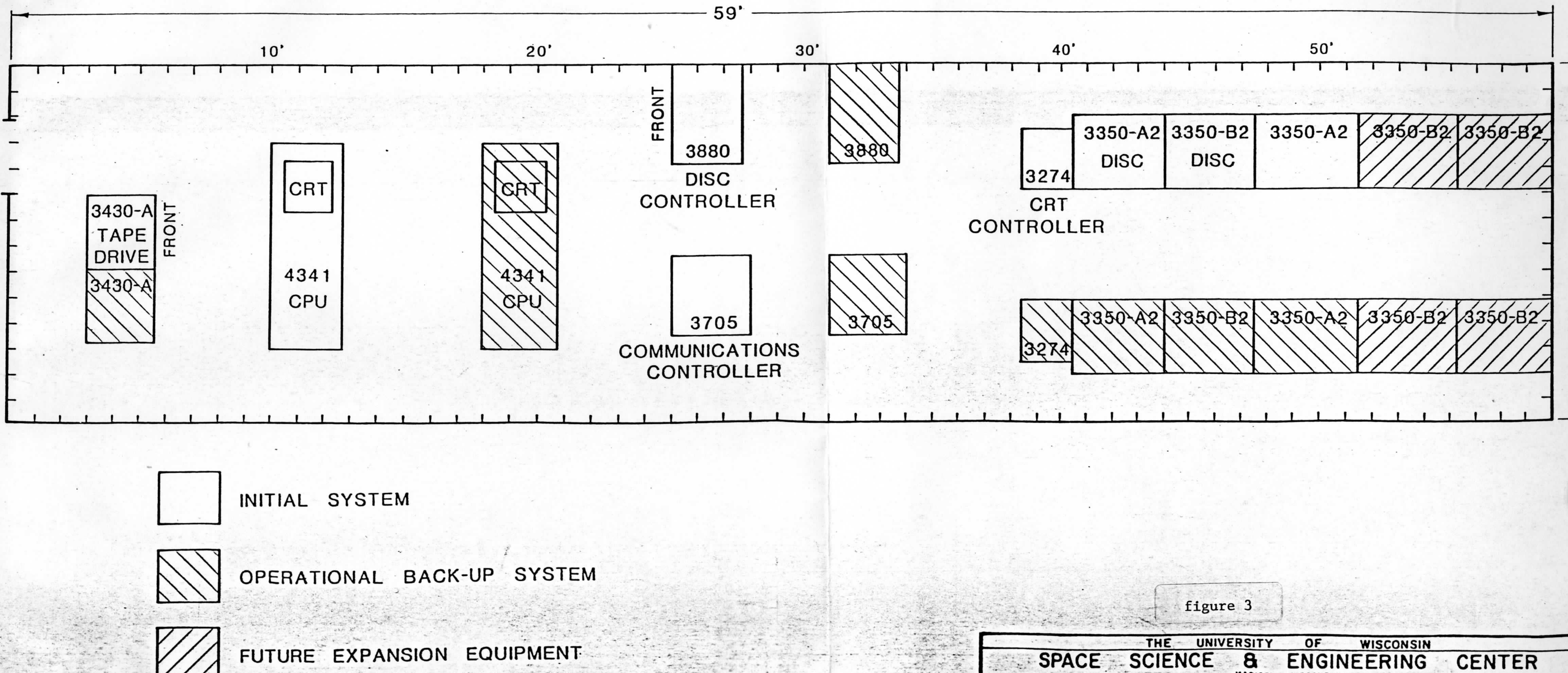


figure 3

THE UNIVERSITY OF WISCONSIN
SPACE SCIENCE & ENGINEERING CENTER
MADISON, WISCONSIN

TITLE

CCFF COMPUTER ROOM

SCALE	DRAFTSMAN DATE	CHECKER DATE	ENGINEER DATE
NEXT HIGHER ASSEMBLY	PRODUCT ASSURANCE DATE	PROJECT APPROVAL DATE	
PROJECT NO.	SIZE	SHEET OF	DRAWING NO.

collected by the ARMS buffer. This link would be a 4800 bps asynchronous link configured on the Cyber to act as a print only connection. Averaged electric field and wind tower data as well as gridded data and model output data would be obtained via this Cyber link. Lightning location data would be interfaced to the existing asynchronous output of the LLP equipment. The A.D. Little Flash Counter should not be interfaced to MIDDS. Conventional weather observations should be obtained from the FAA604 teletype line. Local upper air data should be obtained from the MSS NOVA computer via an asynchronous link. The GOES satellite imagery should be obtained from the SSEC McIDAS data base via a 9600 baud DDS phone link. The radar access requires further study before a final decision is made. The option favored by this report would be configuring the Enterprise radar to operate in a volume scan mode. An interface developed by the Radar Weather Observatory at McGill University would provide volumetric control, CAPPI scan images, RHI scans, automatic tracking of precipitation cells, extrapolated forecast images of precipitation, and point short range forecasts of rain intensity and timing. In order to access the remote radars such as Daytona, this study tentatively recommends a Kavouras RADAC receiver interface.

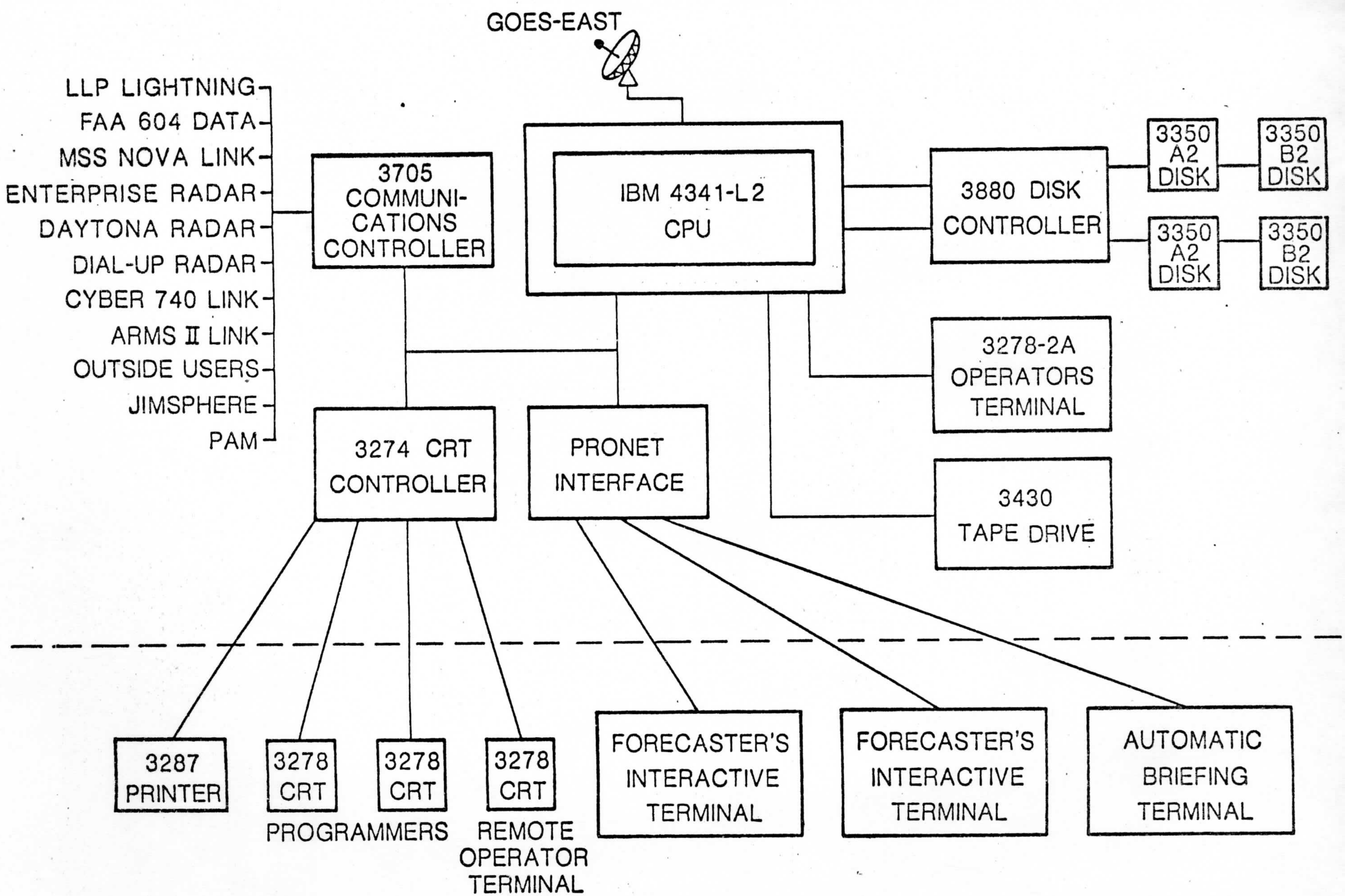
Several of the recommended data inputs would be modified or eliminated in latter phases of MIDDS. The link to SSEC would be replaced after the installation of a local satellite receiving capability. The link to the Cyber would be reduced or eliminated after completion of the ARMS II buffer and the transfer of the software currently on the Cyber to the MIDDS.

2. Phase II - Evolutionary Stage

The second phase consists of an evolutionary development of the MIDDS to uniquely tailor the system to the needs of the CCFF. The system would be upgraded, software would be written to support unique local data processing requirements, the user interface would be improved, the terminal would be improved, standard operating procedures would be developed, etc. The specific tasks would be rather open ended and would depend greatly on the feed back from the users on what is actually required or desired. Experience with the CSIS system at the National Severe Storms Forecast Center in Kansas City has shown the critical importance of this evolutionary phase after the initial installation. This evolutionary stage should last one to two years, although many aspects of the final operational phase can overlap with this intermediate evolution phase. While many of the actual tasks required for the evolutionary development will originate from feedback on the initial system, some of the probable improvements to the initial system as shown in figure 4 follow:

a. Local Satellite Image Acquisition

The local acquisition of GOES satellite data would improve the timeliness and flexibility of the satellite data. A larger area (up to entire U. S. coverage) of high resolution (1/2 mile) GOES data would be available as well as lower resolution (2 mile) data for the whole global disk. A ground mounted 15 foot receiving antenna is recommended along with its associated receiving electronics. The interface to the computer would be a replication of the design currently on the SSEC 4341.



PHASE II SYSTEM UPGRADE

figure 4

While a single antenna receiving GOES-EAST would satisfy the current CCFF mission, we recommend a second antenna aimed at GOES-West. This second antenna would provide information on conditions in the Pacific and over Edwards AFB. Being that this coverage is not routinely required for the current CCFF mission, this second antenna would be considered the hot spare for the GOES-East antenna. If problems occurred within the GOES-East antenna chain, the GOES-West antenna would be repositioned to receive GOES-East.

There is the possibility of radio interference with the GOES antenna caused by radiosonde balloons or rocketsondes. The radiosondes transmit in the same frequency band as the GOES satellite. It is possible to tune the radiosonde transmitters such that interference does not occur. It is recommended that an RFI survey be done at the preposed antenna site. If this survey shows that local radiosonde releases will cause interference, we recommend that the standard operating procedures for radiosonde releases be modified to tune the transmitter such that interference does not occur.

b. Additional Terminals

The single initial terminal probably will not be sufficient to support all of the forecasters and specialists assigned to a critical launch or recovery operation. At least one additional workstation will be required for preparation of forecasts. In addition a briefing terminal will be required. This terminal would be connected to the video briefing network and would routinely display current loops of satellite and radar image data in conjunction with overlaying weather analyses. This operation would be scheduled to happen automatically unless a forecaster wanted to give an individualize briefing manually controlling the terminal. A remote video terminal at Johnson Space Flight Center (JSFC) should also be added at some point to assist in the coordination of the forecast missions of the CCFF and JSFC.

c. Computer Upgrades

Several upgrades to the embedded computer might be required during this phase. An error logger printer should be added to the system to aid in error detection and recovery operations. Other print output would still go to the printers associated with the forecast terminals. As the system loading increases with the additional terminals, a CPU upgrade from the L1 to the L2 might be required. This provides an increase of 60% in CPU speed. There may also be a desire to increase the memory space from 4 megabytes (L configuration) to 8 megabytes (M configuration). Finally additional disk space may be needed. One or two additional 3350-B2 disks could be added to the system (adding an additional 600-1200 megabytes of storage) to allow longer retention of image data.

d. Local Data Direct Ingestion

The initial system will use the Cyber 740 to collect and preprocess the local electric field and meteorological tower data. The current ARMS buffer currently on the Cyber represents a potential single point failure of the system. We recommend that a new ARMS buffer be designed which would interface directly to the embedded MIDDS computer. We recommend that the redesign of the ARMS buffer be given a high priority. Once the ARMS data is available on the MIDDS we recommend that processing programs currently on the Cyber 740 be transferred to the MIDDS. The Pan Am personnel already familiar with these algorithms are the logical people to do this code conversion. They should be trained on the MIDDS software.

During this evolutionary period when many data sources and programs are transferred from the Cyber to the MIDDS, the current processing and display capabilities of the Cyber should be maintained to provide backup to the MIDDS. Only after completion of the final phase of the MIDDS should any consideration be given to dismantling any of the current system.

e. User Interface Improvements

Much of the success of the system will depend on the ability of the users being able to quickly and easily interact with the system. Many of the users of the system will have limited training and experience. The user interface must made simple for the novice user to effectively control the system without restricting the experienced user. The current user interface which is primarily command oriented needs to be modified to become more visually oriented. This would involve upgrading the command data tablet interface to allow computer generated command overlays. The system needs to allow further computer monitoring of the forecast activities to allow the system to insert needed defaults into the command structure. Likewise some of the concepts of expert systems should be experimented with to determine if they would improve the user interface.

The improved user interface will probably require a "smarter" terminal than will be available for the initial terminal. The Intel 8085 microprocessor in the terminal should be upgraded to the more powerful Intel 286 micro. This would allow the development of improved interactive capability directly in the terminal. It also would allow the development of improved protocols for remote terminals (such as the Johnson remote terminal) which can be used on satellite communication links (the current protocol requires a land line).

f. Special Applications Software

One of the most successful management approaches to the CSIS experiment at the National Severe Storms Forecast Center was the provisions for a "wish list". A procedure was set up to test and evaluate the system on an ongoing basis. A focal point was identified to gather suggestions, complaints, etc. These were prioritized into a wish list for evolutionary development. This procedure greatly improved the usefulness of the system to the forecasters. We recommend a similar procedure for the MIDDS.

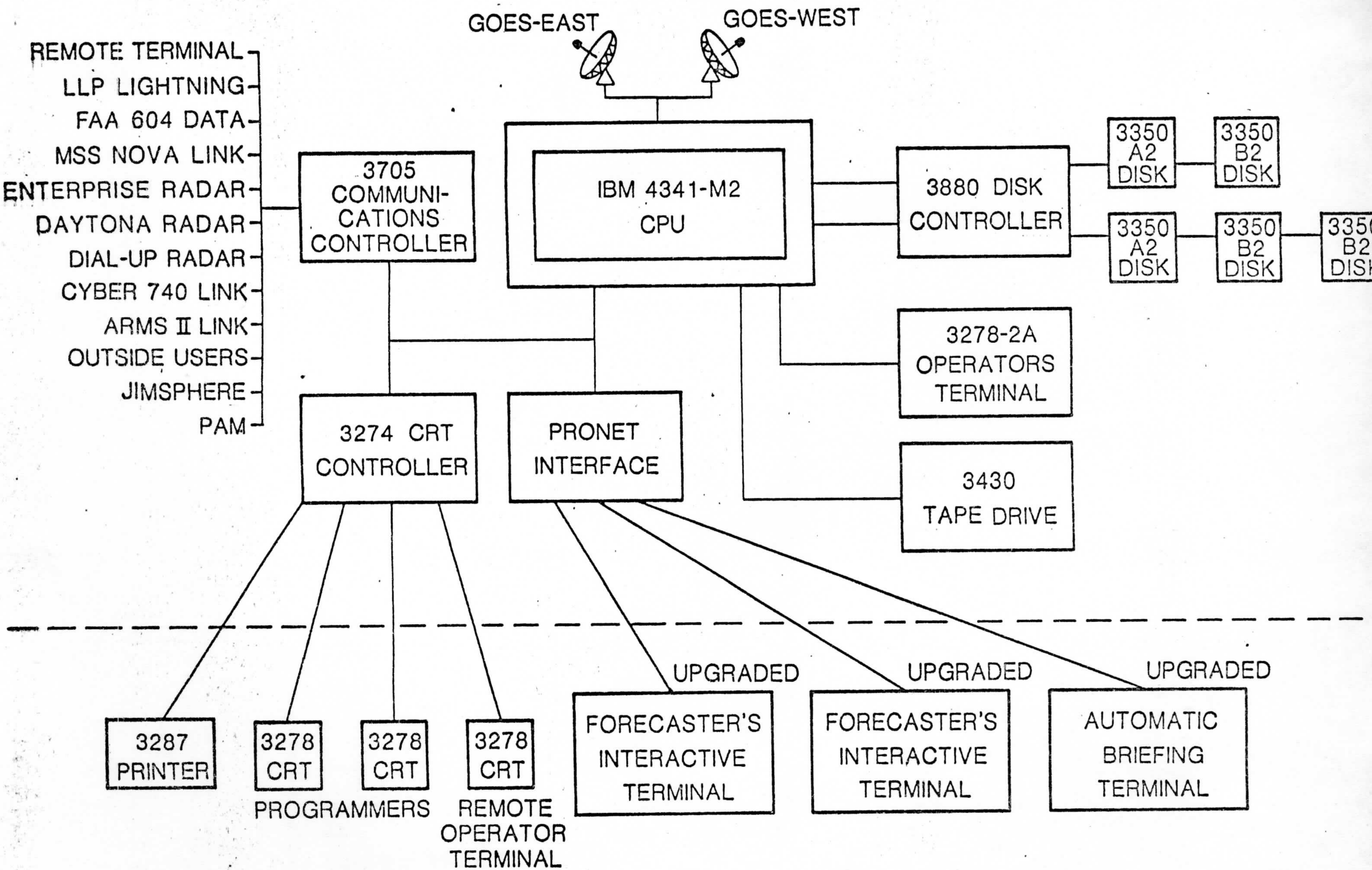
While some of the wishlist will be hardware oriented, most will probably be special applications software. Many of these will probably be associated with assisting the forecaster in the preporation of his forecast product. Examples from CSIS include: the interactive preparation of watch boxes with the computer generating the forecast message including locating key towns; the location of any town in the United States so that reports of severe weather can be related to locations of meteorological features; the monitoring of incoming teletype lines for reports of severe weather greater than threshold values and the computer voice synthesis of the message. While these examples are only applicable to severe weather forecasting, it is envisioned that equally specific desires for forecaster aids will be developed during this evolutionary period.

3. Phase III Operational Phase

The final phase of MIDDS as shown in figure 5 would involve procurement of additional equipment to insure uninterrupted service of the system and the development of any procedures and documentation necessary for operational certification.

The operational system would have two embedded computers, each ingesting and preprocessing all of the data sources. They would both be nodes on the ProNET communications ring so that any terminal could get any data from either computer. This would allow almost instant recovery from any computer failures. There would be at least three terminals in the forecaster's area, so temporary loss of one would not stop operations.

In conjunction with the operational system a local facility should be developed for maintenance of the equipment. This would include a test bed terminal for diagnostic and repair activities without interference with forecasters activities. This facility should also include spare boards and components (such as CRTs, etc.) for equipment located in the forecaster's area. This would allow rapid replacement of the defective equipment with more leisurely repair of the equipment in the maintenance facility.



PHASE III OPERATIONAL SYSTEM (ALL COMPUTER EQUIPMENT HAS REDUNDANT SPARES NOT SHOWN)

figure 5

V. LIST OF ACRONYMS

ARMS - Automatic Range Meteorological System
bps - bits per second
CAPPI - Constant Altitude Plan-Position Indicator
CCAFS - Cape Canaveral Air Force Station
CCFF - Cape Canaveral Forecast Facility
COMEDS - CONUS Meteorological Data System
CPU - Central Processing Unit
CSIS - Centralized Storm Information System
CRT - Cathode Ray Tube
DDS - Digital Data Service
DF - Direction Finder
DOD - Department of Defense
DVIP - Digital Video Integrator and Processor
ESDI - Environmental Satellite Data, Inc.
ETR - Eastern Test Range
ESMC - Eastern Space and Missile Center
FAA - Federal Aviation Administration
GOES - Geostationary Operational Environmental Satellite
JSFC - Johnson Space Flight Center
KSC- Kennedy Space Center
LLP - Lightning Location and Protection, Inc.
LPLWS - Launch Pad Lightning Warning System
McIDAS - Man Computer-interactive Data Access System
MHz - Megahertz
MSFC - Marshall Space Flight Center
MSS - Meteorological Sounding System
NASA - National Aeronautics and Space Administration
NESDIS - National Earth Satellite, Data, and Information Service
NHC - National Hurricane Center
NTSC - National Television Standards Committee
NSSFC - National Severe Storm Forecast Center
NWS - National Weather Service
PA - Position Analyzer
PAFB - Patrick Air Force Base
PPI - Plan-Position Indicator
PROFS - Protype Regional Operational Forecast System
PAMS - Portable Automatic Mesoscale System
RFI - Radio Frequency Interference
RGB - Red Green Blue
RHI - Range Height Indicator
RRWDS - Radar Remote Weather Display System
SDHS - Satellite Data Handling System
SDLC - Synchronous Data Link Control
SFSS - Satellite Field Service Station
SSEC - Space Science and Engineering Center
MIDDS - Weather Analysis and Display System
WINDS - Weather Information Network Display System
WSI - Weather Services International
WSR - Weather Service Radar

McIDAS III: A Modern Interactive Data Access and Analysis System

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Abstract

A powerful facility for meteorological analysis called the Man Computer Interactive Data Access System (McIDAS) was designed and implemented in the early 1970's at the Space Science & Engineering Center of the University of Wisconsin-Madison. Hardware and software experience gained via extensive use of that facility and its derivatives have led to a newer implementation of McIDAS on a larger computer with significant enhancements to the supporting McIDAS software. McIDAS allows remote and local access to a wide range of data from satellites and conventional observations, time lapse displays of imagery data, overlaid graphics, and current and past meteorological data. Available software allows one to perform analysis of a wide range of digital images as well as temperature and moisture sounding data obtained from satellites. McIDAS can generate multicolor composites of conventional and satellite weather data, radar, and forecast data in a wide variety of two- and three-dimensional displays as well as time lapse movies of these analyses. These and other capabilities are described in this paper.

1. Introduction

A Man-computer Interactive Data Access System (McIDAS) was first developed in the early 1970's for processing geosynchronous satellite images of earth as well as meteorological data at the Space Science and Engineering Center (SSEC). Although there were other commercial systems being developed at about the same time, they did not have the capability to process the vast amounts of digital data from the meteorological satellites interactively. Continued use of that facility, with increased data volume as well as technological developments in computers and peripheral hardware, have been responsible for constant improvements in the McIDAS hardware and software. Specifically, we can identify three distinct versions or generations of McIDAS. Many of these developments have come through the fabrication of similar facilities by SSEC for other institutions (see Appendix II). The first generation was based on a minicomputer, had two video display terminals (VDT's) for users, and was primarily used for research. This generation has been described by Smith (1975) and by Chatters and Suomi (1975). The second generation of McIDAS took the form of a network of eight minicomputers and was used for both research and quasi-operational use in support of the First GARP (Global Atmospheric Research Program) Global Experiment (FGGE). This generation is described briefly in Appendix I of this paper. The latest generation of McIDAS, the McIDAS III, although functionally the same, is a departure from the minicomputer as an element of the system and represents a more standardized facility built to work on several scales of mainframe computers. The improvements in this new version are apparent in peripheral equipment hardware such as the video terminals, as well as software and user interface to the system.

We intend to describe here what this facility is and what it can do. A full description of the system and its software and hardware components is beyond the scope of this paper and is not necessary for using the system.

2. McIDAS III Architecture

The distinctive feature of McIDAS III is its ability to ingest meteorological satellite and conventional data in real time and to make it easily available to both local and remote users. It is thus a Data Management System as well as an Analysis System. It is clear then that in addition to the usual components of any image processing system (a Data Base Manager (DBM), a general purpose computer, and video display terminals), McIDAS has another fundamental component: special Data Acquisition Hardware and Software. Some other components are different also. Indeed, McIDAS is best described in terms of six distinct components as follows:

Hardware:

i) Data Acquisition Hardware

ii) A general purpose computer

iii) Local and remote user terminals

Software:

i) Computer Operating System

ii) McIDAS Control Program, and

iii) Applications Programs

These components are described below. There are other features to this facility that are not described here and they include an off-line meteorological satellite data archive, the antennae sub-systems for receiving the satellite data, the communications links between McIDAS and other facilities, etc.

Applications Programs described in the next section represent the immense flexibility of McIDAS in a wide variety of research and operational situations. Most of these programs can be run on any computer, and indeed, the current software is derived from the early generations of McIDAS which used different (smaller) computers. However, the choice of a particular computer dictates the nature of the interfaces required between other hardware systems such as those to the data acquisition hardware. The McIDAS Control Program is really an applications executive that controls the communications between the user terminals and the host computer.

2.1 Meteorological Data Acquisition

McIDAS III ingests GOES (Geostationary Operational Environmental Satellite) visible and infrared (Visible Infrared Spin Scan Radiometer, or VISSR) images as well as the VISSR Atmospheric Sounder (VAS) multispectral imagery and sounding data in real time through three antennae located on the roof of the building housing SSEC. Polar orbiting satellite imagery and sounding data can be ingested via dedicated lines from remote receiving stations and from antennae located adjacent to the GOES antennae. Meteorological data for North America (FAA Service A hourly weather data), the Service C radiosonde observations, weather radar pictures, pilot reports, NMC forecast products etc., are ingested via dedicated and dial-up communications lines as well. The McIDAS III CPU can also communicate with other computers via dedicated communications lines. Most of the satellite and conventional data is ingested into the system for real-time applications are also archived for research analyses in a separate off-line archive system.

SSEC has a large digital archive of GOES imagery dating back to 1974. Since the FGGE (First GARP Global Experiment) beginning in 1978, SSEC has maintained a 24-hour digital archive of VISSR imagery from all the operational US geostationary weather satellites. This represents a data volume of over 10 billion bytes per satellite per day which is maintained on high density digital versions of video cassette recorders (Suomi, 1982). (At present, data from three GOES/VAS satellites is being archived.) Archived GOES VISSR data can be ingested into McIDAS III from a separate channel interface on an off-line basis without affecting the real time ingests. In addition, SSEC also has a large planetary data archive comprised of Mariner 10, Voyager, and Pioneer Venus spacecraft imagery data. These and other data can be ingested into the system via two 9-track tape drives.

2.2 McIDAS III Computer

The current hardware configuration is shown schematically in Figure 1. The previous generation of McIDAS was based on a Harris /6 minicomputer. McIDAS III is based on a medium scale computer (IBM 4341 Group II). The OS/VS1 operating system under which McIDAS operates is available on many different machines having a wide range of computing power. Since quick data access is a key factor of McIDAS, large memory storage is important. The current memory capacity of the McIDAS III is 4 Mbytes (the maximum memory capacity is 16 Mbytes). Peripheral data storage is provided by four IBM 3350 disk units each of which is capable of storing 640 Mbytes. User access to the CPU is provided through three different input devices - (i) locally connected terminals (IBM 3278 or equivalent) through the terminal controller, (ii) asynchronous or bisynchronous terminals through a communications controller, and (iii) bisynchronous McIDAS Video Terminals.

2.3 McIDAS Video Terminals

Present McIDAS video terminals are controlled by a microprocessor that also oversees the communications to the host CPU. They are "dumb" in the sense that they cannot perform any application functions without being connected to a host computer. A new generation of video terminals is being developed that will be more intelligent, with the ability to act as a "smart" local display device with its associated limited storage.

McIDAS III services both remote and local users with video terminals. Local McIDAS terminals are capable of burst communication rates of 10 megabits per second. To save communication costs, the bandwidth to the remote terminals is lower but it is impractical to operate the remote video terminals at data rates below 9600 bits per second since image access delays become too large. Figure 3 shows the terminal configuration schematically. It consists of an image display CRT, an alpha-numeric CRT, a keyboard, and two cursor control joy sticks. Additionally, other devices such as a video cassette recorder and an image hard-copy device can be attached for recording animated or still video output. When a user logs onto a terminal, the local microprocessor informs the user of the current terminal hardware configuration (e.g. number of image frames, number of graphic frames, local or remote etc.). The user can also determine the terminal characteristics from utility programs within an application program. It controls graphic overlays, the number of the graphic and image frames being displayed, current text output device (CRT or any other printer, local, remote or system) or whether the program is being run in background or foreground. The terminal components are described next.

a. Video Display

A typical McIDAS terminal has a number of image and graphic frames that are stored locally for rapid access. Each image frame is 480 x 640 pixels of six-bits, while each graphic frame is also 480 x 640 pixels, but only three bits per pixel. The number of image and graphic frames is determined by the user needs and cost rather than technical limitations. Additional memory can be installed to store and display more frames as needed. The graphic memory is separate from the image memory, and is typically capable of displaying eight levels or colors. The image memory and graphic memory can be combined to display an image on a high resolution color monitor with a graphic overlay that can be toggled in or out from the terminal keyboard. All available frames and graphic overlays can be displayed in a movie loop at variable rates up to 15 frames/second. The red, green, and blue guns of the color monitor are controlled by separate image refresh memories but they can also be fed to a standard television color encoder so they can be displayed on a commercial television or recorded on any NTSC compatible video recording medium such as cassettes or video disks.

b. Text/Data Output Device

The terminal output routines allow the program output to be directed to virtually any CRT terminal and/or local or system printer. The relevant routing code can also be changed from the terminal by a special command.

c. Joy-Sticks

A wide variety of types and sizes of cursors are generated by the local microprocessor and can be positioned anywhere on the monitor display under keyboard control or via a pair of coarse and vernier joy-sticks. The joy-sticks can also be used to define functions such as image enhancement, control of video frame display rates, and drawing on the screen. It is also possible to change the joy-stick functions in specific application programs as needed. For example the velocity of the cursor can be controlled to follow the paths of moving clouds in a "movie loop".

d. Enhancement Tables

A displayed image can be enhanced locally by changing from the default display mode, where the displayed brightness is proportional to the digital data numbers. This change is usually done via look-up tables. On McIDAS one can perform this not only for single image displays but also for a single image display based on the brightness of another separate image. Two video channels (frames) can be displayed together through 12-bit enhancement tables (6 bits per channel). The use of a local microprocessor in the terminal design allows easy insertion of multichannel custom enhancement tables. These enhancement tables have been used to generate pseudo three-color composites from two Voyager images taken in different colors, true and false stereo images, radar/satellite composite cloud images and the like. The available display frames and graphic frames can be looped in a rapid time sequence even in the combined mode of display. Customized enhancement tables can be either entered from the keyboard or generated within a program. The enhancement tables for each frame can be different and can be automatically loaded respectively for displayed frames. Thus it is possible to loop through a sequence of frames while at the same time loading separate enhancement tables for each displayed image. Examples of color composite display of two independent channels can be seen in Figure 4.

e. Data Tablets

As one can imagine there are very many commands to accomplish a wide variety of tasks. In order to simplify entering commands, data tablets have been added. These data tablets can be programmed such that a specific location selected by a pointer can perform a specific function. The data tablet is proving to be a very efficient means of manipulating the complex data in an operational environment.

2.4 Computer Operating System

The 4341 CPU is run under the OS/VS1 (virtual memory system) operating system. Languages include the Assembler and the VS Fortran. As such, the VS operating system is batch oriented and interactive program editing and computing and video processing support is instead provided by either the Editor or the McIDAS control program, respectively. These two control programs do away with the need for the usual interactive processors most commonly found on IBM machines: the TSO (Time Sharing Option) and the CMS (Conversational Monitoring System), and yet allow greater and easier user interaction with the data and programs.

2.5 McIDAS Control Program

The virtual system environment allows separate "partitions" within which programs can be executed independently and simultaneously. The number of these partitions can be changed as needed, although the McIDAS Control Program requires only one partition. All the partitions are in virtual memory. For easy editing of source programs and access to textual data, a text editor executes in a separate partition. Other partitions are used to execute background or batch jobs which may or may not be McIDAS programs or macro commands (see below). All video terminals are accessed via the McIDAS Control Program (including telephone dial-up CRT terminals). Thus the McIDAS Control Program appears as an applications program to the computer operating system, and as an operating system to its applications programs. It executes in a single partition of OS/VS1 or in a single address space in OS/MVS. In addition to simultaneous execution of different tasks (or batch jobs), the system is capable of simultaneously executing McIDAS (application) commands from the user terminals. The degree of "multi-tasking" is controlled at system start-up time by the allocation of the number of "sub-tasks" or initiators in the system start list. Each key-in made by a user at a McIDAS terminal creates a request block which is routed by the Control Program to one of the initiators. More than one request can be active from any single terminal at any one time, but the routing strategy guards against CPU monopolization.

Extensive program and data protection is provided by error abort and/or recovery mechanisms if erroneous command parameters are entered via a key-in. This prevents "crashing" the system, and is crucial in an operational environment. A potential user or program error situation generally results in an elegant exit of the initiator in which the problem program was operational, and not the entire control program. System service subroutines also provide error traceback capability for problem determination and solution.

A log of CPU time and resource usage for each request (by both batch jobs and McIDAS application programs) is kept for performance monitoring and billing purposes. These data can be used to "tune" the VS1 environment for optimum performance under changing conditions.

a. McIDAS Command Language

There are two ways in which commands can be entered to the executive: (i) single letter key-ins that perform both fixed and user defined functions and (ii) explicit commands that can accept an argument list. The single letter commands are used to control the video display or other programmed tasks. For example, the "A" key advances the video display to the next frame in a sequence, "W" key toggles the graphic overlay (WRRRM display) on and off, "L" key starts or stops a video loop between pre-defined loop bounds etc.

Frequently used McIDAS key-ins or commands that tell the CPU to execute a user defined application task are simple to use and remember, and typically constitute only a few parameters that can be coded by position or key words. If necessary a HELP command provides instructions on the command format and parameters. In addition, a manual of all programs is provided for further assistance. All commands have the following structure:

TASK (parameter list)

where TASK is the name of an executable program and the parameter list includes the processing parameters. The parameter list can be specified either as an argument list or as a key word oriented list. If necessary, specific inputs can be solicited from the program itself. For example, a commonly used command is the LA (List Area Directory) command:

LA 100 200

This command causes the directory for the areas 100 to 200 to be listed. An area in this context refers to an image matrix stored in the system. The output is the pertinent directory information for each image such as the satellite/spacecraft code, day and time of acquisition, size of the image etc. If the images are to be listed by specific days, the command is typed as:

LA 100 200 DAY=79100 to 79120

which lists only the images between areas 100 and 200 that were acquired between days 100 and 120 of the year 1979.

It is possible for an application program to solicit input from the user to direct the further execution of that program based on the solicited input. It is also possible to deliberately terminate the execution of an application program at any time.

Finally, there is an additional method in which McIDAS programs can be executed and that is through an application program itself. One can start a second application program through a prior application program; this is frequently done to minimize the need for user input for frequently used operations.

b. Command Procedures (Macro Facility)

Frequently repeated tasks or processing steps can be chained in a single macro command (procedures) or entered in short form via a string handling program. The McIDAS III macro language allows use of standard Fortran statements in addition to a few specific commands, and is thus very powerful in constructing complicated processing run-streams from McIDAS applications programs. Such macro procedures are entered as any other McIDAS commands. The parameters from the macro command are then passed on to the component McIDAS commands as needed in the user defined macro procedure.

Additionally, any or all of the terminal keyboard keys can be programmed to perform a prescribed sequence of tasks through the use of 126 programmable command registers. These registers render each key as a "function key." Each register has a "name" (the alphabetic keys) or a number (the ten numeric keys plus the numbers 11 through 100). The commands entered in these registers can then be executed conveniently by simply entering the register number or its alpha-numeric name.

c. McIDAS Data Management

McIDAS does its own data management. It "owns" several large data sets from which it allocates space for files as requested for applications. Utility routines provide highly flexible input/output operations to the user files with none of the limitations imposed by the operating systems on its files. Through locking conventions these files can be shared by multiple applications programs, permitting both batch and interactive data manipulation.

User "files" for image or other data are actually members of some generic data sets (i.e. they are members of a Partitioned Ordered Data Set), thus allowing greater flexibility in dynamic "file" creation and manipulation without the need for the normal control information that is required by the computer operating system. Sometimes the user data can be organized into a pre-defined scheme format that allows even greater data sorting capabilities without additional overhead. Examples of these are the meteorological data files, spacecraft orbit elements files, etc. Through standard utility commands the contents of these files can be edited or viewed by key-words denoting particular data types. For example, the following key-in will list all stations reporting an observed weather condition in the times specified:

MDE LIS MD=100 WX=SNOW TIME=1000 TO 2000

wherein the Meteorological Data Editor (MDE) is invoked with the key-words LIS and MD to denote the list option and the data file number (100) respectively. The same basic format can be used with proper key words for selectively displaying other data stored in the scheme format. This is a powerful method of accessing a wide variety of data with the same basic utility programs and thus the need for writing customized data sorting and editing routines is eliminated.

Finally, archival and restore utility programs allow many different kinds of data to be saved for future use. Different data catalogs can be maintained for keeping track of the data save tapes by different categories. 3. McIDAS Applications Programs

Almost all McIDAS applications programs are written in Fortran (1977 standard) making the software very portable. Over 300,000 lines of source code are currently operative on McIDAS III, all of which is accessible on-line. Extensive subroutine libraries and the modular design of programs make the creation of new application programs a fairly easy task. They include low-level data access routines as well as high-level utility routines for gridding and interpolation, plotting, Fourier analysis, etc. Usually outside program libraries can be installed with little or no change depending on the language and the input/output operations.

The applications software can be broadly categorized as being image data oriented or non-image data oriented. There is of course a somewhat limited class of programs that deal with the simultaneous manipulation of both the image data and non-image data. Examples of these include displaying conventional weather data on satellite images, contouring of this information in the satellite projection, or the computation of a vertical temperature and moisture sounding from satellite radiance data at a geographical location selected by positioning a cursor on a satellite image.

There is another class of programs for both image and non-image data archival and retrieval. The data base services are an important part of McIDAS as all data ingested in real time is archived for later use by the scientists. In addition to the data, the image navigation data is also routinely archived so that one may use the image data quantitatively at a later time as far as earth locations are concerned. A short summary of the applications programs follows.

a) Image Data Oriented Applications Programs

Any kind of data that can be represented as a two-dimensional spatial image with brightness representing the data can be handled on McIDAS. There are some basic operations that can be performed on a given digital image either for cosmetic or quantitative purposes. The image oriented application software can thus be further categorized as follows:

i) Digital Processing of Image data

In many instances the "raw" image data has to be processed for cosmetic or data integrity reasons. Examples of these include programs for digitally filtering the image data to bring out certain features of specific spatial frequencies, noise removal programs, camera shading and geometry corrections, etc. It is also frequently necessary to remap the image data into another projection, be it cartographic or the perspective view of another satellite. For example, for stereo analysis of GOES images, a user can remap an east satellite image into the projection that would be obtained from the location of the west satellite, so that the two could be viewed together. Or, for comparative analysis of a polar-orbiting satellite data, a remapping into the projection of the GOES satellite may be necessary. McIDAS applications software allows a user to custom design a program to generate any kind of projection and execute it in an efficient manner.

ii) Image Navigation

Image navigation software is a key part of McIDAS, as it is required for almost any quantitative image analysis. Programs exist for image navigation (i.e. the process of determining the geographical coordinates of the data points and vice versa) for many different kinds of observing platforms such as geostationary, polar, planetary fly-by spacecraft and orbiters. These programs are modular and they are used by many other applications programs such as for cloud tracking, rainfall estimates, etc. In addition, there are programs for modelling the behavior of the attitude of the spin-stabilized geosynchronous satellites. The value of this latter class of programs is in predictive alignment of real-time satellite images by determining ahead of time the precise satellite orientation.

iii) <u>Quantitative Image Analysis</u>

This class of programs is mainly oriented to user-needs and thus consists of some commonly used programs and some highly specialized ones. Perhaps the most used programs are those used for determining cloud motions not only from earth images but also from planetary images. Indeed, this was the prime motivation for development of McIDAS. A user can set up multi-frame digital time lapse sequences to show the evolution of a time-dependent weather system on the video terminal. Custom designed enhancement programs can be automatically loaded for each frame on the fly as the loop is being displayed. In addition to providing the capability to interactively track clouds visually as well as digitally, the programs enable the user to display the results as overlay graphics on the images, animate them and provide editing capability also.

Another type of image analysis program is the multispectral temperature water vapor sounding software that is routinely used for analyzing the TIROS and the GOES infrared and microwave sounding data. This allows a user to interactively determine the temperature and moisture profile in the atmosphere at any chosen location in the data area. In this way, soundings can be concentrated in meteorologically active areas and the product can be contour analyzed, displayed over the satellite image with ancillary observations (e.g. cloud motion vectors or radiosonde winds), and manually edited to insure a high quality result.

Rainfall estimation from the satellite and radar imagery is another area where applications software is heavily used on McIDAS. In addition, area statistics programs enable one to outline certain image portions and determine statistical parameters such as one and two dimensional histograms, means and standard deviations, etc.

Cloud top altitude and optical thickness determination is also achieved using GOES multispectral data. Cloud top pressure heights are determined while they are being tracked for the altitude assignment of the cloud "wind" vectors.

Edge detection programs are used for not only planetary applications (in image navigation by determining the bright limb location) but also in protein research for quantitative analysis of electrophoretograms.

iv) Stereo Image Display

Through software control it is possible to display both true and false stereo images on McIDAS. True stereo display is obtained from simultaneous display of two separate images of the same geographical area obtained from two satellites at different observing positions such as the GOES east and west satellites (Bryson, 1977). The two images can be either displayed in different colors (typically one is shown in red and the other in green) simultaneously and viewed with red and green glasses so that one eye sees the east image and the other the west image. The drawback of this mode is that color images cannot be displayed due to the necessity of showing each image in separate colors.

Another method of stereo viewing that enables color displays is to use special electronically shuttered glasses that allow each eye to see only one of the two alternate fields refreshed on the television monitor. In this case the two images are blended together at one-half the normal vertical resolution so that each image is displayed on alternate fields on the television and the electronic glasses then enable the stereo view.

When true stereo images are not available, a false stereo method can be used to create the illusion of stereo through software. For example, a false image can be created from the visible image so that the apparent parallax of the visible clouds is proportional to the cloud top altitudes estimated from the infrared cloud temperature data. A simultaneous display of the real visible image and the false one creates an illusion of stereo. Another method of displaying false stereo images is through the use of multiple frames each of which is created from a single image by artificially creating parallax by some amount, and then rapidly displaying these frames in a loop. Typically three or more frames displayed three to five times per second create a reasonable illusion of stereo view that is similar to rapidly obtaining different perspective views in a very short amount of time. This mode does not require wearing any glasses at all, and by its very nature cannot be reproduced in hard copy form.

b) Non Image Data Analysis

The non-image data applications software includes statistical and graphical analysis programs. Most of these are self-explanatory and hence need only a brief mention. They include the following:

- data interpolation such as curve fitting, two dimensional grid point analysis, etc.
- graphical analysis (x-y plots, contouring etc.)
- statistical analysis of user data
- "nowcasting" or display of current conventional and satellite weather data
- simple advective forecasting of short term mesoscale weather phenomena
- forecast impact experiments with a sophisticated limited area mesoscale primitive equation numerical prediction model.

Of these, the nowcasting and advective forecasting functions are particularly interesting and heavily used on McIDAS. They allow contouring and display on the graphics frames and animation of current and past weather data along with a chosen base map outline. Thus, they are analogous to conventional weather maps with the added benefit of animation for monitoring the weather evolution. The ability also exists to determine and display the derived quantities at will. For example, in a tornadic situation it is possible to compute the equivalent potential temperature distribution and watch it as it evolves in time. The areas of deepest and fastest northward penetration are frequently areas where severe weather develops. The hourly interval VAS profile observations now enable the changing thermodynamic stability of the atmosphere to be monitored to delineate local areas where intense convective storms will occur. Advections, divergences, Laplacians, etc. of any meteorological quantity can be computed and displayed for weather nowcasting purposes.

Finally, as mentioned earlier, it is possible and generally useful to display quantitative data products in the satellite projection along with the satellite image itself. For example, the 300 mb winds can be displayed as isotachs and streamlines on a satellite image enabling a better presentation of the relationship between the cloud patterns observed and the air mass movements.

Figure 4 shows examples of the image and graphic analysis via the applications programs. Figure 4a was generated within 30 minutes of completion of the satellite picture transmission and shows a color composite of the North American portion of a GOES image with an isentropic analysis of the pressure surface topography and the air flow. The visible and the window channel images are displayed at reduced resolution on the monitor. An enhancement program is used to assign different tints to the clouds based on their cloud top temperatures (determined from the infrared data). Thus magenta clouds are the highest clouds in this photograph obtained from the terminal display, and the white clouds are the lowest. The geographic and political map outlines are drawn in magenta and the pressure topography on the 295 degree K isentropic surface is depicted in yellow. Finally another program generates a streamline analysis from this data with the resultant streamlines shown in cyan, in the satellite projection.

A very vivid representation of the onsetting cold air flow upon the Midwest from the upper reaches of the atmosphere is readily apparent in this figure. This example combines many of the software capabilities of the system such as real-time data ingestion, color compositing, image navigation and registration, conventional weather data ingestion, data gridding and interpolation, contouring, and simultaneous display of the satellite image and graphics.

Figure 4b shows a color composite of Titan, a satellite of Saturn, and the only satellite known to have an atmosphere. This was made from two Voyager 1 images taken through orange and green filters. Both the images were first processed to remove the photometric and geometric distortions resulting from the vidicon cameras; they were then navigated and were brightness normalized to remove the effects of varying scattering geometry after determining the Minnaert law coefficients for the normalization. A color compositing program that uses the known filter responses generated the final, lifelike, although grossly exaggerated color display. This processing was all done interactively in a relatively short amount of time and was useful in that only after this processing could the darker northern (top) polar regions and the wispy, bright veil in the northern mid-latitudes be seen. The brighter southern hemisphere of Titan is also strongly emphasized after the brightness normalization.

Figure 4c shows wind vectors derived from cloud tracking and from horizontal termperature gradients determined from geostationary (VAS) as well as polar-orbiting satellite (TOVS) data. The winds are displayed over a blend of images of radiances within the water vapor absorption and atmospheric window channels of the VAS. The white areas denote high clouds and blue areas high upper atmospheric water vapor concentrations. The vectors reveal the upper tropospheric circulation associated with hurricane "Debby".

Finally, Figure 4d shows an example of one type of data used in severe storm research. This is a composite of a satellite image over Oklahoma with a Constant Altitude Plan Position Indicator (CAPPI) image from National Severe Storm Laboratory (NSSL) WSR-57 radar image mapped into the satellite projection. The radar echoes are color enhanced so that regions of higher reflectivity can be displayed inside the storm as seen by the satellite.

There is a capability that is difficult to show in this format and that is animation of different kinds of data. Several video sequences are routinely used for weather nowcasting and in classrooms either directly from McIDAS or via video cassettes.

4. Summary

McIDAS has evolved over the past decade into a general system which enables rapid access to a wide variety of weather data from satellites, from radar, from aircraft, and conventional observations in real time or from archives. McIDAS is only a tool, albiet a powerful one, and in the hands of a skillful operator can bring together a wide variety of data sources for display or computations.

Applications software is an area that needs constant attention, as it needs to adapt quickly to the environment under which it is used. The use of a current standard language at least for McIDAS applications software should make the task somewhat easier than it has been in the past. The hardware on which the software is used is becoming less and less important than in the past as technology advances and the reliability and flexibility of the computers increases. Indeed not all terminals need to be high performance ones. Some very useful work is being done through McIDAS using the so called personal computers.

Acknowledgements

McIDAS development was supported mainly by NASA, NSF and NOAA after seed support from the Graduate School of the University of Wisconsin-Madison. Many sources of encouragement and support large and small have contributed to its success. The McIDAS team gratefully acknowledges this support over the years.

While a number of individuals have contributed to the success of McIDAS, John Benson is its true architect. He has guided the early work using a single Harris minicomputer and as needs grew, expanded it into the second generation system in the form of a network. The latest generation is mainly his handiwork also. Of the many people involved in the development of McIDAS III, the following people deserve special mention: Marty Barrett, Dave Erickson, and Joe Rueden for the design of the McIDAS application software interfaces, Ralph Dedecker for the video terminal software design, Rob Uram for system integration, Tom Whittaker and Dave Santek for meteorological software, and Ron Steiner and Jim Maynard for the video terminal hardware design. Other individuals who have played a key role in the McIDAS system include Paul Menzel, Bob Krauss, Bob Oehlkers, and others. Fred Mosher contributed to the development of the CSIS (Centralized Storm Information System) version of McIDAS for the National Severe Storms Forecast Center in Kansas City. J.T. Young provides the important interface between McIDAS users and its hardware and software engineers. He also has the responsibility for training new users.

Important applications software support has been provided by Hal Woolf, Christopher Hayden, Fred Nagle, Ben Howell, Geary Callan, and Leroy Herman of the NOAA/NESDIS Development Laboratory at UW-Madison (Dr. W. L. Smith, Director),and by

Gail and Russ Dengel, and Anne LeBlanc of SSEC.

GOES data archive system was developed by Eric W. Suomi, and current management of that archive is the responsibility of Elsa Althen. Three operators man McIDAS for operational support--Dee Wade, Janean Stuessy and Dana Davis.

Individuals no longer at SSEC who contributed to the early McIDAS system include Gary Chatters, Dick Daly, Chris Davis, Tom Haig, Bill Hibbard, Bob Linn, Carl Norton, Bob Norton, Dennis Phillips, Bruce Sawyer, Terry Schwalenberg, Mahendra Shah, Eric Smith, and Bob Wollersheim.

We must also acknowledge the many anonymous users who identified needs that we were able to add to the general ability of the system as well as provided the impetus for the system development.

Finally, we would like to thank Gary Wade, Tony Wendricks, and Dr. L. Sromovsky for their assistance with this manuscript.

Appendix I

The Network Implementation of McIDAS

The second generation McIDAS took the form of a network of several Harris /6 mini-computers. The network (schematically shown Figure A1), which is still currently in use, has two computers acting as data base managers (DBM) with over 1 Giga bytes of shared peripheral storage. The two DBM's communicate with each other via wide band communication links (WCL). In addition each DBM communicates with several other computers (the Applications Processors, APs) via similar links. Both local and remote interactive video terminals for the users are connected through a terminal switch to the individual AP's. The Application Processors have their own local peripheral disk storage of typically 160 Mbytes, as well as access to the data managed by the two DBM's. Each application processor has the same McIDAS applications and system software so that they provide the same interactive and computational capabilities and thus serve as back-ups to one another in an emergency if one computer were to fail temporarily.

The network also provides access to the computers via conventional CRT terminals for editing programs or data files, or even executing McIDAS programs in the foreground without the benefit of a video display. Unlike the IBM 4341 implementation, no capability exists on the Harris McIDAS network to execute programs in the background.

Appendix II

Following is a list of institutions which have acquired McIDAS hardware and/or software for their use.

YEAR	INSTITUTION	REMARKS
1975	Air Force Geophysics Lab.	McIDAS hardware Datacraft 6024/5 CPU
1976	DFVLR, West German	McIDAS software (on AMDAHL V6)
1976	UW-Milwaukee	McIDAS remote terminal
1977	WTVT, Tampa, Florida	McIDAS hardware (Harris /6 CPU)
1978	VIRGS, NESS	McIDAS hardware (/6 CPU)
1979	LAS/GSFC, Greenbelt, Md. NASA	McIDAS software on AMDAHL V6 McIDAS terminal
1980	California State University at Chico, California	McIDAS hardware (Harris /6 CPU)
1980	Prototype Regional Observational and Fore-casting System, Boulder, Colorado, NOAA	McIDAS remote terminal
1981	Florida State University Tallahassee, Florida	McIDAS hardware (Harris /6 CPU)
1981	Marshall Space Flight Center Huntsville, Alabama, NASA	McIDAS remote terminals
1981	Institute for Atmospheric Physics, Peoples Republic of China	McIDAS hardware (IBM 4331 CPU)
1982	National Severe Storms Forecast Center, Kansas City, Missouri, NOAA	McIDAS hardware (2 Harris /6 CPU's) and a terminal to SSEC McIDAS
1982	IFFA, World Weather Building	McIDAS hardware (2 Harris /6 CPU's)

YEAR	INSTITUTION	REMARKS
1982	National Hurricane Center Miami, Florida	McIDAS remote terminal
1982	State Univeristy of New York at Albany	McIDAS remote terminal
1983	Hughes Aircraft Company El Segundo, California	McIDAS remote terminal

Smith, E.A., 1975: The McIDAS System. IEEE Trans. on Geosci. Electron., (GE-13), 123-136. Smith, W. L., V. E. Suomi, W. P. Menzel, H. M. Woolf, L. A. Sromovsky, H. E. Revercomb, C. M. Hayden, D. N. Erickson, and F. R. Mosher, 1981: First sounding results from VAS-D. Bull. Amer. Meteor. Soc., 62, 232-236.

Smith, W. L., C. M. Hayden, H. M. Woolf, H. B. Howell, and F. W. Nagle, 1979: Interactive processing of TIROS-N sounding data. Reprinted from (COSPAR) Remote Sounding of the Atmosphere from Space, Pergamon Press, Oxford and New York, pp. 33-47.

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Smith, W. L., V. E. Suomi, W. P. Menzel, H. M. Woolf, L. A. Sromovsky, H. E. Revercomb, C. M. Hayden, D. N. Erickson, and F. R. Mosher, 1981: First sounding results from VAS-D. Bull. Amer. Meteor. Soc., 62, 232-236.

Smith, W. L., V. E. Suomi, F. X. Zhou, and W. P. Menzel, 1982: Nowcasting applications of geostationary satellite atmospheric sounding data. Published in Nowcasting, K. A. Browning (ed.), Academic Press Inc. (London) Ltd., pp. 123-135.

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Limaye, S. S., H. E. Revercomb, L. A.Sromovsky, R. J. Krauss, D. A. Santek, V. E. Suomi, 1981: Jovian winds from Voyager 2: (I) Zonal mean circulation. J. Atmos. Sci., 39, 1413-1432.

Limaye, S. S., V. E. Suomi, 1981: Cloud motions on Venus: Global structure and organization. J. Atmos. Sci., 38, 1220.

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Suomi, V.E. 1977: An Introduction to McIDAS. Interactive Video Displays for Atmospheric Studies, Proceedings of a workshop held at the University of Wisconsin-Madison, 14-16 June, 1977. J. Hilyard, Ed., 322 pp. Available from Librarian, Space Science & Engineering Center, University of Wisconsin-Madison, 1225 W. Dayton Street, Madison, Wisconsin 53706.

Suomi, E.W., 1982: The videocasette GOES archive system-21 billion bits on a videocasette. IEEE Trans. on Geosci. and Remote Sensing, (GE-20), 119-121.

Wylie, D. P., B. P. Hinton, K. M. Millett, 1981: A comparison of three satellite-based methods for estimating surface winds over the oceans. J. Appl. Meteor., 20, 439-449.

Young, J. A., H. Virgi, D. P. Wylie, C. Lo, 1980: Summer monsoon wind-sets from geostationary satellite data. Space Science and Engineering Center, Madison, 127 pp.

Figure Captions:

Figure 1. A schematic diagram showing the current McIDAS III hardware configuration.

Figure 2. A view of a typical McIDAS Video terminal. The two racks on the right hand side on and under the table contain all the electronics hardware that is part of the terminal. A CRT for alphanumeric output, RGB color monitor for the image and graphic display, a pair of joy-sticks and a data tablet can be seen in the picture. A local printer for hard copy of textual information can also be seen on the left.

Figure 3. Schematic diagram of a typical McIDAS Video terminal configuration. Local peripherals such as the data tablet, the printer, the pair of joy-sticks, etc. are connected to the host microprocessor through hardware interfaces. Varying amount of image memory allow a number of image frames to be written and read out. The terminal is connected to the host McIDAS computer through a short haul MODEM.

Figure 4. Examples of McIDAS capabilities that make it so useful to a meteorologist: a) This is a photograph obtained within half an hour of receipt of the satellite images on November 12, 1982, and shows the first winter storm of the season to produce heavy snow and cold-air outbreaks in the midwest. The photograph shows a portion of the visible and

infrared images color composited together. The map outlines are drawn on the overlay display using precise navigation data. The overlaid analyses depict the topography of the pressure surfaces at the 295 degree Kelvin potential temperature level (cyan), and the streamlines on this theta surface that shows the air flow. The descent of cold air from the 400 mb level to the 1000 mb level (assuming adiabatic motions) in the midwest is readily apparent thus forecasting colder temperatures in the Midwest.

b) An example of a multi-channel color composite that can be created using the 12 bit enhancement table. This photograph taken from the McIDAS display terminal is a composite of two Voyager 1 images of Titan, a satellite of Saturn. Images taken through the violet and green filters from the Voyager narrow angle camera are simultaneously displayed through the use of special enhancements. All the processing was done interactively and the following tasks were performed on both the images in the following order: i) photometric correction for vidicon shading, ii) remapping to remove vidicon geometric distortions, iii) reseau removal, iv) image navigation, v) Minnaert scattering law parameters determined, vi) image normalization based on the Minnaert law to remove scattering geometry effects, vii) contrast enhancement to bring out maximum detail, viii) color compositing.

c) An example of cloud tracer winds obtained on McIDAS. This figure shows a comparison of the upper level radiosonde wind observations (500 mb) and tracer winds obtained from a triplet of water vapor band VAS images. The tracer winds are shown in cyan, the radiosonde observations in yellow on the central image of the triplet. d) A simultaneous display of a satellite image and a concurrent digital radar image remapped into the GOES-East satellite projection. Tilted PPI scans from 2° to 11° made by the WSR-57 radar of NOAA's Severe Storm Laboratory (NSSL) were combined into a Constant Altitude PPI (CAPPI) composite at 10 km above the surface. Green areas denote regions of the cloud with radar reflectivities > 10 dbz while blue areas denote > 40 dbz regions.

Figure A1. A schematic diagram of the second generation of McIDAS (the network implementation). "MOM" and "DAD" are the two central Data Base Managers (DBM's) and "REX", "ABE", "KEN", "SUE", "EVA", and "LIZ" are the applications processors that handle the user terminals through a patch panel. The numbers indicate the location of a given terminal. In addition there are several programmers' terminals (either dial-up or direct connect) that allow non-video interaction with the Applications Processors.

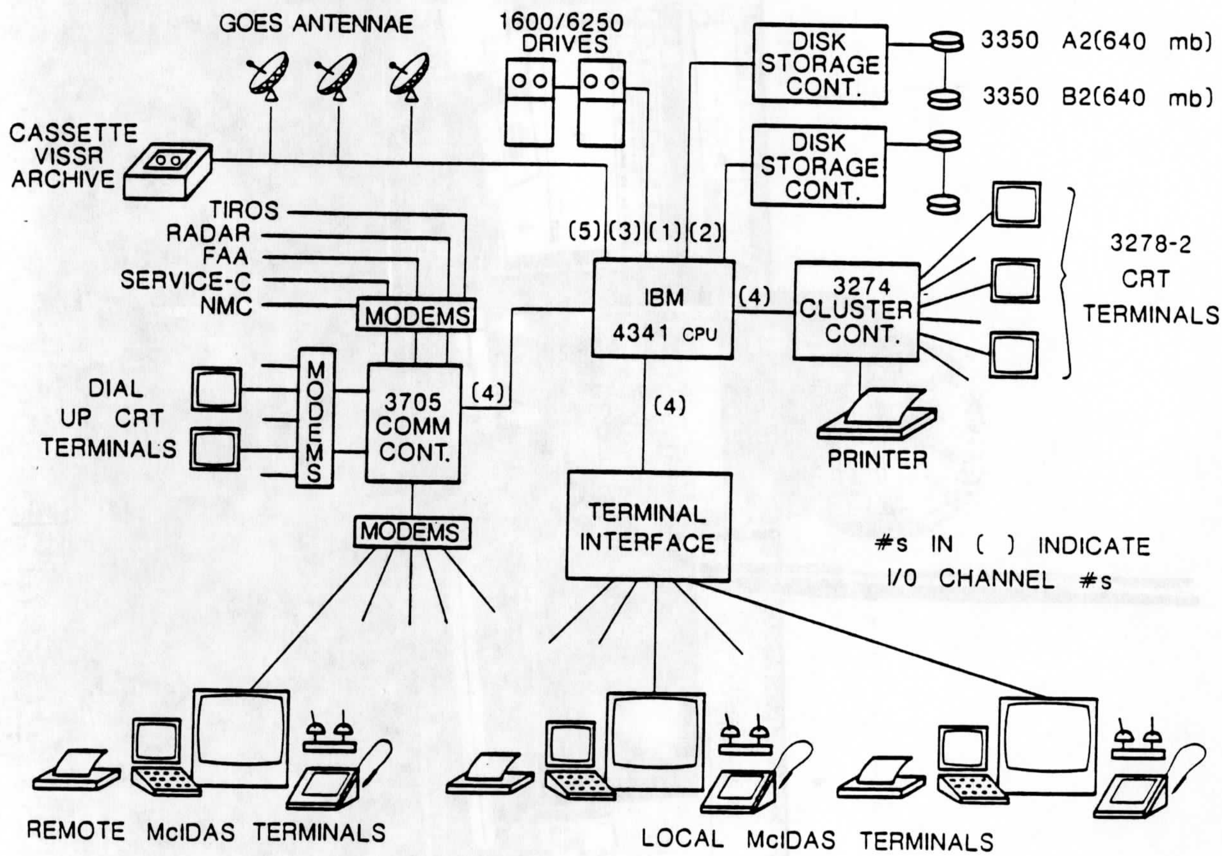

GOES ANTENNAE
1600/6250 DRIVES
DISK STORAGE CONT.
3350 A2(640 mb)
3350 B2(640 mb)
DISK STORAGE CONT.
CASSETTE VISSR ARCHIVE
TIROS
RADAR
FAA
SERVICE-C
NMC
MODEMS
(5) (3) (1) (2)
IBM 4341 CPU
(4)
3274 CLUSTER CONT.
3278-2 CRT TERMINALS
DIAL UP CRT TERMINALS
MODEMS
3705 COMM CONT.
(4)
(4)
PRINTER
MODEMS
TERMINAL INTERFACE
#s IN ( ) INDICATE I/0 CHANNEL #s
REMOTE McIDAS TERMINALS
LOCAL McIDAS TERMINALS

Figure 1

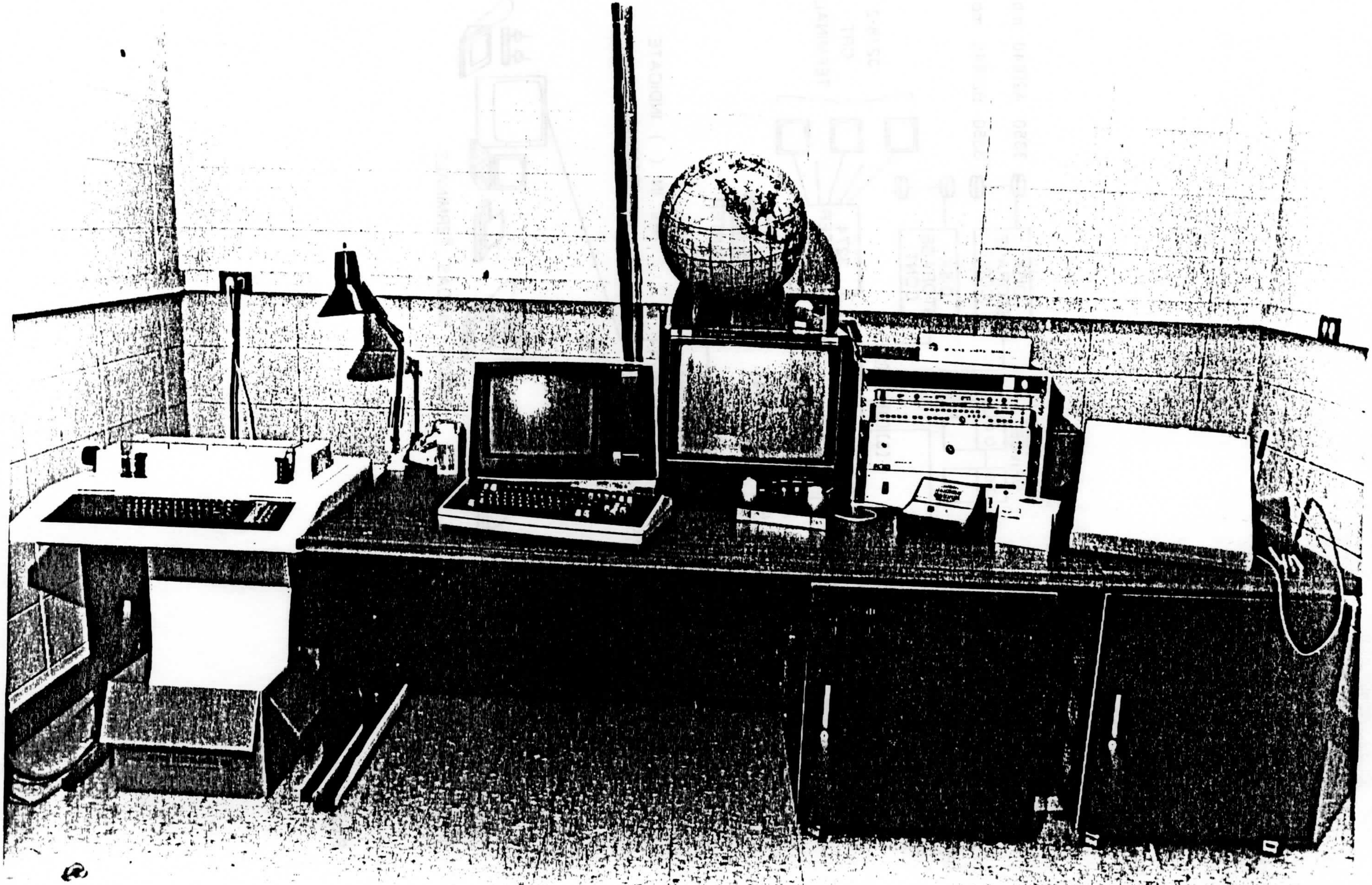
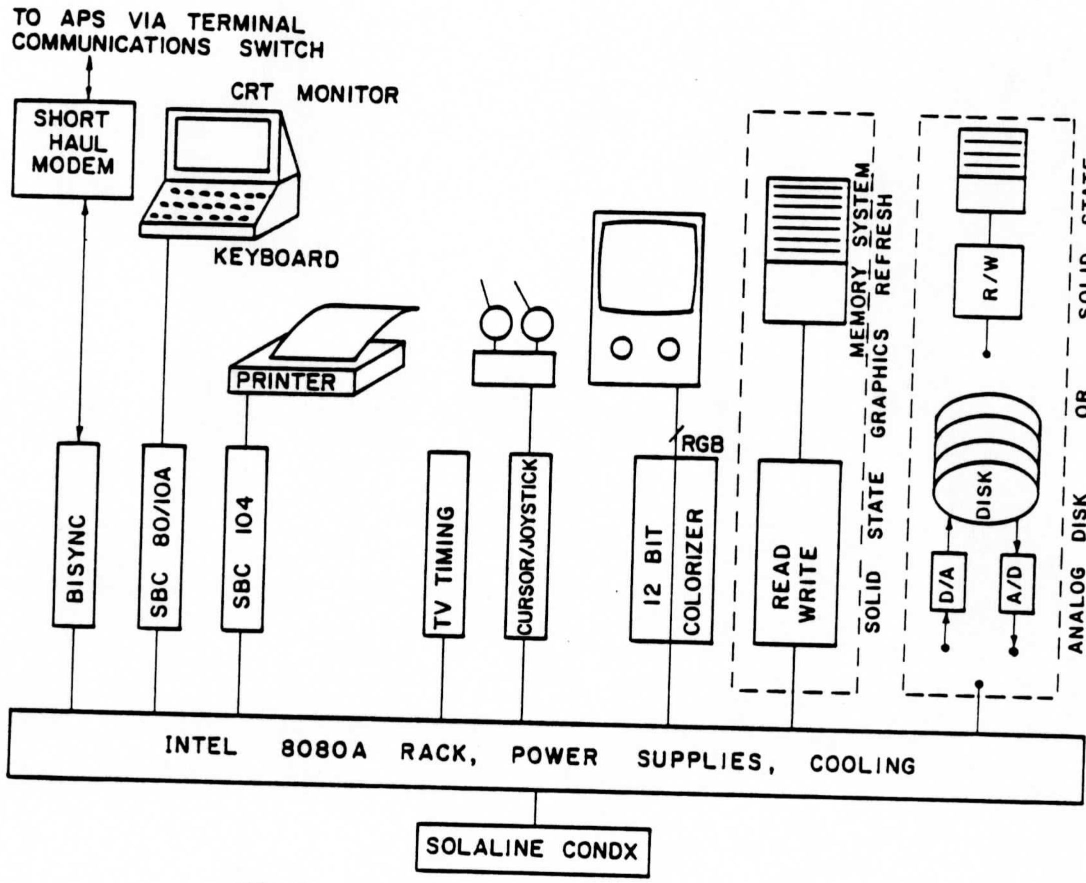
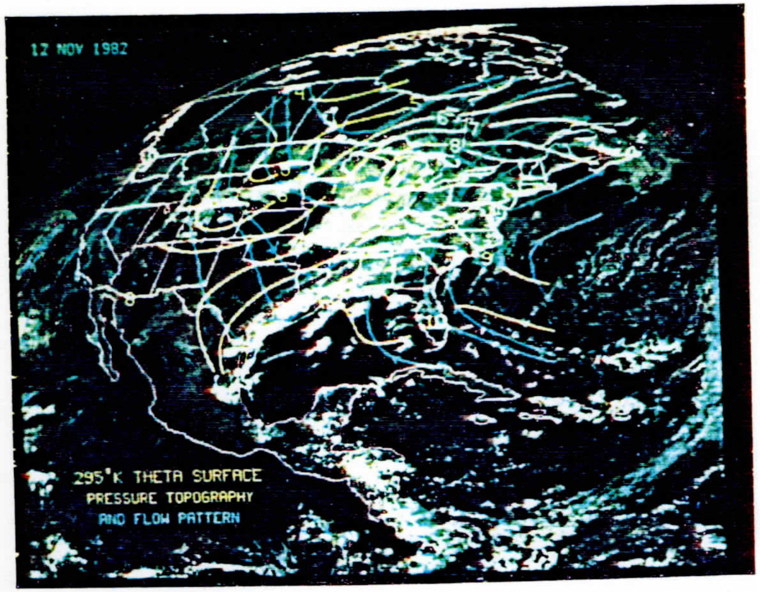


Figure 2

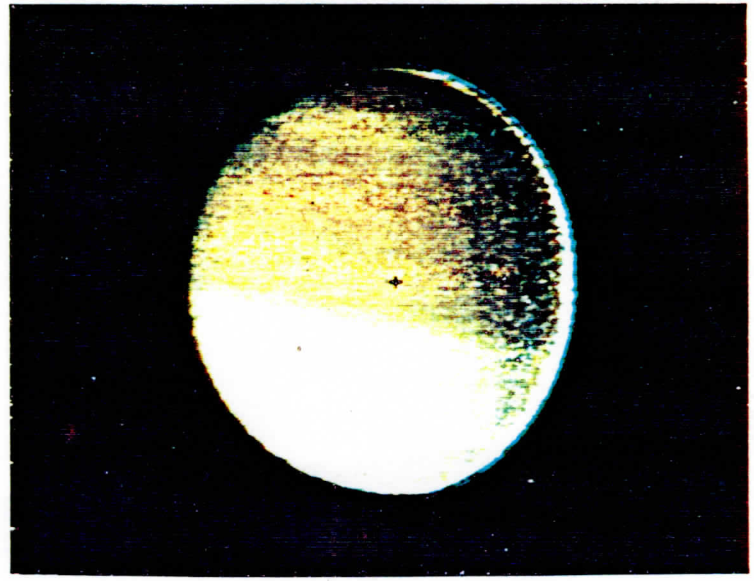


USER TERMINAL FUNCTION DIAGRAM

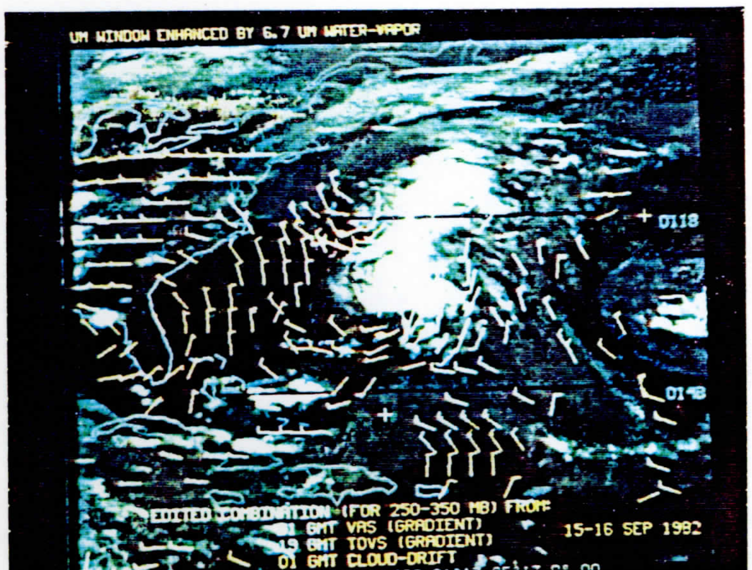
Figure 3.


12 NOV 1982
295°K THETA SURFACE
PRESSURE TOPOGRAPHY
AND FLOW PATTERN

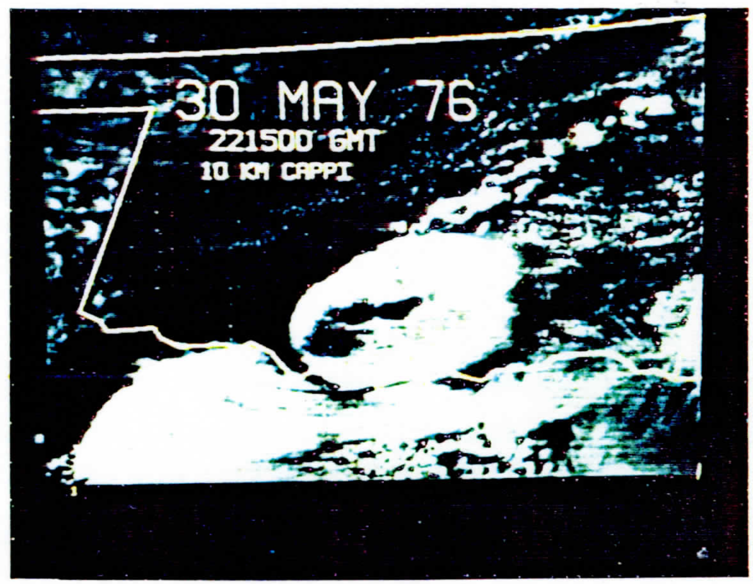
4a



4b


UM WINDOW ENHANCED BY 6.7 UM WATER-VAPOR
EDITED COMBINATION (FOR 250-350 MB) FROM:
01 GMT VAS (GRADIENT)
19 GMT TOVS (GRADIENT)
01 GMT CLOUD-DRIFT
15-16 SEP 1982

4c


30 MAY 76
221500 GMT
10 KM CAPPI

4d

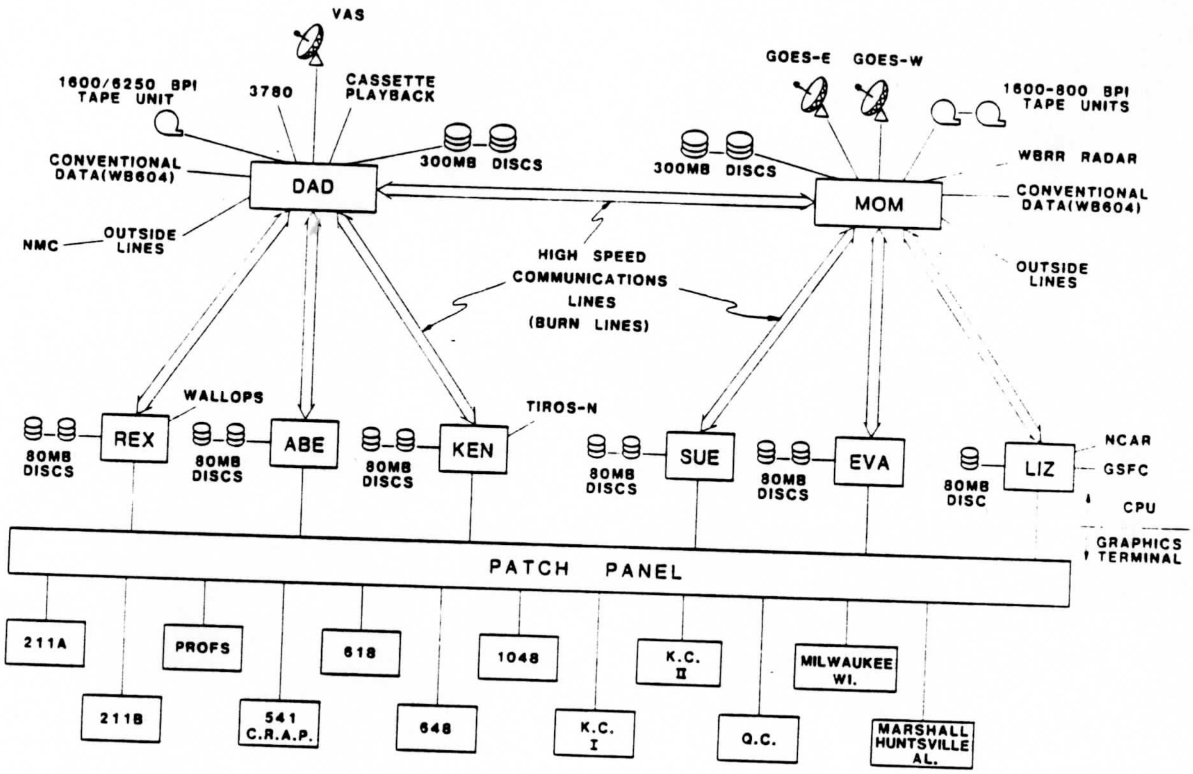

VAS
1600/6250 BPI TAPE UNIT
3780
CASSETTE PLAYBACK
300MB DISCS
CONVENTIONAL DATA(WB604)
DAD
NMC
OUTSIDE LINES
GOES-E
GOES-W
1600-800 BPI TAPE UNITS
300MB DISCS
WBRR RADAR
MOM
CONVENTIONAL DATA(WB604)
OUTSIDE LINES
HIGH SPEED COMMUNICATIONS LINES (BURN LINES)
WALLOPS
TIROS-N
80MB DISCS
REX
80MB DISCS
ABE
80MB DISCS
KEN
80MB DISCS
SUE
80MB DISCS
EVA
80MB DISC
LIZ
NCAR
GSFC
CPU
GRAPHICS TERMINAL
PATCH PANEL
211A
PROFS
618
1048
K.C. II
MILWAUKEE WI.
211B
541 C.R.A.P.
648
K.C. I
Q.C.
MARSHALL HUNTSVILLE AL.

Figure A1

Reprinted from Preprint Volume: 9th Conference on Weather Forecasting & Analysis, June 28-July 1, 1982; Seattle, Wash. Published by the American Meteorological Society, Boston, Mass.

THE CENTRALIZED STORM INFORMATION SYSTEM AT THE NOAA KANSAS CITY COMPLEX

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1. INTRODUCTION

Various attempts have been made to give up-to-the-minute meteorological observations to forecasters who have the responsibility for issuing short-term mesoscale forecasts. The meteorologist's inability to assimilate all the real-time data is a significant barrier to the improvement of short-term forecasts and warnings. Historically, failure to resolve this problem has plagued mesoscale forecast experiments (e.g., Entrekin et al., 1969).

Accordingly, a joint effort by the National Weather Service (NWS), the National Earth Satellite Services (NESS), the National Aeronautics and Space Administration (NASA), and the University of Wisconsin's Space Science and Engineering Center (SSEC) to develop a system to aid the forecaster in evaluating data was initiated. An exciting result has been the implementation of the Centralized Storm Information System (CSIS) (SSEC, 1981) at the colocated National Severe Storms Forecast Center and Satellite Field Services Station in Kansas City, Missouri. CSIS is a progeny of the SSEC Man computer Interactive Data Access System (McIDAS). Its installation is a major step towards the development of a handling, analyzing, intercomparison, and display system for real-time data from all available sources.

The ultimate goal of CSIS is, of course, to improve weather forecasts. However, since CSIS is really the first major interactive system available to the operational forecaster, there are several important questions which need to be addressed. 1) How useful is the system to the forecaster (i.e., helpmate or headache)? 2) What sort of standards (hardware, software, human) need to be established for CSIS to function adequately in the operational environment? 3) What sort of interfaces are necessary for compatibility with the evolving operational system used by NOAA?

CSIS is a demonstration system and, as such, will not be operational in the strictest sense. It exists in an operational environment and supports the operational mission. However, it is experimental in nature. Neither the hardware nor the software are developed to their final state. CSIS is evolutionary! Its components will be modified as the full impact of operational restraints upon an interactive system become known.

CSIS represents the middle step in the logical development of an operational tool. First, the initial concept must be developed and tested in a research mode (McIDAS). Then the system is extensively tested, evaluated, and tuned so that it fulfills operational needs in an operational environment (CSIS). Finally, a contract is let for the final system which will become an integral part of its environment. Even though the original McIDAS development (Suomi, 1977) was geared for operational applications, the penultimate step is required. The operational testing demands use by the same type of people that will be responsible for the final system. It demands use on an operational schedule with all the inherent problems. A simulation, by its very nature, cannot account for all potential problems.

Although the "stand alone" hardware has only recently been installed, the CSIS experiment began as part of the NASA VISSR (Visible Infrared [IR] Spin Scan Radiometer) Atmospheric Sounder (VAS) (Smith et al., 1981) program in March 1980. A remote terminal connected to the SSEC McIDAS via a 9600 baud telephone link was placed in Kansas City during March 1980 to evaluate the operational utility of satellite-derived soundings. This terminal was also used to test the real-time data collection and analysis capabilities of McIDAS.

The pre-CSIS phase was augmented with the installation of a second McIDAS terminal in December 1980. Although this phase was somewhat limited by hardware and software constraints, a formal test and evaluation (NOAA, 1981) provided insight into the potential role of an interactive system in the Kansas City operations (NOAA, 1981a). Finally, CSIS was installed at Kansas City in February 1982. In addition, a remote McIDAS terminal remains at Kansas City for an operational evaluation of VAS data. The CSIS experiment will last through September 1983. This paper details what has been learned from the first portions of the test and is meant to inform the community of CSIS and its capabilities.

2. PRE-CSIS UTILIZATION

During the period of March 1981 through July 1981, meteorologists were assigned to evaluate the system in an operational mode from Monday through Friday, 7:30 a.m. to 4:00 p.m. The evaluator was responsible for operating, manipulating meteorological data, and acting as a consultant to duty meteorologists.

While McIDAS contains an enormous amount of software (over 700 programs), only a small percentage is applicable to the Kansas City operations. Table 1 lists meteorological parameters which can be computed and displayed hourly on McIDAS. Contoured analyses of these fields can be overlaid (Wash and Whittaker, 1980) with current geostationary operational environmental satellite (GOES) data by 15 minutes after the hour. Analyzed data are stored so that change fields can be computed fairly simply. Analysis of upper air data is possible approximately one hour and 15 minutes after data time (00Z, 12Z). Programs which automatically produce upper air charts can be run on a scheduled basis and adjusted to include those fields most appropos to a given season.

TABLE 1
METEOROLOGICAL PARAMETERS AVAILABLE ON CSIS

Absolute Vorticity	Equivalent Potential Temp.
Temperature	Deformation - Stretching
Dew Point	Potential Temp. Advection
Pressure	Equiv. Potential Temp. Advection
Wind Data	Pressure Advection
Cloud Data	Snow Cover
Composite Cloud Data	Temp. Divergence
Potential Temp.	Dew Point Divergence
Mixing Ratio	Mixing Ratio Divergence
Precipitation (6-hour)	Potential Temp. Divergence
Visibility	Equiv. Potential Temp. Divergence
Wind Gusts	Pressure Divergence
Geopotential	Isotachs
Streamlines	Reported Weather Symbols
Current Weather	Wind Flag
Divergence	RAOB Station ID's at Location
Vorticity	Upper Air Temp.
Deformation - Shear	Upper Air Dew Point
Temp. Advection	Upper Air Wind Flags
Dew Point Advection	Upper Air Wind Vectors
Mixing Ratio Advection	Upper Air Surface Height
Vorticity Advection	Upper Air Station Plot

In addition to the conventional analyses, Stüve, skew T-log p, isentropic, and cross section analysis are available to the forecaster. One very useful program allows the forecaster to locate towns nearest a point on the satellite image. It also enables the meteorologist to determine the exact location of any town.

However, given all of the display and analysis capability of McIDAS, by far the most significant operational impact has been flexibility of displaying and using satellite data. Rapid availability of the imagery and flexibility in enhancement choice is now possible. The forecaster can determine the equilibrium temperature (Doswell et al., 1982), tropopause temperature, or use any desired temperature to develop a color enhancement based upon that value. In addition, image enhancement can also be interactively altered, through the full range of colors, by use of "joystick" controls. Software is available which allows the user to create and store different algorithms which transform the 256 possible brightness values measured by the satellite to the 64 shades available for display on the McIDAS TV. Almost ½ degree equivalent black body temperature resolution is possible over selected portions of the atmosphere.

The software also enables the forecaster to compute brightness statistics over any portion of the satellite image. These data can then be listed or contoured, and frequency distributions can be made. Satellite-derived cloud height estimates are easily obtained by comparing the cloud top temperature to a latitude- and month-dependent standard atmosphere. Cloud top heights can be estimated by displaying the closest rawinsonde profile.

3. CSIS HARDWARE AND SOFTWARE

The CSIS hardware consists of a GOES receiving antenna system, three Harris slash six computers, three interactive terminals, FAA "604" teletype input, two autodialers, and an interface to the NSSFC computer. The autodialers provide access to weather radar data, while the interface to the NSSFC computer provides a direct link to the National Meteorological Center (NMC), the NWS-AFOS system, and the FAA-Weather Message Switching Center (WMSC). Also, the phone link to the SSEC McIDAS system remains. The initial complement of equipment was installed in Kansas City in February 1982.

GOES imagery is acquired by a 15 foot antenna on the roof of the Federal Building in Kansas City. The GOES receiving system performs the data reception, demodulation, and synchronization functions necessary to receive GOES data. Digital satellite data are received in real time. Sectorization is performed in CSIS so that any part of the entire hemisphere can be examined.

The three Harris slash six computers are identical, but each performs different functions. The hardware is configured as shown in Figure 1. There is one data base manager (DBM) and two application processors (AP). These computers are linked by a high speed (10 mbit/sec) line. The DBM handles all incoming synchronous (computer to computer) and asynchronous data lines. Its function is to bring in, preprocess, and store all of the data which is used by CSIS. The second computer is used as an AP for the operational support of CSIS. This AP is connected to two interactive terminals and performs all of the analysis and display functions for the forecasters. The third computer is used as an AP for research and development activities. It has a single interactive terminal attached to it.

The system has been designed with enough redundancy for a fail-soft, degraded operational mode. All input data lines go to all of the computers, but only the computer designated as the DBM listens actively to these lines. Terminals are attached to the APs through a patch panel, so any terminal can be plugged into any computer. The criteria

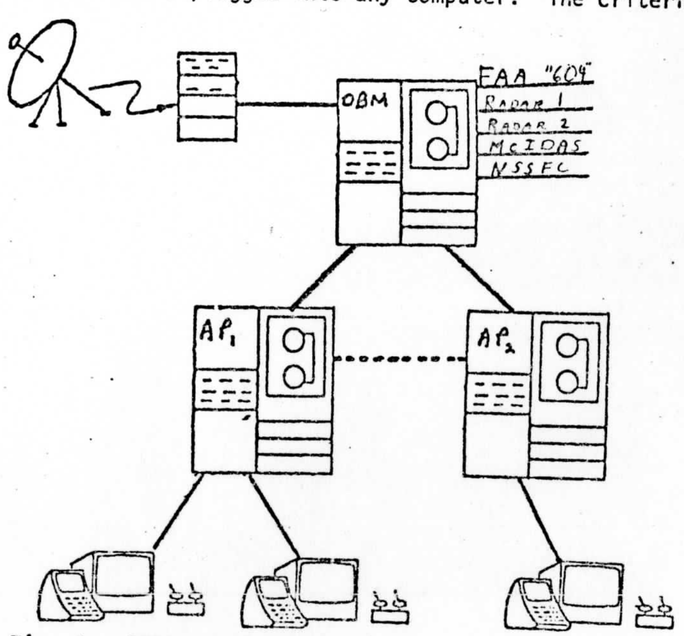

Fig. 1. CSIS configuration.

which determine if a computer is a DBM or AP are contained in software on the disk pack. If one of the computer systems fails, the system is reconfigured with the two remaining computers becoming a DBM and single AP. Reconfiguration takes place through switches on the front of the computer.

CSIS has three interactive terminals. Each terminal consists of an alphanumeric CRT, a high resolution color TV monitor, a joystick pair for input/output, alphanumeric hardcopy printer, terminal electronics, and a terminal enclosure-desk. Each terminal can generate and display two different types of TV presentation (frames). Image frames are essentially pictures and are used to display satellite imagery and radar data. Graphics frames are for displaying less intricate (line segment type) figures. Graphics are used for map backgrounds, analyses, and data presentation. The number of images and graphics is controlled by the number of memory boards in the terminal. Presently, each terminal can store a total of 26 image frames and 13 graphic overlays. Image frames are configured into paired opposites; the contents of one image in a pair can be modified by the other. For example, visual images can be colorized according to the IR temperature. The graphic overlay pictals can have up to seven different colors. These colors are selectable by the meteorologist via the colorizer tables.

Much of the McIDAS software, developed over the past 10 years, makes up CSIS. However, the goals of CSIS are sufficiently different from McIDAS so that some new software was required to tailor CSIS to the demands of the operational meteorologist. There were three types of software developed specifically for CSIS. First, new system software was required to manage CSIS. Second, new application modules were specifically needed to meet operational requirements. Finally, software was needed to respond to operational contingencies and to alleviate previously unforeseen problems.

In addition to those general software types, two specific major capabilities have been made a part of CSIS that were not available on McIDAS. One, called virtual graphics, allows fast access to up to 2000 pre-stored graphic presentations. Contoured fields are generated and stored by a single command, usually at a time when the forecaster's attention is on other duties. Then, during critical weather situations, the contoured fields can be displayed rapidly without having to spend time generating each individual chart. Virtual graphics are generated and stored for both selected hourly surface and upper air fields. An additional feature of virtual graphic generation is that contoured fields are generated and stored without interfering with the forecaster's ability to use the interactive terminal for current forecast problems.

The second capability is the display of radar data. CSIS is capable of ingesting, brightness normalizing, and remapping radar scope presentations to satellite projection. The current radar system is the WBRR (Weather Bureau Remote Radar). This can be color enhanced and superimposed on other data sources. Presentations from several radars can be composited on a single image. The new RADS (radar remote display system) network and commercial systems are being examined as possible replacements for the WBRR.

McIDAS programs developed to satisfy the needs of many projects at the University of Wisconsin are also part of the CSIS software package. The list of programs will grow throughout the CSIS project as software is written specifically for CSIS, and experimental software from other projects becomes available for transfer to CSIS.

4. EVALUATION FINDINGS AND POTENTIAL RESEARCH DEVELOPMENT PROGRAMS

The test and evaluation report (NOAA, 1981a) on pre-CSIS indicated several necessary modifications to the CSIS software that are scheduled for implementation. Perhaps the most important change needed for the system to gain acceptance by the operational forecaster is the capability to modify data and analyses interactively. In order for CSIS to be a truly interactive system, the meteorologist must be able to edit, erase and bogus both the upper air and surface reports, and analyses derived from that data. This modified analysis must be stored for future reference. Also, the objective analysis must be made independent of grid spacing or the size of the area to be analyzed. While such dependencies are a mathematically real phenomenon (Barnes, 1964), the analysis is of dubious value to the mesoscale meteorologist who analyzes habitually to the resolution of reported data.

With these modifications, the analysis process truly will be interactive. The computer will do what it does best: look at large amounts of data and perform a uniform (albeit crude) analysis of the data. The human will be free to concentrate upon a detailed, non-linear evaluation of the meteorological situation in areas of interest. The human will have the computer analysis as a "first guess" solution, but the computer will remember the final subjective analysis.

Another unresolved problem is the amicability of the system to the user. Most commands require a rather involved parameter list. In all operational computer systems, as the flexibility of the software increases, the command structure becomes more complicated. The myriad programs and their multiple nuances make CSIS a casual user's nightmare. A way must be found to obtain the flexibility of the software, but still allow the casual user access to the system.

During the pre-CSIS stage, several mission-oriented products which could be implemented with a little software development were identified. Software should include routines to extract topological features from analyzed fields such as trough and ridge axes and maxima/minima locations. Ideally, the planned interface between CSIS and AFOS via the NSSFC computer potentially will allow the meteorologist to transfer graphic symbology from CSIS to AFOS for dissemination to other NOAA facilities. To streamline NSSFC procedures, an approach might be followed that produces the composite chart (Miller, 1972) semi-automatically, extracting and assimilating data from various levels and superimposing it on the desired background. Eventually, quantitative precipitation estimation techniques (e.g., Scofield and Oliver, 1979) will be semi-automated and should improve the timeliness and quality of SFSS flash flood guidance.

5. POTENTIAL RESEARCH AND DEVELOPMENT VIA THE CSIS VISITING SCIENTIST PROGRAM

With the advent of CSIS, NSSFC possesses the equipment necessary for the operational testing of many forecasting-nowcasting techniques developed by meteorologists not associated with the NWS. Typically, these techniques require real-time access to digital satellite imagery (e.g., Adler and Fenn, 1979) and the ability to superpose conventional and remotely sensed data. CSIS has these capabilities.

To utilize these capabilities more fully, NOAA/NASA is instituting a visiting scientist program to allow non-NWS meteorologists to demonstrate developed forecast-nowcast techniques in the NSSFC environment. The program should serve as a mechanism for technology transfer. Individual scientists benefit by being able to test their concepts in real time, to interact directly with the forecasters, and to receive an informal evaluation of their technique. NSSFC gains not only by having newly developed techniques made available to them, but also through the development of a discourse between forecasters and the rest of the scientific community. Participation in the program will be at the scientist's own expense. However, NOAA will provide the access to CSIS and other NOAA Kansas City facilities. For more information interested parties should contact the Director of NSSFC.

6. SUMMARY

CSIS, as an outgrowth of McIDAS, represents a major step toward providing the operational meteorologist a truly interactive, information-handling, intercomparison, and display system. It allows the meteorologist to display and analyze rapidly both satellite and conventional data. Additionally, it permits the meteorologist to intercompare and superpose many of the various arrays of data that must be assimilated and interpreted.

The basic philosophy governing the development of CSIS recognizes the necessity of a penultimate, operational testing phase as essential to operational system development. CSIS is taking existing hardware and software and performing a mission-specific test and evaluation, to determine the needs of an operational system. In addition to the design of the final system, NSSFC and SFSS reap the benefits of interactive computers immediately, without having to wait until a permanent interactive computer system is procured, implemented and operating.

Finally, in addition to the operational support provided to the meteorologist by CSIS, a cooperative effort involving the severe storm research community at large is planned. This effort will provide the research community access to the operational environments for the demonstration of new techniques and products.

ACKNOWLEDGEMENTS: Many people have contributed to the development of CSIS. In time devoted, Dr. James Dodge (NASA), Mr. Fred Zbar (NWS), Mr. James Giraytys (NOAA) and Professor Vern Suomi (SSEC) have made major contributions. Beverly Lambert and Sherry Elliot typed the manuscript.

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LESSONS LEARNED FROM THE CSIS

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1. INTRODUCTION

Various attempts have been made to give up-to-the-minute meteorological observations to forecasters. However, the meteorologist's inability to assimilate all the real-time data is a significant barrier to the improvement of short-term forecasts and warnings. Historically, failure to resolve this problem has plagued mesoscale forecast experiments (e.g., Entrekin et al., 1969).

Accordingly, a joint effort by the National Weather Service (NWS), the National Earth Satellite Services (NESS), the National Aeronautics and Space Administration (NASA), and the University of Wisconsin's Space Science and Engineering Center (SSEC) to develop a system to aid the forecaster in evaluating data was initiated. An exciting result has been the implementation of the Centralized Storm Information System (CSIS) (SSEC, 1981) at the colocated National Severe Storms Forecast Center (NSSFC) and Satellite Field Services Station in Kansas City, Missouri. CSIS is a progeny of the SSEC Man computer Interactive Data Access System (McIDAS).. The first CSIS equipment was installed in February 1982 and represented a major step towards the development of a handling, analyzing, intercomparison, and display system for real-time data from all available sources.

The ultimate goal of CSIS is, of course, to improve weather forecasts. However, since CSIS is really the first major interactive system available to the operational forecaster, there are several important questions which need to be addressed. 1) How useful is the system to the forecaster (i.e., helpmate or headache)? 2) What sort of standards (hardware, software, human) need to be established for CSIS to function adequately in the operational environment? 3) What sort of interfaces are necessary for compatibility with the evolving operational system used by NOAA?

Even though CSIS is a demonstration system and, as such, will not be operational in the strictest sense, it exists in an operational environment and supports the operational mission. Because it is experimental in nature, neither the hardware nor the software are developed to their final state. CSIS is evolutionary! Its components will be modified as the full impact of operational restraints upon an interactive system become known.

2. CSIS HARDWARE AND SOFTWARE

The CSIS hardware consists of a GOES receiving antenna system, three Harris /6 computers, three interactive terminals, FAA "604" teletype input, two autodialers, and an interface to the NSSFC computer. The autodialers provide access to weather radar data, while the interface to the NSSFC computer provides a direct link to the National Meteorological Center (NMC), the NWS-AFOS system, and the FAA-Weather Message Switching Center (WMSC).

GOES imagery is acquired by a 15 foot antenna on the roof of the Federal Building in Kansas City. The GOES receiving system performs the data reception, demodulation, and synchronization functions necessary to receive digital satellite data in real time. Sectorization is performed in CSIS so that any part of the entire hemisphere can be examined.

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The system was designed with enough redundancy for a fail-soft, degraded operational mode. The input data lines go to all of the computers, but only the computer designated as the DBM listens actively to these lines. Terminals are attached to the APs through a patch panel, so any terminal can be plugged into any computer. The criteria which determine if a computer is a DBM or AP are contained in software on the disk pack. If one of the computer systems fails, the system is reconfigured with the two remaining computers becoming a DBM and single AP. Reconfiguration takes place through switches on the front of the computer.

CSIS has three interactive terminals. Each terminal consists of an alphanumeric CRT, a high resolution color TV monitor, a joystick pair for input/output, a data tablet, an alphanumeric hardcopy printer, terminal electronics, and a terminal enclosure-desk. The data tablet is used for both position dependent inputs and for user defined command sequences. Each terminal can generate and display two different types of TV presentation (frames). Image frames are essentially pictures and are used to display satellite imagery and radar data. Graphics frames are for displaying less intricate (line segment type) figures. Graphics are used for map backgrounds, analyses, and data presentation. The number of images and graphics is controlled by the number of memory boards in the terminal. Presently, each terminal can store a total of 26 image frames and 13 graphic overlays. Image frames are configured into paired opposites; the contents of one image in a pair can be modified by the other. For example, visual images can be colorized according to the IR temperature. Also, instantaneous switching between opposites is possible. The graphic overlay pictals can have up to seven different colors. These colors are selectable by the meteorologist via the colorizer tables.

Much of the McIDAS software, developed over the past 10 years, has been incorporated into CSIS. While McIDAS contains an enormous amount of software (over 1400 programs), only a percentage is applicable to the Kanasas City operations. Contoured analyses of surface fields which are available by 15 minutes after the hour can be overlaid (Wash and Whittaker, 1980) upon current geostationary operational environmental satellite (GOES) data. Analyzed data are stored so that change fields can be computed fairly simply. Analysis of upper air data is possible approximately one hour and 15 minutes after data time (00Z, 12Z). Programs which automatically produce upper air charts can be run on a scheduled basis and adjusted to include those fields most appropos to a given season. In addition to the conventional analyses, Stüve, skew T-log p, isentropic, and cross-section analyses are available. One very useful package allows the forecaster either to locate towns nearest a point on the satellite image or to determine the exact location of any town.

However, given all of the display and analysis capability of McIDAS, by far the most significant operational impact has been in displaying and using satellite data. Rapid availability of the imagery for any region and flexibility in enhancement choice is now possible. The forecaster can use the equilibrium temperature (Doswell et al., 1982), tropopause temperature, or any other desired temperature as a basis for a color enhancement. In addition, image enhancement can be interactively altered, through the full range of colors, by use of "joystick" controls. Software is available which allows the user to create and store different algorithms which transform the 256 possible brightness values measured by the satellite to the 64 shades available for display on the McIDAS TV. Almost ½°C equivalent black body temperature resolution is possible over selected portions of the atmosphere.

The software also enables the forecaster to compute brightness statistics over any portion of the satellite image. These data can be listed or contoured. Frequency distributions can be made. Satellite-derived cloud height estimates are easily obtained by comparing the cloud top temperature and the closest rawinsonde profile.

CSIS is capable of ingesting, brightness normalizing, and remapping radar scope presentations to a satellite projection. The current radar data is obtained from a computer interface to the Kavouras network. This can be color enhanced and superimposed on other data presentations. Data from several radars can be composited on a single image and displayed under a satellite image.

3. IMPACT OF THE CSIS

In the year in which CSIS has been used operationally, it has had a dramatic and positive impact on the NSSFC operations. Because of CSIS, "real-time" satellite images have replaced radar as the main tool used at NSSFC to assess movement and growth patterns of thunderstorms. The capability to pinpoint cities is excellent and aids in all aspects of the NSSFC program. CSIS is used both for subsynoptic surveillance over suspect regions and for detailed mesoscale observations where storms exist. The ability to change the IR-color enhancement breakpoints allows the forecasters to modify the display as upper air conditions change. This flexibility makes the satellite a truly "real-time" data source. Quantitative values of feature velocity and cloud heights have proven invaluable. The meteorologist can determine exactly what the satellite is observing. This, coupled with the ability to superpose other data sets and analysis on the imagery enables the forecaster to truly integrate the various available data sets.

Because of CSIS there has been a general improvement in the work environment at the NSSFC. Productivity has gone up. The forecasters are able to monitor more sections of the country simultaneously. The forecasters are looking at more data. Since the data presentations have a higher information content, the forecaster spends less time just sitting staring at data, and more time understanding what's happening with the weather. Having a computer to help organize the forecaster's work, remind him of the status of his forecast products, and keep him up to date in a rapidly changing weather situation has proven invaluable in dealing with widespread severe storm outbreaks.

4. LESSONS LEARNED FROM THE CSIS

One of the purposes of the CSIS experiment was to gain sufficient experience from a prototype system so that specifications for an eventual operational system could be intelligently developed. This process is in progress. A draft document on the functional and performance requirements of the next NOAA-Kansas City Computer System has been written as part of the National Centers Upgrade program of NOAA (NOAA 1982). The lessons learned from CSIS are reflected in that document. While many of them are specific to the forecasting environment of the NSSFC, some of the lessons are of general interest to other locations which are planning meteorological interactive processing systems. Some of these insights which were unexpected at the beginning of the project are as follows:

4.1 "Bottom up" rather than "top down" design approach

Most, if not all, of the systems developed for the National Weather Service use a "top down" management approach. Service requirements are documented at the outset of a program in order that lower level system and design requirements may be logically developed from them. Even the most detailed features of the ultimate operational system are traceable back through the requirements hierarchy to a basic service need. The top down structured approach provides a methodology and a discipline for assured design efficiency and ultimate operational effectiveness.

While the "top down" approach is conceptually an effective management tool, frequently it does not produce systems useful to the forecaster. One of the basic assumptions of the top down approach is that you know and understand exactly what you need. Actually this is seldom precisely true. Also the top down approach is not conducive to the "but I forgot the" oversights or the "it would be much more useful if" afterthoughts which always seem to occur. The top down approach is generally not flexible enough to accommodate changing work loads, changing technology, and unforseen occurrences. A top down system deals with the problems relevant at the time of system design, not with the problems of the present. Finally the end user of the system, the lowly forecaster, has little or no say in the system which he must use to accomplish his tasks.

In contrast, CSIS used a "bottom up" design management approach. The system was designed to be evolutionary. Requests, ideas, complaints, etc. of the system were collected by a test and evaluation team at the NSSFC. They were pioritized into a "wish list" and passed on to the CSIS design team at SSEC. The system was then added to, changed, or modified according to the needs of the users. In order to mininize adverse impacts on the operational system, the changes were first developed on the McIDAS at SSEC and then installed on the development computer of the CSIS. After checkout of the change at NSSFC, it would be released to the whole system and the forecasters informed of the new capability. Changes to the system range from trivial things such as more enhanced soundproofing in the terminals to a major augmentation of the human interface by incorporating the data tablet. Also the command procedure has been altered and more user definable functions have been added. Many of the changes have centered on new software to add capabilities uniquely required for a specific forecast responsibility such as developing a set of programs for interactively drawing severe storm forecast watch boxes, finding specific cities in the box, and preparing the forecast message.

The evolutionary "bottom up" design philosophy has resulted in a noticeable number of changes to the system and a dramatic acceptance of the system by the forecasters. Since CSIS was an experiment, no one was forced to use it. All of the preexisting NSSFC capabilities were left intact during the CSIS experiment, and forecasters could use anything they wanted to. When CSIS was first installed there was a group of forecasters who immediately made good use of the system. As the system evolved during the first year, more and more forecasters came to use and depend on the CSIS. Having a system which can evolve in response to the individual forecaster's needs and desires has resulted in improved system efficiency and acceptability.

While it is recognized that procurements involving hundreds of sites require "top down" design management in order to maintain any semblance of control, "one of a kind" systems do not. CSIS has shown that the benefits of "bottom up" design management can be effectively used in an operational environment as well as in research environments. "Bottom up" should be given more consideration in future operational systems.

4.2 Scheduler function is crucial to any real time system

CSIS has a macro facility which allows a user to define a sequence of commands into a process which can be initiated with a single entry. Included in this macro facility is a scheduler which can start the macro at predetermined times. This capability has proven invaluable. Data comes in automatically. The system ingests the data, files it, processes it, and displays routine products without manual intervention. The data is ready for use at the forecaster's convenience. Having the system automatically stage data has resulted in improved forecaster efficiency. Currently over half of the programs executed on CSIS are initiated automatically by the scheduler.

4.3 Meteorological interactive terminals requirements are different from image processing terminals requirements

Interactive meteorological processing has inherited a lot from the interactive image processing field. It is possible to buy off the shelf image processing systems which can be adapted to meteorological processing. The interactive terminals are generally quite "smart" and can do a fair amount of image processing on the data. They are designed to extract quantitative information from a limited number of images. CSIS has shown that forecaters do not need traditional image processing terminals. The images are used more qualitatively as straight image loops and as background to other data plots rather than as quantitative products for image manipulation. The only quantitative products derived from the satellite images were simple things such as cloud temperature, cloud height, a few cloud drift winds, etc.

Even though the CSIS terminals have capabilities for traditional image processing, most of them were not used. The forecaster just does not have time to sit down, stare at an image, massage it, and bring out some quantitative product. All he wants to do is see the pictures; and he wants to see a lot of pictures. At PROFS (personal communications), there was an off-the-shelf interactive image processing terminal with four image frames; the forecasters complained that was not enough. The CSIS terminals were custom built by SSEC and had 26 image frames; the forecasters said that is still not enough! The draft requirements for the national centers upgrade program has each forecaster having 50 frames for individual work space and access to another 400 frames shared by all work stations. Because of the different requirements of meteorological interactive terminals from the more traditional image processing terminals, one cannot currently buy an off-the-shelf terminal which will meet the needs of operational forecasters.

4.4 Hand drawn maps still have a place in the age of computer generated graphics

One of the most noticeable features of any forecast office is the maps on the wall. Some are fax maps, while others are hand drawn maps. First AFOS and then CSIS has given forecasters at the NSSFC the ability to generate computer drawn maps. One would have expected that the hand drawn maps would disappear when the computer can draw them so much quicker and easier than the human. While the number of hand drawn products has decreased somewhat at the NSSFC, they have not disappeared. There are several reasons for this. One is that drawing a map forces a forecaster to look carefully at the raw data. Severe storm phenomena are generally subsynoptic or mesoscale in extent and affect only a few surface reporting stations. Drawing maps in those critical regions is a form of note taking. It makes the forecaster think about and remember what is happening in those regions.

In general what happens is that the forecaster will have the computer draw a contoured map on the TV display of the field in question. If it is of critical interest to the forecaster he will then hand contour a base map of the observations produced by the computer. He generally does a non-linear subjective analysis in the region of interest. He puts in more detail where the weather is critical and the observational network is sufficiently dense. The resulting analysis is generally better than the computer analysis. Another reason for drawing maps is long standing work habits which are hard to break. However it has been noticed that no one does hand drawn products which aren't critical to the forecast process. Hand drawn radiosonde profiles are a thing of the past. The computer plots them all now. (And because of the speed of the computer plots, the forecasters are looking at a lot more radiosonde profiles than they did previously.) It appears that hand drawn products are sufficiently useful to forecasters that future systems should consider including computer generated base maps and work space for the forecaster to hand analyze maps.

4.5 Forecasters generate a large peak load on computer resources.

The CSIS equipment grew out of the McIDAS developed in the research environment at the University of Wisconsin. One of the most noticeable differences between the operational environment of CSIS and the research environment of McIDAS is the computer load leveling. CSIS has a much higher peak load demand placed on its computers than McIDAS. Even though the McIDAS might have a higher overall computer load than CSIS, the research environment allows tasks to be strung out allowing easier load leveling. In the operational environment of CSIS time is precious. Data comes in at specific times, the satellite image every half hour, the surface reports every hour, the upper air every 12 hours, etc. Often the time of arrival of several data types coincides with one another. The forecaster needs the most up-to-date data for his job. As soon as the data is available, it is needed in a final presentation form. Hence the system generally has demands for simultaneous data ingestion, data checking and filing, data analysis and data display functions. This puts a very high peak load requirement on any interactive computer used in an operational forecast environment.

4.6 Modular design of the terminal layout

Many of the operational interactive terminals such as AFOS (Mielke 1982) are designed as a complete console with all functions and controls being built into the console. The consoles generally are similar to an airplane cockpit where the controls and monitors surround the person, all within easy reach. The CSIS terminal design was a more open, modular design which the forecasters preferred over the AFOS console design. The CSIS terminal consists of an equipment rack, a table, a TV monitor, a CRT with detachable keyboard, joysticks, data tablet, and printer. The terminal had ergonomic design considerations for table height, distance to the monitor, etc. However, the terminal layout allowed all of the control and viewing functions to be detached and moved according to the forecaster's personal preference for placement.

The AFOS terminal was designed as a work station for a single forecaster. While CSIS terminals were primarily intended for a single forecaster, it was recognized that other forecasters would want some occasional use of the terminal. As it turned out, the forecasters tended to frequently "pass through" the terminal area and not spend prolonged periods glued to the screen. Terminal viewing and control actions were made from both sitting and standing positions. There was considerable movement between forecast work stations. The forecasters felt that the AFOS console design tended to isolate them, while the more open modular design of CSIS allowed more of a team effort in dealing with forecast problems.

5. SUMMARY

CSIS, as an outgrowth of McIDAS, represents a major step toward providing the operational meteorologist a truly interactive, information-handling, intercomparison, and display system. It allows the meteorologist to display and analyze rapidly both satellite and conventional data. Additionally, it permits the meteorologist to intercompare and superpose many of the various arrays of data that must be assimilated and interpreted.

The basic philosophy governing the development of CSIS recognizes the necessity of a penultimate, operational testing phase as essential to operational system development. CSIS is taking existing hardware and software and performing a mission-specific test and evaluation, to determine the needs of an operational system. In addition to the design of the final system, NSSFC and SFSS reap the benefits of interactive computers immediately, without having to wait until a permanent interactive computer system is procured, implemented and operating.

While many of the lessons learned from the CSIS are specific to the operational forecast environment of the NSSFC, there were several unexpected insights which are relevant to other operational meteorological interactive processing systems. A "bottom up" system evolutionary design management philosophy has been shown to be very effective in the operational environment as opposed to the more traditional "top down" design used in most governmental systems. The scheduler function of CSIS which allows automatic ingestion of data and processing of products has proven invaluable on CSIS. Over half the programs executed on CSIS are initiated automatically by the scheduler.

Requirements for meteorologicaly interactive terminals were found to be different from commercially available image processing terminals. The meteorological terminal requires many frames (over 50) which are used largely in a qualitative fashion for image loops or background for other data products. Computer generated graphics have not totally replaced the need for hand drawn maps in a forecast office. Hand drawn maps are a form of note taking in that they force a forecaster to look carefully at the raw data. It was found that the operational environment generates a very large peak load on computer resources. In research environments, the computer loads may be higher, but the tasks can be strung out, allowing load leveling. In the operational forecast environment, time is precious. There are simultaneous demands for data ingestion, data checking and filing, data analysis, and data display functions for several different types of data. This puts a very high peak load on the computer. The modular terminal design of CSIS had greater forecaster acceptance than the console design of AFOS. The CSIS terminals had a lot of "pass through" traffic, rather than one person sitting glued to the screen for prolonged periods. The open terminal design encouraged a team effort in dealing with forecast problems.

6. ACKNOWLEDGEMENTS

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RECENT TECHNICAL ADVANCES AT THE NATIONAL SEVERE STORMS FORECAST CENTER THAT WILL IMPROVE SHORT-TERM AVIATION ADVISORIES

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1. INTRODUCTION

Last May, the National Severe Storms Forecast Center (NSSFC) entered its fifth year of issuing short-term aviation advisories for strong thunderstorms. Since the onset of the convective SIGMET (WST) program, working conditions have been hectic during active weather situations. Rapid technological advancements at NSSFC have given the WST meteorologist many more tools with which to work. Real-time satellite imagery, real-time radar monitors, and data handling capabilities allow continuous monitoring of existing conditions. The pace is still hectic in the WST unit, but there is no question that these advances allow the meteorologist to obtain a more complete picture of thunderstorm evolution. Consequently, WSTs are based on greater understanding today than they were five years ago.

The biggest technical advancement came in February, 1982, when the experimental Centralized Storm Information System (CSIS) was installed at NSSFC. The primary purpose of CSIS is to demonstrate and evaluate real-time interactive computerized data collection, interpretation, and display techniques (Anthony et al., 1982). CSIS provides the capability to ingest all available data into a single computer system. It assists the NSSFC meteorologist in displaying, analyzing, and intercomparing data sets.

Conventional surface and upper air data are obtained via the FAA "604" line. GOES imagery is acquired directly by an antenna on the roof of the Federal Building in Kansas City. Two autodialers provide access to weather radar data. Work is nearly complete on an interface with the NSSFC computer. This will provide a direct link to the National Meteorological Center (NMC), the NWS-AFOS system, and the FAA-Weather Message Switching Center (WMSC).

Other advancements at NSSFC include access to real-time PPI radar data from over 85 radars via radar dial-up systems and the recent addition of new word processing units that speed message composition and allow the WST meteorologist more time for data analysis.

The WST meteorologist has two primary responsibilities: short-term forecasting of strong thunderstorm development, and monitoring of existing thunderstorm activity to detect changes in intensity and movement. These are not distinct functions. Often existing thunderstorm evolution helps determine when and where new thunderstorms will form. This paper will show how CSIS and other advances have helped the WST meteorologist streamline operational procedures and how new ideas that were developed by the research community were transferred to the operational environment.

2. APPLICATION OF NEW TECHNOLOGY TO WST PROBLEMS

2.1 Forecasting Thunderstorm Development

Aspects of thunderstorm phenomena which affect aviation safety tend to occur on time and space scales much smaller than standard weather observing networks. For example, tornadoes, downbursts, and gust fronts generally have spatial dimensions of 1-100 km. Their routine detection is limited to special observing networks designed for research purposes. Because of the two-way interaction between thunderstorms and the larger scale synoptic setting, current methods of prediction depend primarily on the diagnosis and prognosis of synoptic scale circulations favorable for thunderstorm development. Consequently, the timely and accurate prediction of thunderstorms hinges upon the recognition of detectable synoptic and mesoscale mechanisms that not only provide sufficient thermodynamic instability to support convective storms but also provide for upward vertical motions to release the potential instability.

Conventional surface and upper air data can be printed, plotted, or contoured on CSIS displays. The plotted and analyzed data can be superposed over the satellite imagery. Derived fields such as divergence or advection of any standard parameter can be obtained. In addition, a lifted index computation is available every hour utilizing hourly surface data and advected 500 mb temperature fields. Time and level changes of parameters are also available. Easy access to CSIS data is possible by the use of the menu shown in Fig. 1. The menu is part of a data tablet that is activated with a pressure pen. It is a matrix that the meteorologist selects one from column A, one from column B, etc., to get the desired display.

Surface observations are used to construct detailed analyses of the atmospheric structure near the ground and provide the meteorologist with a most important source of information. The principles of mesoanalysis originally devised to analyze data from special research networks have been found to be applicable in the operational environment (Magor, 1959). In particular, conceptual models of thunderstorm

oper	param		time	levl	map	
PLOT	T	THE	NOW	SFC	SAT	
CONTOUR	TD	Q	-1 HR	850	MERCATOR USA	
	PRE	Z	-2 HR	700	MERCATOR CTR	
PRINT	WIN	STR	-3 HR	500	color DFLT	interval DFLT
LIST	PLT	SPD	-6 HR	400	2	1
					3	2
	DIV	THW	-12 HR	250		4
CLEAR UP PROBLEM	WX	LCL	-24 HR	200	4	5
					5	10
ERASE	LPT	VOR	-48 HR	TRO	6	20
	SAVE MYP___	ABV	set time change	set level change	7	50
GO	param DIV	param ADV	change off	change off	dash on	100

Figure 1. Menu used by WST meteorologists to generate surface and upper air data displays on CSIS.

mesosystems such as the generation of surface mesohighs and the attendant ageostrophic flow in the vicinity of the cold dome (Fujita, 1959), can be readily utilized in the routine analysis of surface data.

Of primary interest is the proper identification of boundaries such as fronts, drylines, and thunderstorm outflows. As previously mentioned, the primary goal of the WSI meteorologist is to delineate areas of upward motion in areas of potential instability. Since lifting due to low-level convergence is often maximized in discontinuity zones, upward motion is often maximized near surface boundaries.

At times, short-term pressure changes can also be utilized to infer vertical motion. Of special interest is the existence of isallobaric couplets which may indicate the presence of thunderstorm mesosystems. A thunderstorm with a mesolow has a high potential for severe weather production. Occasionally, a mesolow can be located by a mesoscale pressure fall immediately followed by a mesoscale pressure rise.

Detailed analyses of surface temperature and dewpoint fields can often aid in the delineation of airmasses with the highest thunderstorm potential. Intense convection often develops in the region on the west side of a low-level moist axis and east of a thermal ridge (Kuhn et al., 1958), as well as along thermal gradients attending fronts or outflow boundaries (Maddox et al., 1980).

Owing to the large temporal (every 12 hr) and spatial (300-500 km separation between stations) scales of upper air data, it is of less value to the WST meteorologist's short-term forecast problem. Detailed upper air analyses from CSIS can be used to identify large scale features known to relate to the development of thunderstorms. Various stability indices and processes related to upward motion such as thermal advection and differential vorticity advection can be calculated. The juxtaposition of upper and lower level wind fields and attendant zones of divergence may also be analyzed. The analysis of individual soundings, vertical wind shear and icing probabilities are available on CSIS. In addition, isentropic and cross section analyses can be performed by the meteorologist.

Visible and infrared satellite data are available on CSIS for an area which includes all of the contiguous United States. Satellite data are received in real-time and are automatically displayed five minutes after the image start time. The display system stores four separate satellite loops with each loop consisting of the six most current images. Sectorization is performed by CSIS so that the meteorologist can select a loop which covers any part of the U.S. Typically, there are two kinds of loops used: one type covers roughly half of the U.S. and is used for monitoring activity; the second type loop covers approximately a four state area where a threat situation exists or is expected to develop. The satellite images can be color enhanced. Because the data are in digital format, a quantitative analysis can be made of any temperature interval in the atmosphere. For example, low cloud tops or cold cloud tops can be displayed with the maximum temperature resolution available from the satellite sensor. Standard enhancement tables have been created for color highlighting thunderstorm tops. In addition, two images may be functionally combined in a variety of ways, for example, the IR color enhancement can be used to overlay a visible image. Instant change from visual to infrared imagery is also possible.

On CSIS, each pixel of a digital image is navigated with respect to earth coordinates. The latitude and longitude of a cloud feature can be immediately retrieved with a touch of a key. Azimuth and distance from a weather reporting station or FAA VOR (VHF Omnidirectional Ranging) can be obtained. The speed of cloud features can be computed, and the movement of features can be extrapolated to future positions. This knowledge is crucial in forecasting where new thunderstorms are most likely to form.

While analysis techniques for conventional data have been around for years, only recently has visible satellite imagery analysis emerged as a short-term forecast tool. High resolution visible imagery from geostationary spacecraft has been available since the launch of SMS-1 in 1974. Since that time, a number of researchers have established the utility of visible imagery in predicting the development of deep convection. For example, rain-cooled air which moves outward, from a thunderstorm is often seen as an arc-shaped cloud which may have a lifetime of several hours. Purdom (1979) has shown that such arc clouds can be tracked easily in visible imagery. Furthermore, the intersection of an arc cloud with another arc cloud or frontal boundary in the presence of unstable air is often accompanied by the development of new thunderstorms.

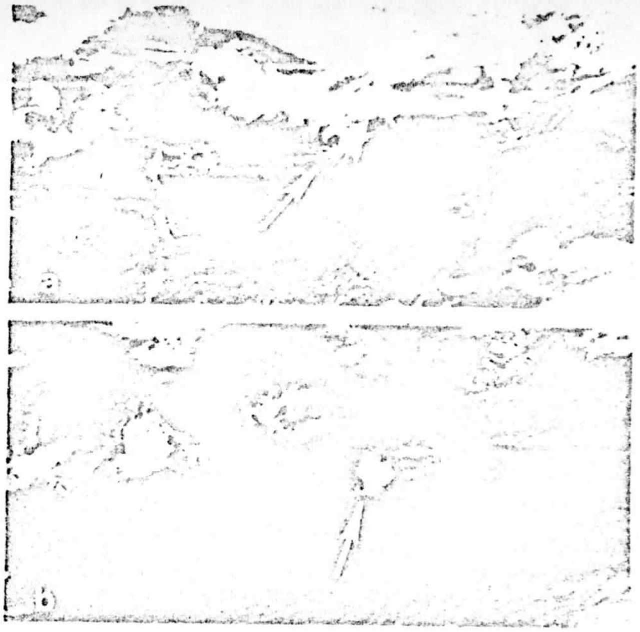

Figure 2. Visible satellite imagery showing development of a thunderstorm from a mesoscale comma cloud (located by arrows):
a. 1631Z, 7 September 1977
b. 2001Z, 7 September 1977.

Figure 3. Visible satellite imagery showing development of a thunderstorm along the edge of banded low clouds:
a. 2000Z, 24 August 1981
b. 2300Z, 24 August 1981.

Johnston (1982) noted that prolonged convection often produces a mid-tropospheric vorticity center which persists even after the originating thunderstorm has dissipated. Frequently, this feature serves as a trigger mechanism for thunderstorms. Typically, these systems are small and high resolution visible imagery is the only means of detecting and tracking these convection-induced comma clouds. An example of this phenomenon is shown in Fig. 2.

Stability gradients are often revealed in visible pictures as an abrupt change in cloud type or as a change from cloudy to cloud-free conditions. Effects of differential heating along these interfaces often produces a zone that favors the development of convection. Beckman (1982) observed that a certain banding formation of low and mid-clouds often appears prior to the onset of severe convection (Fig. 3). The bands indicate where the airmass is "capped" (a strong inversion above the moist layer). Convection forms along the edge of the banded clouds. CSIS further aids the meteorologist with these situations by computing surface moisture convergence which can be superposed on the imagery. This technique can suggest where thunderstorms are most likely to form up to 3 hours in advance (Hirt, 1982; Hudson, 1971).

2.2 Monitoring Existing Thunderstorms

Once thunderstorms form, the emphasis shifts to looking at infrared satellite imagery and radar. The forecasting techniques described above are helpful in monitoring thunderstorms, but conventional surface data are too sparse to monitor individual storms. Further, much of the detail observed in visible imagery before deep convection develops becomes obscured by anvil blowoff when storms reach maturity. While radar is an important monitoring tool, WST meteorologists, by incorporating infrared analysis in their shift routine, understand more completely the current state of thunderstorm activity. Enhanced infrared imagery frequently provides information on the areal coverage and growth of thunderstorms that radar and especially the MDR observations simply can not (McCann, 1981). This is especially troublesome since the criteria for WST issuance are radar-oriented (severe storms, lines of storms, embedded storms, and areas of storms of reflectivity level 4 or greater at least 3000 sq. nm and 0.4 coverage). While radar remains the primary input to WST formulation, infrared imagery from CSIS serves to complement radar data and provides unique information in helping identify thunderstorm complexes that meet WST criteria.

Research in severe thunderstorm identification has shown a relationship between an enhanced-V signature observed in infrared data and the occurrence of severe weather (McCann, 1983). An estimated 70% probability of severe weather within one hour after enhanced-V identification was found. The location of severe events with respect to the thunderstorm infrared imagery was reported by McCann (1982). Most reports of severe weather occur in a very small area southwest of the enhanced-V (Fig. 4). Thus the WST meteorologist, using CSIS data, can locate with reasonable accuracy the area of greatest threat when an enhanced-V is observed.

Growth rates on infrared imagery can be related to the 0.4 coverage of VIP level 4 radar criteria through rainfall estimation techniques (McCann, 1981). During a four month study period, approximately 80% of all severe turbulence and severe icing reports occur within an "active" IR contour defined as 6°C warmer than the equilibrium temperature (McCann, 1982). After twice daily rawinsonde data is processed (Doswell

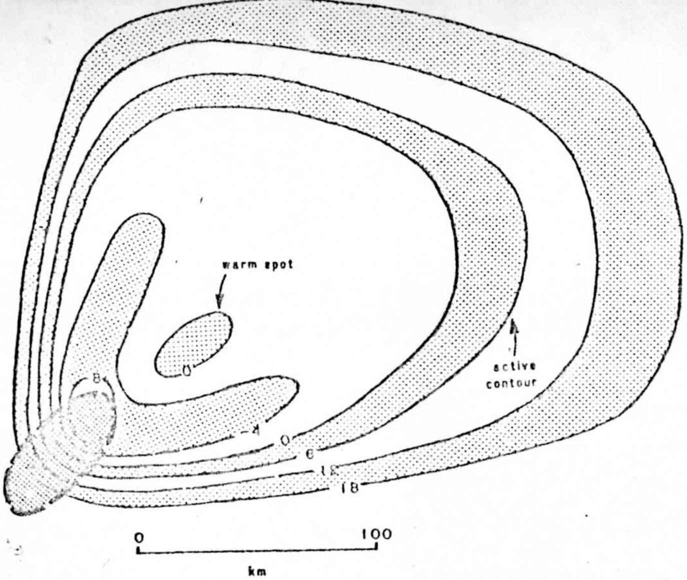

Figure 4. Schematic model of an enhanced-V storm as observed on infrared satellite imagery. Temperature contours are lavelled with respect to the equilibrium temperature. Eighty percent of all severe weather reported in enhanced-Vs occurred in the dark shaded area on the southwest flank (see text).

et al., 1982) the colored enhancement curve on CSIS is set to the equilibrium temperature. The active area is enhanced in red on the CSIS screen. Any growing thunderstorm area in which the red area is greater than 3000 sq. nm likely requires a WST. The word "growing" is emphasized since 90% of severe aviation reports occur in non-contracting areas.

CSIS satellite imagery greatly increases the ability of the WST meteorologist to monitor thunderstorms west of the continental divide. Radar coverage in the western U.S. consists of three WSR-57 stations without DVIP, five WSR-74C radars used mainly for local warning information, and radars operated by Air Route Traffic Control Centers. Accurate thunderstorm intensity measurements are almost impossible. Fortunately, the satellite method works equally well west of the divide as it does elsewhere in the U.S. In McCann's 1982 study, 81% of all severe aviation reports west of the divide occurred within the active infrared contour, nearly the same percentage as elsewhere.

Embedded thunderstorms remain a problem at NSSFC in spite of the help from CSIS. Radar and satellite data are not capable of detecting all embedded thunderstorms. However, of 171 reports of severe turbulence and icing reported from April through July 1981, only eight (5%) were in embedded thunderstorms. Further, seven of these eight were within the active contour. Two factors may be the cause of such a low number of severe aviation reports in embedded thunderstorms. First, a thunderstorm of a given intensity is not more dangerous simply because it is embedded. Second, since clouds and low visibility accompany embedded thunderstorms, VFR pilots are grounded so there are fewer aircraft in flight to encounter these storms.

As mentioned earlier, one very important capability of CSIS is the ability to locate points on the satellite imagery using various coordinates. When a report of severe weather, either surface or pilot, is received, the meteorologist may accurately locate the report's position on the image and thus locate the storm that caused it.

CSIS is capable of scanning lists of surface and pilot reports for important information. Such information includes thunder and strong wind gust reports from surface observations and moderate or greater turbulence and icing reports from aircraft. Additionally, all UUA PIREPs are alerted on the CSIS console when received.

CSIS can also ingest WBRR radar data via two autodialers. Information from several radars can be composited on a single image and remapped into a satellite projection. The data can be color-enhanced, looped and superposed on other data sources. Although these capabilities are not often utilized because of the low quality of WBRR data, it has been demonstrated that the melding of satellite and radar data by CSIS adds a new dimension to the analysis of convective activity.

Real-time radar images are available to the WST meteorologist through two separate radar dial-up systems. These are displayed on a color monitor. One system allows storage of four images creating a looping capability. Looping radar images is very helpful in bow echo situations when large anvils make satellite movements to be slow. Also, since both network and local warning radars can be dialed-up, the meteorologist can cross check a network radar report with an overlapping local warning radar. Additionally, local warning radars which are far removed from network radars can be accessed.

2.3 Message Composition

Most of the radar and satellite data used by the WST meteorologist to make his decisions comes in about 35 minutes after the hour. The WST message must be transmitted to WMSC by 55 minutes after the hour. Since there is not a great deal of time to digest the data, it is important to have a reliable and fast message composition and transmission system.

The design of the terminals now in use at NSSFC is such that one can configure the terminal to suit the needs of the user. Message composition is eased because the terminal stores oft used formats and phrases that may be accessed at the touch of a button. The ability to move text from one portion of the message to another far exceeds any other message composition terminal at NSSFC.

The terminal is connected to the NSSFC computer which is interfaced via a high speed line to the WMSC computers. Transmission time of WSTs is usually less than 30 seconds. All computer protocol is handled by the NSSFC computer. The WST meteorologist is kept aware of the progress of messages on their path to WMSC. Messages from WMSC indicate if the transmission was successful. Due to the chance that the terminals might fail, messages are stored in the NSSFC computer so that the last message can be restored when a malfunctioning is repaired. This keeps the meteorologist from wasting valuable time re-typing long messages.

3. FUTURE DEVELOPMENTS

CSIS is the first major interactive system available to operational meteorologists. It represents a major step towards the development of a real-time interactive handling and display system for data from all available sources. Future data sources to be added to CSIS include lightning detection network data and higher quality radar imagery. Further into the future are NEXRAD data and satellite sounding data.

New forecast and analysis tools are constantly being added to the system. For example, the research suggestion that the expansion rate of the thunderstorm's anvil during the first hour determines its subsequent intensity (Adler and Fenn, 1979) is being evaluated with CSIS.

CWSU meteorologists have expressed a need for an aviation product that would give them a forecast of medium term (2-6 hr) thunderstorm development. With CSIS to handle data, NSSFC can produce such a product. While the format and frequency have yet to be resolved, it appears this product may be in a test and evaluation phase by the end of 1983.

With the recent increase in capabilities and future technical advancements at NSSFC, it is apparent that some revisions in the thunderstorm aviation advisory program are needed to take full advantage of the advancements. An alternate WST criterion for areas, which incorporates satellite imagery analysis, should be considered. It could be worded "thunderstorms actively affective 3000 sq. nm", in lieu of the somewhat ambiguous all-radar criterion. NSSFC would like to be of service and requests a feedback from our users.

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IBM 4341 Processor

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The 4341 Processor is available in four model groups–Model Group 10, 1, 11 and 2. The internal performance of the 4341 Processor model groups is as follows, expressed in terms of multiples of the Model Group 1 running commercial jobstreams:

Relative internal peformance

Commercial

Model Group 10	Model Group 1	Model Group 11	Model Group 2
.86	1.00	1.25	1.66

Engineering/Scientific

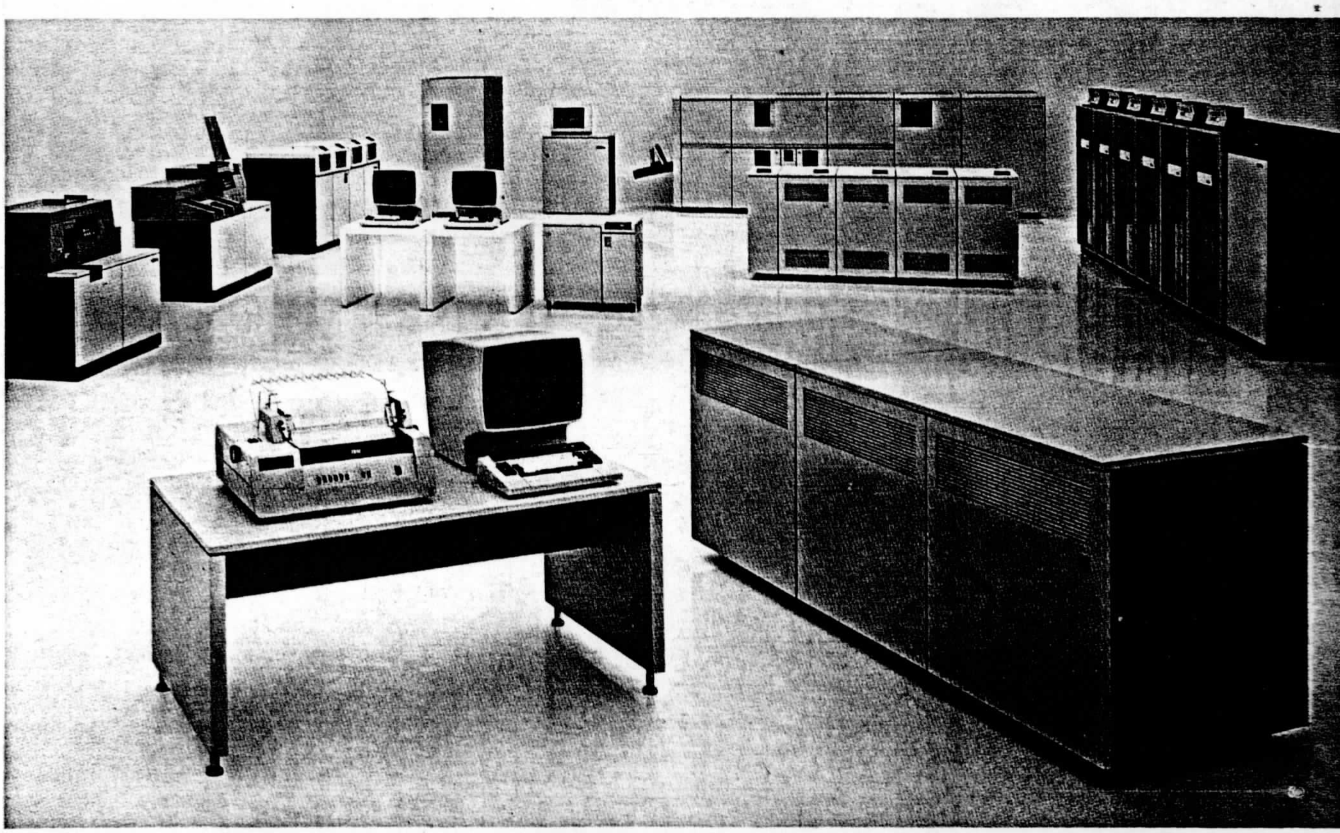
Model Group 10	Model Group 1	Model Group 11	Model Group 2
.99	1.06	1.33	1.48

The internal performance of a 4341 Processor Model Group 1 with ECPS:MVS has been measured to be .8 to 1.1 times as fast as an equivalently configured System/370 Model 158-3. Individual performance rates will vary depending on factors such as jobstream, operating systems and input/output devices.

The 4341 is a virtual storage system with System/370 and System/360 compatibility, and features extensive use of advanced large scale integration (LSI) technology. Broad use of the new technology makes the 4341 a compact system with substantially reduced requirements for power and cooling.

The IBM 4341 provides most of the capabilities of larger IBM systems through a wide range of standard and optional features. These include higher internal performance through the use of a high-speed buffer, up to 16 megabytes of processor storage, a separately powered support processor, a standalone display console, and up to six channels for attaching a wide variety of high- and low-speed input/output devices.

The greatly expanded facilities of the 4341 allow it to do more work at a faster rate and with fewer



Photograph shows design models

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system constraints than the System/370 Model 138, 148, 158 and 3031. They also make it feasible to implement or expand data base/data communications applications at lower cost, and to initiate the use of interactive computing using the CMS component of VM/370, VSE/Interactive Computing and Control Facility (VSE/ICCF) of DOS/VSE or the TSO component of OS/VS2 (MVS).

Standard features

- Processor storage provides 2,097,152 bytes (2 megabytes) of high-density LSI storage for system control programming and application programs. Some processor storage is required for microcode, depending on the processor configuration.
- High-speed buffer storage is used to improve performance of repetitive references to main storage. The buffer storage is transparent to and may not be addressed by user programming.
- Reloadable control storage is provided to handle microcode requirements for system functions and control routines.
- System performance may be further enhanced by Extended Control Program Support (ECPS) facilities for DOS/VSE, OS/VS1, VM/370 and MVS/System Product.
  - A reduction of up to 13% of supervisor-state time for both the Model Group 1 and Model Group 2 has been measured with ECPS:VS1, compared to the same version of the operating system running without these facilities on the 4341 Processor.
  - A reduction of up to 84% of time in the supervisory state for Model Group 1 and 74% for Model Group 2 has been measured with ECPS:VM/370 when compared to the same VM/370 versions running without ECPS. When running VS1 under VM/370, the internal performance of the Model Group 2 processor is up to 1.7 times that of the Model Group 1.
- ECPS:MVS provides prerequisite functional capabilities for operation of the system under OS/VS2 (MVS/SP). On the Model Group 2, both ECPS:MVS and ECPS:VM/370 can be utilized concurrently to allow MVS/SP to run as a guest under VM/370.
- The 4341 Model Group 10 and Model Group 1 provide three channels as standard and offer three additional channels as an option. Two of the standard channels are block multiplexer channels, each with a transfer rate of up to 3 megabytes per second, permitting simultaneous operation of many high-speed input/output devices. The aggregate data rate of the two standard block multiplexer channels is up to 6 megabytes per second.
  - The third channel, a byte multiplexer channel, provides for concurrent operation of many low-speed devices. It provides up to 240 subchannels and a data transfer rate of up to 16 kilobytes per second in single-byte mode, 64 kilobytes per second in four-byte mode, and 1 megabyte per second in burst mode. The capability for automatic I/O power sequencing for up to 24 separately attached control units is standard.
- The 4341 Model Group 11 and Model Group 2 provide six channels as standard. One of these is a byte multiplexer channel. The other five are block multiplexer channels, one of which may be designated as a second byte multiplexer channel. The first byte multiplexer channel provides up to 240 subchannels and a data transfer rate of up to 24 kilobytes per second in single-byte mode, 96 kilobytes per second in four-byte mode, and 2 megabytes per second in burst mode. The second byte channel is identical except it provides up to 256 subchannels.
  - The maximum data rate of each of the first two block multiplexer channels is 3 megabytes per second; for each of the next three block multiplexer channels it is 2 megabytes per second.
  - The aggregate data rate of the five block multiplexer channels is 12 megabytes per second. The aggregate data rate of the four block multiplexer channels, if a second byte multiplexer channel is designated, is 10 megabytes per second.
- Data Streaming mode permits faste data transfer rates and increased channel-to-control unit cable length. Data Streaming protocol does not require any additional programming considerations.
- The IBM 3279 Color Display Console Model 2C can be attached to all models of the 4341 processors as the requisite console and provides for operator interaction for both normal operations and maintenance. Console messages can be displayed in four colors: white, red, blue or green.
  - Alternatively, the monochrome IBM 3278 Display Console Model 2A can serve as the requisite console for the processor.
  - Both the 3279 Model 2C and the 3278 Model 2A have a 1,920 character display with 24 lines of 80 characters each. Lines 21-24 are reserved for system status information and are not accessible to the user.
  - An Operator Console Keyboard is required for either the primary 3279 Color Display Console Model 2C or 3278 Display Console Model 2A. It is utilized for powering the 4341 processor on or off, initial microcode load (IML), and starting or stopping processor operations.
- Console printer-keyboard compatibility with System/370 or System/360 is provided by using the 3278 Display Console Model 2A and a recommended 3287 Printer to emulate operations of either a 1052, 3210, or 3215 Console Printer-Keyboard.
- The Support Processor is a standard function in the 4341 and is designed to automate and simplify failure diagnosis and maximize total system availability.
- The Remote Support Facility allows the on-site IBM Customer Engineer to use public telephone lines to inquire into the RETAIN data base for the latest service aids and information. Additionally, field technical support specialists can

remotely monitor and/or control problem diagnosis on the 4341.

- Remote Operator Console Facility, an extension of Remote Support Facility, gives personnel at a host location the ability to dial-up and control a remote 4341 by means of host-site programming support.
- Time-of-day clock measures real-time, interval time and elapsed time.
- Clock comparator provides an interrupt when the time-of-day clock reaches a program-specified value.
- CPU timer provides a readout resolution of one microsecond and causes an interrupt when decremented past zero.
- Extended precision floating point provides precision of floating point instructions up to 28 hexadecimal digits, the approximate equivalent of 34 decimal digits.
- Reliability and data integrity features include storage protection (both fetch and store), expanded machine check handling, error checking and correction code, channel command and instruction retry, and program event recording.

Optional features

- Increments of processor storage are available which, with the standard high-speed buffer storage, provide the following processor sizes:

Processor storage (megabytes)

Model Group 10	Model Group 1	Model Group 11	Model Group 2
2	2	2	2
4	4	4	4
		8	8
			12
			16

High-speed buffer (kilobytes)

Model Group 10	Model Group 1	Model Group 11	Model Group 2
4	8	8	16

Amount of processor storage required for microcode (kilobytes)

Model Group 10	Model Group 1	Model Group 11	Model Group 2
(14 to 108)		(14 to 112)	

- An additional group of three block multiplexer channels for I/O device attachment is available on Model Group 10 and Model Group 1. Two have a data transfer rate of 2 megabytes per second; the third, 1 megabyte per second.
- One of the 2-megabyte channels may be designated a second byte multiplexer channel.
- Channel-to-channel adapter provides processor connection via a block multiplexer channel to System/370, System/360 or another 4341 Processor. Only one of the interconnected processors requires the adapter.
- Additional channel control unit positions allow for the automatic I/O power sequencing of 24 additional control units for a system total of 48.
- The IBM 3287 Color Printer Models 1C and 2C can be attached as a console printer to provide output in black, red, blue, and green.
- Up to three additional display consoles (3279 Model 2C and/or 3278 Model 2A) or printers (3287 Models 1 or 2 or color models 1C and 2C) may be directly attached in any combination as optional consoles.
- The 3380 Direct Access Storage device can be attached through the 3880 Storage Control Model 2 or 3. If the 3880 is attached to block multiplexer channels 1 or 2, it will operate at a data rate of 3 megabytes per second. If the 3380 is attached to block multiplexer channels 3 or 4, or 5 on the Model Group 2, it must be attached with the Speed Matching Buffer feature for the 3380 and will operate at a data rate of 1.5 megabytes per second.
- The 3880 Storage Control Model 1, 2, or 3 operating in Data Streaming mode can be attached to the 4341 block multiplexer channels. 3375, 3370, 3350, 334X and 333X DASD can attach via a 3880 Storage Control Model 1 or 2 set to operate in Data Streaming mode.
- For the 4341 Model Group 2 Processor only, an ECPS Expansion Feature is available to allow concurrent operation of ECPS:VM/370 and ECPS:MVS.

Programming support

Operating system support for the 4341 is provided by DOS/VSE with VSE/Advanced Functions Release 2, OS/VS1 Release 7, OS/VS2 (MVS) Release 3.8 with SP (System Product), VM/370 Release 6 with SP (System Product) and ACP/TPF Program Product.

Installation aids

System Installation Productivity Option/Extended (System IPO/E) offerings are available for easier installation and use of DOS/VSE or VM/370 Release 6. System IPO/E provides preconfigured, pregenerated, and preserviced operating systems, along with IBM licensed Program Products that make the 4341 easy for the non-DP professional to access and use. They also can make it easy for the DP professional to install, tailor and operate the 4341.

Wide range of I/O

The 4341 Processor can take advantage of IBM's newest high-performance, large-capacity DASD units such as the IBM 3370, 3375 and 3380, and the 3880 Storage Control, and other units including the 3279 Color Display Station, the 3287 Color Printer, the 3800 Printing Subsystem and the 3848 Cryptographic Unit. The IBM 4341 Processor also can function with many other IBM units and optional features, enabling implementation of a balanced system at an attractive price.

Long range growth

Installed model groups may be field upgraded for increased internal performance and processor storage as outlined below:

Field Upgradability

Model Group 10	Model Group 1	Model Group 11	Model Group 2
To MG11	To MG2	To MG2	N/A