INTERACTIVE VIDEO DISPLAYS FOR ATMOSPHERIC STUDIES

PROCEEDINGS OF A WORKSHOP AT THE UNIVERSITY OF WISCONSIN-MADISON

14-16 JUNE 1977

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PREFACE

At the January 1977 meeting in Tucson of the American Meteorological Society, Thomas Whittaker (Meteorology) and Ralph Dedecker (Space Science and Engineering Center) of the University of Wisconsin-Madison described the use of UW's Man-computer Interactive Data Access System (McIDAS). Their presentation included examples of conventional weather graphics as well as satellite imagery processed by McIDAS for atmospheric research.

Attendees at the Tucson meeting expressed great interest in the presentation, and that interest was the impetus for the workshop described in these proceedings.

With funding support from the National Science Foundation, a three-day Workshop on "Interactive Video Displays for Atmospheric Studies" was presented by the Space Science and Engineering Center and the Department of Meteorology on the campus of the University of Wisconsin-Madison, from 14 - 16 June 1977. Attendance was by limited invitation only, to allow satisfactory access to equipment and displays, and to permit significant interaction among participants. (A list of attendees is included in the Proceedings, Appendix B.)

The intent of the workshop was to inform the university community about the use of interactive video display systems in atmospheric science education and research.

These Proceedings were prepared from audio and video tape recordings of the workshop, under the direction of Joseph Hilyard, Publications Office, Space Science and Engineering Center.

August 12, 1977

BACKGROUND

Meteorology is characterized by an enormous flow of highly perishable data from all over the globe -- a data flow that has increased dramatically in the last decade with the introduction of polar-orbit and geostationary meteorological satellites. For example, one GOES satellite generates more than 10^{11} bits of data every day, which would be sufficient to record the name and address of everyone on earth, and give him a telephone number as well.

This data processing task is further complicated by more recent interest in mesoscale (short-lived, small scale) weather phenomena, which requires data of very high temporal and spatial resolution over small geographic areas. The basic problem in such research is to convert a high-volume data flow of low information density to one of less volume and high information density -- and to do it quickly.

Video graphic display systems have proven very useful in this data-reduction task. Such systems couple a video display to a computer, under the control of an operator who manages and interacts with the system to assemble and manipulate data of interest. One such system is the McIDAS at the University of Wisconsin-Madison. Several others exist in government laboratories, industry and at other universities; five of these other systems (as well as McIDAS) were described at this workshop.

The costs of video displays and their associated computers and peripherals have been falling at a surprising rate, even as their data-handling capabilities have increased. Display systems that were very costly just a few years ago are now within reach of typical Atmospheric Science departments seeking new techniques for teaching and research.

In view of these developments, this workshop was held to show the university community:

* what kinds of video systems now exist;
* what is technically possible with these systems;
* what costs and availability factors are associated with each; and
* what applications for teaching and research have been developed.

An important aspect of the workshop was feedback from current and potential users of video systems. It is essential that future systems reflect the needs of the university community, so that the meteorology scientist or teacher can concentrate on problems of interest, without being overwhelmed by the data-processing task. When this goal is reached, the study and teaching of meteorology (and especially the application of satellite data to these areas) will achieve a new level of effectiveness.

ACKNOWLEDGEMENTS

The success of the workshop on Interactive Video Displays for Atmospheric Studies was made possible only through the dedication and hard work of many staff members of the Space Science and Engineering Center and the Department of Meteorology. The following is only a partial list of individuals whose contributions were outstanding.

Brian Auvine
Gary Banta
Gary Chatters
Richard Daly
Joanne Edwards
Phil Glasser
Joseph Hilyard
Donald Johnson
Sanjay Limaye
Frederick Mosher
Robert Norton
Ralph Petersen
Frank Sechrist
John Stremikis
David Suchman
Eric Suomi
Robert Vitense
Gail Washington
Tom Whittaker
J.T. Young

We want to express our appreciation to those who participated in the workshop by presenting details of the design and use of video display systems at their institutions.

Finally, our thanks to the National Science Foundation for their encouragement and support in sponsoring the workshop.

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WEDNESDAY 15 JUNE

THURSDAY 16 JUNE

(Attendee interaction with McIDAS;
no record kept of proceedings.)

I. INTRODUCTION

Dr. David D. Houghton
Chairman/Department of Meteorology
University of Wisconsin-Madison

I'd like to welcome you to the Workshop on Video Displays for Atmospheric Sciences. We are all very much indebted to the National Science Foundation (NSF) for urging us to put on this workshop, and for providing the funds so we could invite so many from across the country to be with us here today.

There is certainly a need for this workshop. We've had many visitors here at the Space Science and Engineering Center (SSEC) to see our video equipment and to see it demonstrated, and there have also been important developments in video graphic systems elsewhere in the country. It was clear that we had to bring this information together for the benefit of the whole profession, to see where we stand and where we need to go from here.

I'm very pleased to see that we have about 50 representatives from the academic community, and many representatives from the Federal Government. I won't go into an elaborate acknowledgement of all the people who have worked hard to put this workshop together. There are, however, two junior members of the staff here I do want to mention by name: Ralph Petersen of the Meteorology Department, and Ralph Dedecker of the Space Science and Engineering Center (SSEC) have worked very hard to bring together the many pieces that will make up this presentation.

The logistics of the meeting have been handled mainly by SSEC, and again I wish to express my appreciation for their efforts.

At this time it is my pleasure to introduce to you Dr. Verner Suomi, who is, in one sense, the father of all this. His visionary approach, his engineering aptitude, and his broad meteorological interests have fostered the development of the video display system at SSEC, and also created a national interest in the use of video systems to handle the vast amounts of meteorological data being generated today.

AN INTRODUCTION TO McIDAS

Dr. Verner E. Suomi
Director/Space Science and Engineering Center
University of Wisconsin-Madison

I would also like to welcome you on behalf of the Space Science and Engineering Center. Let me take a moment to acknowledge the role the National Science Foundation played in supporting this symposium. We are able to come together today because NSF has supported our efforts over the past four years or so. The antenna on the roof is direct evidence of this NSF support. We have a video graphics system because of the combined support of NSF, NASA, and NOAA. Indeed this symposium is a direct result of NSF support and encouragement.

The video display system is simply a tool. It does not provide any forecasts; it does not provide any wisdom. The symbol of this symposium should probably be a wrench because all we are showing you is a tool, but a very powerful tool. We wish to show how you might use this tool in atmospheric studies. We have not changed our overall goal to predict and understand the weather. We merely wish to illustrate how the use of this tool can help us to reach that goal.

Basically, meteorology is characterized by enormous quantities of highly perishable data from all over the world. It can also come from local sources. We wish to convert that data into information and, on the basis of that information, take appropriate action. Figure 1.1 shows the main purpose of McIDAS. For example, in one day, 10^{11} data bits are collected by only one spacecraft. This is a difficult number to appreciate. It is large enough to record the name and address of every person living on earth today, and give him a telephone number besides. This high volume of data has very low information density. Our objective is to have a low volume of data with high information density. And McIDAS (or any other analysis system) is simply a set of tools (call them hardware or software if you wish) to accomplish this task under the control of a man who operates it. The operator cannot be "inside" the data flow "box" of Figure 1.1 because he cannot process the data fast enough. He would present an enormous bottleneck.

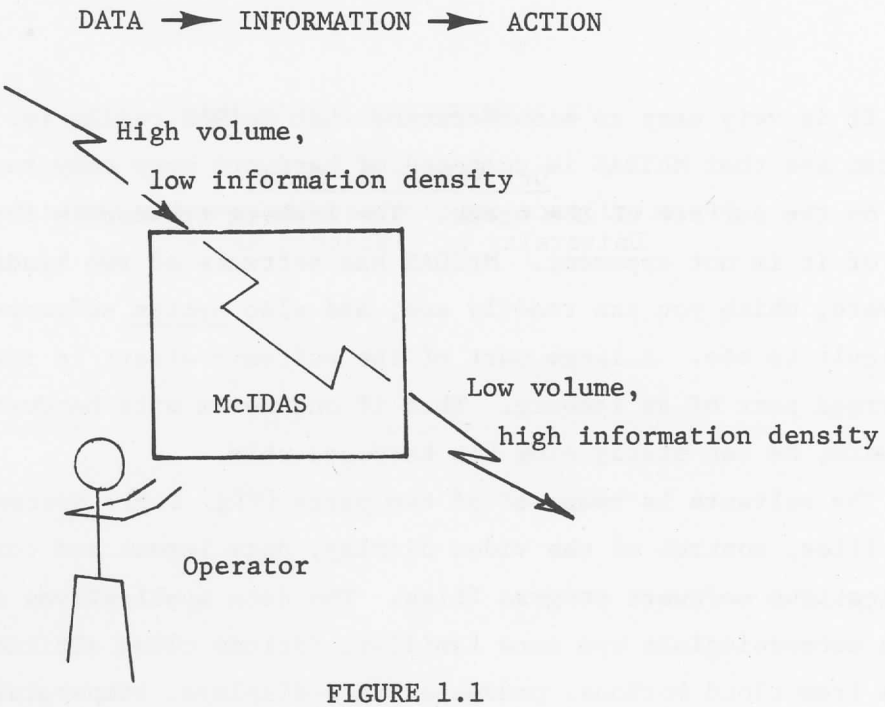


FIGURE 1.1

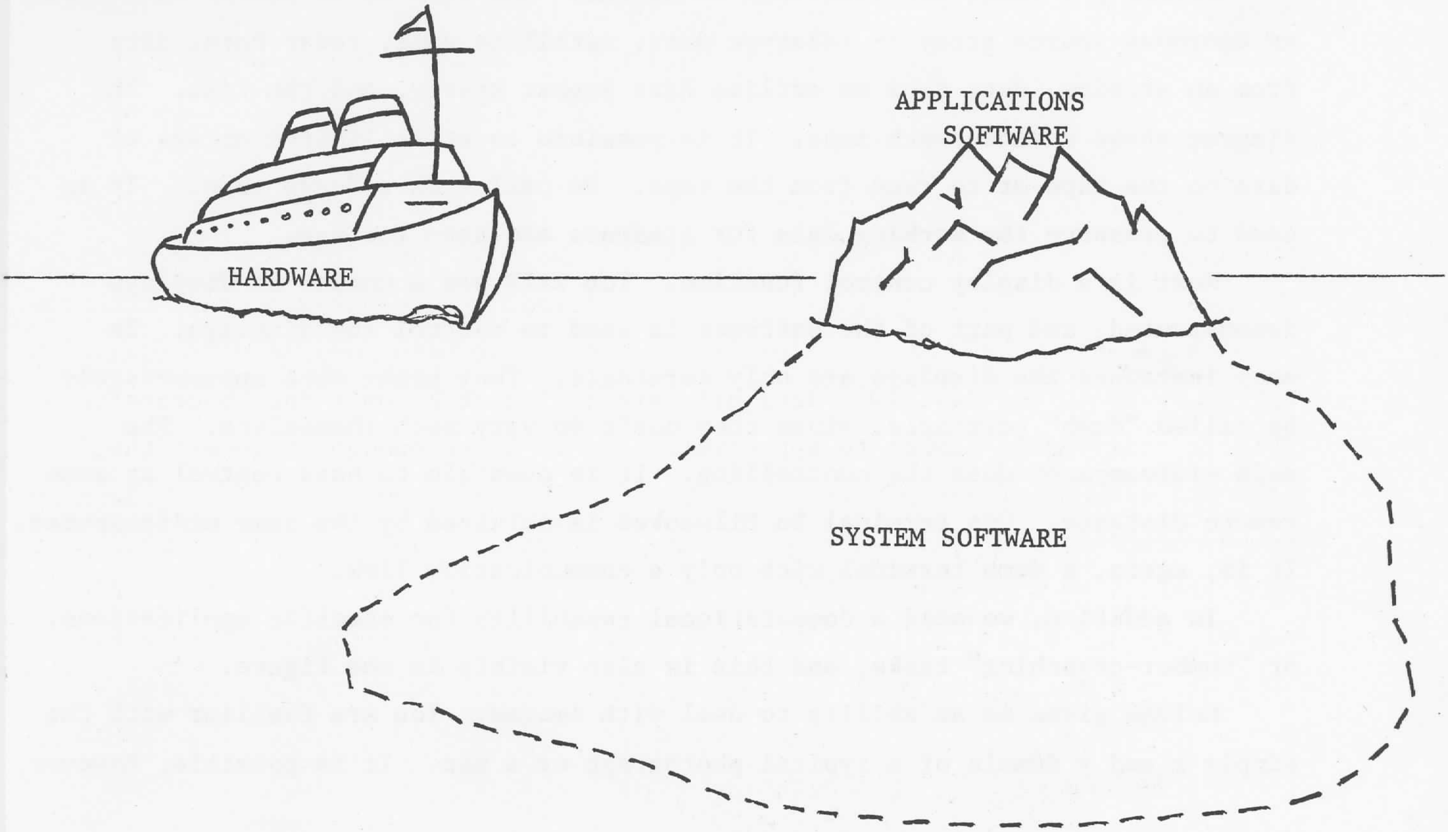


FIGURE 1.2

It is very easy to misunderstand what McIDAS really is. In Figure 1.2 one can see that McIDAS is composed of hardware very easy to see, much like a ship on the surface of the ocean. The iceberg represents the software, and much of it is not apparent. McIDAS has software of two kinds -- applications software, which you can readily see, and also system software which is more difficult to see. A large part of the software effort is invisible, like the submerged part of an iceberg. Thus if one moves with hardware and ignores the software, he can easily sink his hardware ship.

The software is composed of two parts (Fig. 1.3). System software consists of data files, control of the video display, data ingest and control of data applications software program files. The data applications software, with which meteorologists are more familiar, include cloud altitude algorithms, winds from cloud motions, pressure field displays, temperature displays, gridding, curve-fitting, statistics -- all the things that one does with a computer.

Figure 1.4 shows the functions of McIDAS. One task is to accept data from an enormous source array -- teletype data, satellite data, radar data, data from an archive, data from an offline data ingest system, and the like. The diagram shows a nine-track tape. It is possible to write limited arrays of data on the tape or to read from the tape. We call this a "save tape." It is used to preserve the working data for students and then for use.

Next is a display control function. You will see a number of displays demonstrated, and part of the software is used to control the displays. In many instances the displays are only terminals. They might more appropriately be called "dumb" terminals, since they don't do very much themselves. The main midicomputer does the controlling. It is possible to have control at some remote distance. One terminal in Milwaukee is serviced by the same midicomputer. It is, again, a dumb terminal with only a communication link.

In addition, we need a computational capability for specific applications, or "number-crunching" tasks, and this is also visible in the figure.

McIDAS gives us an ability to deal with images. You are familiar with the simple x and y domain of a typical photograph or a map. It is possible, however, McIDAS SOFTWARE

SYSTEM SOFTWARE:

Data files

Video display

Data ingest

System software files

DATA APPLICATIONS SOFTWARE:

Winds - altitudes

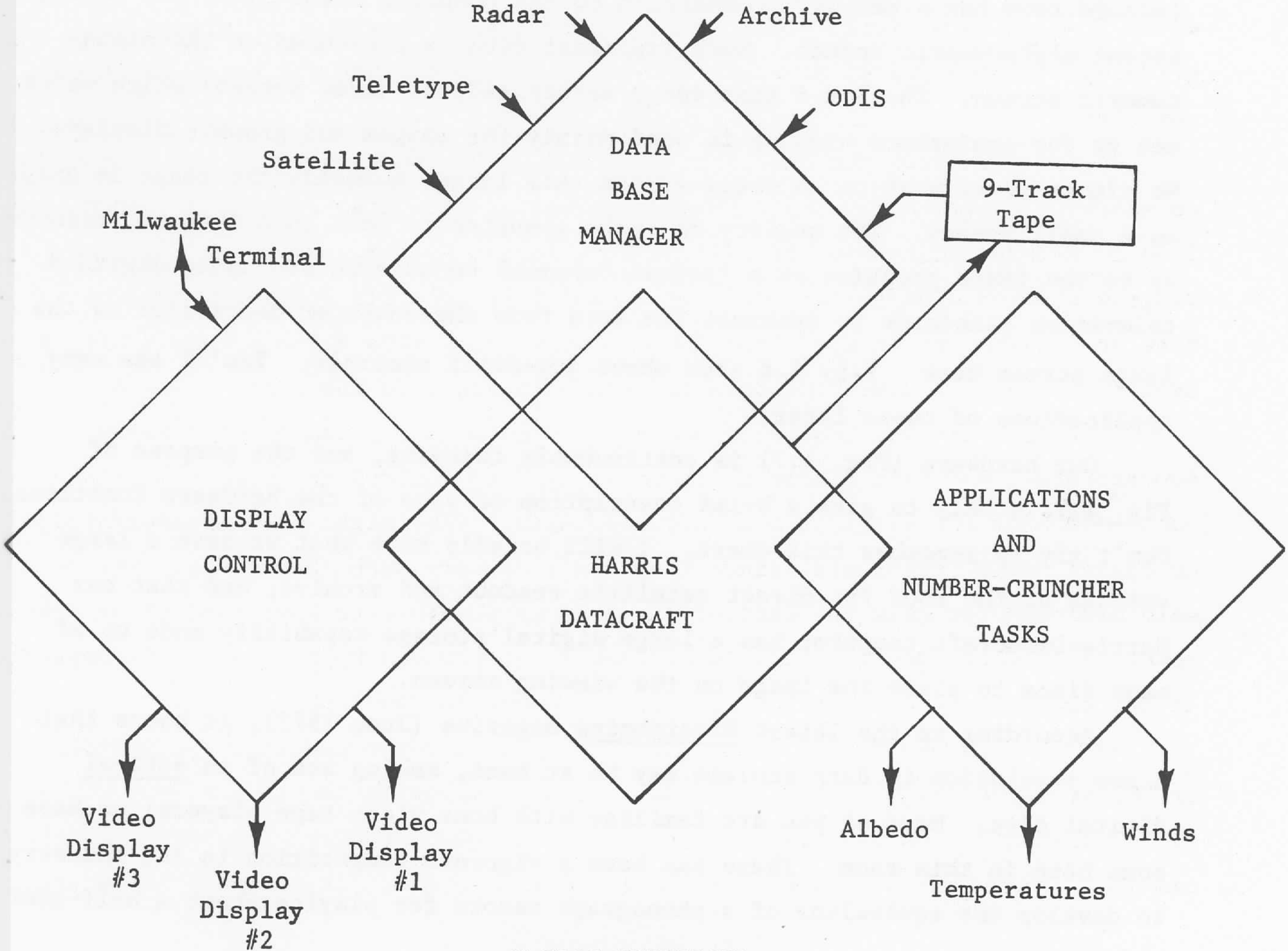
Pressure - temperature - etc.

Gridding

Curve fitting

Statistics

FIGURE 1.3



McIDAS FUNCTIONS

FIGURE 1.4

to work with another dimension, in the z domain, for example (Fig. 1.5). This might be the height of clouds, it might be intensities, or it might be color representing different wavelengths. Probably the most powerful ability a video system provides us is the ability to deal with a variety of images in the time domain. As you know, weather is really the atmosphere in motion, so the time domain is a very important one.

It is also possible to use a time sequence of images representing views in a wavelength domain in the same instant of time. (We have not yet learned how to change both the wavelength and the time simultaneously, but that is probably too complicated psychologically for us to appreciate.)

A vital part of the McIDAS system is user access terminals (Fig. 1.6), an important topic about which you'll learn a lot later in this workshop . This lecture room has a keyboard connection to the computer downstairs, and also a second alphanumeric screen. Much important data is presented on the alphanumeric screen. The 5 x 5 foot image screen (Advent video screen) which we've set up for conference viewing is used mainly for images and graphic displays. We almost never work on an image screen this large; normally the image is only on a small screen. The quality of image graphics in this room does not measure up to the image graphics at a typical terminal because we are using degraded television standards to transmit the data from the computer downstairs to the large screen here. Fig. 1.6 also shows joy-stick controls. You'll see many applications of these later.

Our hardware (Fig. 1.7) is continuously changing, and the purpose of Fig. 1.7 is only to give a brief description of some of the hardware functions. Don't try to remember this chart. I will briefly note that we have a large antenna on the roof for direct satellite readout and archive, and that our Harris-Datacraft computer has a large digital storage capability made up of many discs to place the image on the viewing screen.

According to the latest Electronics magazine (June 1977), it seems that a new revolution in data storage may be at hand, making use of an optical digital disc. Most of you are familiar with home video tape players; we have some here in this room. There has been a vigorous competition in the industry to develop the equivalent of a phonograph record for playing about a half-hour video program.

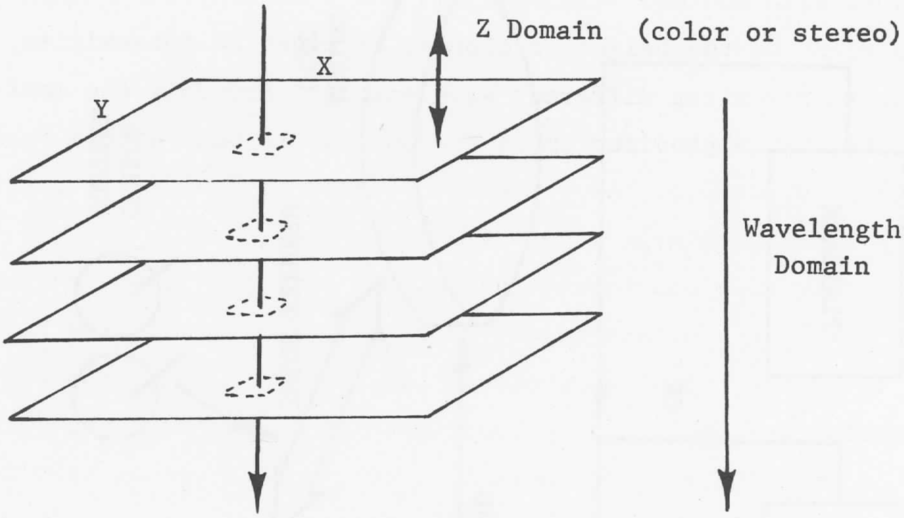
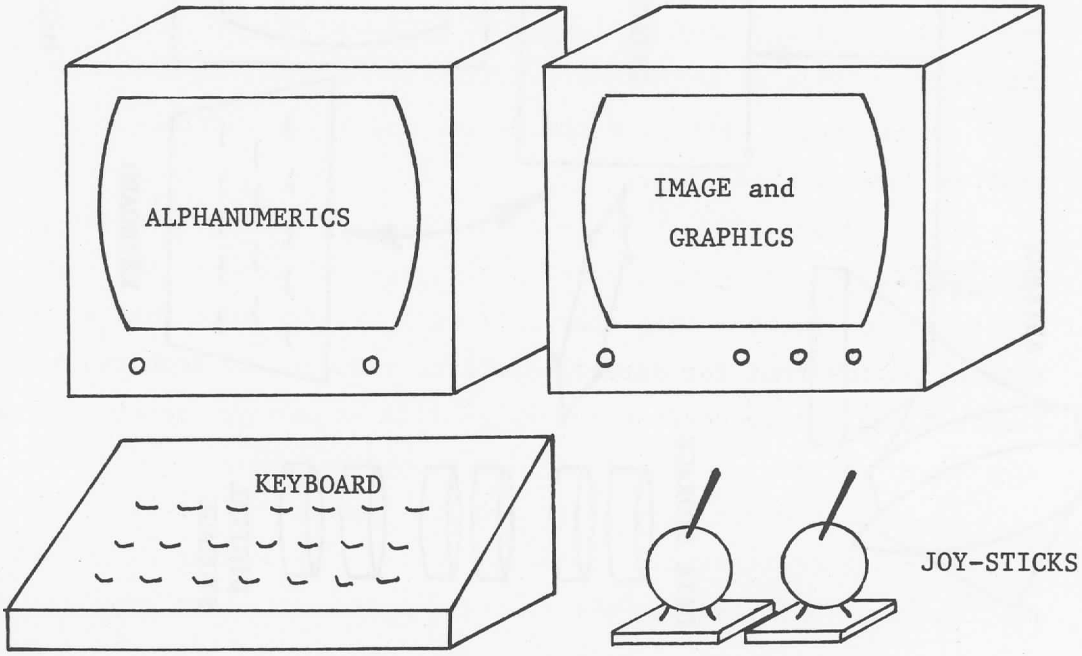
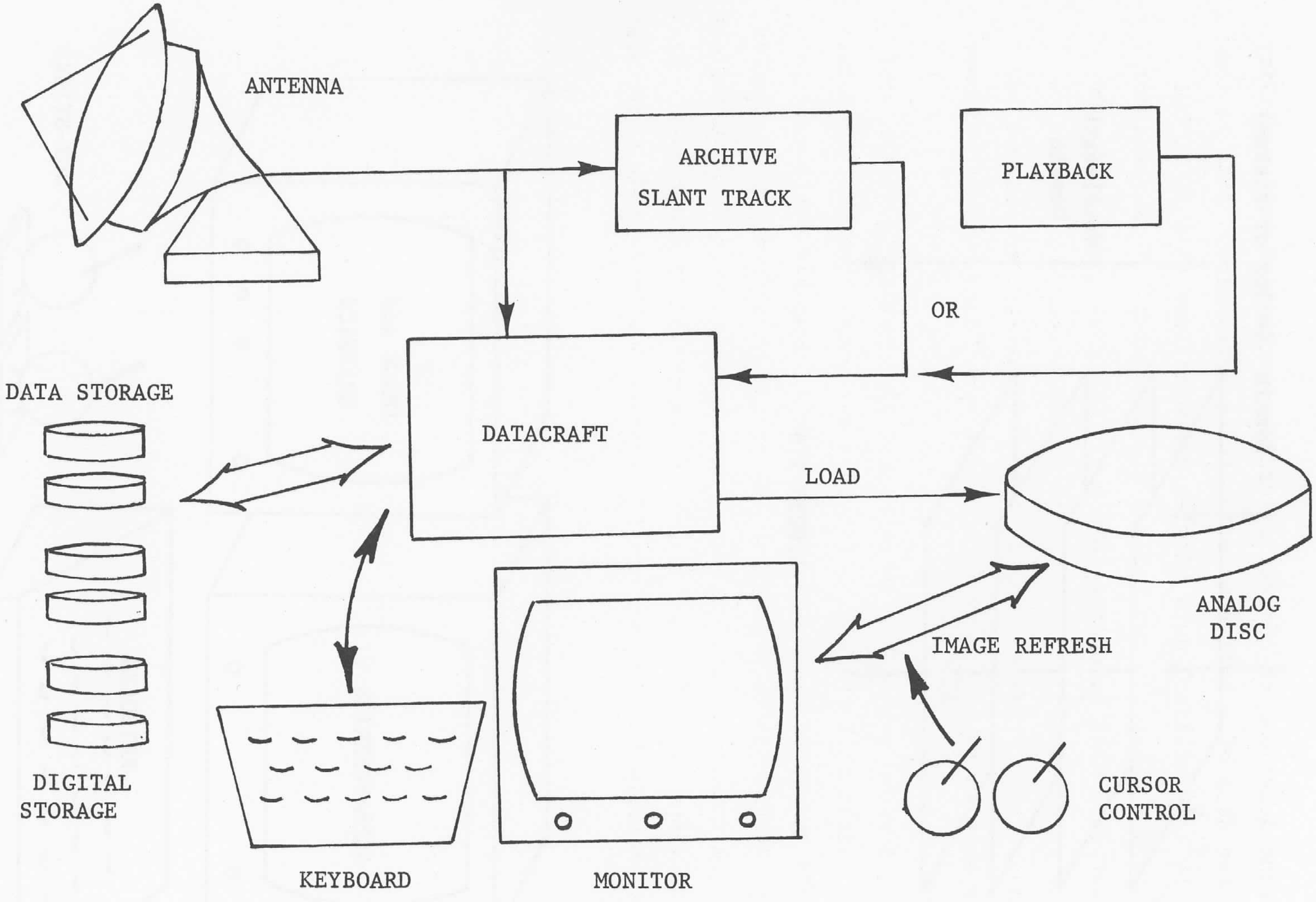


FIGURE 1.5



USER ACCESS

FIGURE 1.6



McIDAS HARDWARE

FIGURE 1.7

The magazine describes an optical recording system with the capability of preserving the data of a half hour of ordinary television. This is the equivalent of 10^9 (10 billion) data bits -- somewhat less than 10^{11}, but still a very large number. In the not too distant future, I am confident that much of our data will be stored this way. One disk could store one year's complete climatological data for the United States, or the entire climate record for one city. We will have the capability, as someone has said, of being able to take a drink from a wide open "data hydrant" without getting all wet.

In closing I would again like to emphasize that McIDAS is just a tool. One can use it wisely or foolishly. This is a workshop. You must look for yourself and ask questions. We will try to make it possible for you to get a close look at McIDAS, to interact with the system, and even try it out for yourselves. I will consider this conference a success if you gain a sufficient appreciation of video display tools to ask useful questions about them. At the end of the workshop we will ask you to indicate how your needs might best be met.

PROCESSING AND DISPLAY OF SATELLITE AND CONVENTIONAL METEOROLOGICAL DATA FOR THE CLASSROOM

Thomas M. Whittaker
Specialist/Department of Meteorology
University of Wisconsin-Madison

In January, 1977 Ralph Dedecker and I attended the American Meteorological Society annual meeting in Tucson to tell our colleagues about the McIDAS system. It opened a lot of eyes, and as an indirect result of that presentation, we are all gathered here today. To set the stage for everything you're going to see in the next few days, I'd like to give this Tucson presentation again. We emphasized education in our presentation; we wanted to look at what an instructor does when he wants to make use of real-time weather data in classwork.

The most readily available data is from facsimile or FAX charts such as Fig. 1.8. These, however, tend not to be very timely. If you want to keep right up-to-the-minute, generally you must take the observational data from a teletype machine, plot it by hand and then use it for classwork or instruction. To make use of satellite data, again, you can turn to the FAX charts. The system which I am going to describe, called McIDAS (for Man-computer Interactive Data Access System) provides not only very high quality, high resolution satellite pictures (Fig. 1.9), but allows these pictures to be accurately aligned for time sequencing and for the placement of geography upon the images. And finally, in a major advance, McIDAS can overlay conventional data such as surface temperature (Fig. 1.10) on top of satellite images. The system that does that is here in this building, controlled by a small Harris (Datacraft) computer with 65,000 words of memory.

We will concentrate on two areas -- the surface conventional observations and the satellite imagery. Satellite images are received through the antenna on the roof of the building (Fig.1.11); the data then is transferred to demodulating equipment. At that point it can either be stored on digital discs or it can be stored on nine-track tapes. There are other storage capabilities, as Prof. Suomi mentioned. The digital data then can be transferred to an analog disc (Fig.1.12) for television display. This analog disc is similar to those used for "instant replays" on sports telecasts. Once the images are on the analog disc, they can be viewed at a McIDAS terminal (Fig. 1.13).

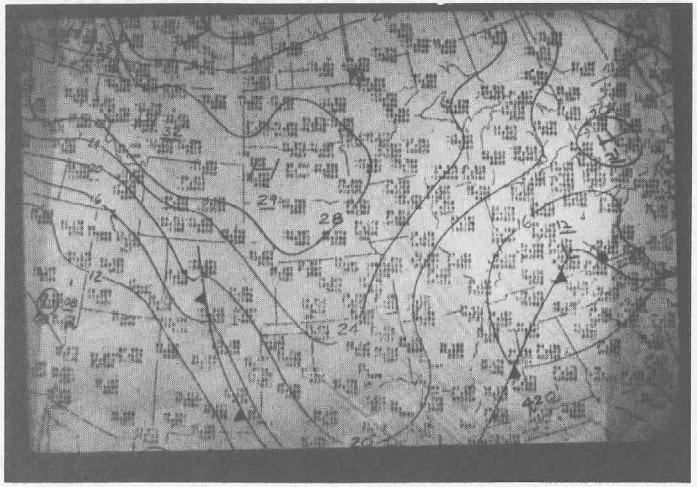


FIGURE 1.8

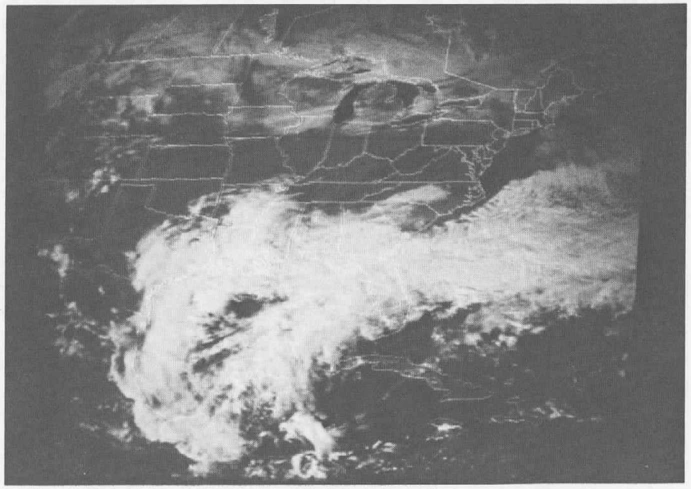


FIGURE 1.9

SEE APPENDIX A
FOR FIGURE 1.10

FIGURE 1.11

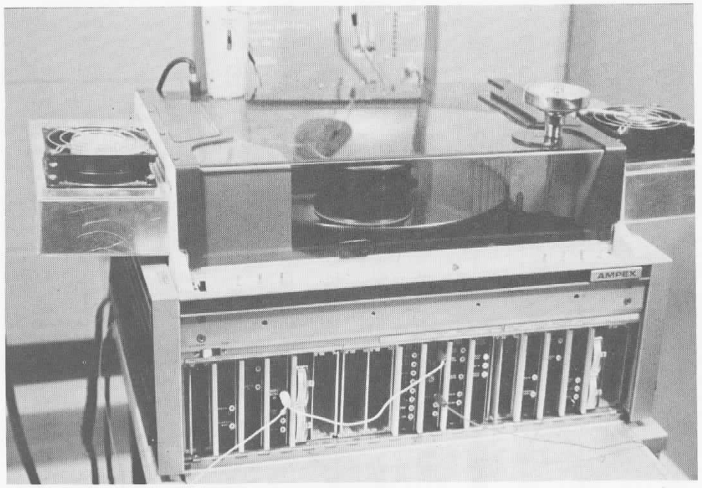


FIGURE 1.12

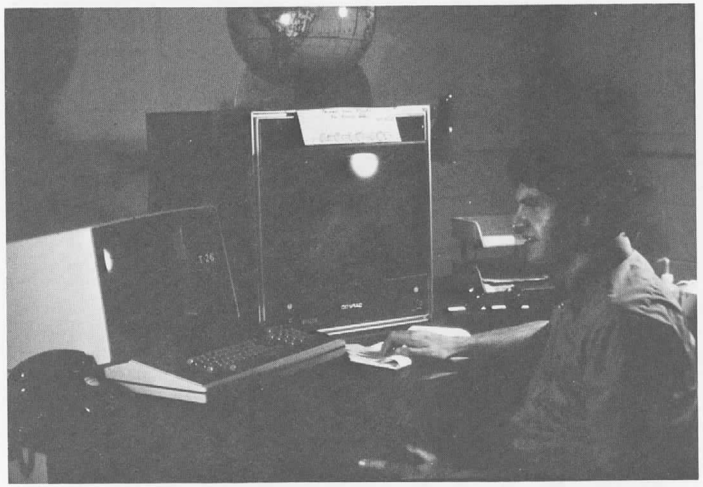


FIGURE 1.13

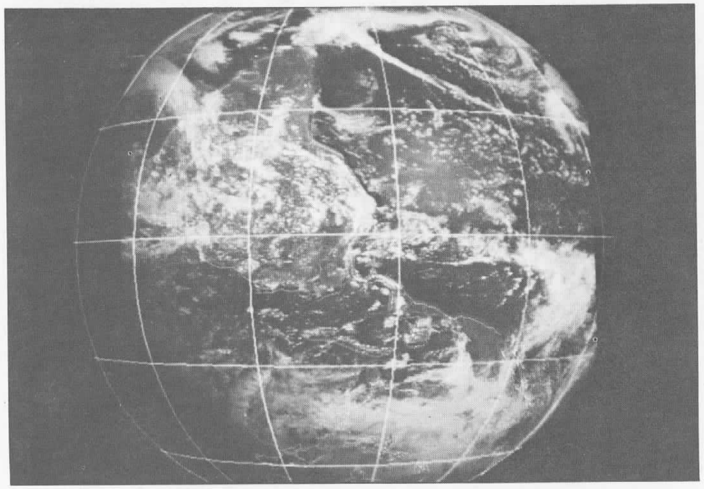


FIGURE 1.14

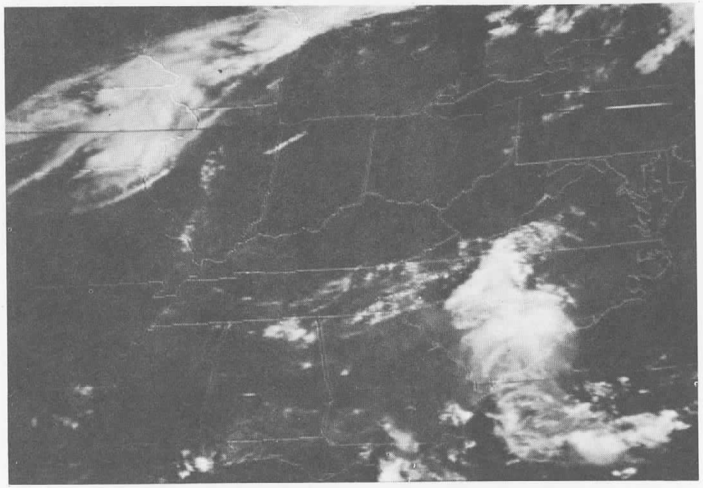


FIGURE 1.15

Before any practical use can be made of the satellite data, however, a process called "navigation" is necessary, because the position and the orientation of the spacecraft is constantly changing. Navigation takes 10 to 15 man-minutes a day using such a terminal. The users of the navigated data then may relate, in terms of geography or in terms of latitude-longitude coordinates, two points on the picture. One can look at a full disc image (Fig.1.14) or select only a small portion of the digital data for display on the TV screen as a blow-up (Fig. 1.15).

Conventional data is received over circuit 604. This medium-speed circuit (Fig.1.16) is essentially a dump out of Kansas City containing hourly weather observations for all of North America and six hourly synoptics and upper air data for most of the northern hemisphere. The data coming in on this wire are transferred directly into McIDAS. Access to the data is at a typical McIDAS terminal. Figure 1.17 shows the TV set used for image graphics and the alphanumeric CRT and keyboard primarily used for operator communication; however, retrieval of some of the information from the hourly weather data archive is available. For example, Figure 1.18.a shows a single listing of an observation from Madison. By another key-in you can list consecutive hourly observations for any particular station (Fig. 1.18.b). Our data base consists of 100 hours of on-line recall, and every two days the data is archived onto magnetic tape. We have up to 1100 stations available each hour. Figure 1.18.c shows the output listing when the computer was asked to scan the data base for a particular hour and list all the stations reporting light snow showers. Simple plotted maps are also available of any region of the country on this alphanumeric CRT (Fig. 1.18.d).

In our Facsimile and Communications room another type of McIDAS terminal is provided -- a DECwriter with a 132-column hard-copy printout (Fig. 1.19). This is the terminal which is used most by students to get plotted maps for analysis and for work in synoptic lab. Some examples: Figure 1.20.a is a plot of the equivalent potential temperatures at the surface of each station over the continental United States. This gives you some idea of the data coverage within the continental U.S. that we have on this circuit. Regional maps are also available simply by keying in the state postoffice abbreviation. For example, in

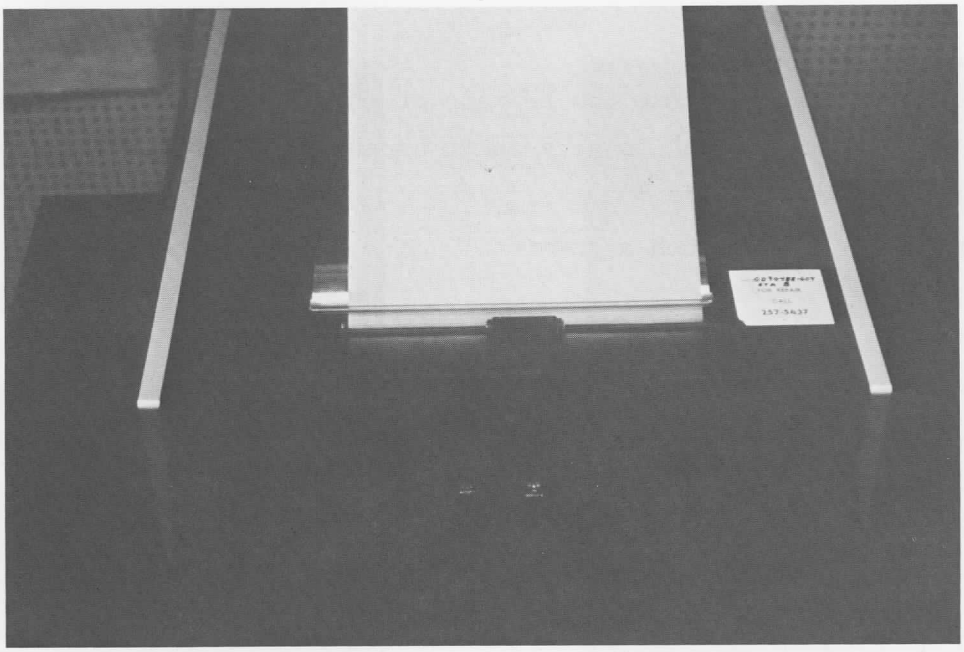


FIGURE 1.16

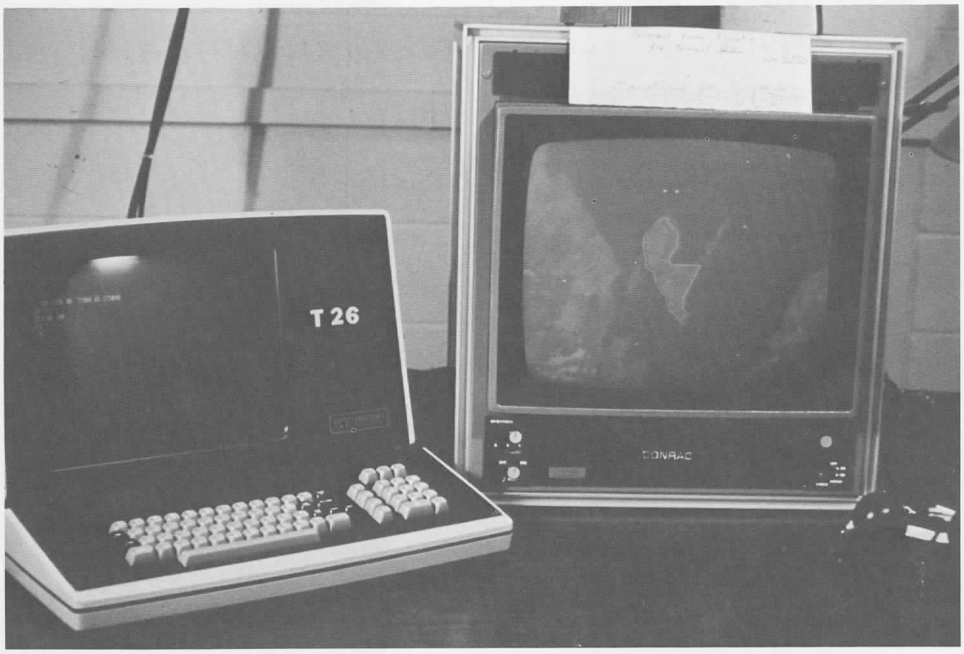


FIGURE 1.17

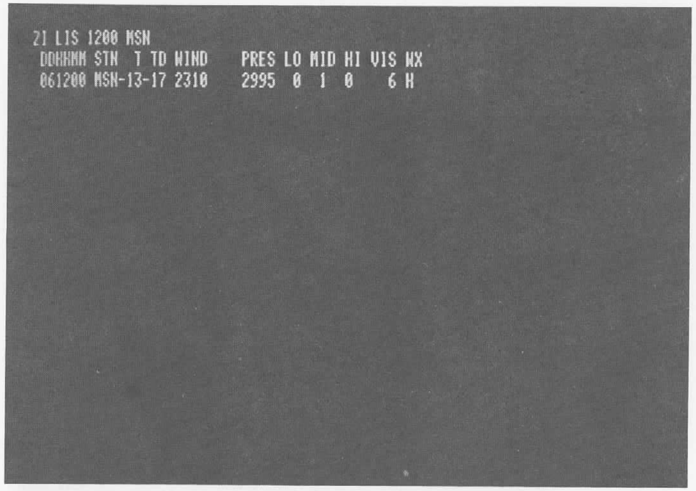


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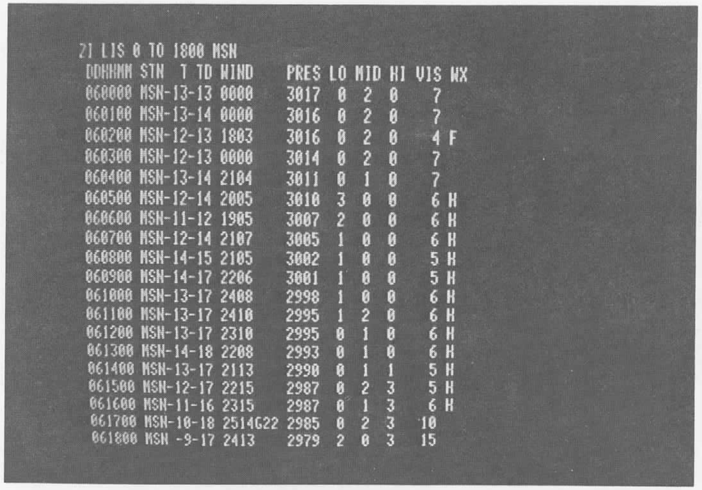
FIGURE 1.18.a



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 060100 MSN-13-14 0000    3016  0  2  0    7
 060200 MSN-12-13 1803    3016  0  2  0    4 F
 060300 MSN-12-13 0000    3014  0  2  0    7
 060400 MSN-13-14 2104    3011  0  1  0    7
 060500 MSN-12-14 2005    3010  3  0  0    6 H
 060600 MSN-11-12 1905    3007  2  0  0    6 H
 060700 MSN-12-14 2107    3005  1  0  0    6 H
 060800 MSN-14-15 2105    3002  1  0  0    5 H
 060900 MSN-14-17 2206    3001  1  0  0    5 H
 061000 MSN-13-17 2408    2998  1  0  0    6 H
 061100 MSN-13-17 2410    2995  1  2  0    6 H
 061200 MSN-13-17 2310    2995  0  1  0    6 H
 061300 MSN-14-18 2208    2993  0  1  0    6 H
 061400 MSN-13-17 2113    2990  0  1  1    5 H
 061500 MSN-12-17 2215    2987  0  2  3    5 H
 061600 MSN-11-16 2315    2987  0  1  3    6 H
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 061800 MSN -9-17 2413    2979  2  0  3   15
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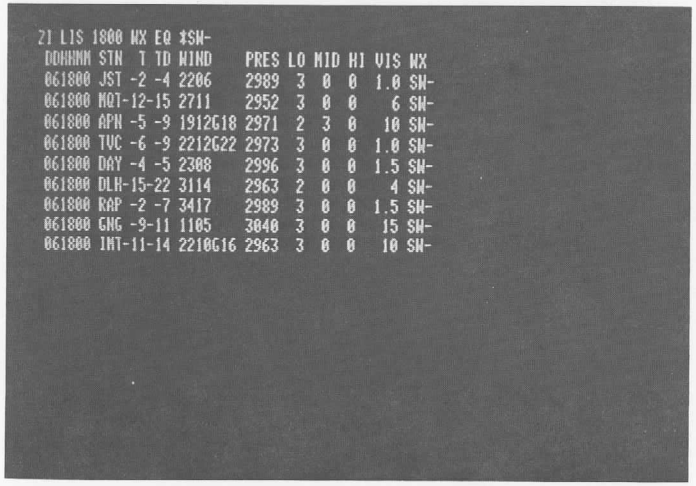
FIGURE 1.18.b



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 061800 MQT-12-15 2711    2952  3  0  0    6 SW-
 061800 APN -5 -9 1912G18 2971  2  3  0   10 SW-
 061800 TVC -6 -9 2212G22 2973  3  0  0  1.0 SW-
 061800 DAY -4 -5 2308    2996  3  0  0  1.5 SW-
 061800 DLH-15-22 3114    2963  2  0  0    4 SW-
 061800 RAP -2 -7 3417    2989  3  0  0  1.5 SW-
 061800 GNG -9-11 1105    3040  3  0  0   15 SW-
 061800 IMT-11-14 2210G16 2963  3  0  0   10 SW-
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FIGURE 1.18.c

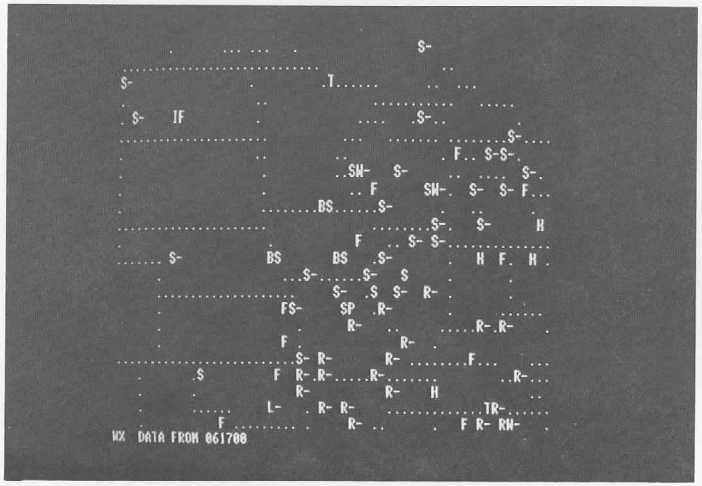


FIGURE 1.18.d

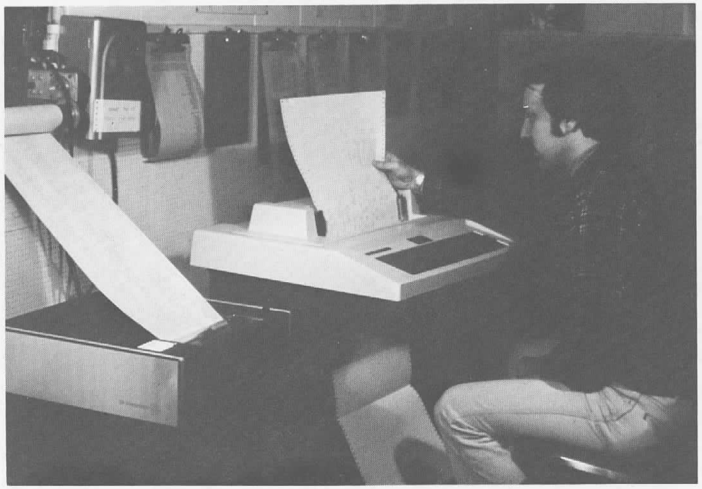


FIGURE 1.19

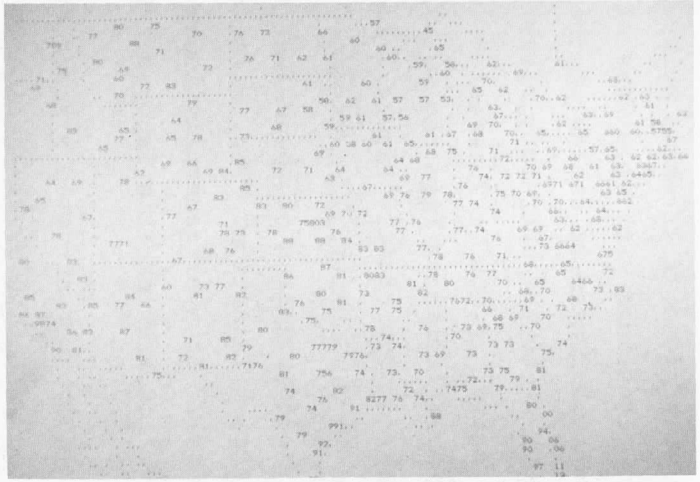


FIGURE 1.20.a

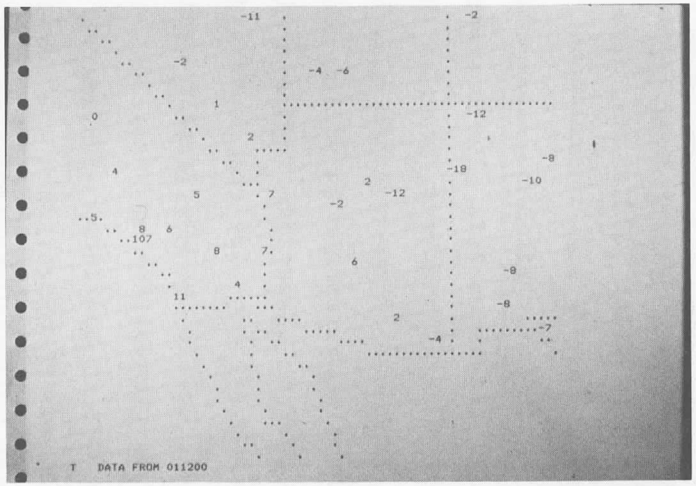


FIGURE 1.20.b

Figure 1.20.b, the computer was asked to show temperatures over Arizona. Change charts are also available; Figure 1.20.c shows 24-hour pressure change information. The computer can also interpolate the data to a grid and present it at the grid points (Fig. 1.20.d) or, alternatively, contour it on the line printer (Fig. 1.20.e).

In the synoptic laboratory classroom, the same terminal is used in conjunction with a television set. The conventional weather data is displayed on this television in the form of analysis, such as the surface streamline analysis shown in Fig. 1.21.a.

Multiple parameters may also be analyzed. In Fig. 1.21.b, the isotach field has been superimposed in yellow dashed lines on top of the streamlines. One could also look at a specific region of interest, studying the temperatures or streamlines, for example, just for the upper midwest. Because the data is available at grid points, derived parameters are available, and we attempted in the software to allow as much flexibility as possible. For example, in Figure 1.21.c the temperature advection is indicated (in degrees Celsius per day). The real benefits of the system come, though, when you combine the two sets of data. In Figure 1.22.a, surface temperatures have been plotted over the satellite image for the same time period. Political and geographic boundaries have also been added.

You may notice, near Pittsburgh, a 65°C reading, which is obviously an error. When we analyze it, it shows up as a big bull's-eye. This is one side benefit that we've found with this type of video work. Sometimes it is hard for the computer software to decide whether a piece of data is in error, but when you present it to the operator, often he can just say, "Yes, that has to be wrong."

Again, if you're interested in a regional blow-up, you can select a portion of the digital data from the satellite image and plot the hourly weather observations on top of it. Figure 1.22.b shows the surface winds and weather superimposed on the clouds.

No description of the McIDAS system would really be complete without showing the system in action. The following film was made right from the McIDAS video terminal. It's of generally lower quality than the other graphics you'll see today, but I think it's important to illustrate how fast the system works.

> [Whittaker narrated a short film showing how McIDAS' time-sharing computer can overlay weather parameters and map outlines at the same time. Parameters included: sea level pressure for the entire U.S.;

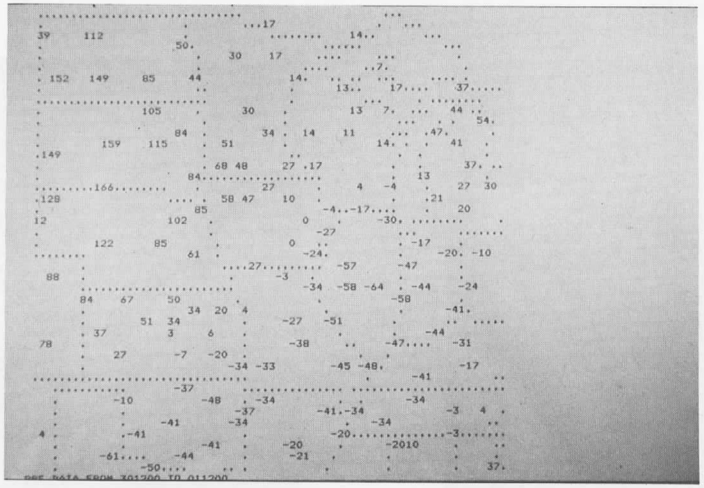


FIGURE 1.20.c

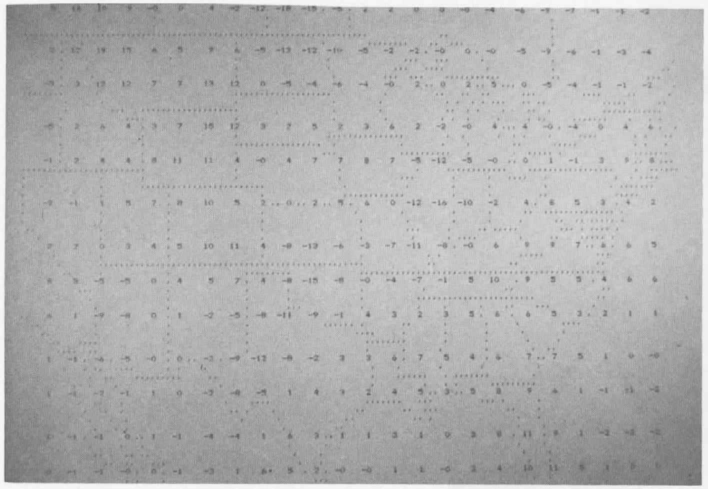


FIGURE 1.20.d

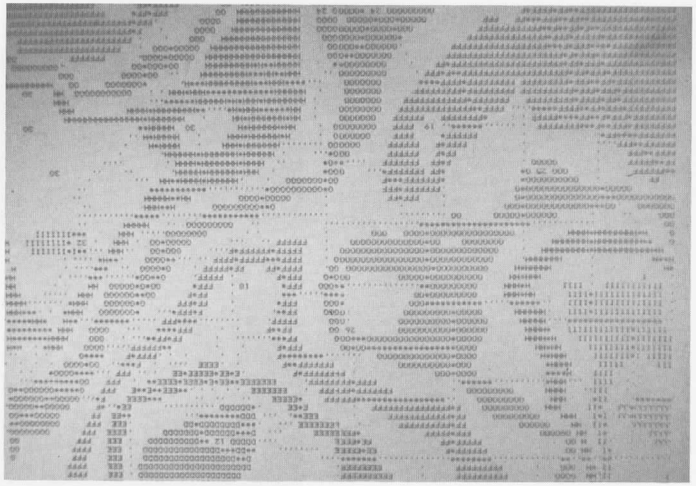


FIGURE 1.20.e

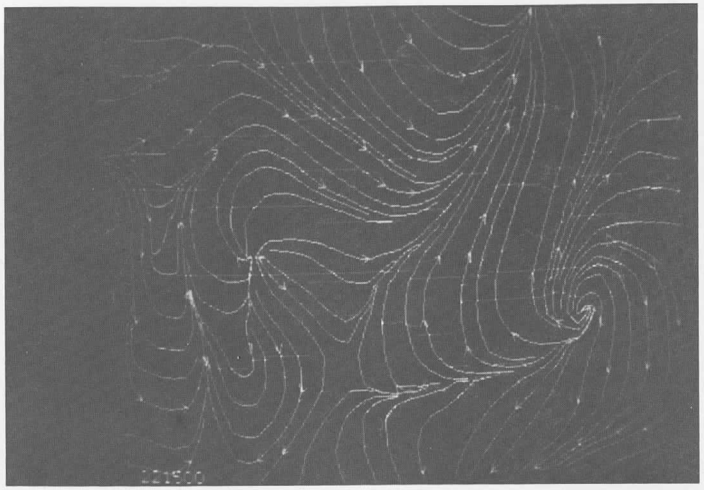


FIGURE 1.21.a

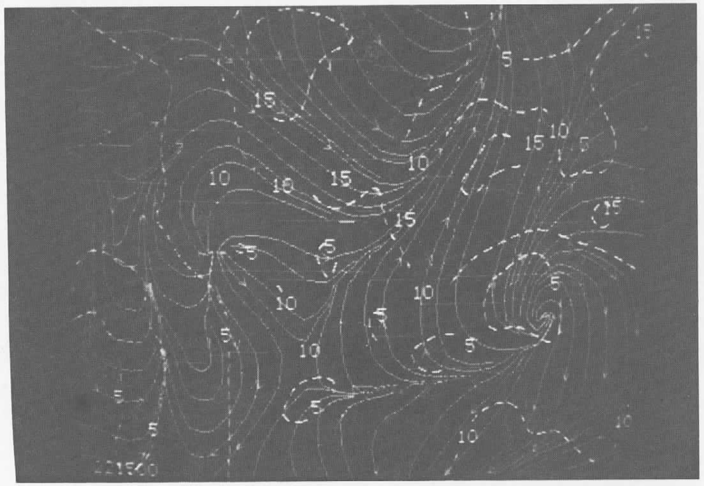


FIGURE 1.21.b

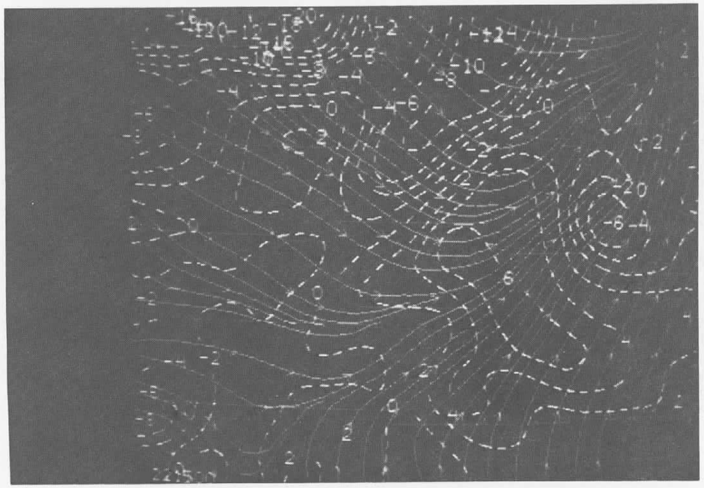


FIGURE 1.21.c

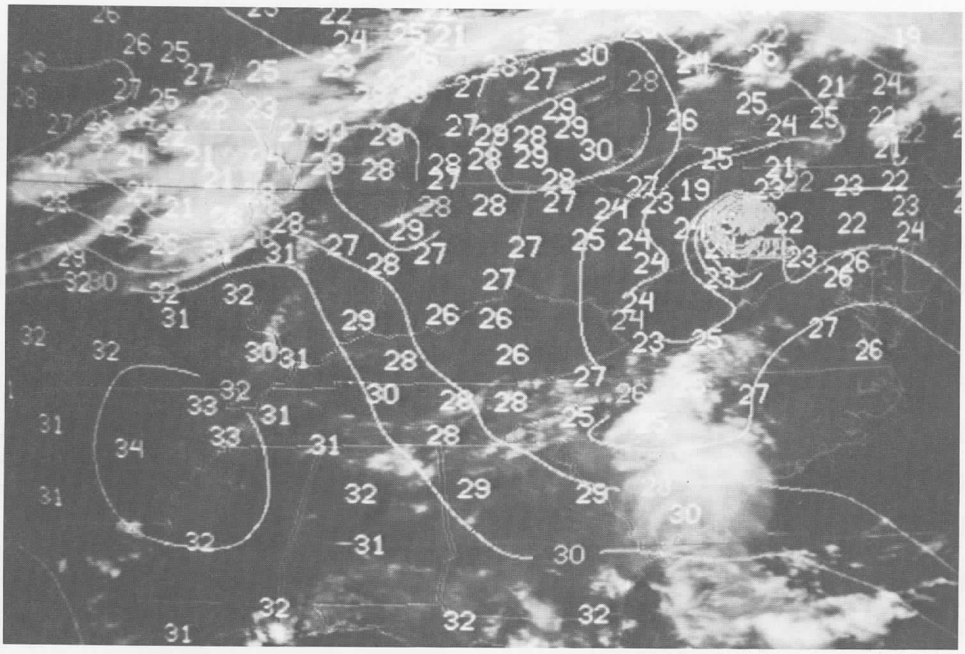


FIGURE 1.22.a

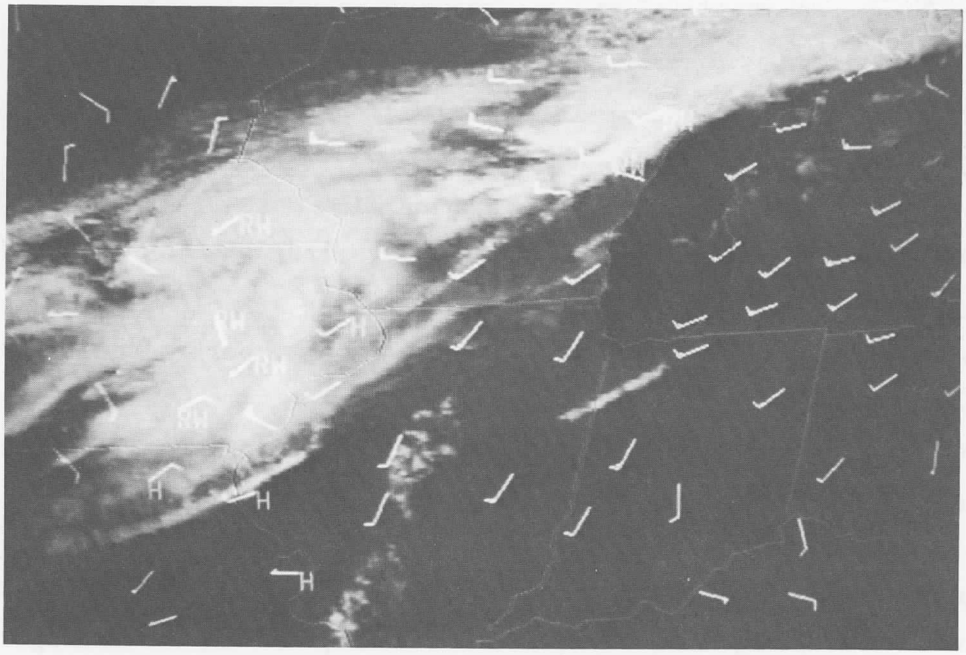


FIGURE 1.22.b

temperatures for the state of Arizona; surface streamlines for the U.S.; and a closeup streamline analysis for Illinois to examine a feature of interest. The required data base can be maintained easily, since each observation is packed into either 48 or 72 bits, which represents 2 or 3 words on the Harris computer. Because of this data "packing," McIDAS can maintain on line 100 hours of data for 1100 stations each hour.

The film also showed the superimposition of map outlines onto satellite-image data with automatic transformation of image data from the coordinates system of the spacecraft, to the latitude-longitude of the earth, to the coordinate system of the television screen.]

McIDAS can also take a sequence of satellite images (normally available every half hour) and put them on consecutive frames on the video or analog disc. It is possible to form an instantaneous time loop of the images. In one sequence a three-hour loop, around noon, was set up for a summer day to show a storm system entering Wisconsin, cumulus building up on the lee side of the Great Lakes and also along the Gulf Coast, and a rather strange anti-cyclonically circulating mass of clouds in the Carolinas.

The computer only controls the flow of data, including the rate at which image loops are displayed. Speeding up the loop provides a much better idea of the continuity in weather movements.

The research applications for something like this are very well known, and the teaching applications are enormous. What better way for students to learn than to actually see the weather as it's happening? A cloud mass entering Wisconsin was examined in more detail by selecting a portion of the digital data for display, and adding the base map coordinates to it. Wind and temperature data were plotted over the satellite imagery, verifying that it was indeed cooler under the clouds than in the clear air.

One can analyze any of the common observed parameters on top of the satellite image for the same time period, with or without the base map. This involves two separate graphic systems. The satellite image is on the analog disk, while contours, plotted data and the base map coordinates are simultaneously displayed from a random-access memory capable of displaying three colors on each of two terminals.

It seems very clear that the video systems we'll discuss in the next few days are vastly superior to the FAX charts approach.

QUESTIONS AND COMMENTS

Q: How did you get enough spatial resolution to draw, for example, that little swirl there in Illinois?

A: On Service A, the data density is very high from the hourly reports. The grid is dynamically created. Now, for example, on the full U.S., you're working with the 2^o latitude-longitude grid. On the smaller scale in the upper midwest, it's down to a 1^o latitude-longitude grid. But you do have data to support even a 110-kilometer grid space.

Q: What is the cost of a system like that?

A: I was told before I went to Tucson that to do everything except the satellite imagery, it would cost $100,000. By satellite imagery I mean full reception of the data down through all the processing. I think that that figure did include the display of some of the satellite images. But keep in mind that this system was developed starting in 1973, and there have been a lot of changes and additions made to the system. I don't know if it's fair to use this prototype to gauge costs. We'll talk more tomorrow (15 June) about costs.

Q: How much of the McIDAS software are we going to see in the next two days? For example, what is the objective analysis scheme to produce the streamlines?

A: The objective analysis scheme involves first interpolating to a grid; the streamline program simply analyzes streamlines on that grid. In order to keep down the cost to users and to keep the system very fast, the grid-point interpolation method -- a very short, very unglamorous method -- does the job. It essentially takes a Cressman-type weighting function and applies it once to the field. However, modifications were made so that as the station density varies, so will the search radius, so when you have a highly dense network of stations, you can also support short wavelength features.

Q: Were you analyzing direction as a scalar function, for example, in the Sangstrom sense, or was it a different scheme that produced those streamlines?

A: Talk to me later about that.

COMMENT [T. Vonder Haar, Colorado State University]: Since we're here to share information, the actual source of the data in the western part of the United States is from the Bureau of Reclamation's Skywater Network. They have a computer in Denver, and they bring in all the conventional data in cooperation with NCAR [National Center for Atmospheric Research] on a high-speed line. There are at least 50 small terminals connected to that network, and you can do the kinds of things that Tom showed at the very beginning -- the black-and-white printing of data, for instance. The cost is about $100-200.00 per month to get into this network. They only store the surface data west of the Mississippi River. This has been a tremendous aid to us at Colorado State in support of field programs. It's just a source of data; it doesn't do all the other good things Tom described, but it is a central data source.

Q: How interactive can you be with satellite information?

A: [Dr. Suomi]:

It is possible to be interactive with the satellite image, too. In my teaching application, which I will give in a few minutes, I will give a slide illustration of how you can interact with the satellite data to change the contrast, for example, or change the brightness function. Of course you can't move clouds out of the way. But it is possible to treat the analog data digitally, and then convert the analog back to digital, so it can be manipulated, giving it to you under full computer control. Then it is displayed as an analog video signal. This is probably not the wisest way to go, but in terms of cost, and so on, this is feasible.

II. OVERVIEW OF TEACHING APPLICATIONS

Dr. Houghton

I would like to introduce Professor John Cahir who will be chairing the section on teaching applications.

Dr. John Cahir

Department of Meteorology
Pennsylvania State University

It's almost trite to say that the operational weather services ought to automate and use modern techniques for the display and analysis of weather data. But some of you, in this room, worked on that problem and know how difficult it is to actually bring that into effect. It is certainly very significant for us to be considering the impact of video graphics on the teaching of meteorology, and especially synoptic meteorology in the universities in the way it impacts on that data automation problem. That's certainly not a trite problem. I often say to my classes that the onus is going to be on the forecasters when a system such as AFOS (Automated Field Operations System) is in place, to really show that they have something to offer. Because if they don't, if they merely move files from one location to another and move guidance forecasts from one place to another, it will be seen very quickly that they won't be needed.

It seems, to me, the problem in the university is a different one: whether or not our students are going to approach a weather data system like AFOS with a mind set to roll up their sleeves and really make a system like that "sing." I think that is one of the problems we'll be addressing this morning in our session on teaching applications. The speakers you are going to hear are people who have thought about that problem and worked with it, and I think we could say that there are some things that we have to learn. We really don't know whether we are talking about students who are going to be working in weather stations at all, but we think that, even so, they could learn a great deal in the kind of classroom experience that you are going to be hearing about.

Three people [Dr. Suomi, Dr. Frank Sechrist, and Dr. Cahir] are going to make presentations, and at least two of them are very famous teachers. Dr. Frank Sechrist has been a prize-winning teacher, and is very well known for his tremendous teaching ability. Dr. Verner Suomi has been a teacher of the world. He has taught everyone (including, I think, all of us in this room) about the potential of meteorology. In recognition of his efforts in this regard, Dr. Suomi was recently selected (May 1977) for membership in the American Academy of Arts and Sciences. Finally, to start things off, I'll let you see for yourself what Frank Sechrist can do.

McIDAS AS ARTIST AND TEACHER

Dr. Frank Sechrist

Professor, Department of Meteorology
University of Wisconsin-Madison

McIDAS is a very personal friend of mine. I work with it very closely in my synoptic weather lab, and it occurred to me last night how far the McIDAS has advanced in recent years. Eight years ago we made a film demonstrating what the McIDAS system could do. It took a whole summer - $5,000, producers, directors, work in the darkroom - trying to animate single frames to show satellite image motion. Making 24-hour temperature-change blobs move across the map was sort of a nightmare, but we got it out. It took about 5 or 6 months before we showed it.

And then it occurred to me that Tom Whittaker put together the program you just saw in about a month or two, and it cost considerably less than our film eight years ago. Then, just two or three weeks ago, Tom and I started making the videotape, live from McIDAS, that you are about to see. That only took a couple of hours, and hardly any money at all. And today I see that we're going to present a live, current weather McIDAS discussion, and I have to do practically nothing. Eight years ago I had my hands in it up to the hilt; today, in our current weather discussion, Tom will push some buttons and the computer will do the whole thing. I'm liable to feel kind of left out.

Well, I got a message, a ringing in my ear, this morning about 5 o'clock that said, "Hello, Frank? This is McIDAS. If you don't feel well this morning, why don't you let me take care of the presentation." It makes me wonder what the next step will be with McIDAS.

Right now I'd like to demonstrate some ways we use McIDAS in synoptic laboratory. As Tom pointed out, one valuable function is the video capability, and the other one is hard copy capability. You'll see examples of this tomorrow from the DEC printer. We can get all the charts we want for surface parameters (observed or derived) for any region, any state; listings of individual stations. and upper air observations have been added.

But today I just want to show you what we have done with the TV since the Tucson show in January. We've tried to improve the analysis techniques and to animate some of the conventional data. You won't see too much animated satellite data here because there are other presentations to show that. So, if we can get our video system to work, we can roll some tape to show you how we've tried to improve some of the analyses that show up on the McIDAS TV system.

[The videotape presentation began with some examples of the use of color banding contours (which can be animated) instead of single-line contours to illustrate weather parameters. Temperature, pressure and mixing ratio data, for example, can be represented as bands of different color (or as shades of the same color), then animated in a time-lapse sequence to examine weather pattern development. Grid or map boundaries, as well as wind observations and streamlines, can be overlaid, and the operator can switch back and forth from satellite-image to plotted or animation data for comparative analysis.

One animated sequence, using banded dew point contours, illustrated the advance of moist air from the Gulf of Mexico into the midwest. Another used shaded temperature contours to show changes in surface temperature in the upper Midwest from the cool 3 a.m. readings, through sunrise, and on into midday. Professor Sechrist pointed out the value of such animated analyses in the study of diurnal temperature change as influenced by lakes and other topographic features.

The next sequence combined upper-air wind data, isentropic constant pressure data and dew point data on the same display, to illustrate the options the operator has in deciding what parameters (and what combinations of parameters) to study and compare. Professor Sechrist also emphasized the ability of McIDAS to present wide-area data, or to focus on a state or on any region of interest world-wide. He also noted that at any time, the operator can obtain a hard-copy printout of any plot that appears on the video screen.

The final sequence demonstrated the use of contour bands to study upper-air soundings of the moisture in the atmosphere. By coloring, animating and overlaying dew point temperature data, the vertical movement of moisture in the atmosphere can be studied. The technique has important applications for the teaching of diurnal temperature/moisture change patterns and for the prediction of approaching storm systems. The upper air data (temperature, wind, dew point) can also be overlaid on a satellite image for closer study.]

QUESTIONS AND ANSWERS

Q: Is this banded contour technique in use now at SSEC?

A: We got into this in just the last few months, and it's not all integrated yet, but we are using this type of thing daily. The animated sounding could be done; it just has to be set up.

Q: Eventually are you going to dispense with the FAX charts and go to this completely? Do you think this will make the facsimile machine, at least from a teaching aspect, obsolete?

A: In one sense it will make it obsolete, as far as looking at analyses. I think McIDAS is the most desirable system. However, I think the biggest problem is what to do about the forecast charts. You still need that FAX machine to get all your forecast products, unless you could get them into the video system machine, which is conceivable. Already we can put the radar [Neenah, Wisconsin radar] on here as a signal through the FAX circuit. So I think we can do FAX maps, too, but they are going to need some cleaning up.

Q: Are the satellite photographs from a stationary or polar orbiter?

A: They are from a stationary geosynchronous satellite.

COMMENT (Dr. William Klein, NWS/AFOS):

You'll have all the FAX maps through the AFOS System.

COMMENT (Frank Sechrist):

I don't know that much about [AFOS]; I want to see more about it. That's why we are here.

Q: Do you have a cross-section capability?

A: We don't have that capability in the machine yet, but that is certainly one of our high priority projects. J.T. Young [SSEC] envisions the idea of just putting a cursor on the screen and saying, "I want a cross-section from here to here." We can't do that right now, though.

Dr. John Cahir

When one visits a university of the very first rank, one can expect to be exposed to some legitimate genius like the next speaker, Dr. Verner Suomi.

METEOROLOGICAL SATELLITE APPLICATIONS

Dr. Verner Suomi

What I propose to do is present a very short section of one of the topics which I give to my class in meteorological satellite applications. I chose a topic related to some of the materials and equipment we have been seeing because I want to speak of image properties, and of the use one can make of them, first from an image pattern point of view and then from a quantitative point of view.

Figure 2.1 indicates the scale of the phenomena in which we are interested. It shows a large-scale weather phenomenon -- a tornado in Wisconsin. It's interesting to look at large-scale weather systems that cover the earth, but on such a scale, the energy distribution in small-scale phenomena is barely detectable. (The tornado just barely visible in Fig. 2.1 actually touched down in the Green Bay area.)

Resolution, the first important parameter I want to discuss, is dependent on how far one is from the object one is photographing. If one is close to the subject, one achieves high-scale resolution; if one is a great distance away, one does not. It is possible to produce high resolution images from spacecraft; Figure 2.2 is a high-resolution picture of Madison taken from ERTS [Earth Resources Technology Satellite].

In dealing with an imaging system, we must consider two resolutions. One is the resolution of the camera, itself, which is what we tend to discuss most often. But, in addition, we have the resolution of the system which displays the image. Unfortunately, in this hall, the resolution of the display devices (the monitors and the Advent projection TV) is limited by the signal bandwidth available in this room. But using a resolution chart (Fig. 2.3), it is possible to talk about one

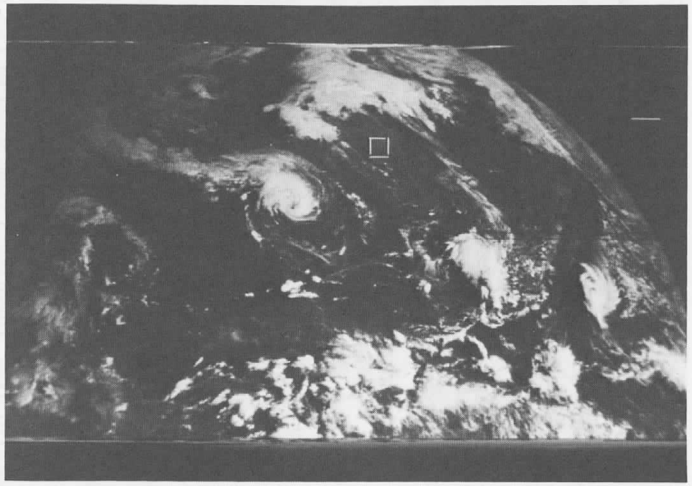


FIGURE 2.1

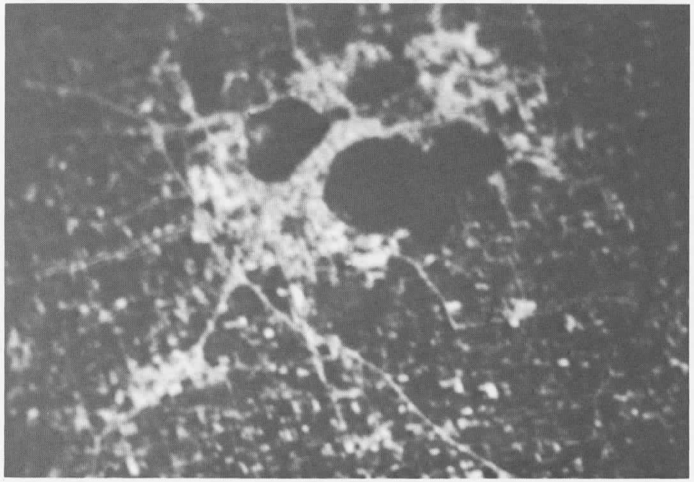


FIGURE 2.2

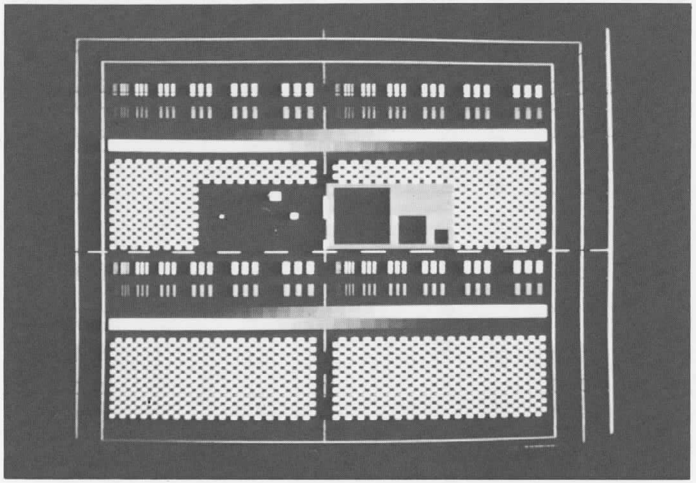


FIGURE 2.3

pixel or "picture element," composed of lines and spaces along the line or picture element. Such charts give the resolution of different picture elements.

We can also talk about dynamic range -- an indication of the bright and dim portions of an image. If one is up close, or if one's photography is good, one can detect a large number of brightness levels in an image, and these levels constitute the image's dynamic range. We must consider both resolution and dynamic range.

Figure 2.4.a from ATS-1, shows Baja, California. ATS was south of Hawaii, and Baja was at the limit of the field of view, so the resolution of Baja was rather unsatisfactory.

On the other hand, from the SMS satellite more directly over Baja, the resolution of Fig. 2.4.b is very high. It has been stated that the resolution of the SMS camera is a half-mile. But resolution can fool an observer; what is really important is the energy change. In other words, one could detect an object in a photograph that was much smaller than one-half mile, if it was illuminated with sufficient brightness that energy coming into the camera system was detectable. However, in the display system, it will appear to be one-half mile in size because that is the basic resolution of the camera system (provided that the resolution of the display system is equal to that of the camera).

What good is high resolution, meteorologically speaking? The right half of Figure 2.5 shows a fog bank, for which one does not need high resolution. The left half (a picture of Scandinavia taken from a low orbiting satellite) indicates that with high resolution, one can easily distinguish between clouds and snow-fields, due to the dendritic pattern of the snow on the mountains. High resolution helps one get more information from an image.

Figure 2.6 is a simulation of a planetary imaging system, taking the best resolution from the old ATS and purposely degrading it. If, for example, you were to look at the top-right image first, you would not see much detail; it would be very difficult to interpret. But, if you saw the top-left image first, and then gradually degraded the picture, you could still obtain quite a bit of information about the structures.

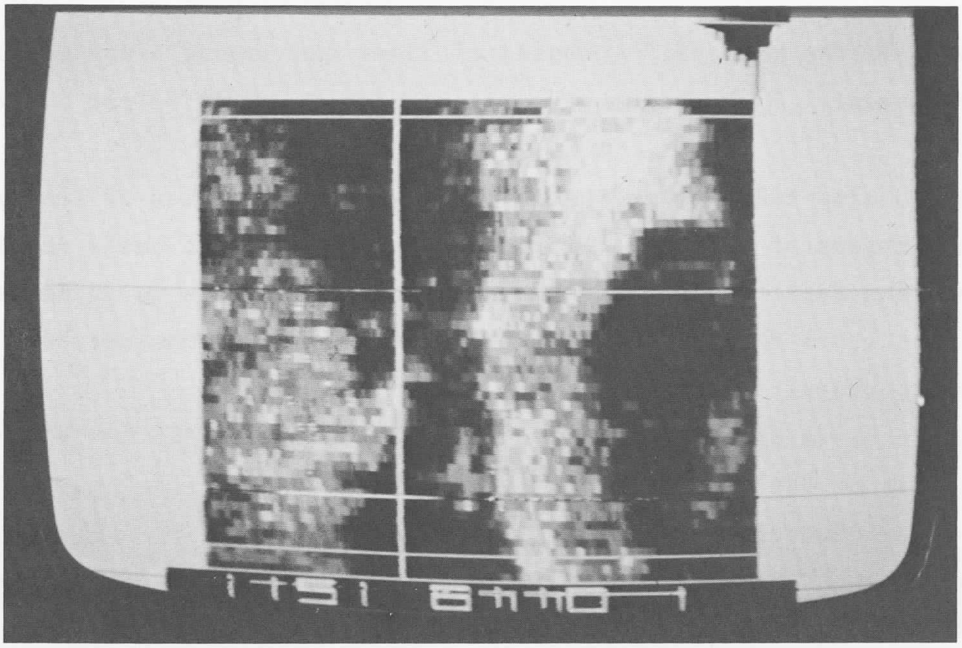


FIGURE 2.4.a

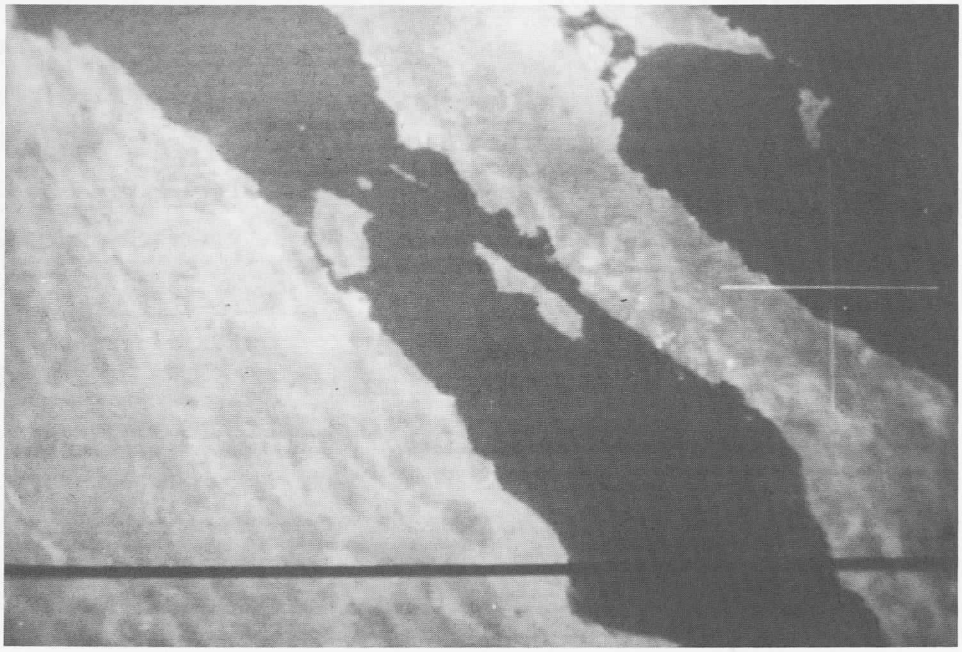


FIGURE 2.4.b

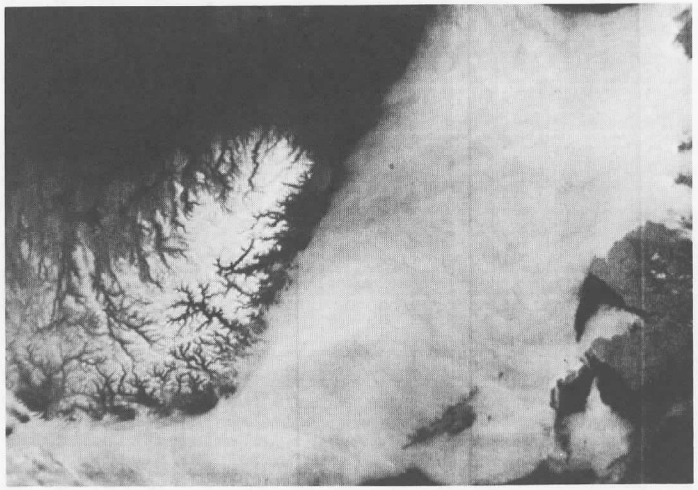
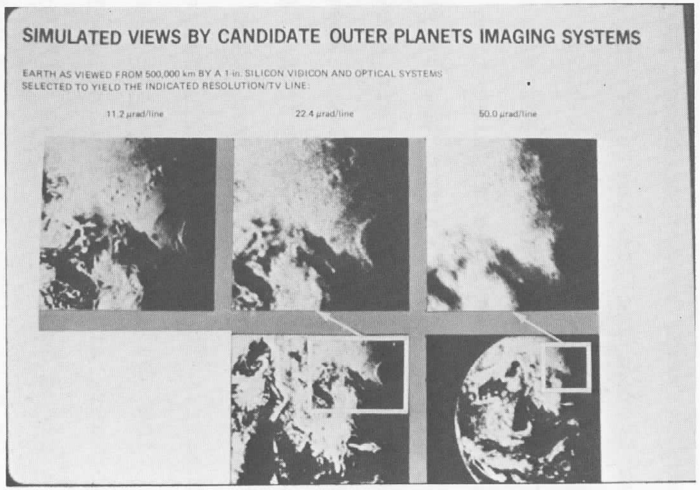


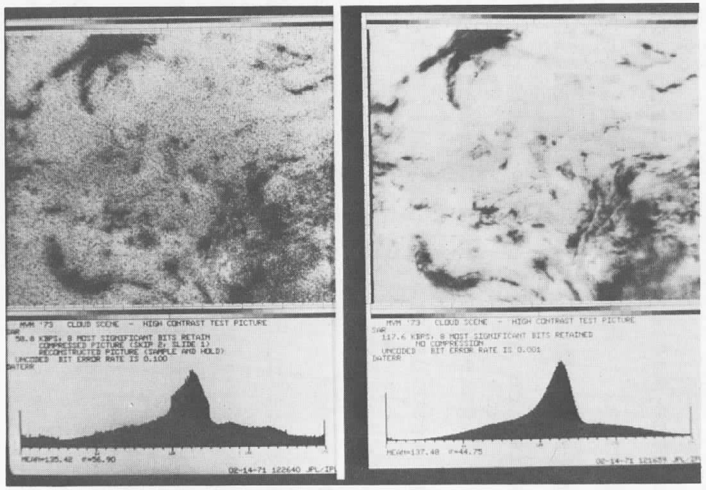
FIGURE 2.5



SIMULATED VIEWS BY CANDIDATE OUTER PLANETS IMAGING SYSTEMS

EARTH AS VIEWED FROM 500,000 km BY A 1-in. SILICON VIDICON AND OPTICAL SYSTEMS SELECTED TO YIELD THE INDICATED RESOLUTION/TV LINE:

FIGURE 2.6



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 MVM '73   CLOUD SCENE  -  HIGH CONTRAST TEST PICTURE
SAR
 58.8 KBPS, 8 MOST SIGNIFICANT BITS RETAIN
      COMPRESSED PICTURE (SKIP 2, SLIDE 1)
      RECONSTRUCTED PICTURE (SAMPLE AND HOLD)
 UNCODED  BIT ERROR RATE IS 0.100
DATERR
```

```
 MVM '73   CLOUD SCENE  -  HIGH CONTRAST TEST PICTURE
SAR
 117.6 KBPS, 8 MOST SIGNIFICANT BITS RETAINED
        NO COMPRESSION
 UNCODED  BIT ERROR RATE IS 0.001
DATERR
```

FIGURE 2.7

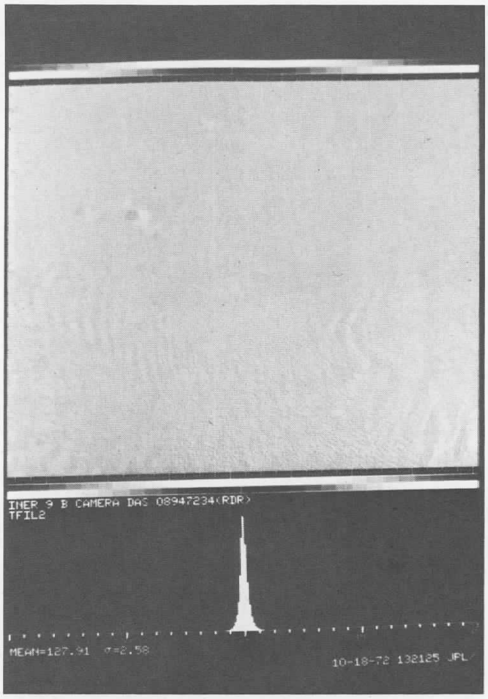
In addition to the pattern and resolution, one must consider the human brain. The brain can interpret a pattern differently, even though the basic features are exactly the same, or even if the statistics are similar, but not identical. Pattern recognition comes into play. We all know that one can detect the difference between a beautiful woman and an ugly one, even though their basic statistics are the same. That is pattern recognition.

Figure 2.7 shows two photographs taken with the same resolution (not very good resolution); it also includes a frequency distribution of the brightness of each image. In the left image, a considerable amount of random noise has been added. You can see that if the picture is large-scale and the noise is small-scale, in some regions the image information is easier to get because a false dynamic range has been created. However, if one is dealing with small-scale phenomena, then the noise is actually a detriment to picture interpretation.

We sometimes do not understand the difference between resolution, dynamic range, and sensitivity. The dynamic range implies the brightest and the dimmest part of the picture that can be captured. Figure 2.8 (taken by Air Force satellite with an exceedingly sensitive camera) enables us to see the lights of cities at night. However, you can see that in such a camera system, the dynamic range is not as great as one would like; the clouds are washed out, even though the dim parts of the picture are useful. Figure 2.9.a is an exceedingly flat image, with the brightness level plotted at the bottom. There is very little change in brightness distribution; the image looks perfectly flat. If, however, we have a noise-free system -- a very high quality camera system -- it is possible to expand the brightness range of this data (Fig. 2.9.b), and we can begin to see a certain amount of structure. If the noise is low, this can be expanded even further (Fig. 2.9.c) to get even more structure. Finally, with a great deal of expansion (Fig. 2.10), one sees an enormous amount of structure. Figure 2.10 was taken above Mars, showing waves in the clouds behind a crater. Thus, the dynamic range is very important.

The ability to manipulate the dynamic range and use parts of it is very important, and this manipulation is possible with the McIDAS system. Figure 2.11.a is a cloud image taken with ATS in the eastern Atlantic. The clouds are bright and the background dim, but by using a non-linear brightness-to-intensity-of-signal

FIGURE 2.8



```
INER 9 B CAMERA DAS 08947234(RDR)
TFIL2

MEAN=127.91  σ=2.58
                                    10-18-72 132125 JPL
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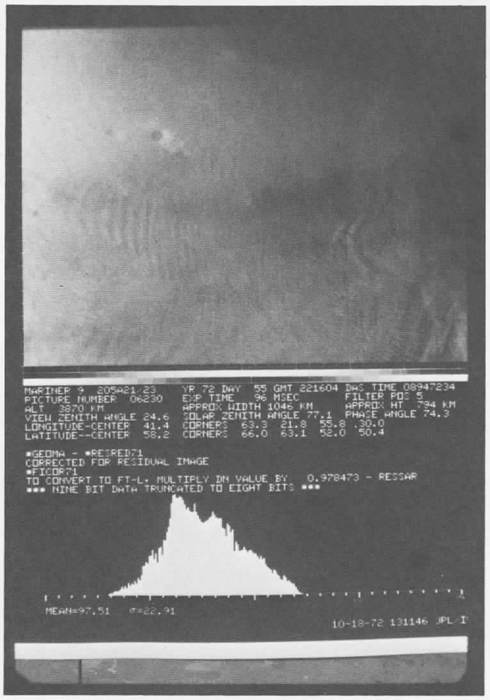
FIGURE 2.9.a



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MARINER 9  205A21/23      YR 72 DAY  55 GMT 221604 DAS TIME 08947234
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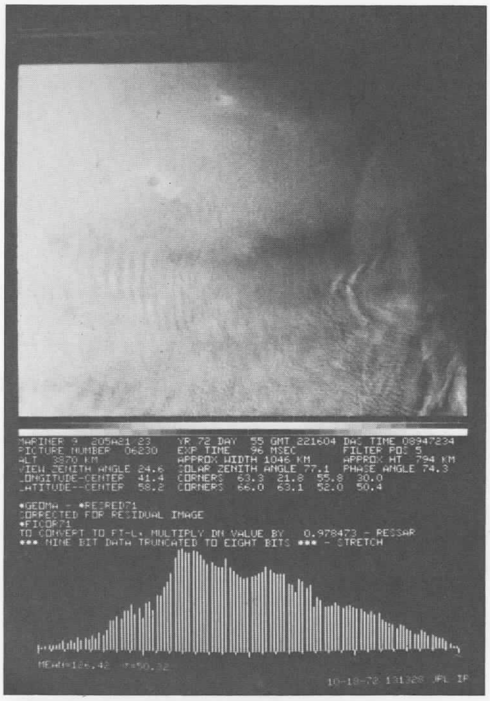
ALT  3870 KM              APPROX WIDTH 1046 KM      APPROX HT  794 KM
VIEW ZENITH ANGLE 24.6    SOLAR ZENITH ANGLE 77.1   PHASE ANGLE 74.3
LONGITUDE-CENTER  41.4    CORNERS  63.3  21.8  55.8 .30.0
LATITUDE--CENTER  58.2    CORNERS  66.0  63.1  52.0  50.4

*GEOMA - *RESRED71
CORRECTED FOR RESIDUAL IMAGE
*FICOR71
TO CONVERT TO FT-L. MULTIPLY DN VALUE BY   0.978473 - RESSAR
*** NINE BIT DATA TRUNCATED TO EIGHT BITS ***

MEAN=97.51   σ=22.91
                                    10-18-72 131146 JPL/I
```

FIGURE 2.9.b



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MARINER 9  205A21/23      YR 72 DAY  55 GMT 221604 DAS TIME 08947234
PICTURE NUMBER  06230     EXP TIME   96 MSEC        FILTER POS 5
ALT  3870 KM              APPROX WIDTH 1046 KM      APPROX HT  794 KM
VIEW ZENITH ANGLE 24.6    SOLAR ZENITH ANGLE 77.1   PHASE ANGLE 74.3
LONGITUDE-CENTER  41.4    CORNERS  63.3  21.8  55.8  30.0
LATITUDE--CENTER  58.2    CORNERS  66.0  63.1  52.0  50.4

*GEOMA - *RESRED71
CORRECTED FOR RESIDUAL IMAGE
*FICOR71
TO CONVERT TO FT-L. MULTIPLY DN VALUE BY   0.978473 - RESSAR
*** NINE BIT DATA TRUNCATED TO EIGHT BITS *** - STRETCH

MEAN=126.42  σ=50.32
                                    10-18-72 131328 JPL IP
```

FIGURE 2.9.c

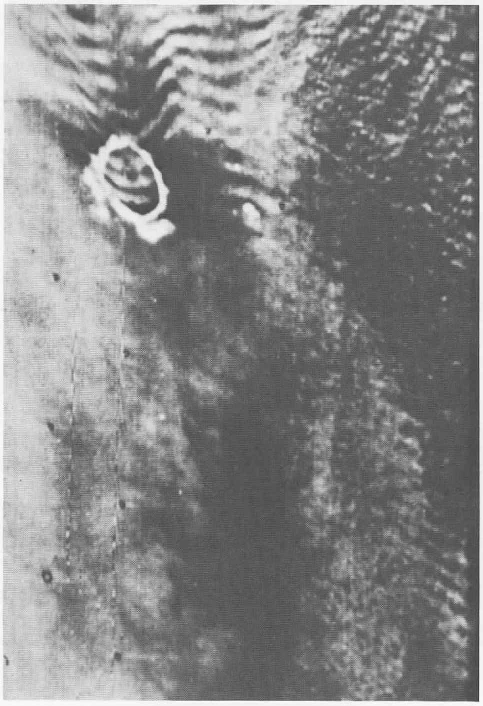


FIGURE 2.10

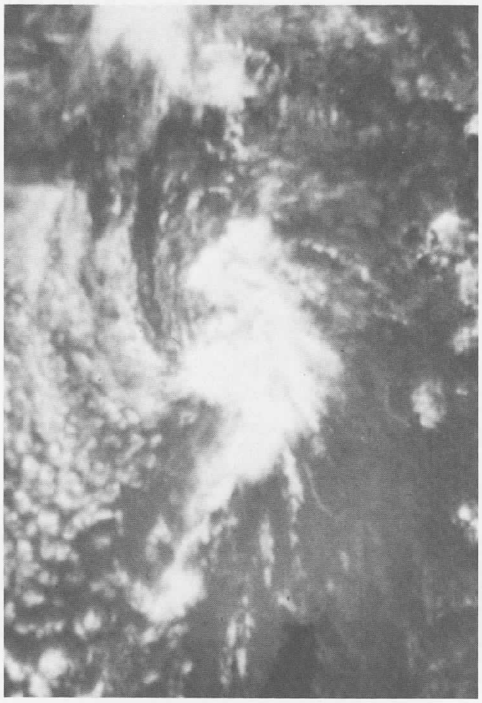


FIGURE 2.11.a

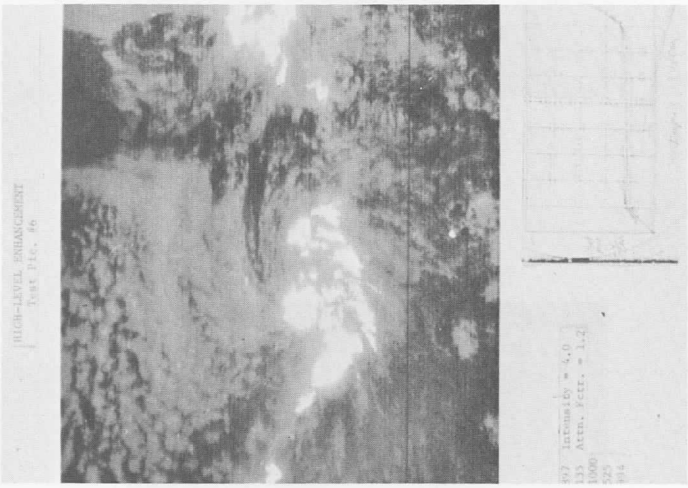


FIGURE 2.11.b

relationship (Fig. 2.11.b), it is possible to see the background material which registers on the dimmest part of the scale. The mid-range then is not used at all (it is not sensitive), and finally the very brightest part of the dynamic range is used. The brightest part of the clouds are presumably the thickest part, and you will see data later on in this workshop in which the correspondence between bright parts of the cloud (which are really the deepest parts of the cloud) and radar echoes is surprisingly high. One has a simulated radar set in the sky if one knows how to use satellite image properties.

Figure 2.12.a is another example of a fairly flat photograph. This is taken by Nimbus in the 6 point water-vapor band, and represents a series of images from a polar orbiter. In addition to the clouds, one sees the top of the moisture layer. Where the picture is dark, the moist layer is shallow; where the picture is light, then the moisture is cold and, therefore, high. I would like to show you that proper image control allows you to get quite a bit more information. Figure 2.12.b is an unenhanced picture of the Nimbus spacecraft water-vapor channel. By controlling the gain of the system through an enhancement table, we can sharply enhance the image (Fig. 2.12.c). It is also possible to use a sequence of pictures even though several hours apart, as Fred Mosher [SSEC] has done, to obtain the winds from water-vapor motion. Figure 2.12.d superimposes water-vapor winds and cloud winds, to show that there is really rather good agreement. This might be a tool of the future. Enhancement is very useful in quantitative as well as qualitative image analysis.

When one has an enormous range of brightness, one can actually reduce the resolution (Fig. 2.13.a) to save bandwidth, or one can use contours of brightness (Fig. 2.13.b), or one can combine the two and use color to represent quantity (Fig. 2.13.c).

If one has an enormous dynamic range, one can even make use of things such as cloud shadows. Figure 2.14.a was taken in the sun-glint region; note the clouds and their shadows on the bright ocean background. So, a wide dynamic range is very helpful indeed if it can be included in the system. Figure 2.14.b also shows sun glare on the ocean surface. It has been shown by Levanon in his paper in the Journal of Atmospheric Sciences that one can get the surface

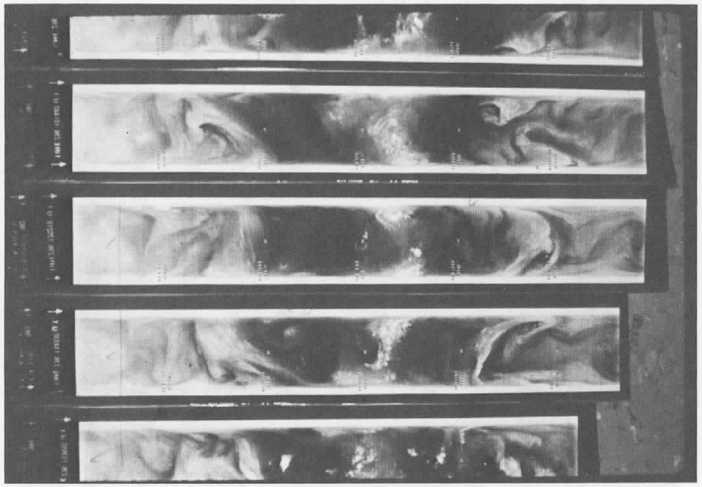


FIGURE 2.12.a

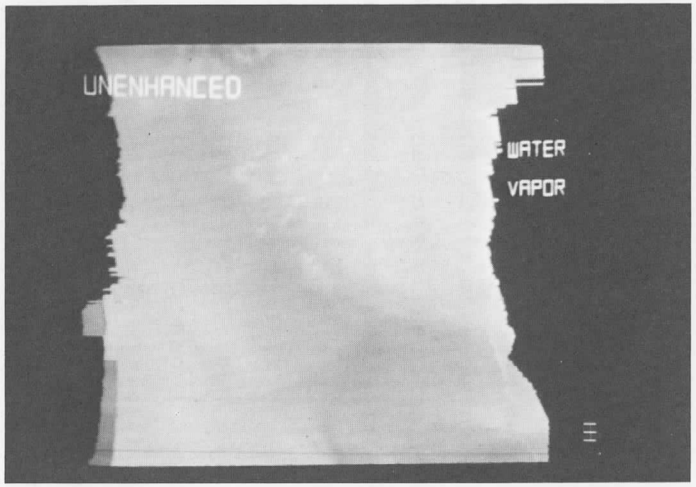


FIGURE 2.12.b

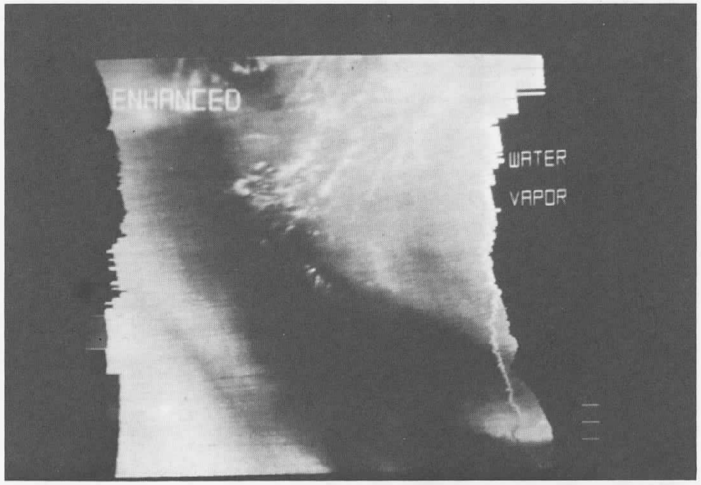


FIGURE 2.12.c

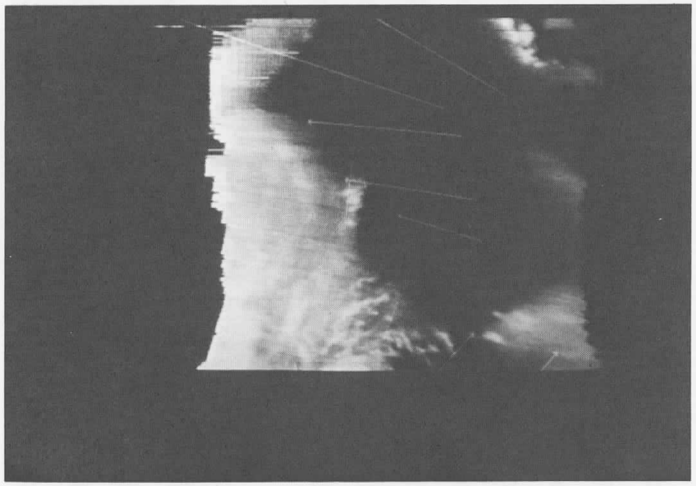


FIGURE 2.12.d

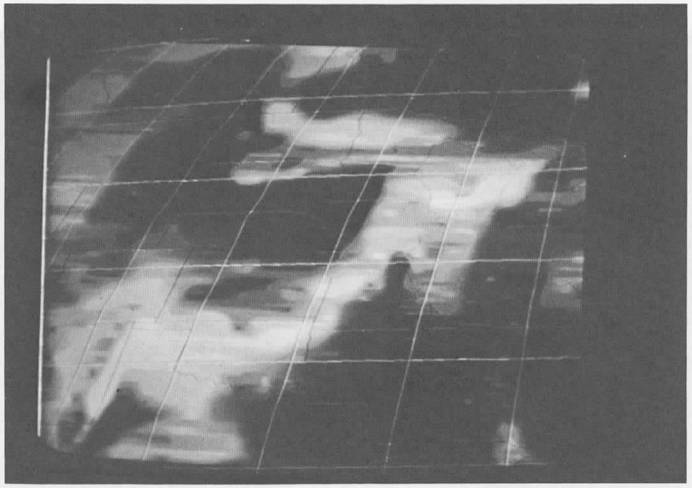


FIGURE 2.13.a

FIGURE 2.13.b

SEE APPENDIX A
FOR FIGURE 2.13.c

FIGURE 2.14.a

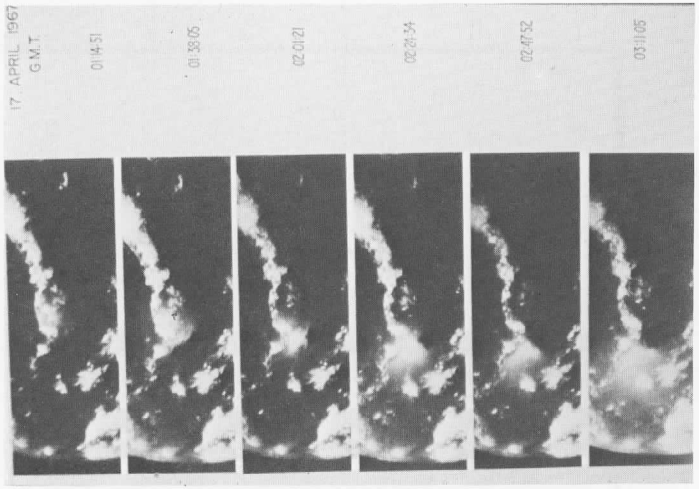


FIGURE 2.14.b

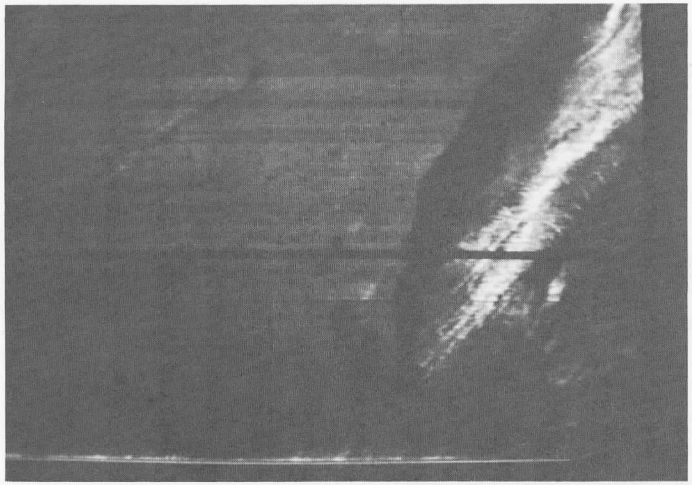


FIGURE 2.15.a

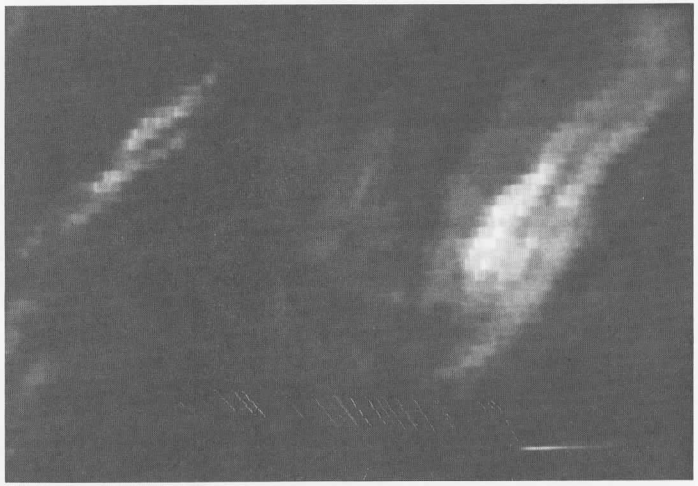


FIGURE 2.15.b

wind speeds (not the surface wind velocity) from sun-glitter analysis, based on the work of Cox and Monk in the late 1950's. So it is possible to use just the brightness on the ocean surface to get surface wind.

Figure 2.15.a is a visible wavelength image of Wisconsin; you can barely see some clouds. Figure 2.15.b is an infra-red image of cirrus cloud formation over the midwest; notice how much more clearly the clouds stand out. By using different wavelengths for our analysis we can bring out image properties of interest. But in the use of different wavelengths, we also must use a different resolution, and degraded resolution takes away some of the information we might like to have. By analyzing images in several wavelengths -- including high-resolution visible images -- it is possible to gain a great deal of information on cloud systems.

Figure 2.16.a is an image created by Bill Smith's Nimbus sounder [the HRIS, High Resolution Infra-red Sounder], measuring (in one of its several wavelenths) the brightness of a part of the image shown in Fig. 2.16.b. The sounder uses this information in various wavelengths to deduce the amount of cloud present, and then makes corrections to the sounding. By combining brightness information and sounding information we can greatly improve the quantitative aspects of the sounding information.

This concludes my discussion on the treatment of quantitative aspects of the image to extract the maximum amount of meteorological information.

QUESTIONS AND ANSWERS

Q: What kind of an evolution do you see for video graphics systems?

A: In just three or four years microprocessors have become very economical and more powerful, so it is possible to separate the number-crunching tasks from the terminal display tasks. Display terminals are "smart" rather than "dumb," and by devoting a separate computer to their control, the load on the central processor is very much reduced. As I see it, future systems will be simpler and less expensive, but more powerful. At a symposium like this, I think we should be addressing wider, overall questions, because software development is the key. We don't have a monopoly on software development here in Madison; it exists in other parts

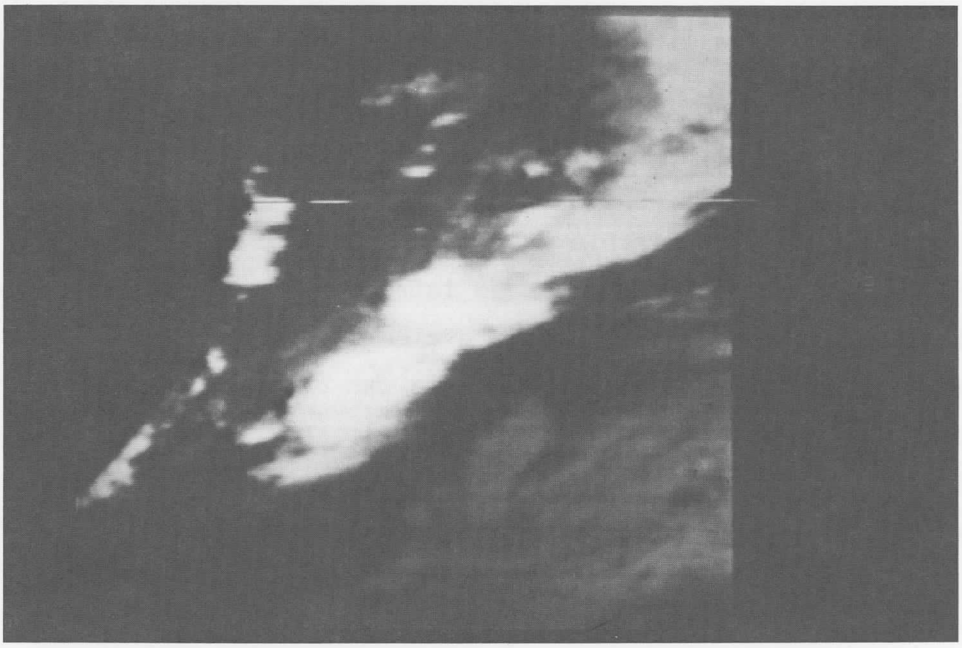


FIGURE 2.16.a

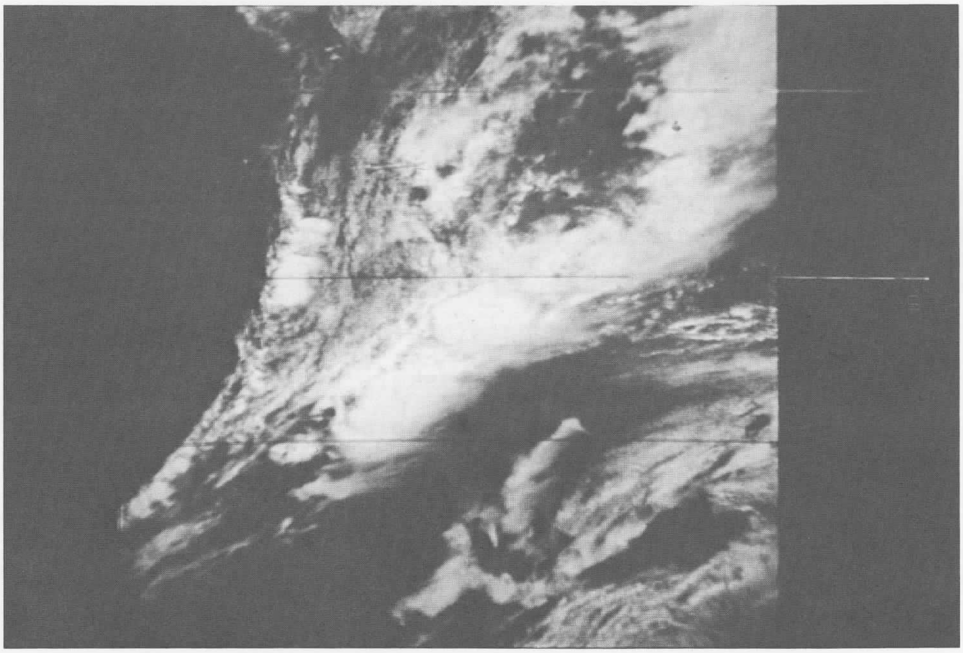


FIGURE 2.16.b

of the country, as well. Some notion of standardization would be useful so that the total community could contribute to the development of display systems.

We are planning, in the next two or three years, to use roughly the same kind we have now, but to add sounding data as well, as part of the VAS [VISSR Atmospheric Sounder] system being developed by NASA and NOAA for flight in the 1980's. In fact, six people from NOAA will be coming to SSEC this summer to work with us on VAS. In the future we hope to be able to display vertical structure of the atmosphere -- temperature, moisture and wind, not just clouds -- in real time.

Q: Can you comment on the portability of the software?

A: There are certain aspects of the system software which have to be tied to a particular computer. I am sure a session tomorrow will deal with the applications software, which is written in ordinary FORTRAN. I think that part is also portable. John Benson [SSEC], who created much of the software for McIDAS, is in Germany now, trying to adapt it to another computer system, so I would say that it is portable to some extent. Perhaps that is one of the important questions we can address at this symposium.

PENN STATE TEACHING APPLICATIONS

Dr. John Cahir

I'm going to show you a few things that we are doing at Penn State with a system that's less expensive than McIDAS. One reason we can keep our costs down is that we do not deal with the very high data rates and the tremendous amount of information that Dr. Suomi just showed in satellite pictures. We keep the satellite information out, and deal just with the other meteorological data. I should point out, however, that we do have a Litton Datalog so that we can check satellite pictures simultaneously, and we find that useful. Figure 3.1 shows our system, which includes a PDP 11 Model 10, a tape drive (on the right), a DECwriter, a Tektronix CRT system for display and a hard-copy device. This system represents an investment of something less than $50,000.

The data come in on a line from the FAA (Federal Aviation Administration), that is the same as the one used here at the University of Wisconsin. It is the

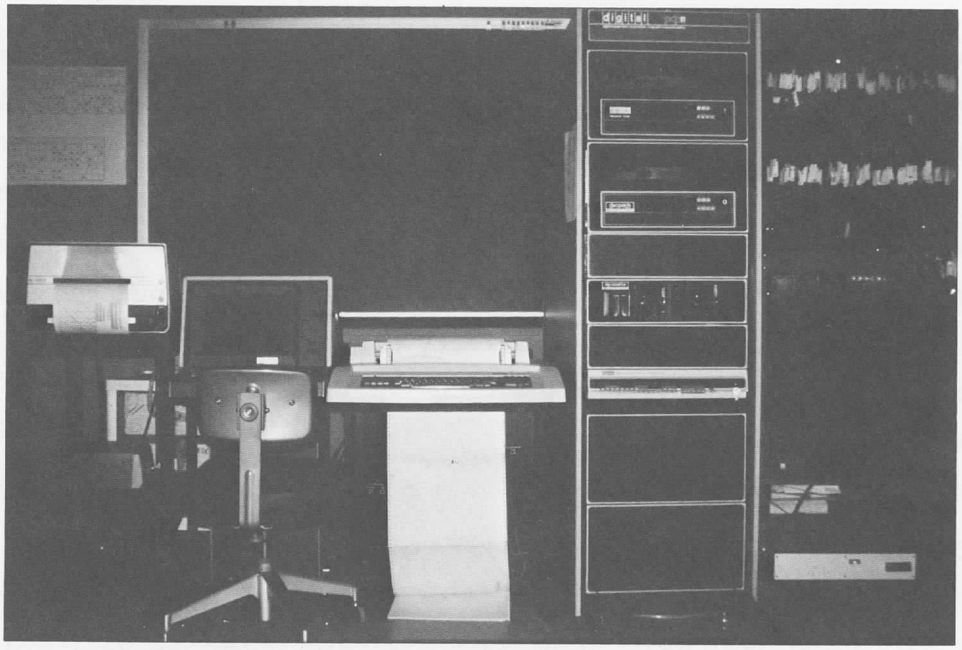


FIGURE 3.1

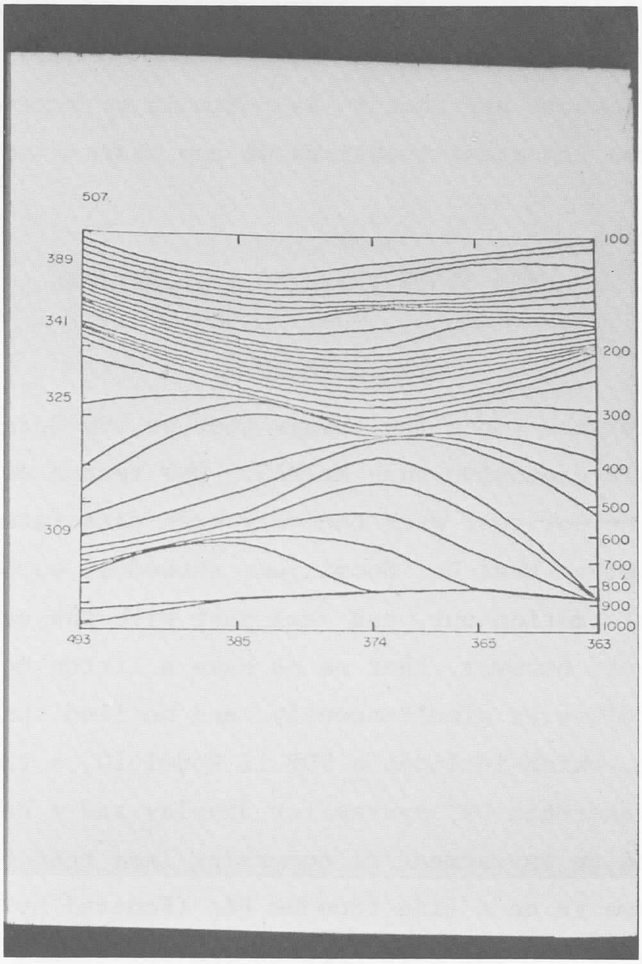


FIGURE 3.2

medium-speed, 1200-baud line, which is a combination of Service A, Service C, and Service O; we find that the cost of that combined service is actually less than those services taken separately. We decode the TTAA part of the radiosonde message, the significant level data. (Some of you may have noticed how often the significant levels seem to occur at 500 milibars, 700 millibars, and so on.) We also decode the hourly airways data in a manner similar to the way Tom Whittaker described.

I am trying to limit my discussion to what we do in our synoptic laboratory. We have chosen to emphasize the cross-section analysis technique that was asked about earlier today. We are not restricted to that, but we think that any new system ought to give some new kinds of products, if only for psychological reasons. But I think that there are even more things that we can do. I have about a thirty-page problem set that I give students to familiarize them with the use of cross-sections. Figure 3.2, for example, represents a case in which there was a big storm in northeastern Nebraska, a cold outbreak over the Rockies, an upper-trough in the northern Rockies and a strong jet-stream across the southern plains. Note the very pronounced front linked up with the stratosphere. You can see the very stable stratosphere in the cross-section, a very mixed and windy troposphere below the upper front, and a very strong jet stream associated with this feature.

Now, I give this to my students and they have to root their way through the cross-section to determine the lapse rates in different regions, the vertical shear of the wind, the regions of high and low humidities -- structural questions to get them used to cross-sections in which the potential temperature is a principal variable. Then we bring that into the classroom. We can decode the synoptic data, the upper-air data, in real time, by about 10:30 a.m. (Eastern Time) and have those data ready for cross-section analysis anywhere in the country. We use the isentropic cross-section because Mel Shapiro and Gordon Hastings at NCAR (National Center for Atmospheric Research) developed a very nice algorithm using Hermite interpolation for getting quite accurate potential temperature cross-sections; it is quite adequate, since we have no superadiabatic lapse rates at the stations. The interpolation involves calculating the slope, so you get a fairly good value in between.

Figure 3.3.a is an upper-air chart showing a strong trough running north-south across Arizona. Figure 3.3.b, the surface map, shows a very well developed surface low down in New Mexico, and a strong northerly flow over the west. A cross-section taken at the same time as those maps (Fig. 3.3.c) shows the very stable stratosphere. The tropopause practically jumps out at you, and the upper front is recognizable extending over toward station 493 (San Francisco), with the cold air mounding up over station 374 (Winslow).

We can also calculate and fit by regression techniques the reported winds associated with that structure, which I find very useful in teaching about the thermal wind. Figure 3.3.d is a cross-section looking almost straight north, with the plus 100 knot winds from the south to the right. The isentropes slope shows warmer temperatures to the right; the cold air is in the middle at zero wind speed, then plus 100 knot winds out of the north are to the left where the isentropes slope the other way. (You could overlay them, but I won't do that now.)

In Figure 3.4.a, the upper front is mounding up over the cold air. It seems to me this technique can show some mesoscale structures; at least the hyperbaroclinic zone is something like a mesoscale structure. Figure 3.4.b for the same day, shows a little more detail, a cross-section from Lander down to San Diego (Station 572 to 290). Note the cold front well off to the south of San Diego, but well shown in the upper air features. Figure 3.4.b also shows the associated winds, with the jet stream actually south of San Diego with speeds greater than 70 knots, with actually some easterly flow at Lander.

We can calculate and display the shear of the wind and calculate from that a Richardson number. Figure 3.5 is an analysis of the Richardson number for the preceding case. Regression techniques, as you know, sometimes extrapolate to ridiculous values; the values are a little bit low at the bottom, and go below zero up in the very strong negative shear region above the jet stream. But such a chart does show students where clear-air turbulence is likely, for example.

I try to get the students to actually work with the cross-sections, run *them up in real time and use them in map discussions that we give at the end of* the lab each day. [They give the lab.] They give the map discussion, and we argue a little bit about what we are seeing. It gives you an opportunity to deal with the current weather in an interesting way, without getting hung up on

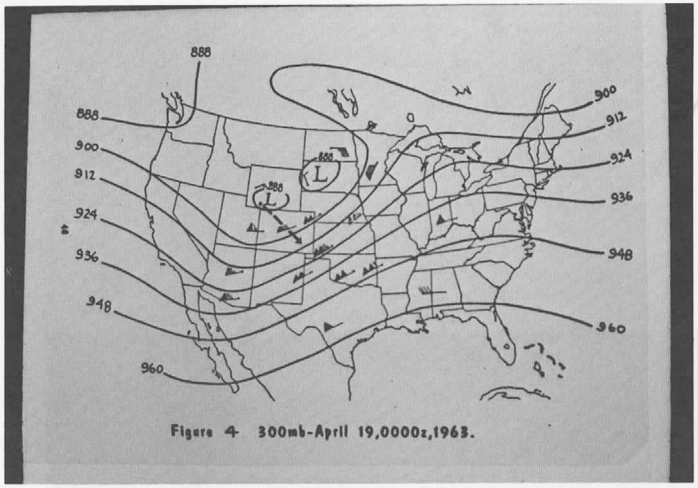


FIGURE 3.3.a

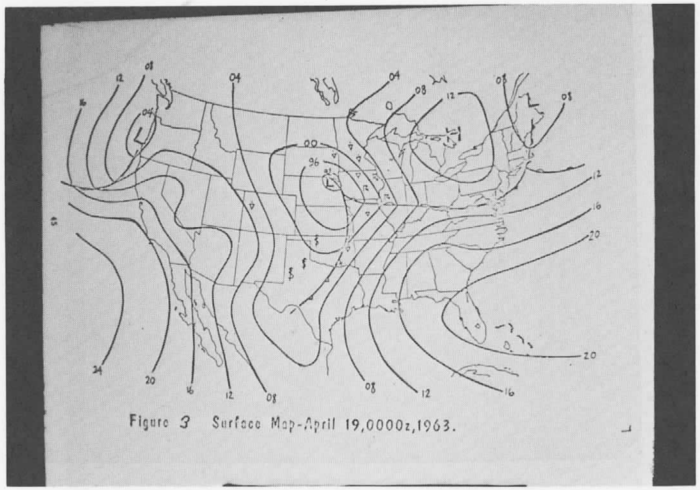


FIGURE 3.3.b

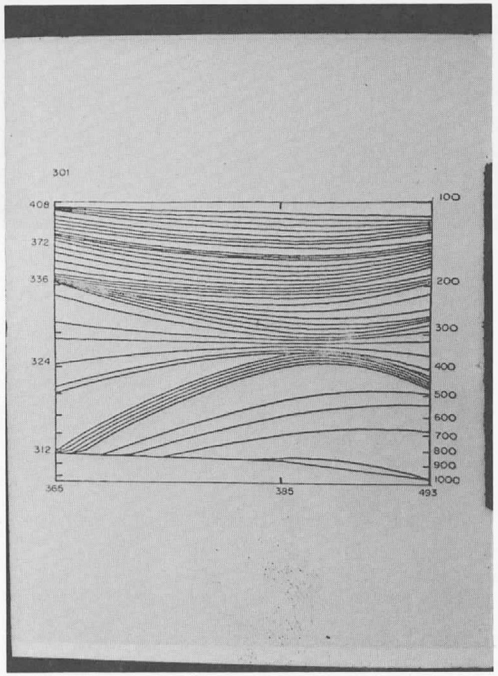


FIGURE 3.3.c

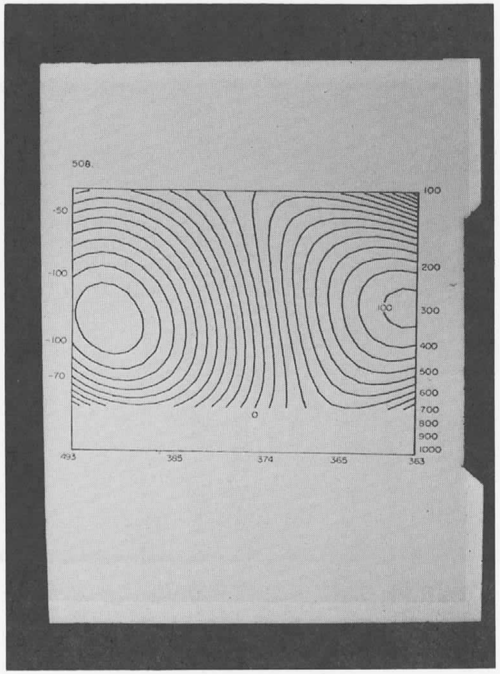


FIGURE 3.3.d

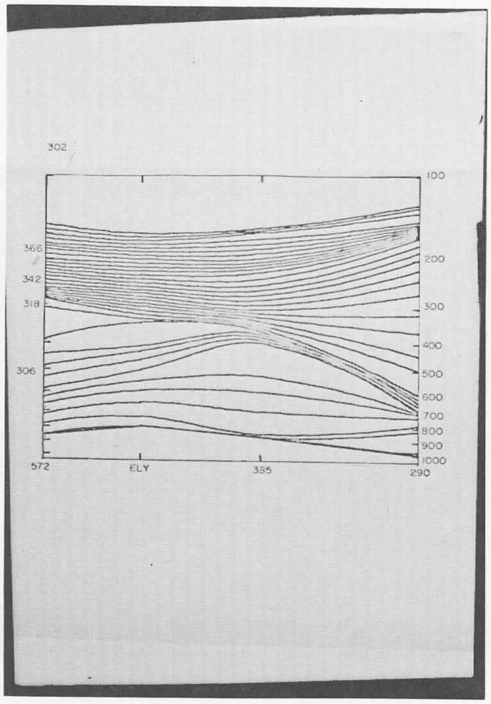


FIGURE 3.4.a

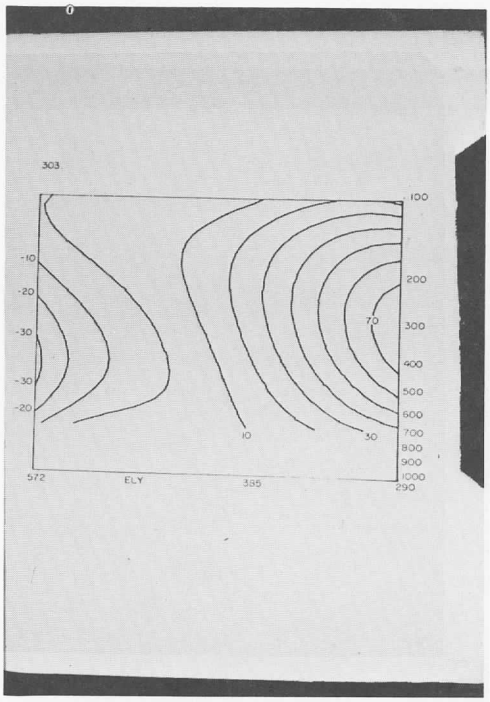


FIGURE 3.4.b

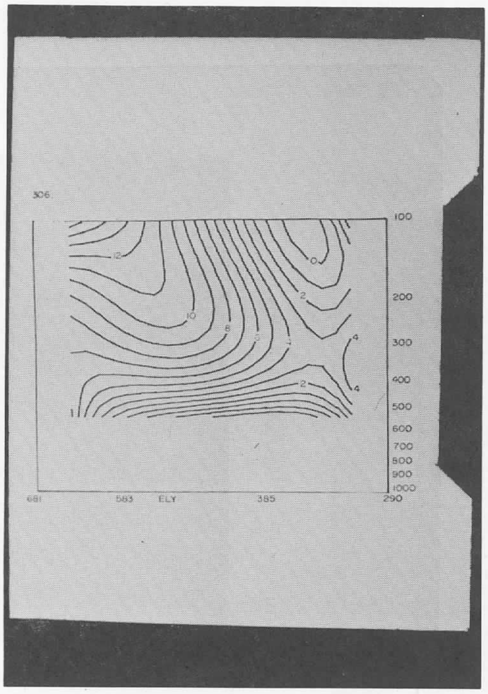


FIGURE 3.5

forecasting so much. You focus more on the actual structural details of what is going on, comparing it to existing models, seeing where the models may not be working well in a particular situation. Naturally, students make mistakes when they do this, and I encourage them to make mistakes. I think that questions about structural aspects can be very useful, and even the mistakes can be instructive.

We can do other things, as well; we can analyze moisture fields and make soundings, for example. I've made a videotape to show some of these other techniques, and to show how our less expensive system operates in real time.

[Professor Cahir narrated a video tape describing, first, an interactive sequence for forecasting fog. One calls up a station or teletype data, gets a bit of programming instruction, and then enters the current temperature and dew point and the expected wind speed for the coming night. To obtain a predicted minimum temperature for the next morning the operator also inputs values (on a 1-to-10 scale) of expected high, middle and low cloudiness. The computer then generates a predicted low temperature for the next morning, which the operator can compare to the present dew point in order to predict fog. After-the-fact comparisons with satellite pictures can be helpful in learning to use the computer technique.

In a second application the Penn State system can plot (in 2-4 minutes) isentropic cross-sections between any stations of interest to show atmospheric humidity. Data from each station (surface or upper air data) can be listed, along with the plot, so the operator can check for anomalous data. (The program can process and plot early morning observations for use in making forecasts for that same afternoon and evening.)

The system also allows the operator to ask for plots of soundings at any individual station of interest, or for interpolated soundings between any two stations. The sounding program also lists the potential temperatures, relative humidities, and winds at various levels to provide a quality control check of the plot.]

To conclude, I would say that there are ways for a university to include a less expensive system in its teaching program, to process real time data, and to get cross-sectional analyses for lab use and discussion. Such a system, however, is most successful when satellite images can be studied, as well, on a TV screen. I think the best systems are those that link the two methods of presentation.

QUESTIONS AND ANSWERS

Q: What are your system's hard-copy capabilities for cross-section plots?

A: To get copies of the plots I showed, we use a little hard-copy device; you just press a button and make it. It's quite inexpensive.

COMMENT (Dr. Suomi):

I think that the inclusion of prompting on your display screen is a very valuable educational tool. It allows a kind of "talking" to the computer that is different from our McIDAS system.

A: Yes. One gets surprises in that prompting process that can be quite instructive, even if one is the instructor.

III. OVERVIEW OF RESEARCH APPLICATIONS

Dr. Donald R. Johnson
Department of Meteorology
University of Wisconsin-Madison

Video-computer graphics for research applications are in an initial stage of development. In some sense, the system has been born, but it's only beginning to crawl. To place things in perspective, I would note that the attendees at the Workshop and my colleagues at the University of Wisconsin are a collection of theoreticians, diagnosticians, experimentalists, numerical modelers and other scientists. It's an interesting collection of talent. We all have a common interest in the atmosphere -- a very complex, dynamic three-dimensional system -- and we welcome technical developments that will help us analyze and understand atmospheric structures and processes. With computer-video graphics theoreticians are learning to evaluate models by comparing predictions with the real atmosphere in attempts to increase our understanding of the dynamic evolution of atmospheric structures. Diagnosticians are learning to use these systems to look at the atmosphere to isolate valuable ideas and apply theory. Such efforts and systems should ultimately have an impact on research itself by expanding its scope, breadth and depth.

I think the ultimate impact will be in the classroom. We are now training a new generation of atmospheric scientists who will view our systems with a lot more insight than we do. I ask that each of you think and dream a bit about how video graphic systems might be used to meet your research needs. I think it's important that such systems be used and developed in a university setting, where new research ideas and concepts can be transferred directly to the classroom.

McIDAS RESEARCH APPLICATIONS: AN HISTORICAL APPROACH

Dr. Verner E. Suomi

In the development of McIDAS we found that certain research applications required a particular capability. We developed that capability and then found that it allowed one to do other things as well. I would say that McIDAS was not designed for teaching alone, or for routine work alone. It was designed basically as a research tool, and so it has a considerable amount of flexibility.

In designing our McIDAS hardware we drew heavily on the talent and imagination of the people in our College of Engineering, and I would suggest that you make use of the same talent on your campus. Our system is, in large part, a tribute to our engineers; they argue a lot, they debate, but they work hard and get things built. And now, let me show this videotape.

[Dr. Suomi narrated a videotape demonstrating some of the research applications of the McIDAS system. The major points from his commentary and notes about the videotape follow.]

The first sequence shows how one can vary the resolution of the image, shifting from a full-disc picture of the earth to a much smaller region of interest. McIDAS is seldom used to study full-disc images. As noted earlier, the key to image analysis is the navigation process -- eliminating the effects of spacecraft motion and changes in spacecraft orientation to produce an aligned loop of images in which the geography remains stationary.

Once the image is obtained, a cursor is used to delineate smaller sections of the large image. Then we can tell the computer to find the same data subsets on its digital disc and to correlate the image pieces to find out how far the cloud has moved during the time interval between the pictures. Changes in the position of the clouds in two sequential images are an indicator of wind speed; this was actually the first research use of McIDAS. The digital data which describes the wind can also be plotted as a field of numbers, and the numbers can be displayed over the vectors which we just found from cloud motion. They compare very well.

The same naviagation scheme applied to satellite images can also be applied to facsimile chart data. Weather radar data from the Neenah, Wisconsin station can be put into McIDAS, for example, and by using the same wind calculation scheme, one can predict the motion of radar-echo disturbances. The radar data can be superimposed on satellite cloud images -- a technique that has been used to combine surface-ship radar data and satellite cloud image data gathered for GATE (GARP Atlantic Tropical Experiment). As noted earlier, there is a strong correspondence between the radar echoes and the brightest areas of the clouds.

It is also possible to make quantitative measurements of the area of radar echoes or cloud images, by concentrating on those areas exhibiting a particular brightness level. One can measure the growth in area of the cirrus cloud field, and by using the method of measuring cloud thickness developed by Fred Mosher [SSEC], one can estimate the quantity of precipitable water in the storm. Dr. David Martin [SSEC] has done much work in the area of GATE rainfall estimation based on analysis of cloud growth. Michael Fortune [a graduate student in meteorology, UW-Madison] has studied the growth of storms over Africa using this same basic technique. From the technique for measuring winds we have learned to measure divergence and, to a limited extent, vorticity.

In cloud system analyses like the ones described above, one can alter the coordinate system at will, to keep either a geographic feature or a cloud feature stationary. Fortune made excellent use of this capability in his Master's thesis on African squall systems, keeping a storm system stationary to examine internal cloud development.

Professor James A. Weinman [Department of Meteorology, UW-Madison] used McIDAS in another application, processing information from a high-intensity laser radar to examine the properties of a vertical cross-section of the boundary layer. In this application, as in others, the ability of McIDAS to enhance the displayed data was very helpful.

McIDAS has also been used by Robert Madding [Institute for Environmental Studies, UW-Madison] to display and analyze data from an airplane-mounted infrared scanner. One survey in early 1977 pinpointed rooftop heat loss from buildings in the Beloit, Wisconsin area. By using such multispectral analysis one could also isolate wetlands, rivers, wheat fields or other features of interest.

Dr. Sanjay Limaye[Meteorology] and Robert Krauss [SSEC] have used McIDAS to study the motions of the atmosphere of Venus, using images transmitted from fly-by spacecraft. The computer not only enhanced the contrast of the images to aid analysis, but also allowed researchers to manipulate the image coordinate system to study features of interest and to construct images of the planet's polar regions.

It is important, as part of this symposium, that we start to deal with the problem of software exchange. It is not going to be possible for everyone to use the same system, nor should it be. But if we can solve the standardization part of the software, then whatever one group creates will be available to others.

I would like to make a few closing remarks. First, McIDAS was designed for research. It is a flexible system, and, considered totally, it is an expensive system. If one were to start again from scratch, one would certainly design it in a different way, as we will hear tomorrow from my engineering colleagues. Second, one application begets another. One uses a program in a certain instance, then discovers it can be used in another instance as well. The power of the system really comes from many people using it, not one individual or one dreamer. It's a "people project," and if we can work together, its power will be enhanced.

QUESTIONS AND COMMENTS

Q: Can the navigation scheme be used on any spacecraft image data?

A: The basic navigation program will work on all spacecraft. It is based on the laws of motion, so it will work if you use the appropriate parameters -- distance from the planet, gravity, and so on. It is not the most sophisticated planetary motion program. It does not take into account, for example, the changing mass distribution. But for purposes of image consideration, it could be any planet.

Let me explain this navigation scheme a bit more. We did not assume (as other researchers did) that a geostationary satellite never moves. Some motion always occurs, and we realized that if it moved even one kilometer, it might as well move 1000 kilometers; the physics of the problem created by such motion is the same.

We solved the problem by devising a navigation scheme based on the orbital dynamics of the spacecraft, and found that our data throughput increased enormously. Sequential satellite images could be fed into McIDAS already aligned and ready for analysis with no further pre-processing needed.

We have also found that, with slight modifications, the same navigation technique can be applied to image data from other earth satellites or planetary probes.

Let me give one example where this navigation capability is important. If one has properly navigated photographs, one can take two adjacent pictures and say to the computer: "Remember the dimmest portion." Then, using a technique developed by Fred Mosher [SSEC], McIDAS removes all the clouds, permitting study of the albedo of the earth. If one examines the brightest portion, then one can look at the maximum cloudiness.

This ability to deal with images quantitatively is the heart of the McIDAS system. With hard-copy pictures, one can only perform qualitative study. But one must be quantitative. For example, if you have many views of the same planet from different angles, that is the same as having different initial conditions, so you can make use of the phase function. Navigation, which is buried deep in the software, gives great power to each of the observations. For instance, Dr. Limaye took fly-by images of Venus and rearranged them to get a view of the planet's polar vortex. Information is so much more useful when it can be manipulated in a quantitative way.

study. But the rest is organization. For example, if you have many views of the same planet from different angles, what is the same as having different natural conditions, so you can make use of the whole function. Navigation, which is buried deep in the software, gives great power to each of the observations. For instance, Dr. [illegible] took thirty-images of Venus and rearranged them to get a view of the planet's polar surface. Information is so much more useful when it can be manipulated in a quantitative way.

OCEANOGRAPHIC APPLICATIONS OF SATELLITE IMAGE ENHANCEMENT SYSTEMS

Dr. Robert Evans

Division of Meteorology and Physical Oceanography
Rosenstiel School of Marine and Atmospheric Sciences
University of Miami

At the University of Miami we have been principally interested in applying image processing techniques in areas of physical oceanography, but as the affiliation indicates, our division title is now Meteorology and Physical Oceanography, following the merger of those two divisions. In fact, one of our interests is to combine applications in oceanography with some of the applications in atmospheric sciences.

Our user group at Miami presently consists of two scientists and two programmers. Our experience with processing problems, data flow and equipment is probably analogous to that of any small scientific user community. Quite early we realized that although the hardware is certainly an integral part of the system and that it, to some extent, determines analysis techniques, software is also very important. We have been involved in satellite remote sensing data analysis for about two years, but our image processing hardware has been on-line for about six months. Initially we used electrostatic printer-plotters for data display, but the products of these units were clearly inadequate for the intended functions and for the volume of data that had to be processed. The need for an image display system quickly became apparent.

In the six months the system has been on-line, over 100 hardware commands have been implemented. The following examples will illustrate some of these. This presentation will be divided into two areas: an overview of display system utilization, and then some scientific applications. This is far from a complete description of all that is being done, but it will at least give you some idea of our work.

The image display (Fig. 4.1) is broken down into four sections: satellite image processing, graphics, color contouring, and (since our system is solid state and fully bi-directional) the refresh operation. This refresh -- implemented as a large solid state memory -- is also available to the computer, and has a wide range of applications itself.

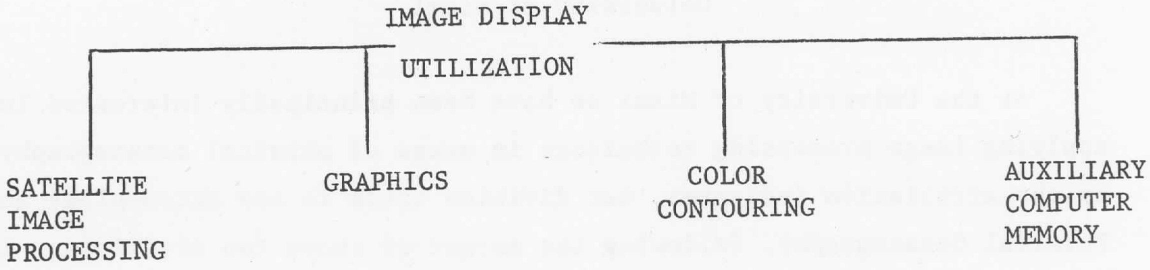


FIGURE 4.1

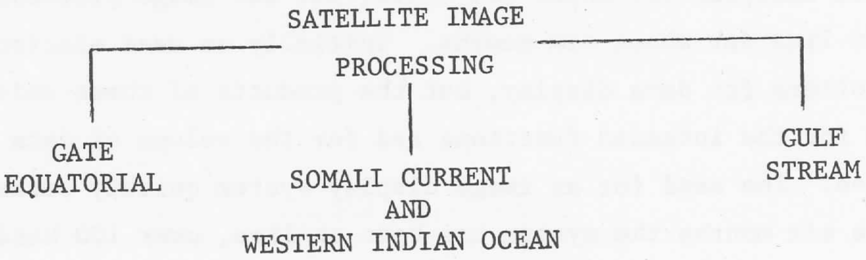


FIGURE 4.2

Satellite image processing (Fig. 4.2) supports three specific program areas: the GATE equatorial area, the Gulf Stream, and (our principal area of investigation at present) the Somali Current in the West Indian Ocean.

Some of the graphics applications (Fig. 4.3) include generation of classroom material such as I am using today. Using the graphics display and a meta language that was developed by our group for slide making, it took about two hours to prepare both this presentation and the one I'll give this afternoon.

The color contouring applications (Fig. 4.4) are not related strictly to satellite image processing; they are used to present data more effectively from a number of oceanographic instrumentation sources. The infrared imagery can also be color contoured, and is used to prepare time- and space-series of various satellite images.

As an auxiliary computer memory (Fig. 4.5), the image display can also be used to perform large sorts and actual computations on the image data themselves. Loading an image into the machine each time a manipulation is necessary slows down processing due to I/O overhead time. If a digital picture is available to the analyst all the time -- and in our system it is, via the solid state memory -- processes such as spatial filtering, histogram construction, rectification and convolution can be done quite rapidly.

Shifting to some scientific applications of image processing, let me start by offering the opinion that satellite remote sensing was quite oversold to the oceanographic community. Early applications were not satisfactory. Let me first provide some background about why satellite imagery works in our particular applications.

Our prime research area is the West Indian Ocean; this study is a component of both FGGE and pre-FGGE, under the aegis of INDEX and MONEX. At Miami we are conducting a three part program (Fig. 4.6). Ships of opportunity -- coastal freighters, tankers, Navy ships and the like -- launch XBT's and put other instrumentation over the side to establish ground truth data for comparison with satellite imagery. Moorings are sited off the coast to measure current, temperature and pressure at a number of discrete points. Finally there is the remote sensing program component.

Satellite remote sensing becomes extremely attractive in view of the logistical problems surrounding surface observation operations. The remote sensing studies are aimed at understanding the response of the Western Indian Ocean to seasonal variations in monsoonal forcing. The Western Indian Ocean

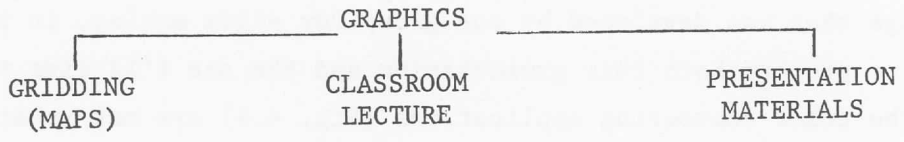


FIGURE 4.3

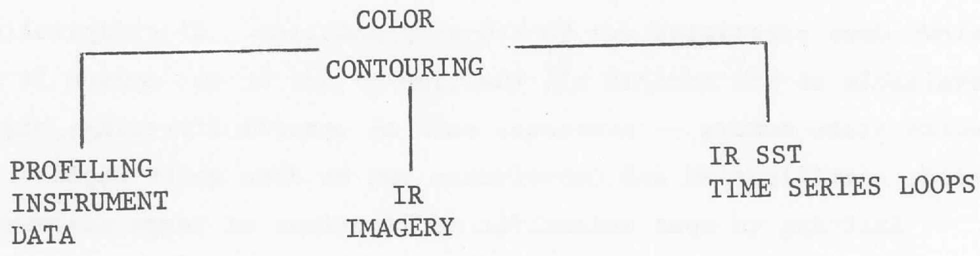


FIGURE 4.4

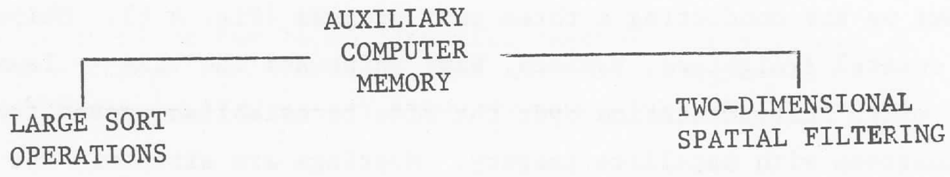


FIGURE 4.5

EXPERIMENTAL PROGRAM

(PART OF INDEX)

* SHIPS OF OPPORTUNITY - Coastal freighters, tankers and Mo
Mombasa Base

* MOORINGS - Current/temperature recordings off Kenya and Somalia. Great difficulties logistically (no ships) and politically.

* REMOTE SENSING - At the moment, predominantly sea surface temperatures.

FIGURE 4.6

SUMMARY OF KEY FEATURES

1. Evolution of current and temperature fields over a very short time span (a few weeks or months) involving stront temperature gradients and very intense currents.
2. Existence of large-scale eddies of about 500 km diameter (mode eddy about 100 km).
3. Occurrence of large-scale oscillations with time scales of 30 to 50 days.

FIGURE 4.7

WHY SATELLITE REMOTE SENSING?

1. No logistical and political problems.
2. Synoptic mapping of large areas (impossible or too costly with ships) - particularly well adapted to large-scale eddies study in the Arabian Sea.
3. Synoptic and frequent observations of mesoscale areas with large-scale temperature gradients and upwelling regions - particularly during the rapid monsoon-onset period over an extended area.
4. Acquisition of long-period time series data.

FIGURE 4.8

acts as a prime heat storage and transfer area for the world's atmosphere and oceans during Northern Spring. Comparison of rough calculations of heat exchange with satellite measurements shows that from 10 to 25 percent of the world heat budget is accounted for in the morthwestern Indian Ocean. In addition to the significant effects on the heat budget and cross equator heat flux, the southwest monsoon also is a primary cause of the Somali Current.

The Somali Current (Fig. 4.7) is a unique seasonally reversing low-latitude (equator-crossing) western boundary current. Observation of spin-up from one year to the next gives an opportunity to study the dynamics of the process and to extend this knowledge to other areas of the world. The evolution of the current is extremely short (on the order of weeks), and takes place over an extended geographic area. The spin-up is associated with extreme changes in the current, temperature and height fields. For now, the satellite remote sensing program consists of sea-surface temperature analysis. The area of analysis is 40°E to 70°E, 10°N to 25°N. Many large eddy features have been observed in the Western Indian Ocean, some extending north-south for some 500 kilometers, whereas a typical MODE eddy in the Atlantic Ocean, for example, has a scale of 100 to 200 kilometers. The ocean responds quite rapidly to the monsoon on large scales, which makes observation of these features very difficult with a ship or a fixed instrument program.

Why use remote sensing? First, the features of interest to us (Fig. 4.8) are very difficult to observe with ship-based or fixed instruments. Second, there are no serious logistical or political problems attendant to satellite observation of the Western Indian Ocean. Third, frequent satellite coverage permits development of time series over sufficiently long periods to study the evolution, the steady state and the demise of features of interest.

As an example of this application, I would like to present a series of slides, taken from a movie loop illustrating the onset effects of the southwest monsoon on the sea-surface temperature field. Fig. 4.9 shows East Africa and the Gulf of Aden, with the Somali current along the coast. Displayed in the top panel are the sea-surface temperatures, color coded in such a way that white is the warmest, through the blues, to green as the coldest. Viewing the slide sequence in Fig. 4.10, you will notice several things. One is the intense development of the blue areas, showing the characteristic large scale monsoonal cooling of the Western Indian Ocean. The green that appears along the coast indicates upwelling induced by local winds and offshore advection of surface waters by the Somai Current. In the bottom panel of the

SEE APPENDIX A

FOR

FIGURES 4.9 and 4.10

figures is a retrieval conficence interval, which is a measure of the confidence of a good retrieval at the corresponding location in the upper panel. This data is taken from the NOAA scanning radiometer polar orbiter, based on a 0.5° latitude-longitude averaged square. The confidence level, based on the number of actual retrieved pixels in each of the 0.5° square averaged areas, is indicated by the intensity of red in the bottom panel.

To display a movie loop on our system, the image display memory is subdivided into a number of segments (in this case, sixteen). Each daily image is magnified to fill the screen and then the loop selects each of the subimages over some time interval. Figs. 4.11 through 4.18 show how the color changes from white (quite warm) to a deep blue, toward green; this represents a cooling of about 4 to 5°C.

These images were made at eight-day intervals from early April to about mid-August. Toward the middle of August the southwest monsoon was fully developed. The Somali Current had spun up, giving rise to very large scale transports and corresponding thermal gradients. Cooling of the general basin interior is caused both by advective movement of cold water into the interior and wind induced cooling of the upper mixed layer.

Looking at the same area (Fig. 4.19) with a much higher resolution instrument (the NOAA VHRR), we can see much finer scale features. The image is coded such that white corresponds to warm, the darker colors are cooler areas, and the clouds are blue. Three areas interest us: a large intense upwelling zone at 5°N, a second upwelling zone at 10°N, and the dark area next to the coast which is the Somali Current. The warmer area of the Great Whorl (a large scale anti-cyclonic feature at 7°N) is clearly visible, as is a second eddy-like structure further south.

As an illustration of the immediate value of the remote sensing program, it was thought that the Somali Current was a standard boundary current of fairly uniform northward flow. After analyzing a number of satellite pictures, however, we discovered two distinct areas where northward flow turns offshore, coupled with large scale upwelling areas. Conventional ship-based observation programs in the Western Indian Ocean had not correctly reported these features. By composing a series of navigated satellite images, the frontal structure of the north wall of the 5°N upwelling region could be studied (Fig. 4.20). From this was developed a set of spatial scales and propagation speeds for this front. These measurements were compared with phase speeds derived from a set of moored instruments and from satellite tracked drifters. The comparison was

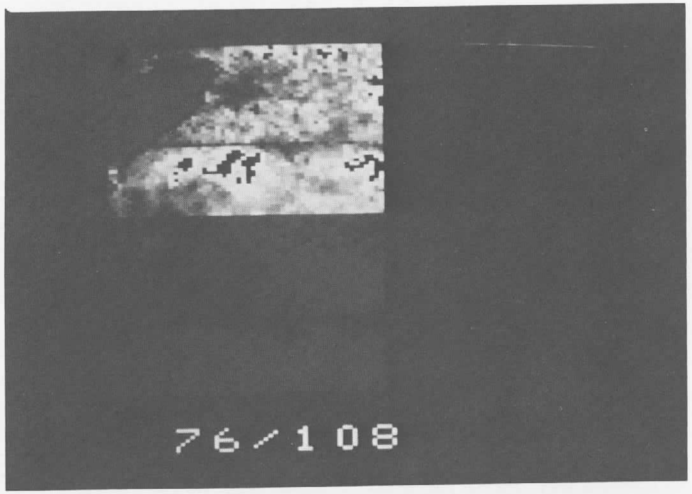


FIGURE 4.11

FIGURE 4.12

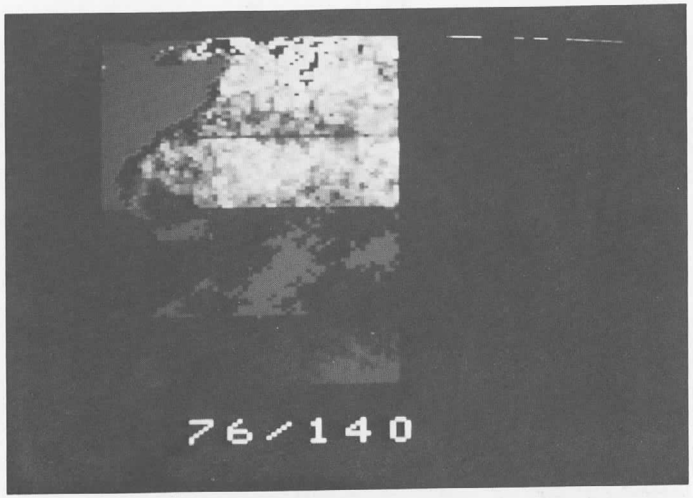


FIGURE 4.13

FIGURE 4.14

FIGURE 4.15

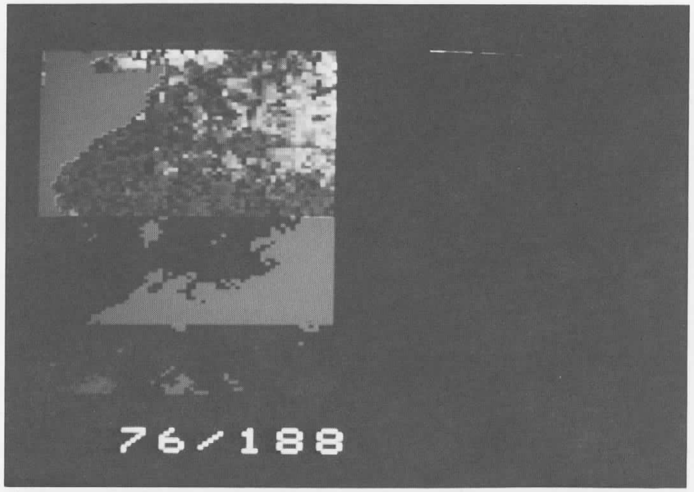


FIGURE 4.16

FIGURE 4.17

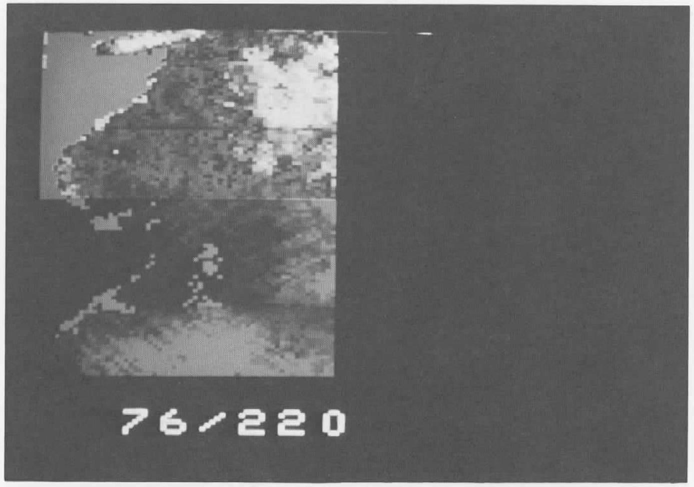


FIGURE 4.18

SEE APPENDIX A
FOR FIGURE 4.19

5^{o}N FRONT PHASE SPEEDS

TIME INTERVAL (1976)	DISTANCE (km)	SPEED (cm/sec)
13 July - 25 July	136	10.5
13 July - 25 July	171	5.7
13 July - 25 July	257	6.5

FIGURE 4.20

quite favorable for both.

I would like to present some background on our approach to GOES data analysis from the GATE area. The cloud removal techniques we used (Fig. 4.21) were developed at SSEC by Fred Mosher; in fact, part of the data you will see was extracted from the GATE archives here. Our composition program is dependent on the following assumptions (Fig. 4.22): first, precise navigation is required. Since composites are geing generated for a number of different images, the pixels that are being compared must be co-located. Second, the process is dependent on a low noise radiometer, so temperature differences from image to image, sensed by the satellite, are not a function of random instrumentation noise. Third, existence of low level winds driving the clouds implies clear viewing conditions over the ocean at various times and places. Finally, the assumption that the oceanographic variability scales are much longer than those found in the atmosphere implies that a steady state can be found which is observed over an atmospheric time scale chosen to maximize clear viewing.

Utilizing the navigation transform, we choose a set of pixels from the series of images -- in our case, the warmest image point set. These are then placed together to form a composite of the equatorial Atlantic sea-surface temperatures. Oceanographic observations in the equatorial GATE area consist of surface moorings, deep moorings and profiling observations. These observations are non-uniform in both time and space. However, they do show meandering of both the Equatorial Undercurrent and the South Equatorial Current, north and south of the equator, in an episodic manner. Furthermore, the ship-based observations seem to show that motions of the Equatorial Undercurrent were quite closely coupled with changes in the position of the South Equatorial Current. Since strong north-south and east-west thermal gradients exist in the surface layer of the equatorial Atlantic, it is possible to infer the position of the South Equatorial Current from thermal maps. Thus satellite remote sensing of the sea-surface temperature allows the determination of the spatial extent and the temporal variability of these large scale motions. From this imagery other features such as surfacing of the Equatorial Undercurrent and large scale equatorial divergence are also observed.

Fig. 4.23 represents a composite GOES thermal infrared image for 12 July 1974 of the equatorial Atlantic, color coded so that each color change indicates a temperature variation of 0.5°C. The continuity of a given color band, with very little speckling, indicates the excellent noise (cloud) reduction achieved by the composition technique. Thermal variations shown in this figure are

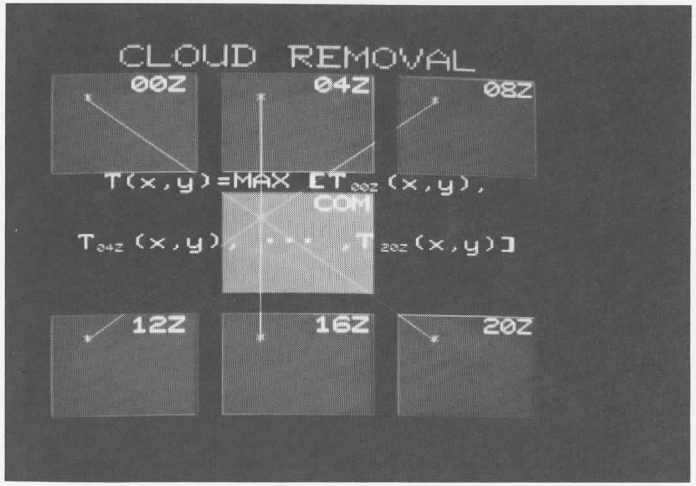


FIGURE 4.21

GOES COMPOSITION TECHNIQUE
FOR GATE VISSR IR DATA
(AFTER MOSHER, SSEC)

1. Precise navigation.
2. Low noise radiometer.
3. Low level wind.
4. Oceanic variability time scales larger than atmospheric variability time scales.

FIGURE 4.22

SEE APPENDIX A
FOR FIGURE 4.23

in excellent agreement with both our own in-situ observations and sea-surface temperature analyses made by other investigators. The wavelengths inferred for the South Equatorial Current are in good agreement with other surface layer observations.

In summary, we at Miami are trying to generate quantitative results from satellite remote sensing observations which are relevant to physical oceanography. Typically, this means we are taking a large mass of data -- a number of images, each composed of many millions of information points -- and producing quantitative space- and time-series. These results are then used as input to more traditional analysis techniques.

[No questions or comments.]

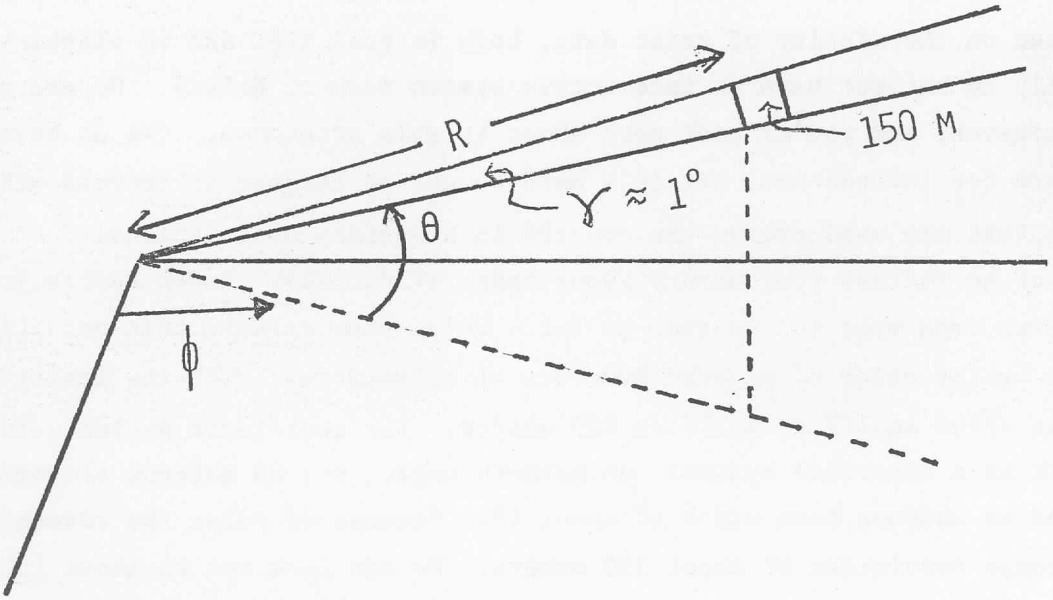
COLOR VIDEO DISPLAY OF METEOROLOGICAL DOPPLER RADAR DATA: RESEARCH APPLICATIONS

Dr. Robert Serafin
National Center for Atmospheric Research
Boulder, Colorado

Dr. Suomi compared McIDAS to a crescent wrench, and if McIDAS is a crescent wrench, then what we have at NCAR is probably a monkey wrench. We've been monkeying around with our wrench for three years or so, and our emphasis has been on the display of radar data, both in real time and in playback. We actually do not yet have an interactive system such as McIDAS. We are planning one, however, and you'll hear more about it this afternoon. (We do have some hardware for interaction, but it's hard to get at because it travels with our radars that are used around the country in a variety of locations.

Let me refresh your memory about radar (Fig. 5.1). Radar scales are entirely different from what you've seen so far. We've been talking this morning about scales on the order of several hundreds of kilometers. With the research radar we're talking about scales as small as 150 meters. The coordinate system with which we work is a spherical system: an azimuth angle, ϕ ; an antenna elevation angle, θ; and an antenna beam width of about 1°. Because we pulse the transmitter, we have range resolution of about 150 meters. We can look out to about 150 kilometers, measuring the reflectivity factor -- proportional to the summation of the sixth power of the particle diameters within our sample volume. We measure the average radial velocity (the component of the three dimensional vector particle motion in the radial direction), and also the variance of those radial velocities within the sample volume. What we typically produce is a typical 360° scan picture, with about 1000 range gates out to 150 kilometers. A typical scan will contain 360,000 picture elements. Figure 5.2 shows one of NCAR's 5-cm Doppler radars; the antenna is housed under a radome, and measures 12 feet in diameter. The transmitter-receiver and processing electronics are housed in a van.

Figure 5.3 is a real-time color display with two color codes: the one on the right identifies Doppler velocities; the one on the left identifies the reflectivity factor. Velocities receding or moving away from the radar are color-coded grey through violet; velocities approaching the radar are grey through red. Date, time, azimuth angle and elevation angle are also displayed. Figure 5.3 is a Doppler velocity display for a radar in Seattle. The color-codes clearly distinguish the moving precipitation echoes from the ground clutter. (The Olympic Range is to the west, the Cascades to the east.)



QUANTITIES MEASURED

$$Z \propto \sum_{V} D_i^6$$

$$\bar{v} = \mathrm{AVG}_{V}\,(v_i)$$

$$\sigma_v^2 = \mathrm{VAR}_{V}\,(v_i)$$

RESOLUTION CELLS/PICTURE ≈ 360,000

FIGURE 5.1

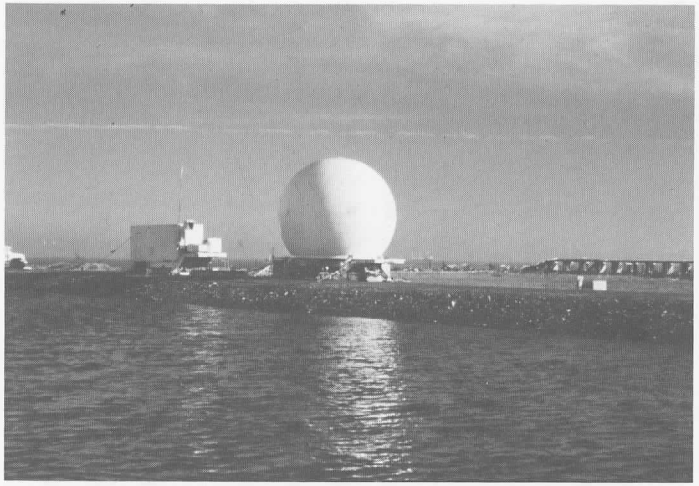


FIGURE 5.2

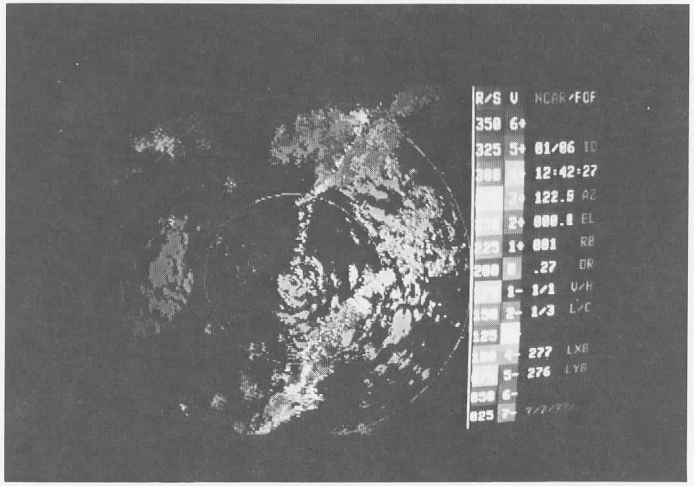


FIGURE 5.3

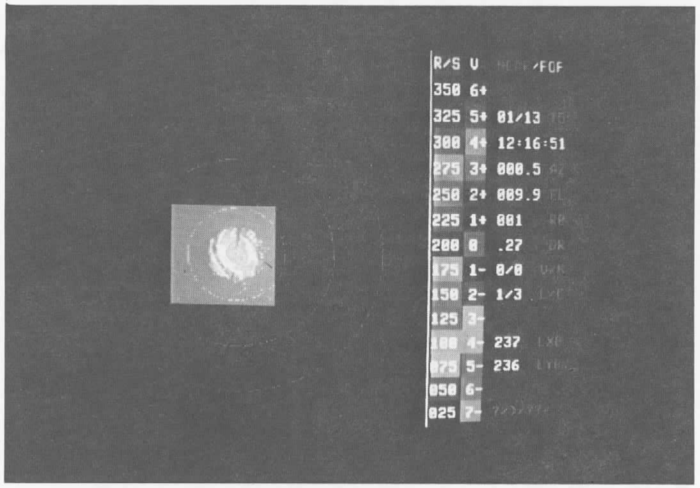


FIGURE 5.4.a

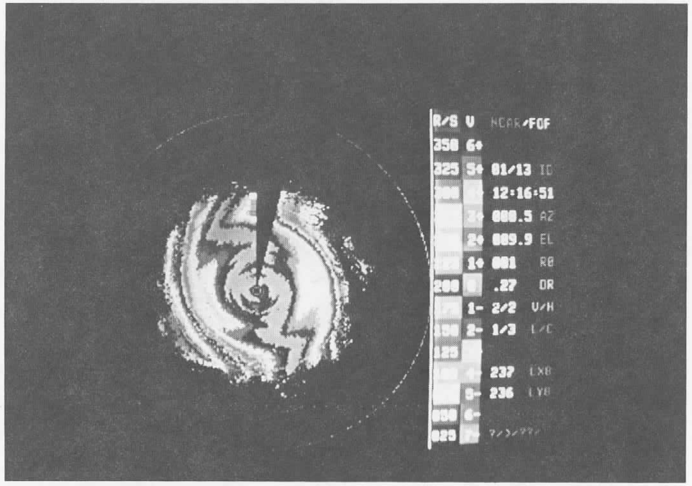


FIGURE 5.4.b

The range markers are at 40 and 80 kilometers.

Let me explain another feature of the system. Although receding velocities normally register as grey through red, we do have what's known as "aliasing." When volocities exceed the unambiguous velocity range of the radar (for Fig. 5.3, ± 15 meters per second) the next receding velocity larger than red (15 meters per second) would appear as violet, and so forth. It acts as a continuous film strip. However, because of spatial continuity, it's possible to identify and resolve these ambiguities.

Figure 5.4.a shows the zoom feature built into the system, operated by a joy-stick. We're looking out with a magnification of 1. The precipitation region of interest is right over the radar; we're making a conical scan. It is possible for the operator to superimpose this intensified region over the larger region of interest. This is about one-fourth (in both dimensions) of the total area. Figure 5.4.b is a 4:1 magnification of Figure 5.4.a, yielding a true high resolution look, ignoring all data outside the region of interest.

Let's talk a little bit about interpretation. For those of you familiar with Doppler radar meteorology, Figure 5.5.a shows what might be considered a continuous velocity azimuth display. The range rings are 20 and 40 kilometers and the elevation angle 7°; this then is a projection of a conical scan onto a flat surface. Looking at the Doppler velocities, note the white curved band through the center of the display. If we measure zero Doppler velocity, that means that the radial velocity being measured is zero, so the wind must be at right angles to the radar beam. (The projection of the radial velocity onto the radius vector is zero.) If we move that around 90° at a constant range, we can then measure the wind speed.

In this case, you can also see aliasing. We've gone through greens (approaching) up to violets (15 meters per second) and three more colors -- about 21 meters per second approaching the radar at a range of 20 kilometers, which represents a height of about 2.5 kilometers above the surface. Forty kilometers out, the winds are about 30 meters per second, approaching the radar from a more westerly direction.

You can also see an indication of convergence. Look at the air moving into the 20 kilometer circle -- coming in at 20-23 meters per second, leaving at 15 meters per second. We actually computed convergence on this day on the order

SEE APPENDIX A
FOR FIGURE 5.5.a

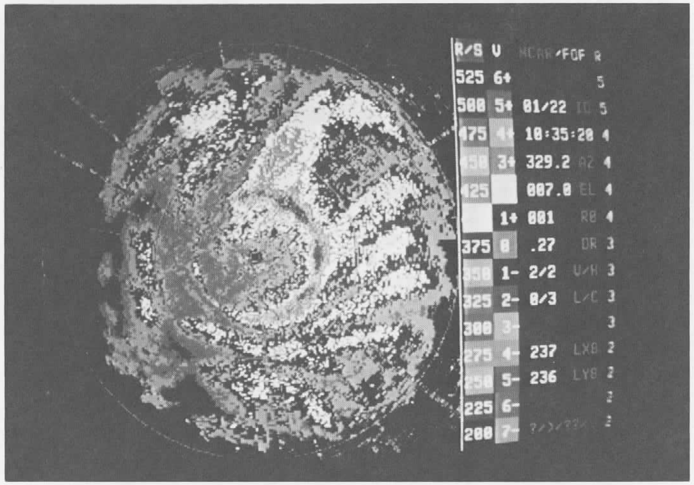


FIGURE 5.5.b

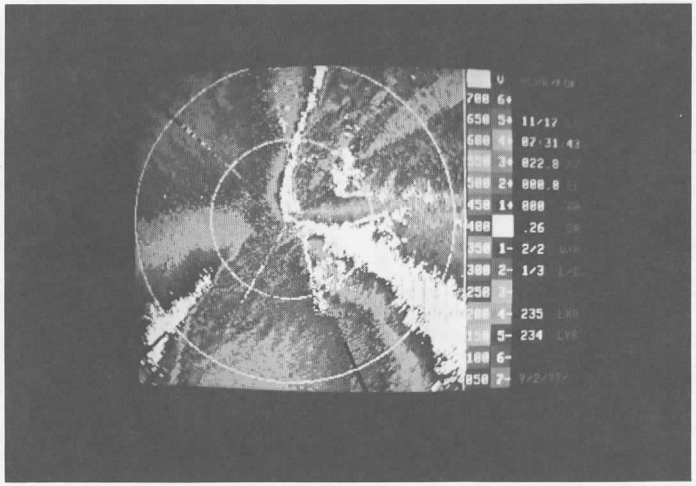


FIGURE 5.6

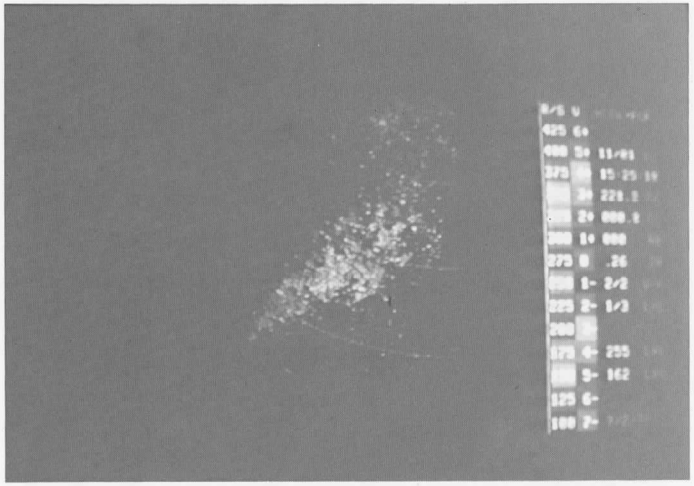


FIGURE 5.7

of 10^{-4} over that same scale. The curvature indicates veering of the winds with height.

Figure 5.5.b is a reflectivity picture, again at an elevation angle of 7°. You see precipitation generators at the top of the clouds with trails coming down; the melting level is the bright band indicated by the bright circle.

Figure 5.6 represents the passage of a front in November 1975; this is a 0° scan. To the east of the radar we have winds at right angles to the white strip, or out of the southwest. To the west of the radar the winds are out of the northwest. Strong convergence along the front is indicated by the very sharp change in colors with distance. (We were able to identify those features while the storm was well off the coast and then direct the research aircraft to it.)

Many people say that radar meteorology or radars are "... for the birds," as far as meteorology is concerned; in fact, radars are quite good for observing birds. Figure 5.7 shows flocks of birds some 80 kilometers off the coast. I might add that several people are interested in studying bird migrations and bird flight patterns with Doppler radar.

Figure 5.8.a shows the super-cell storm that produced four inches of hail in northeast Colorado in June 1976. The reflectivity display is at 10° elevation; note the hook, the weak echo vault and heavy precipitation behind it. Reflectivity factors here have actually exceeded the range of our scale, and have come back in black -- some 65 DBZ at C-band. (That's about 75 DBZ as measured by an almost co-located S-band radar.) A very intense storm like this actually lends itself well to analysis because it's relatively simple.

Figure 5.8.b shows the simultaneous Doppler velocity display of that storm. (Again, there is aliasing, going from greens into violets and reds.) Note the strong approaching velocities on the outside of the hook and relatively strong cyclonic shear (on the order of 10^{-2}). Such shear is capable of producing tornados, although we observed none in this storm. Note also the relatively low velocities in the region occupied by the updraft in the weak echo vault and in the heavy precipitation region. This indicates a diversion of the environmental flow, causing both anti-cyclonic and cyclonic vorticity in different areas of the storm.

Figure 5.8.c shows the same storm as in Figure 5.8.b, at an elevation angle of 16.5°, perhaps 7 km above the ground. Note that the weak echo vault is no longer apparent; actually, heavy precipitation (hail) is forming aloft over that vault. Figure 5.8.d shows that the cyclonic radar signatures persist with altitude through the storm.

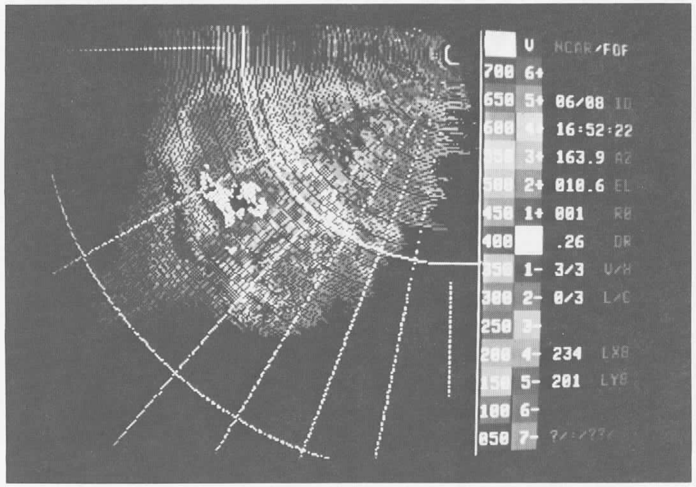


FIGURE 5.8.a

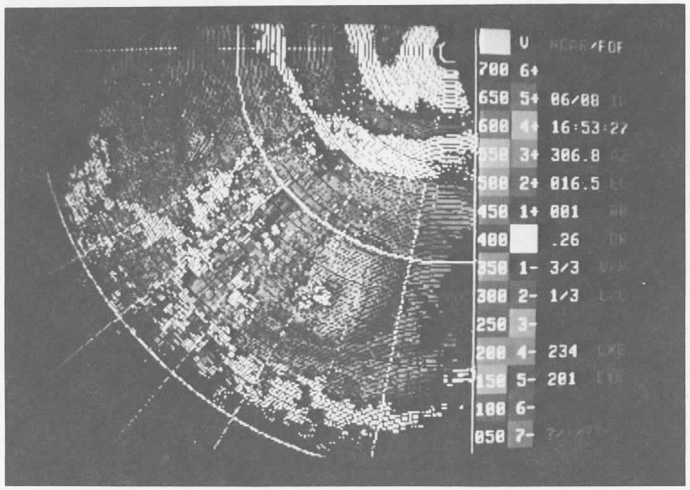


FIGURE 5.8.b

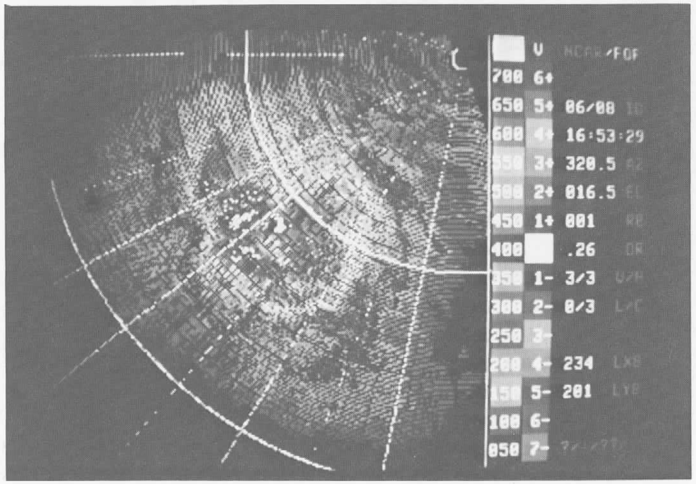


FIGURE 5.8.c

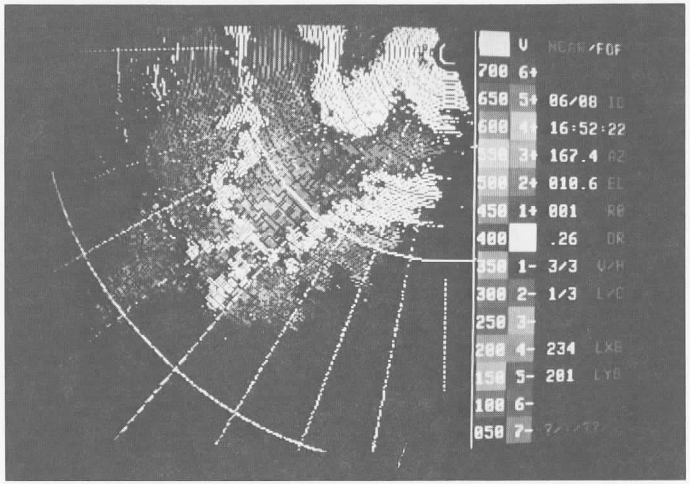


FIGURE 5.8.d

Figure 5.9.a shows a more complex storm situation in May 1977. It occurred near Norman, Oklahoma during the NSSL spring season. This was a tornado-producing storm; a tornado in Oklahoma City (and I think there were several others) was observed on this particular day (May 20, 1977). This is a 0^o scan, a Doppler velocity scan. The grey band is analogous to those VAD's I showed before. Prevailing wind then is at right angles to that, out of the southwest. Note the strong approaching velocities and strong receding velocities, indicative of a circulating storm.

Figure 5.9.b is the reflectivity display of that storm, and note that there is no indication of any circulation there; it would be very difficult to identify where the storms are rotating. Going to the next elevation angle, 3^o (Fig. 5.9.c), we see the cyclonic signature persisting on the velocity display. Figure 5.9.d shows the 3^o reflectivity echoes -- still no indication of circulation. I think this sequence has illustrated the ability of Doppler radar to identify rotating storms and possibly to identify regions likely to produce tornados. The National Weather Service is now investigating techniques of this type for its national weather radar network.

Figure 5.10.a illustrates the dropping of radar chaff from an NCAR aircraft, and Figure 5.10.b shows what happens 25 minutes later. The chaff is dispersed quite nicely, and we can see variations in the velocity field indicative of longitudinal rolls. We should expect to see spatial fluctuations in the radial velocity, and indeed we do.

Figure 5.11 shows the image created by insects. We can use insects just as we use precipitation particles in cyclonic storms to measure the wind speeds. Note that insects also produce a characteristic VAD pattern, which permits us to measure the winds above the radar.

QUESTIONS AND COMMENTS:

Q: Why are some of the radar picture cells black?

A: If we have more resolution in a zoom picture than we had in the radar data themselves, some of the pixels on the picture are left black.

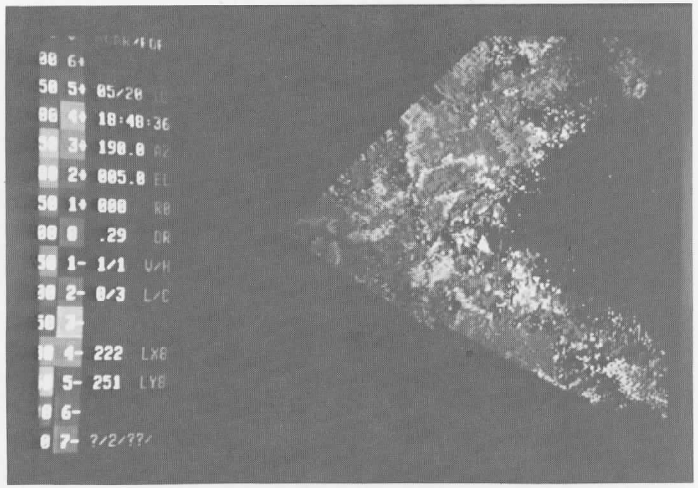


FIGURE 5.9.a

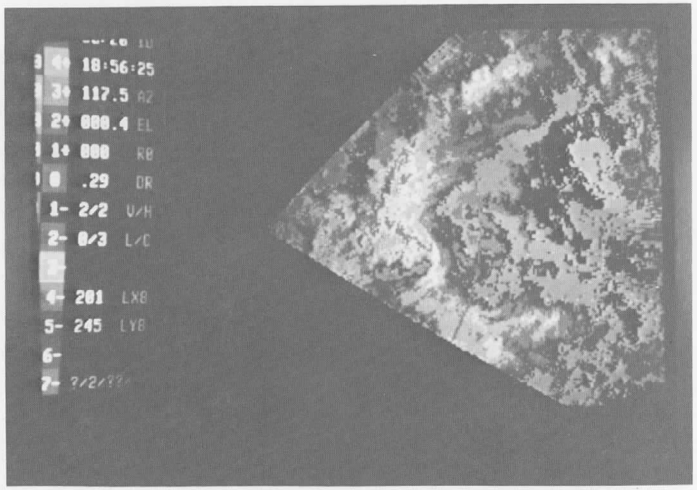


FIGURE 5.9.b

SEE APPENDIX A
FOR FIGURE 5.9.c

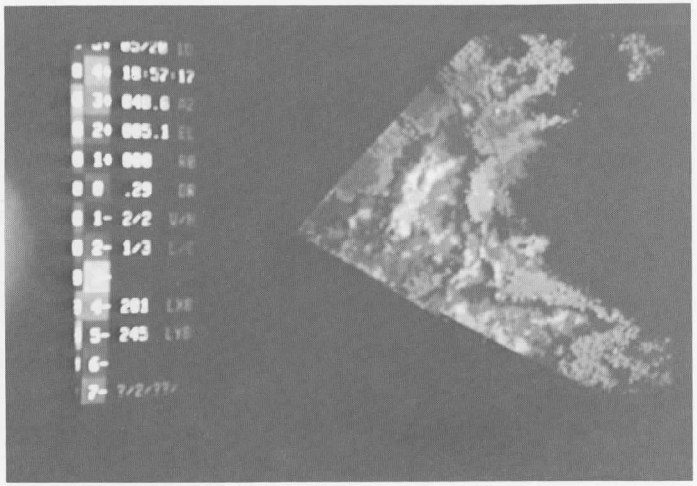


FIGURE 5.9.d

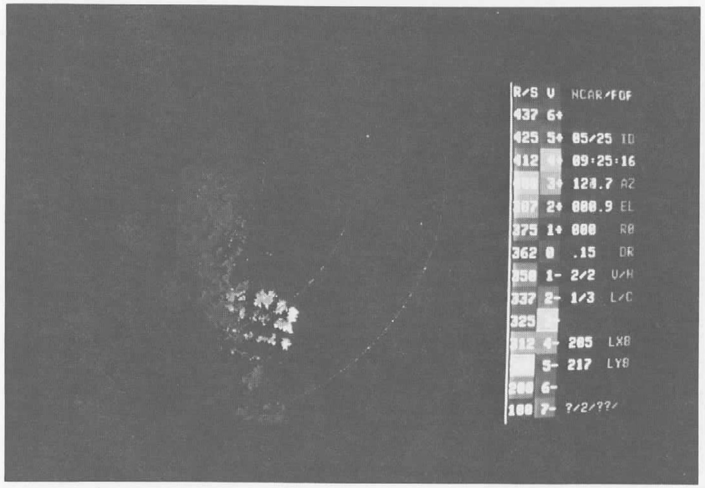


FIGURE 5.10.a

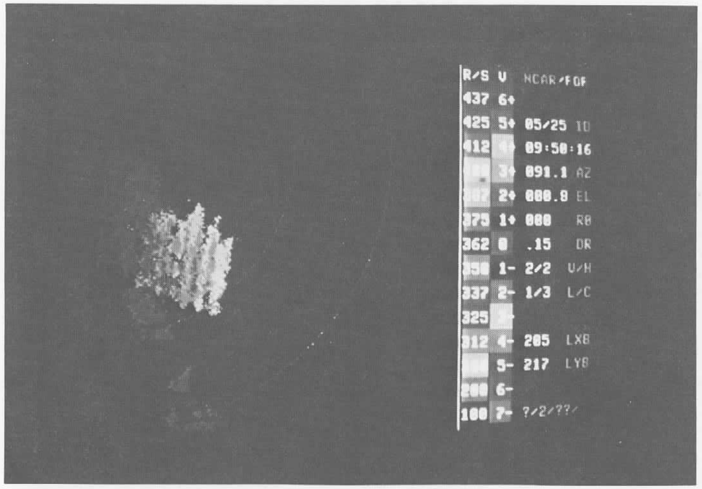


FIGURE 5.10.b

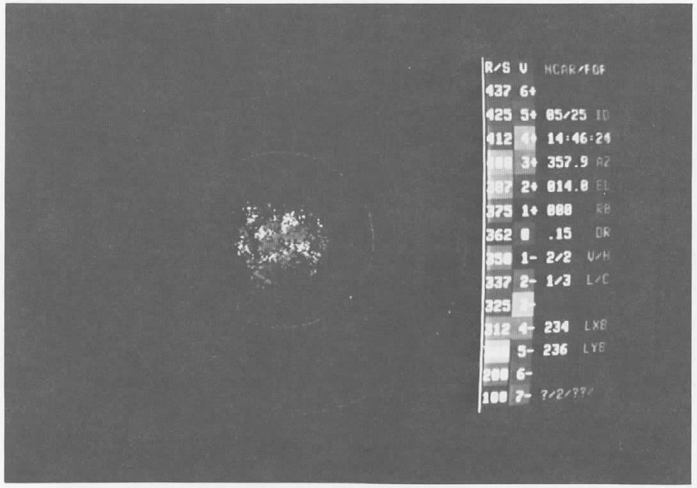


FIGURE 5.11

COMPUTER-LINKED VIDEO DISPLAYS IN MESOSCALE RESEARCH IN SUPPORT OF FIELD PROGRAMS

Dr. Thomas H. Vonder Haar
Department of Atmospheric Science
Colorado State University

Having worked with computers and with satellite data for many years, beginning back here at Wisconsin, I think it is good once in a while to stop and think about what we are doing and why. I will be talking not only about some of our research applications, but I will also try to tell you why we are interested in doing them at Colorado State University. This afternoon Eric Smith [CSU] will talk about some of the details of our computer links and our solid-state rapid-refresh system which can do the time-lapse things shown by Professor Suomi and Fred Mosher, as well as many other things you have seen already.

We are not just chasing the tail of technology, which is easy to do. The research going on in our department -- which is typical in many ways of what may be going on in your department -- involves many observational programs. I made a short list (Fig. 6.1) of some of the field programs that we are involved in, from recent experiments in the BOMEX and GATE, to something that many of you may not have heard of: the South Park cumulus experiment; the upcoming stratoform cloudiness experiment (STRATEX) related to climate; the high plains experiment; a Venezuelan international meteorology and hydrology experiment completed by Real and Betz in recent years; FGGE; and many special satellite experiments. Many of these emphasize mesoscale analysis, and much of our observation allows us to look at the mesoscale in ways that we could not before.

Why do we need computer linked video systems? For any of these field programs (Fig. 6.2) we need an experiment design. We've got to plan our experiments well. Many of you know the years of planning and looking at data that took place before the GATE experiment in order to even choose the location and the study plan. Then, once you are in the field, you have a limited amount of resources, so your operational deployment in the use of your aircraft, your manpower, your expendibles are very critical.

During the course of the experiment some type of assessment or debriefing is needed. You have to know if you have captured good cases that will satisfy your experiment design. You have to decide whether to go home or stay another

COLORADO STATE UNIVERSITY

RECENT METEOROLOGY FIELD PROGRAMS

BOMEX*
GATE*
STRATEX
VIMHEX*

South Park Cumulus Experiment*
High Plains Experiment*
First GARP Global Experiment
Special Satellite Experiments*

(* = large mesoscale emphasis)

FIGURE 6.1

ESSENTIAL STEPS IN MEETING THE SCIENCE OBJECTIVES OF FIELD PROGRAMS

1. Experimental Design
2. Operational Deployment
3. De-briefing and Experiment Assessment
4. Data Analysis

(All are aided by rapid, quantitative data processing and display.)

FIGURE 6.2

week, whether you must fly certain types of aircraft missions or deploy the ships again. Then you go home to perform data analysis that can take many years. All of these efforts are aided by rapid quantitative data processing and display, and that's why we are doing things with video graphics at Colorado State.

Figure 6.3 illustrates the observational aspect of our research. Located adjacent to our normal meteorological sensors are three data collection platforms that transmit their data to the GOES west satellite at about 401 megahertz. These data collection platforms are being tested before deployment in the field. At Wisconsin, Colorado State, and other places you receive information from data collection platforms like these located all over the world. In this way we can use the satellite not only as an imaging platform, but also as a communications platform because in addition to all the image data that Professor Suomi was talking about, satellites now can also handle the data from 10,000 of these stations every six-hour synoptic period. I am sure many of us will be taking advantage of this observational data and interlacing it with image data.

Figure 6.4 shows some of our wintertime radar cloud research that led to weather modification. Figure 6.5 is a more recent experiment in the Vail Valley of Colorado where air quality is a matter of concern. (Professor McKee and students are studying this.) We track and acquire polar orbiting satellite data, as well as the geostationary satellite data that we have been talking most about today, and Figure 6.6 shows the output of one of our displays on our digital refresh system. This is over the GATE region, off the coast of Africa, showing one cloud system in the GATE array and another moving offshore.

Let me talk more now about our research, some of which involves the use of spectral analysis. We recently published a paper on the use of bi-spectral analysis (using both visible and infra-red data concurrently) to extract more information than would be available on either single channel. (Eric Smith will talk more about the capability of this system this afternoon.)

But we must also assimilate the satellite data. Figure 6.7 is an example of the radar display over the GATE region again -- the Researcher 5-centimeter radar -- and each cell is about 4 kilometers. We have mapped the radar into

FIGURE 6.3

FIGURE 6.4

FIGURE 6.5

SEE APPENDIX A
FOR FIGURE 6.6

SEE APPENDIX A
FOR FIGURE 6.7

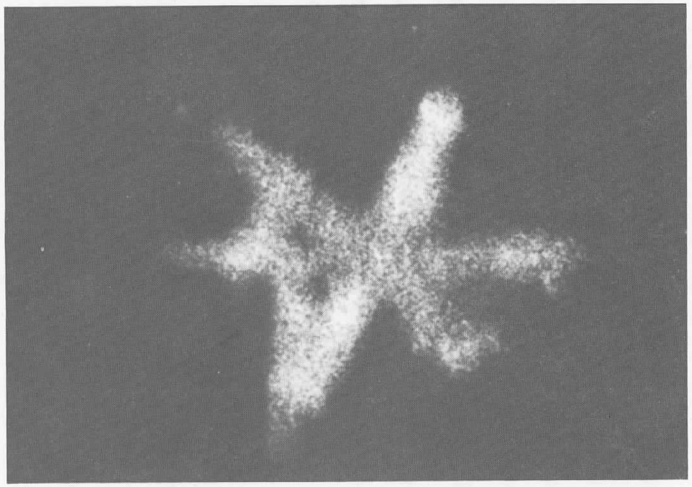


FIGURE 6.8

this particular framework in order to map it with the satellite data of 4 kilometer resolution. Figure 6.7 shows the visible-light satellite data from the SMS-1 satellite in blue, superimposed with the radar data in red. We are interested in discerning precipitation, and the white portions of Figure 6.7 indicate areas of radar and satellite data. Where things are non-white we don't have quite that radar/visible image correspondence. We are also turning to other types of data to help us understand the relationship between the satellite visible reflected radiance and the 5-centimeter radar, such as the passive microwave data from the NIMBUS satellite.

To go to an entirely different scale of atmospheric research, Figure 6.8 is a photograph of an ice crystal captured by the NCAR sailplane over South Park, Colorado, two years ago. Cloud physicists are analyzing crystals like this in more quantitative form, and aerosol chemists, for example, also need to quantify and work with these images in a computer. So our research ranges from very large to very small scales.

Our system can digitize any transparency, which allows us to bring a lot of data into the system. One can take a photographic input, for example, quantify it, put it in the computer and analyze it in the ways that we have been hearing about this morning.

Figure 6.9 illustrates some of the work of our students who worked on the NASA Goddard Space Flight Center system, which is quite similar to the one at Colorado State. This was a case of severe weather over the United States on the 24th of April, 1975, in the Missouri, Arkansas, Kansas, Oklahoma region. (This period has been studied by quite a number of people, and there will be quite a number of papers on it, I think, at the severe storm conference coming up in October, 1977 in Omaha.) Figure 6.10 shows some low-level wind vectors that Bob Maddox and Andy Negri (two of our students) extracted, using the NASA system which is very similar to McIDAS and CSU systems. Note the convergence of the low-level winds along a front. Figure 6.11 is simply the output of an objective or smoothed-wind analysis at 1800 Z, about three hours before the severe weather occurred. Figure 6.12 shows the divergence patterns (x 10^{-5}); we have only contoured the regions of low-level convergence. Figure 6.13 is a combination of two data sets from satellites (the low-level wind field at 1800 Z), and some output from the NOAA sounder that passed over just two hours

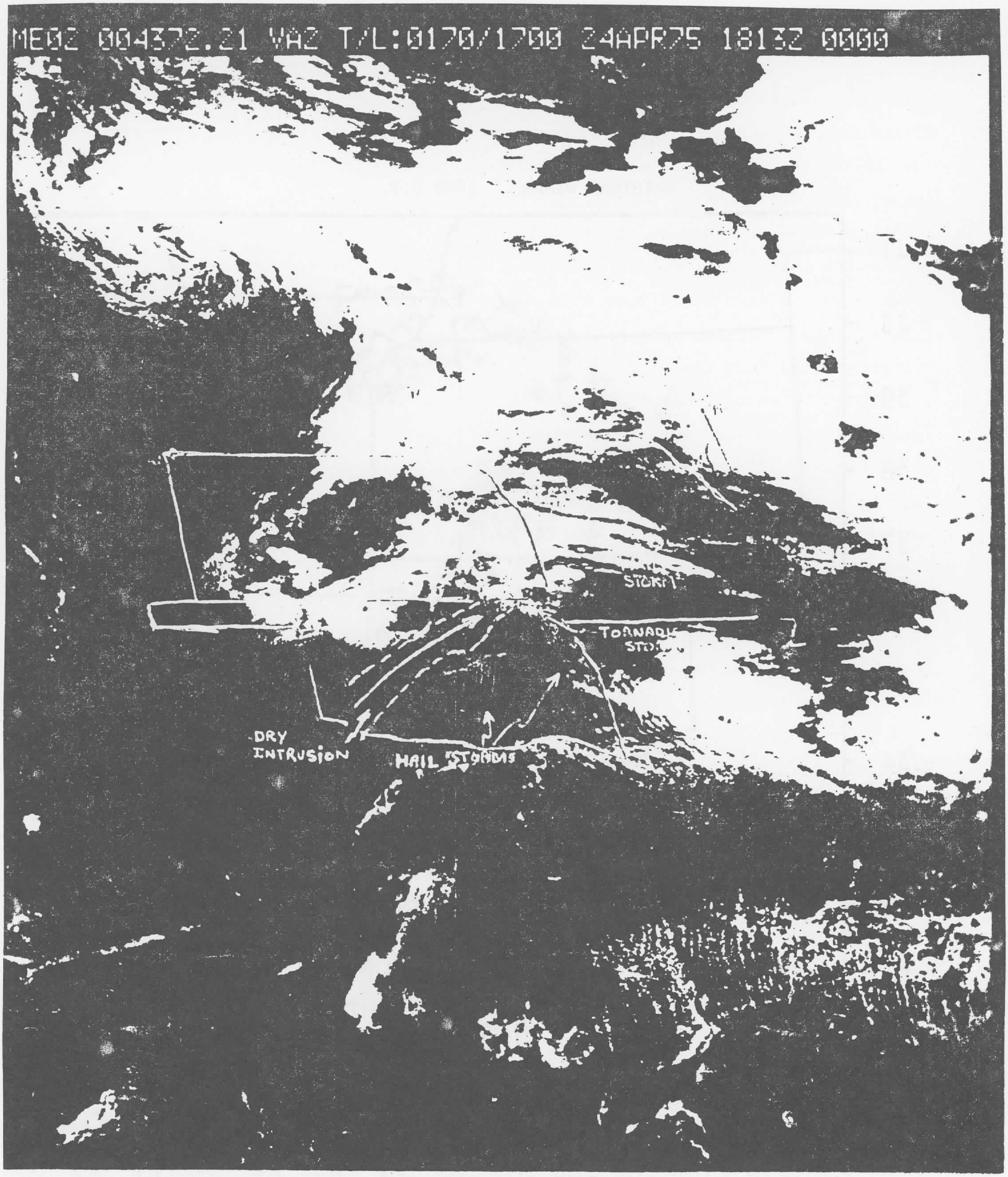

ME02 004372.21 VA2 T/L:0170/1700 24APR75 1813Z 0000
STORM
TORNADO STORM
DRY INTRUSION
HAIL STORMS

FIGURE 6.9

ORIGINAL WINDS 1800 U.T.

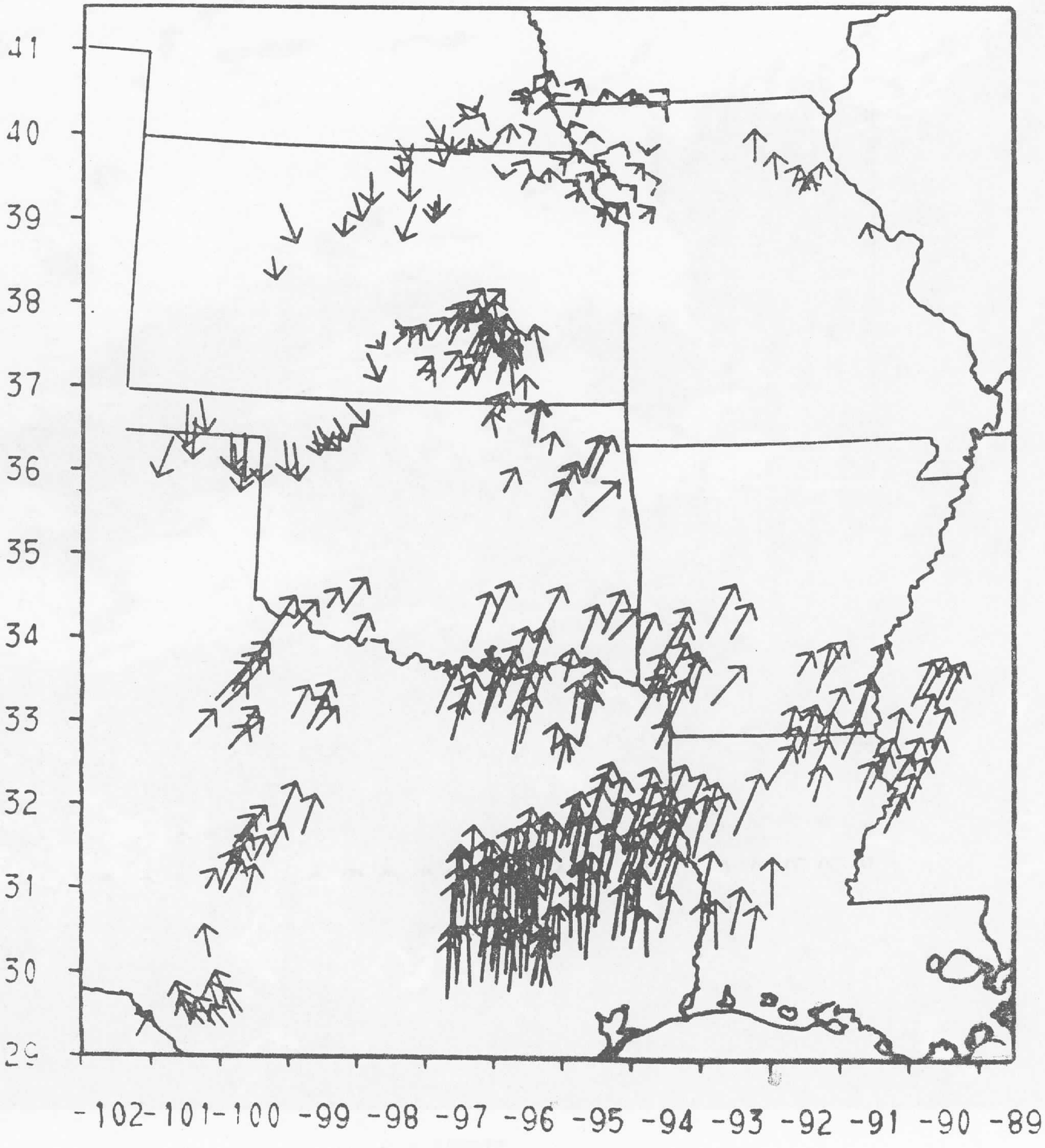


FIGURE 6.10

SMOOTHED WINDS   1800 U.T.

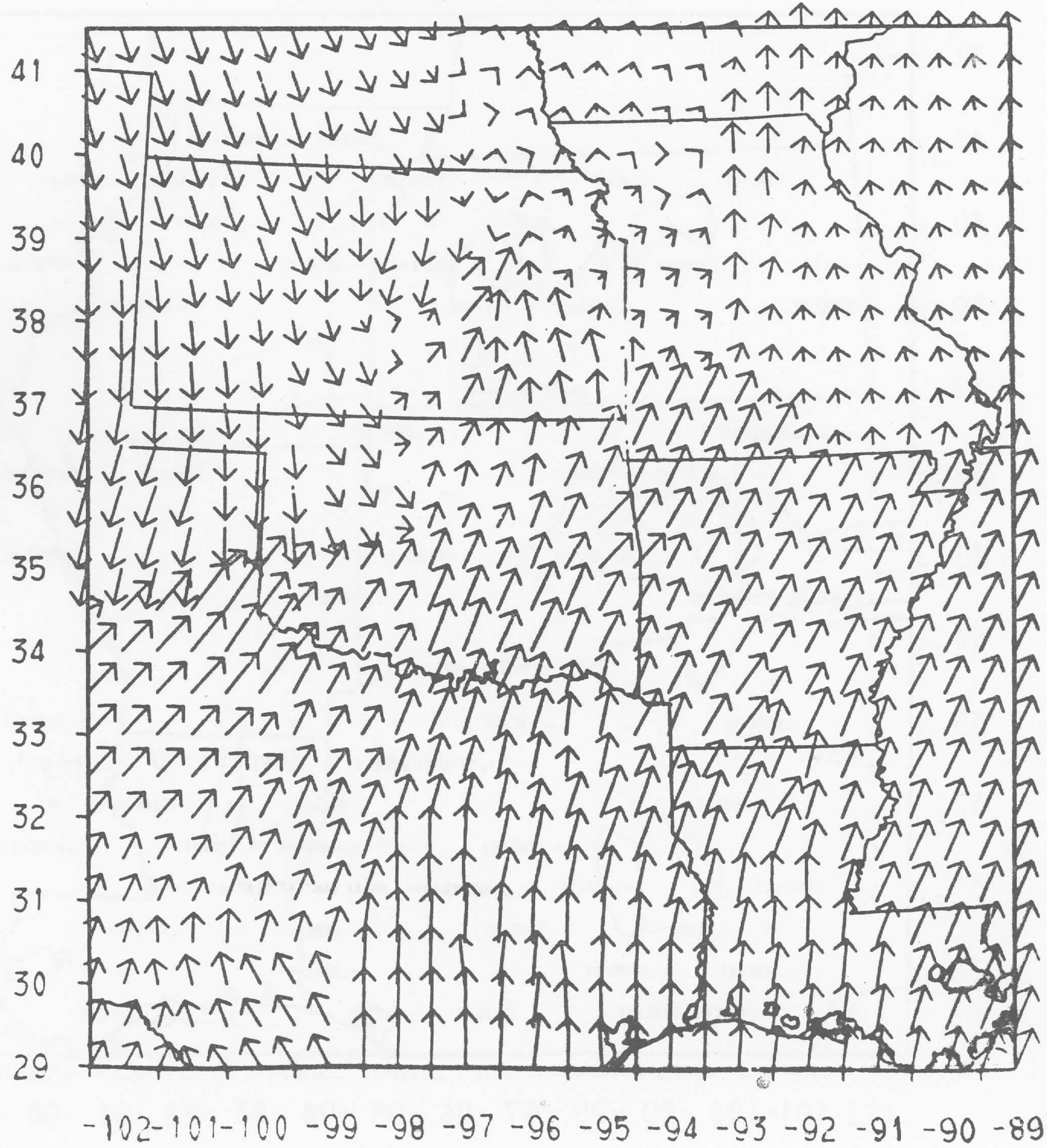


FIGURE 6.11

DIVERGENCE 1800 U.T. (10E-5)

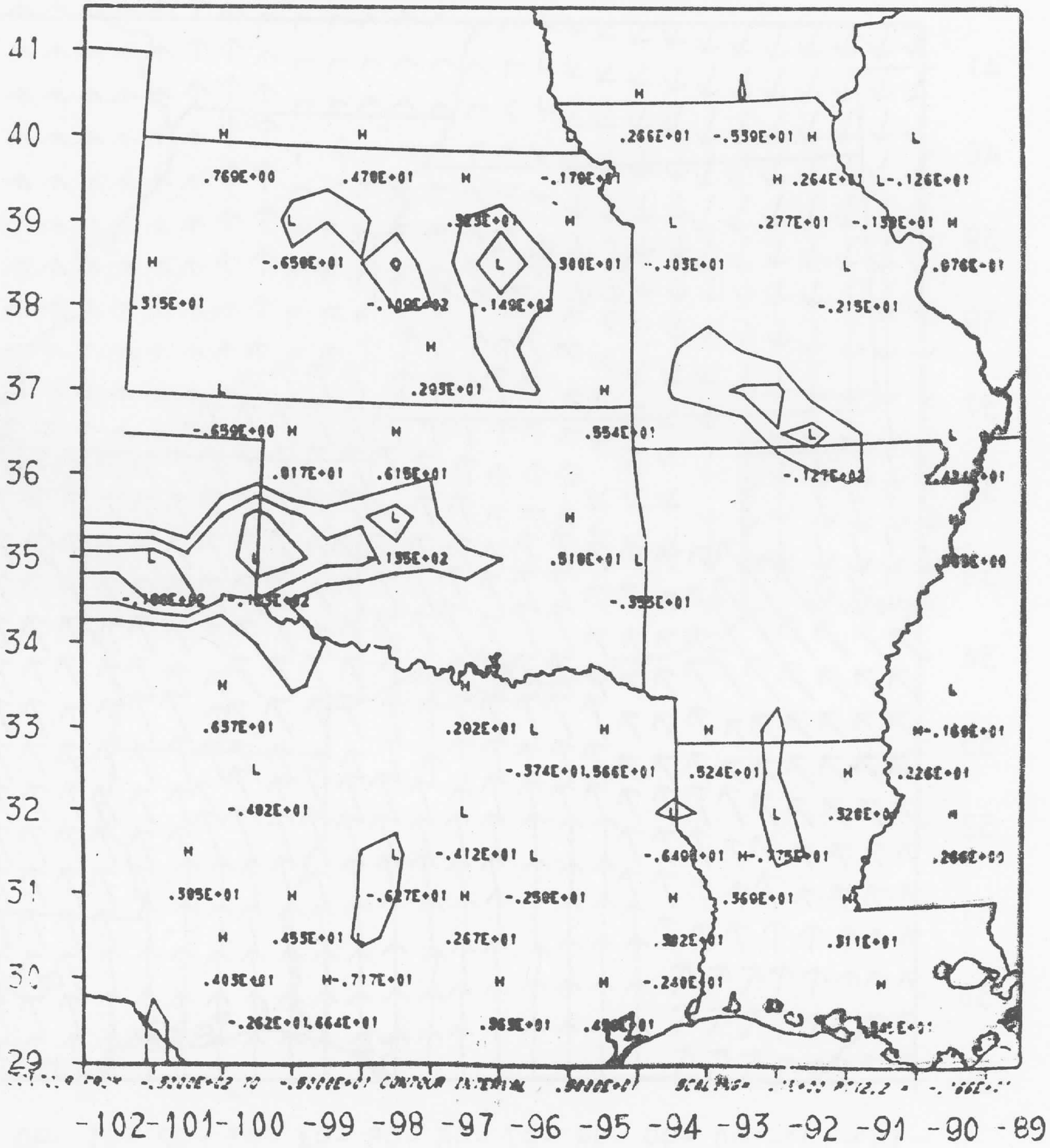


FIGURE 6.12

MOISTURE DIVERGENCE 1800 U.T.

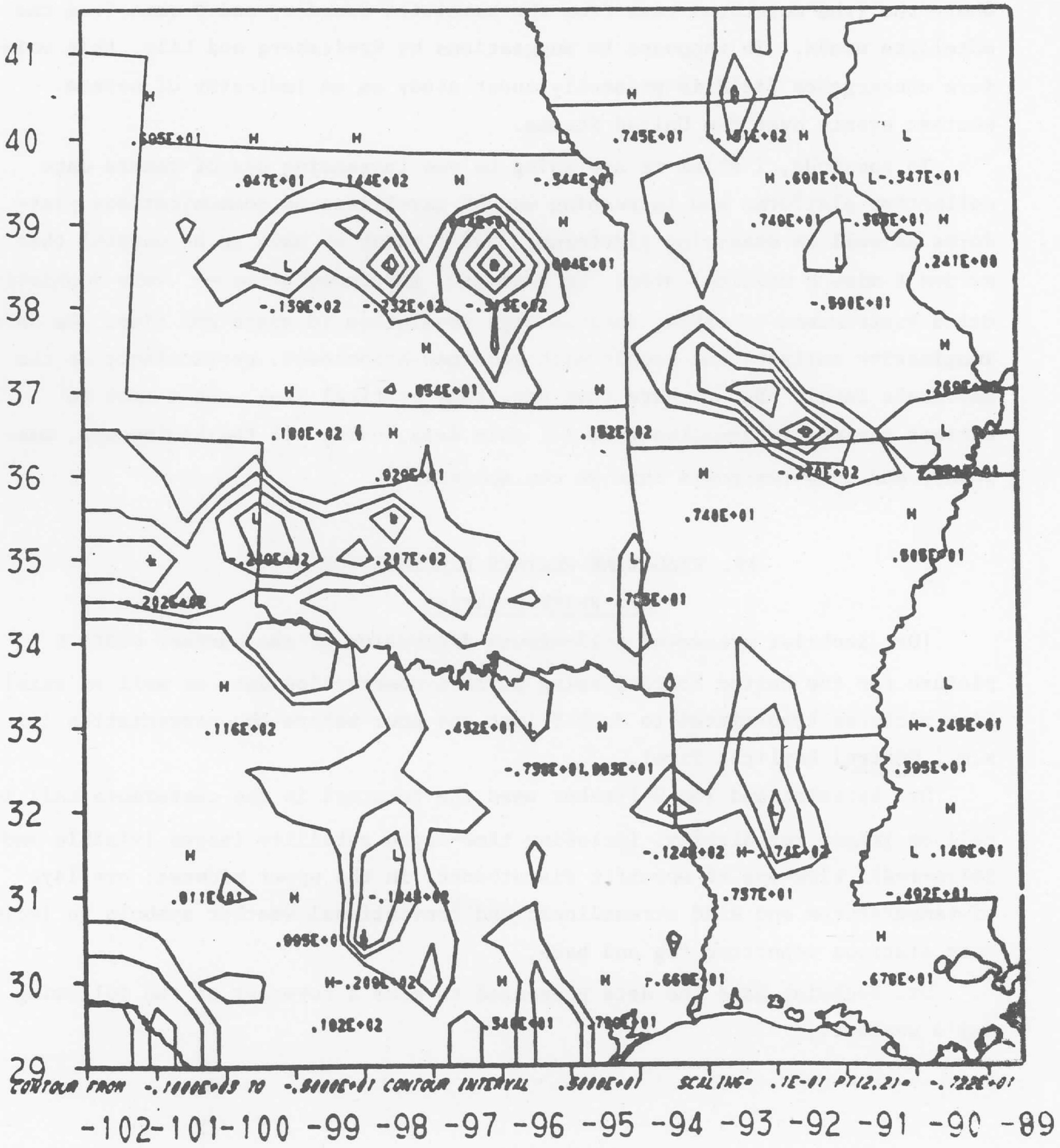


FIGURE 6.13

earlier. This sounder allowed us to determine the total water vapor content in this region at relatively high resolution (approximately 75 kilometers). This is actually a moisture divergency field which is delta point rho V [$\Delta . \rho V$], where rho (the moisture) came from the satellite sounder, and V came from the satellite winds. In response to suggestions by Kreitzberg and Lily, this moisture convergence field is presently under study as an indicator of severe weather events over the United States.

To conclude, I think we are going to see increasing use of remote data collection platforms and increasing use of satellites as communications platforms as well as observing platforms. But I think we have to be careful that we don't miss a critical step. We have good instrumentation -- very sophisticated instruments -- taking data at high resolution in space and time. We have imaginative analysts and people with good new hypotheses, particularly at the mesoscale level. But we have that gap, that critical link. We've got to extract maximum information from all this data, using all the brainpower, manpower, and computer-power that we can muster.

IV. REAL-TIME WEATHER PRESENTATION

Dr. Frank Sechrist

[Dr. Sechrist presented a 15-minute discussion of the current weather picture for the United States, using surface observation data as well as satellite pictures transmitted to McIDAS just one hour before the presentation (11 a.m., Central Daylight Time).

Dr. Sechrist and Tom Whittaker used the terminal in the conference hall to call up images for display, including time-lapse satellite images (visible and infra-red); blow-ups of specific disturbances in the upper midwest; overlays of temperatures and wind streamlines; and conventional weather symbols to indicate stations reporting fog and haze.

Dr. Sechrist used the data presented to make a forecast of the following day's weather.]

V. STATE-OF-THE-ART CAPABILITIES OF VIDEO GRAPHICS DISPLAY SYSTEMS

Dr. Verner Suomi

Much of the hardware we've heard about represents a substantial investment -- hardware that would not, one would hope, become obsolete too quickly. We will look at the long-range capabilities of some of this hardware this afternoon, and the first speaker, Mr. Arthur Hansen from the National Weather Service [NWS], will describe the AFOS system, or the Automation of Field Operations and Services. I would ask you to pay particular attention to this presentation because, in the not too distant future, this is going to be the new national weather service, presumably replacing the clattering teletype. In order for you to anticipate the needs of the future, you should be familiar at least with the concepts behind AFOS system.

THE AFOS SYSTEM OF THE NATIONAL WEATHER SERVICE

Mr. Arthur L. Hansen

NWS/AFOS, Silver Spring, Maryland

I'm in charge of the Systems Engineering Branch at NWS, which is responsible for the initial hardware implementation of AFOS. I'm going to try to describe AFOS, try to tell you why there is an AFOS, show you how it's used, and describe a few of its special features. First, why AFOS? NWS has offices throughout the country, and it's important that data be exchanged between these offices, and exchanged between the weather service and other agencies: the military, the FAA, users such as yourself, the television media, and so forth. To meet user needs, speed, accuracy and cost effectiveness are essential.

What is AFOS? Figure 7.1 illustrates the data communications aspect of the AFOS network. The line tying together the major cities in the country is called the National Distribution Circuit. This is a 2400-baud, full duplex communications line, operating synchronously, using ADCCP protocol [Advanced Data Communications Control Procedures] which was just recently promulgated as a Federal standard. I believe the Navy and Air Force will also adapt to this standard. It's not too different from SDLC protocol of IBM. Data can enter anywhere on this network; observation data would generally enter randomly, and derived data

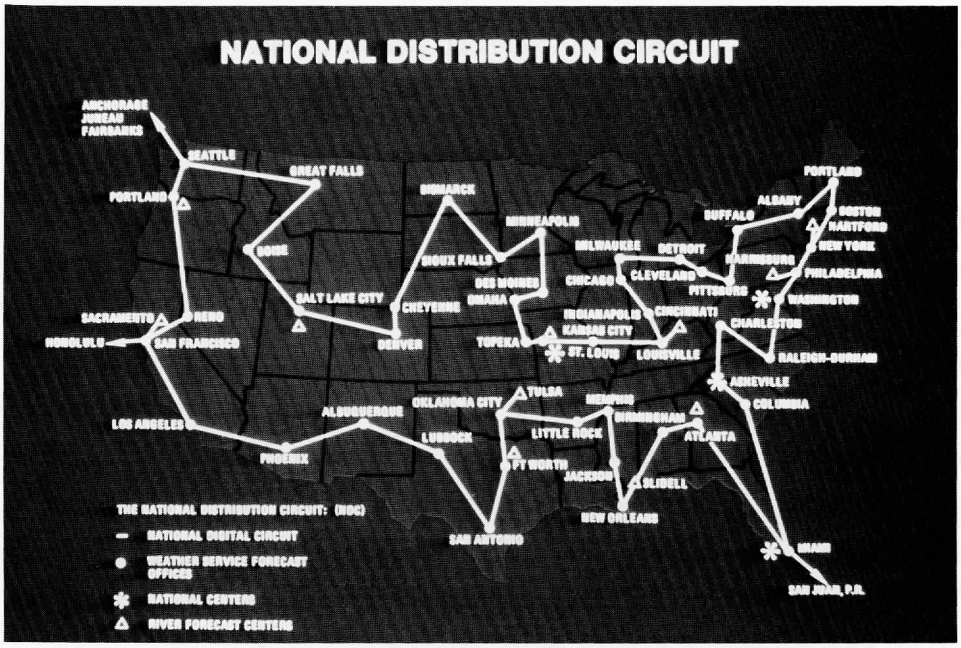


FIGURE 7.1

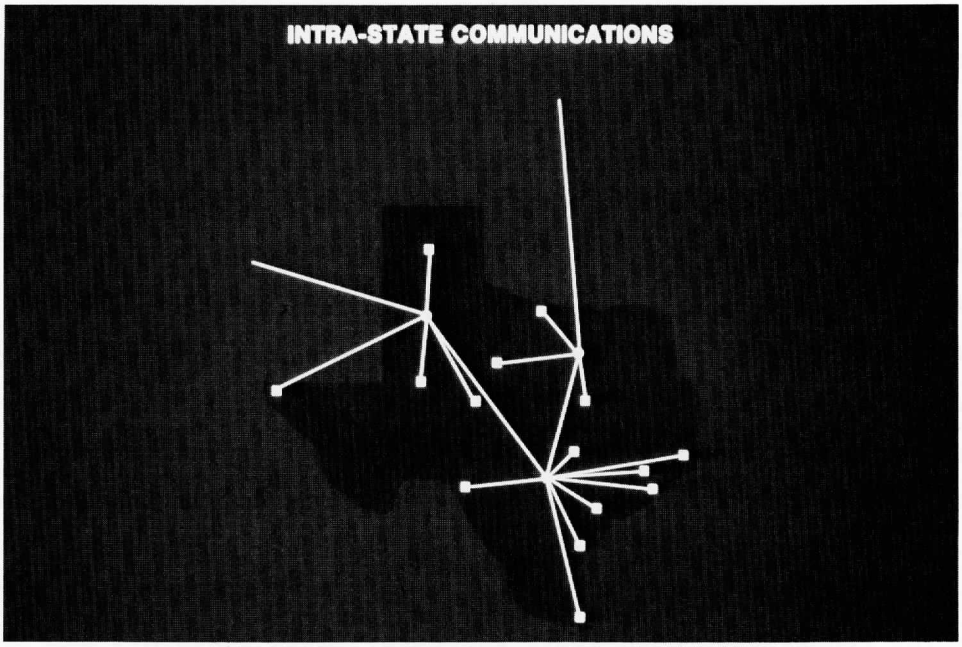


FIGURE 7.2

would primarily come from the National Meteorological Center. It enters the circuit, and goes in both directions around the circuit until it reaches a point where it's received in both directions; then the message is extinguished. This line ties together the weather service forecast offices. Within a forecast area the communications to the weather service offices and other users is on a star network or radio type of network, (Fig. 7.2), but again on a full duplex 2400 baud, synchronous communication line. These are voice-grade, dedicated telephone lines. We have stations serving up to about 10 or 12 weather service offices in some of the larger areas.

Figure 7.3 is an artist's depiction of what the AFOS system looks like, including two equipment racks (a computer and communications module for weather service forecast office) and one of the work stations. This station has one alphanumeric display and two graphics displays, but our design has been modular, so we have work stations that can vary from a single alphanumeric terminal up to a combination of an alphanumeric terminal and three graphics terminals. These, in general, work off the communications and computer module.

A weather service forecast office (WSFO) has two Eclipse S230 minicomputers. One is primarily a communications minicomputer, and the second is for on-site data processing and data retrieval. More important is the redundancy this gives us; to maintain the integrity of that national distribution circuit it is important that the WSFO remain on the air. If one of the minicomputers fails, the other minicomputer could take over the entire function of the station. An operator or technician would throw a series of switches to move the various peripherals from one minicomputer to the other. A weather service office and river forecast center (WSO) has only a single rack of equipment, a single minicomputer, and a single ten-megabyte disk. Fig. 7.3 shows a forecast office which has two ten-megabyte disks. River forecast centers would also have two ten-megabyte disks. Both disks are accessed by both minicomputers. The system also includes two floppy disks for archiving of data. Data generated within the station is archived to conform with legal requirements.

Figure 7.4 is a closeup of the alphanumeric terminal, not much different from the McIDAS terminal. It's a standard keyboard with text editing features

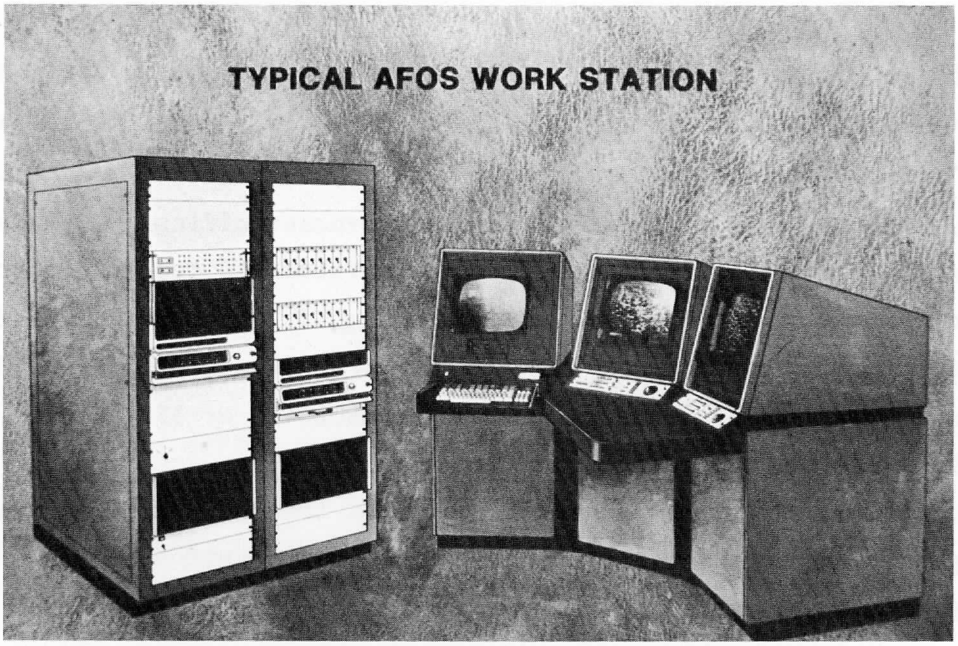


FIGURE 7.3

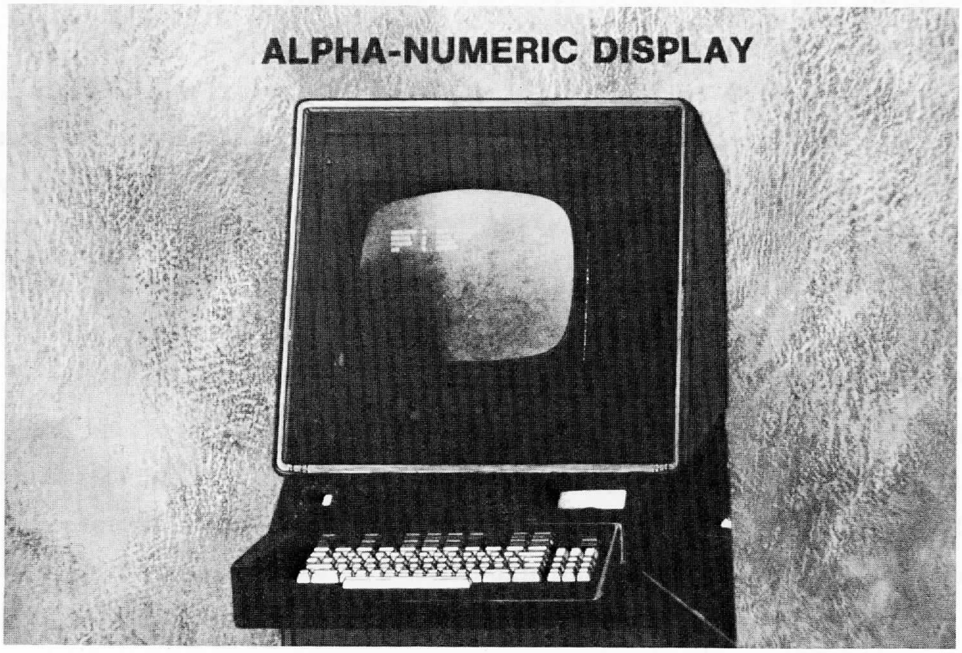


FIGURE 7.4

and certain functional keys that are unique to the AFOS system; four are for display select. Since we have up to four consoles in a bay, one would enter a request for products on the keyboard, and select the display on which he wants it shown. To enter data or prepare a message or warning, one would call up a standard format, type the addressees, and compose a message, using the text editing features. When the operator is satisfied with the message, he would hit the return key and the message would automatically be transmitted to the addressees.

Figure 7.5 is a block diagram of the WSO system with only a single minicomputer; this system differs from that of the WSFO, which has two minicomputers and two cartridge discs. Data comes in on the state or the national distribution circuit, through the modem and multiplexer, and into the minicomputer. The minicomputer will look at the heading on the message and compare it with its own product inventory list, and if it's a piece of data or type of message that is normally stored it will route that data into disc storage. If this is in the national distribution circuit, it would also compare to see if it has received the message from the opposite direction. If it had not, it would then re-transmit it to the next station. Part of the ADCCP procedure is to make a message check, using a cyclic redundancy check, comparing a cyclic redundancy code computed on site to that which is part of the message to check for accuracy. If there is any inaccuracy detected, it would request a re-transmission of that message.

Once data is in local disc storage, it can be requested for display and manipulation by use of the alphanumeric keyboard. First, one can call up a product inventory list of what is stored on disc locally to get the keyboard codes to call up that product. You select the display you want, and key in the code; the data would then be moved from the disc through the minicomputer to the selected display. Data can be generated on the alphanumeric keyboard, for example, transmitted over the network onto the data archiving system (one of the floppy discs). Any information that is displayed, whether it be graphic or alphanumeric, can be printed or plotted on the printer plotter. It is a Versatec electrostatic printer plotter, normally eleven inches wide, but a few centers will have larger width copy. Figure 7.6 shows several different sizes of work stations, the two-bay computer terminal, and the printer plotter.

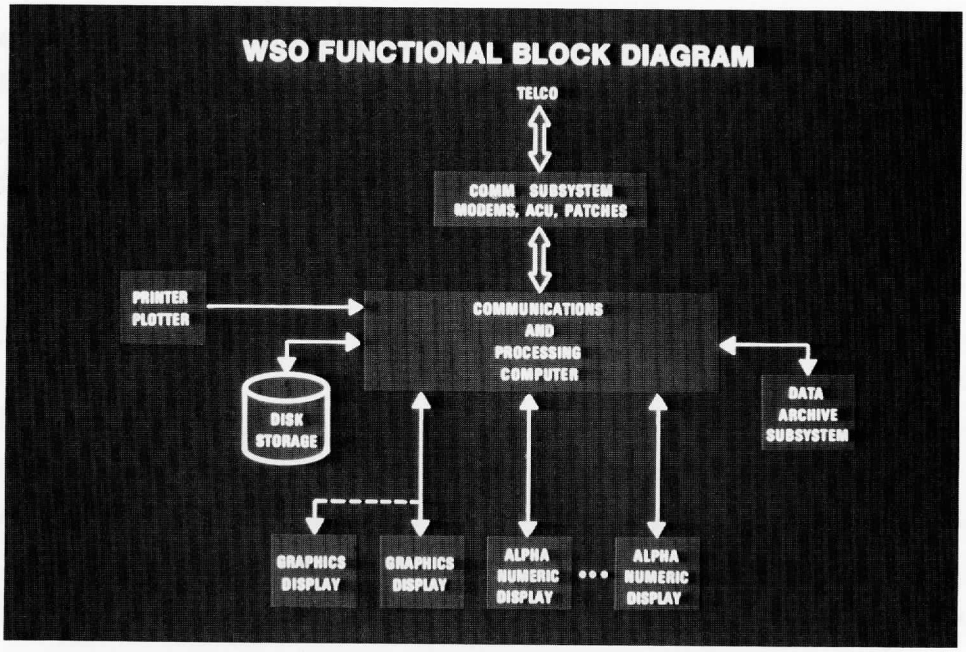


FIGURE 7.5

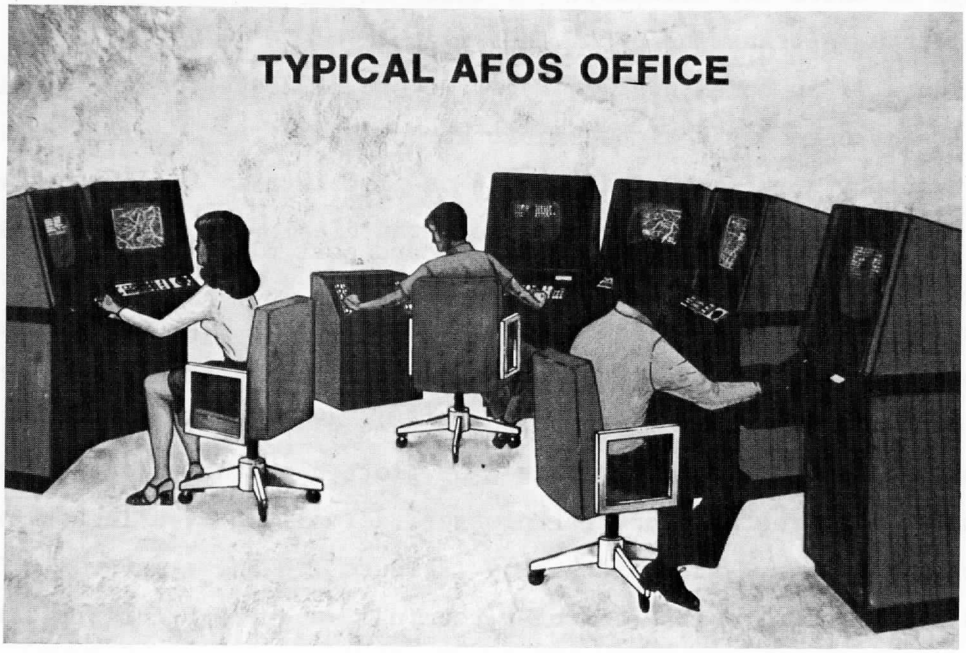


FIGURE 7.6

What type of AFOS equipment might you install in a university? You can see that the equipment is modular. If you wanted a graphics display, you could get by with a two-bay console. The device that generates the graphic data is the largest cost item within a display console. One generator drives up to three displays, so the cost increase of going from a two-bay to a four-bay console is primarily the cost of the extra monitors, the panel and the refresh memories.

Figure 7.7 is a closeup of the graphics display. Unfortunately, we could not make a videotape for use today because our graphics display is 800-line television, and the system we're getting also refreshes 50 frames per second; that would be a bit difficult to display here. But that doesn't mean that the product will not be compatible with 525-line systems. I'll talk more about this later.

One feature on the graphics display is the flicker-free picture of line graphics. We eliminated flicker by increasing the refresh rate to 50 frames per second, because 30 frames per second gave quite an annoying flicker. We have 800 lines because the operator sits very close to the screen; we also wanted to be able to present very high data content. Figure 7.8 shows a map background, on which we can put up to three overlays. (Figure 7.8 shows only two.) We can select the texture of the overlay to be solid, dashed, or dotted, and we can list, in either the lower lefthand or righthand corner, the name of the respective overlay.

Figure 7.9 is a blowup of the display control panel. For each overlay we can select solid, dashed or dotted texture and control the intensity independently for each overlay. Our system is monochrome, but since we have three distinct video circuits, it's easily adaptable to color, if and when a monitor is available. We also have a track ball to adjust the position of the cursor. The cursor selects the center of the area on which you want to zoom, and by depressing one of these buttons, you select the zoom ratio you want for that area. You can also adjust the intensity of the cursor. The translate button is for use if you want to stay in the same zoom ratio and move the field. You move the cursor to where you want the center and hit the translate button.

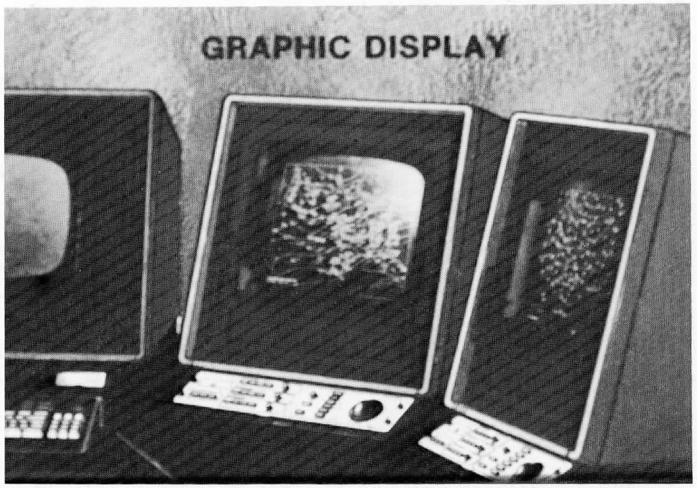


FIGURE 7.7

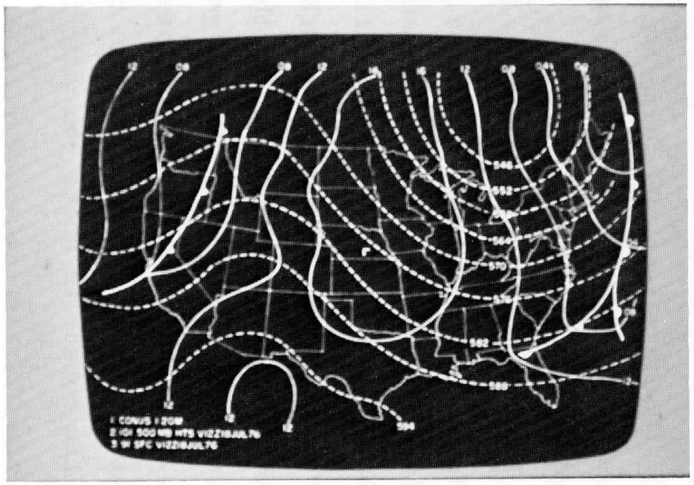


FIGURE 7.8

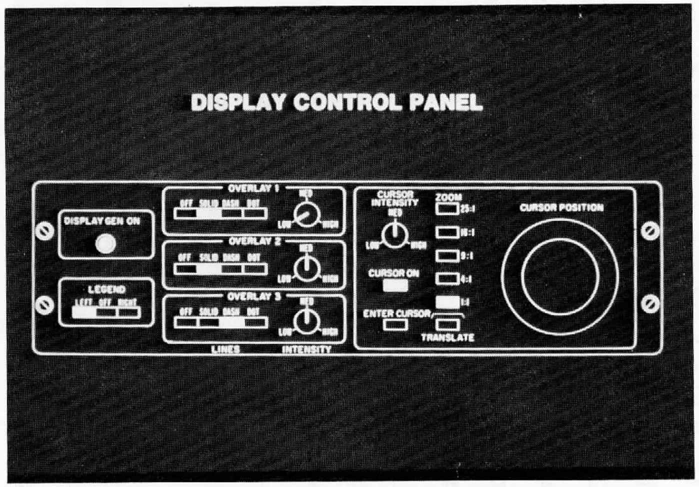


FIGURE 7.9

Figure 7.10 is a zoom picture on which we have added the wind barbs and the surface observations. In the code for the symbols and vectors that are to be presented we have a bit that can be set to show in which zoom level a certain piece of data will first show. This helps to unclutter the picture. If you try to put the whole surface analysis chart on one picture, you have a jumble that's unreadable. So we code this so that the density of data will increase as you magnify the geographic area. The characters remain the same size in zoom, and the wind barbs will be drawn in vectors. But we have another bit we can set in the vector code which makes anything drawn with that particular set insensitive to zoom, so the wind barbs remain the same size. We also have a control code to keep the surface data centered as you change zoom ratios.

Figure 7.10 also shows how one can draw a line which is not already on the chart. You enter a series of points by moving the cursor along that line and hitting the "cursor enter" button. This transfers the coordinates of the line to the computer, and the computer then draws the line.

Another feature of the AFOS system is animation. We have very rapid generation of graphics and alphanumerics and characters, and we have added a feature allowing the operator to draw on two separate refresh memories, and then ping-pong back and forth beteen the two to create a digitally generated lapse time picture. You might watch movement of a weather front, weather radar data, or some derived satellite product in time-lapse sequence (Figures 7.11.a-7.11.c).

We're restricted in the number of frames that can be shown by the amount of data that you can put into the local memory of the graphics display. Raw data is moved from disc into this local memory in the graphics display, which will have either 32,000 or 64,000 16-bit word capacity. The basic system will be 32,000 words, but we have a slot for plugging in an extra board to get additional memory. If each chart contained 2,000 words (counting vectors and alphanumerics) you could show about 30 frames in sequence with 64 K words. I'm not certain how long it takes to draw a 2,000-word picture, but it might be on the order of 100 milliseconds; that would be the minimum time of each step through the sequence.

SEE APPENDIX A
FOR FIGURE 7.10

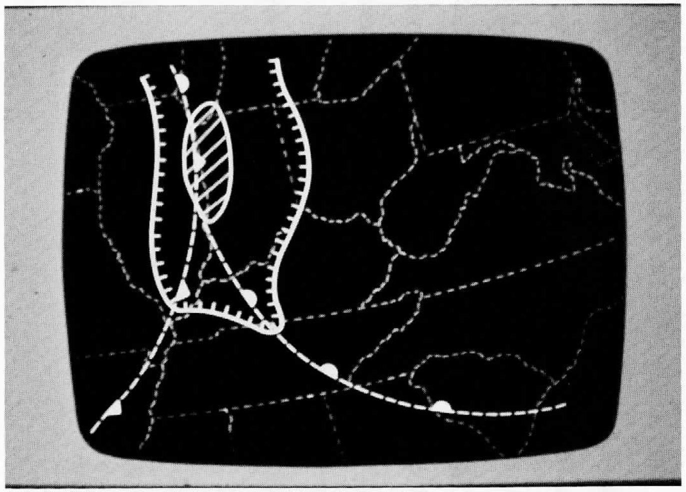


FIGURE 7.11.a

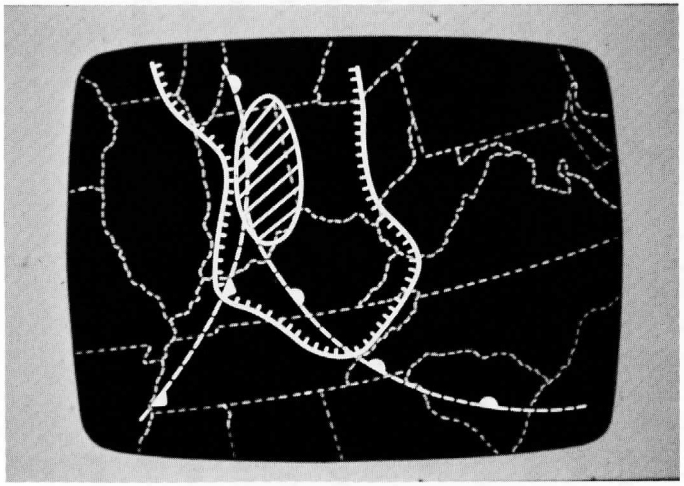


FIGURE 7.11.b

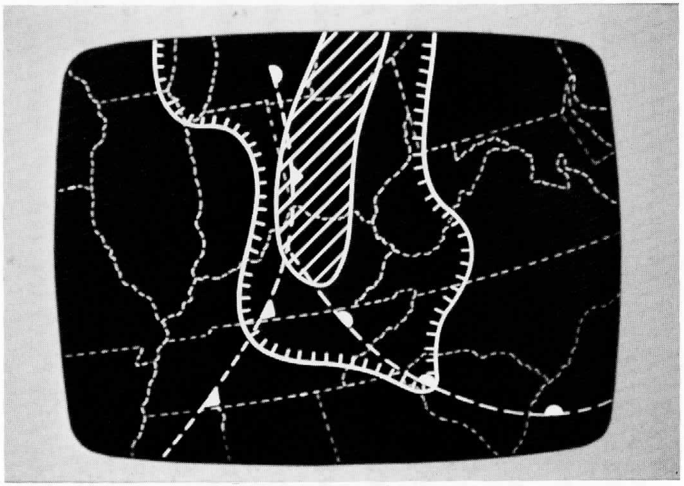


FIGURE 7.11.c

AFOS also will have 119 special character fonts that are the same fonts used on surface analysis charts. These can be addressed by going through an escape sequence from your alphanumeric set into the special character set, and these can be generated very rapidly. If, someday, we don't like that set, we can just unplug it and put in a new one.

Let me say just a couple of words about software. We are implementing AFOS, using the mapped RDOS system created by Data General. We have an option to go to their advanced operating system, and that option is at no extra cost except for the cost of hardware. The cost of adding the extra memory and a few other gadgets is about two million dollars, so we think we'd rather invest about half of that in a new operating software system. We are very serious about going forward with development of the new operating system which would be a multi-partition system (M-RDOS has only two partitions: foreground and background.) We feel this is very important in providing the type of applications that, for example you saw in McIDAS: the generation of local products. We have the communications function, we have the function of the forecaster input and control, and we have remote job entry capabilities, and we want to be able to run several program simultaneously.

QUESTIONS AND COMMENTS

Q: What sort of time table is there for implementing AFOS in various parts of the country?

A: We are now receiving our first equipment at our experimental facility in Silver Spring, Maryland. In November 1977 we'll get our first complete systems, to be located around the Washington area. We'll then go to the field, and Pittsburgh will be our first installation, in January 1978. We'll be installing six systems per month, concentrating primarily in the eastern area. Then we'll move out very rapidly into Fort Worth, Salt Lake City and Minneapolis, and then fill in behind these stations.

Q: When will it be fully implemented?

A: It should be completed near the end of 1980, including Alaska and Hawaii.

Q: When did you decide against color? Do you expect to go to color later on?

A: I'm not sure if we expect to; it may or may not be desirable. We chose to go to higher resolution, and there just is not an acceptable monitor commercially available at this time.

Q: When would these systems be made available to universities and other private concerns?

A: After we get things shaken down operationally, if a university or external user had a system like the WSO with its own computer that could handle its own data base, it could probably link up with AFOS fairly soon. The user could be handled as any other of our WSO's.

Q: Many of the features of your display are like the French television system (800 lines and 50 frames per second). Knowing what good graduate students can do, when will the communication interfaces be specified well enough so that capable university groups might build one of their own?

A: That's a very definite possibility. The ADCCP procedures are fairly well documented, and there are also chips on the market, I understand, that will do the ADCCP decoding for you. As far as the graphics format, we are adopting a universal graphics format; the Navy's also going along with this format, and I imagine the Air Force and the FAA will also follow suit. This will allow identification of the type of coding that has been used, so that your microprocesser can do the decoding for you.

Q: Is there any estimate of when the facsimile and teletype transmission system will be eliminated as a result of the implementation of AFOS?

A: As far as I know, we intend to continue those facsimile transmissions indefinitely. We are installing AFOS to eliminate our own internal facsimile and teletype. We may even enter into a development to generate facsimile from the local AFOS stations and perhaps give more regionally tailored products.

Q: Is your software in a higher level language or assembly language?

A: I think it's going to be in assembly language, except for the applications which will probably be in FORTRAN.

Q: Will AFOS data feed into the FAA?

A: We think it will. We are already talking to the Navy and to the Air Force about a gateway.

Q: What are your plans for satellite capabilities?

A: Since we're a line-graphic type of system, we would hope to distribute derived products like cloud graphics and other derived data that could be presented in line or vector-type drawings. We also have a feature on the monitor to switch to the 525-line display because it seems likely that NESS is going to use a TV-type output in place of the hard-copy or facsimile devices in the near future. We hope to be compatible with that TV format. We want to have that type of storage inventoried within the AFOS data base, an inventory of what's on an analog or a digital disc, controllable from the AFOS keyboard. Satellite video distribution would be on a separate data network.

Q: Is the weather service emphasizing the communications aspect of AFOS, or also putting a lot of effort into the local data processing potential of system?

A: At this time, we're concentrating on going operational. The applications will follow later.

Q: If a private user wants to buy an AFOS terminal, does he do it through the weather service, or does he deal directly with the manufacturer?

A: He should deal with the manufacturer.

Q: Can you estimate costs?

A: I can tell you what it's costing us, but it might be a different price if you went out to buy one. I think a WSO -- with a single minicomputer, a single ten-megabyte disk, an alphanumeric terminal with a couple of graphics displays, and a hard copy device -- should run around $100,000. This is with about 64,000 words of memory.

Q: Is the weather service software in the public domain and available to anybody?

A: The present software, M-RDOS, is licensed to the weather service, and it's licensed with the machine. If you went to our contractor and bought the AFOS equipment, you would be licensed to use it. If we develop a new operating system, I hope it will be in the public domain.

Q: Does the weather service encourage outside organizations to apply for permission to join the network?

A: It's a little too early to say. There is no NWS policy yet on that question.

THE PENNSYLVANIA STATE UNIVERSITY SYSTEM

Dr. John Norman
Department of Meteorology
Pennsylvania State University

This morning John Cahir described the Penn State system very briefly to you. I want to talk about it now in a bit more detail. Our system is about as small a system as you could have, and of very minimal configuration. Actually, the computer configuration in Figure 8.1 is not the original one. We've added some things to it. The original system -- 16K core, a cassette, one disk drive, the graphics, and hard-copy -- cost us $30,000 or so; I think you can buy it for less than that now. We operate somewhat intentionally under the constraints of a small system, feeling that we don't want to end up being the "dog wagged by the tail."

Figure 8.2 shows a closer view of the graphics terminal, and Figure 8.3 shows the hardware in schematic form. The PDP 11/10 forms the heart of it. All of our analysis routines operate in 16K now, including the operating system, so it's very efficient. We get our data by means of the 1200 baud FAA medium-speed line; they have a higher speed one now, I guess. It's quite a clean line; the characters come in in ASCII format, so the PDP11 computer handles them very easily. It's got byte-addressable instructions directly, so handling the data iself, once it's in the computer, is really trivial. However, we don't achieve the efficiency of data storage that is achieved in McIDAS; in one word of memory we get only two bytes of data, so we don't have anywhere near the packing you have with the McIDAS system. We lose a little bit there, but we gain something in ease of working with the system. There is a console terminal, but often the graphics terminal serves as a console terminal too. The areas cross-hatched in Figure 8.3 represent additions to the original system.

The graphics display is a Tektronix 4012 terminal, which is really quite a nice graphics system -- very simple and cheap, easy to program and easy to work with. However, you lose one very useful facility with a storage-tube terminal such as the Tektronix: you don't have animation capability. You can write to the screen any way you want, up to about a thousand characters a

FIGURE 8.1

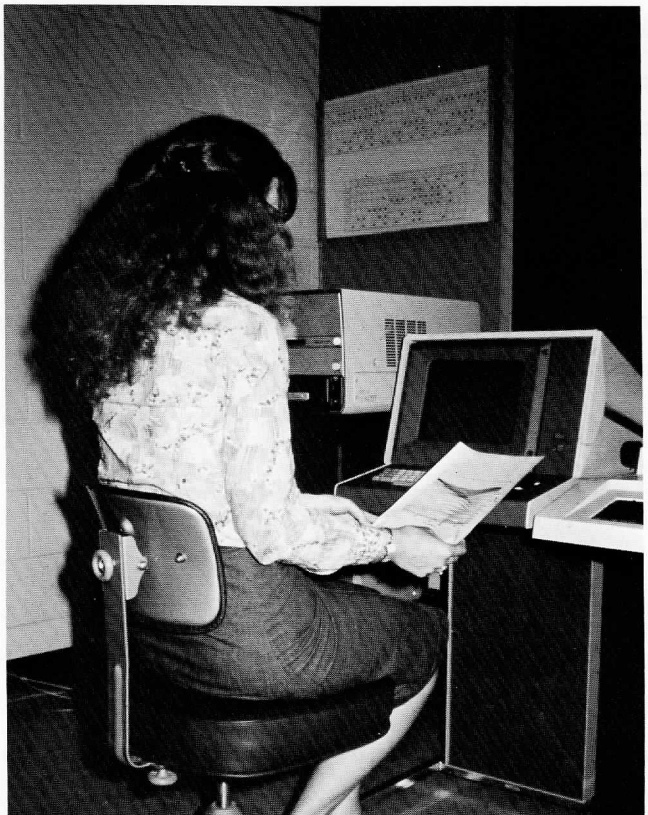


FIGURE 8.2

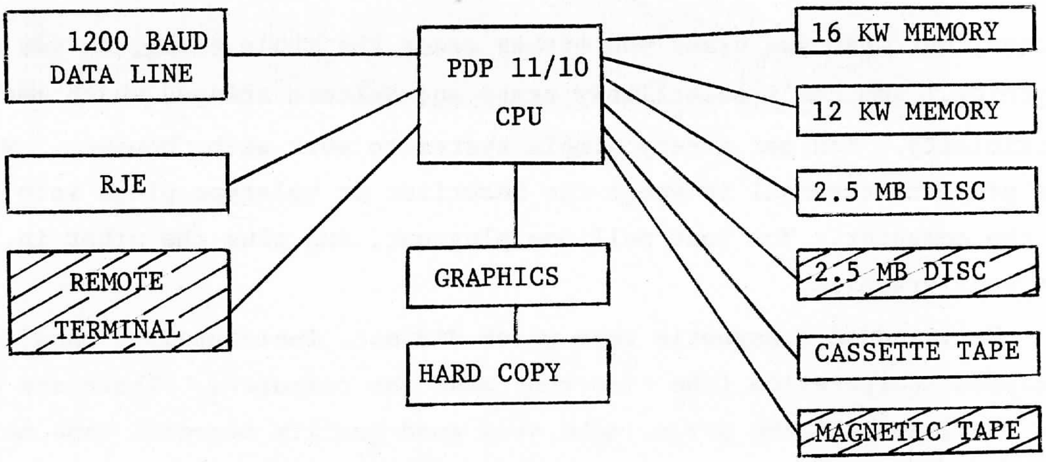


FIGURE 8.3

PENN STATE UNIVERSITY SOFTWARE

SINGLE JOB: RT-11
MULTI-TASKING: RSX-11M

FIGURE 8.4

SINGLE JOB RT-11

* SIMPLE
* CORE AND TIME EFFICIENT
* CANNOT COLLECT AND PROCESS DATA SIMULTANEOUSLY
* ALL PENN STATE ANALYSES WORK IN RT-11

FIGURE 8.5

second, but when you erase you either erase the whole thing, or you don't erase anything. You can't selectively erase and animate things, which costs you some flexibility. You get a very simple system to work with, however. We just plug the graphics terminal in where the Decwriter or teletype plugs into the console in the computer. You just pull one plug out, and plug the other in, and you've got your graphics.

We've added a magnetic tape which did not, incidentally, come from Digital Equipment Corporation [the firm that made the computer]. There are companies now that, at half the price, make very good quality magnetic tape units which interface directly to this DEC machine. The hardware and software are all compatible; there's no alteration of any kind. You can even buy the connecting cable from DEC to plug them into the computer. All of the diagnostics that come on a disk from DEC test this magnetic tape, so the computer can't tell; as long as you put the plug in the right way, you're safe.

We also added a second disk and 12K of memory, which helps us a little bit in expanding the core. We also have a remote terminal now to supply the Service C/Service A data to our weather observatory for students (just the uncoded messages). We also have an RJE terminal now to the 370 computer, so that we can operate this computer as a terminal, replacing a typewriter, or we can transfer files back and forth. We found that transferring files from a minicomputer to a file on the 370 system is not a trivial exercise. I guess that's about all there is on the hardware system.

Let me talk, now, about software (Fig. 8.4). It's hard to distinguish sometimes between hardware and software. When you buy a computer from someone you usually buy their software system with it; you can't afford to develop one yourself. We bought a software package from Digital called RT-11. It's a very minimal operating system; it only takes 1.5K of core in its smallest configuration, so that leaves you 14.5K to program in a 16K computer, which is quite efficient for small simple applications. We had intended eventually to get the foreground/background adaptation of RT-11, but we ran into a few snags. Of course it takes a little more core (5K insteak of 1.5K), but that's still very tolerable. You're down to 11K in your programming.

To illustrate some of the problems you end up living with, we found that, for some unknown reason, the foreground task would not handle an asynchronous device like the telephone line on which all our data is received. We had intended to be able to monitor a telephone line, and at the same time (in a background mode), to process that same data being collected on the telephone line. We wanted to be able to collect and analyze data at the same time, but we found we couldn't do it. We ended up with a system (the RSX-11M, described later) that is about an order or magnitude more complex and more sophisticated, which takes 8K of core for overhead and will do almost anything you can imagine. So the RT-11 system is called a single-job system, although it is expanded to limited foreground/background operation.

While the single job system (Fig. 8.5) and the software system within which you do your programming are very simple and efficient in time and core, you can't use them to collect data and process it simultaneously. I think that's a very severe constraint. You've got to be able to get the data in and have that happen in a cycle-stealing mode where it just happens automatically. All of our analysis work to date runs in RT-11, and I believe (I can't be sure with the latest modifications) that all of it runs on a 16K computer. I do know that everything runs in RT-11 with room to spare on a 28K computer.

The multi-tasking system, RSX-11M, which is what we are going to (Fig. 8.6), will be a department facility as an educational center, and not just a synoptic analysis tool, or a data collection tool, or a research tool. The RSX-11M multi-tasking system is extremely powerful. We have used the RSX-11M to accomplish quite a number of the tasks shown in Figure 8.6, but not all of them. It monitors the data line continuously, edits that data, and picks out anything you want to save. (It has a dynamic table with which you can save or discard whenever you desire.) It sorts out those data and stores them in their own files, partitioned to different locations on the disk. It dumps selected data on an economical DEC-writer, identical to the one on the 14th floor at SSEC that's used with the McIDAS system to generate hard-copy.

It's a very reliable, simple, sound device, but it prints only about 30 characters a second, so you need buffers to absorb data when it's coming in fast.

MULTI-TASKING RSX-11M DOES MANY TASKS SIMULTANEOUSLY:

1. Monitor FAA data line
2. Edit data and sort files
3. Dump selected data on economical printer in observatory
4. Run analyses programs on disc files
5. Dial up and record data from remote weather stations
6. Perform A-D converter interrogation
7. Provide terminals for student access
8.......

FIGURE 8.6

RSX-11M

* COMPLEX

* SLOWER THAN RT-11

* REQUIRES AT LEAST 28KW CORE (AND SHOULD BE MORE)

* OFFERS BETTER PROTECTION FROM STUDENT BLUNDERS

FIGURE 8.7

This just replaces the old teletypes in the conventional observatory that most universities have.

With 9 or 10K of core we monitor the line, edit the data, and dump selective information to the printer. It's all written in assembly language and quite efficiently done. Then, of course, you have the big section of your core in which your analysis programs are run, and which, for us, is all written in FORTRAN 4 language. We're still working on some other tasks: a system that will dial up a remote weather station and record the data periodically (once a day or once an hour, whichever you choose); an analog-to-digital converter for experiments in the laboratory; and some terminals for student access. Those things could all be handled by the RSX-11M at the same time.

However, that power does not come cheap; it's a very complicated operating system (Fig. 8.7). In half an hour, an intelligent student who's had some experience with a computer could use RT-11. For RSX-11M it takes more like a week. RSX-11M also executes more slowly, since it has more complicated instructions to go through, and it requires at least 28 kilowords (56,000 bytes) of memory. Now this is still a small computer. My own rule of thumb is that 32K is the borderline between the minicomputer and not a minicomputer. I think that when you get above 32K core, we ought to have another name for it. I think Dr. Suomi referred to it as a midicomputer -- a mesocomputer. Costwise, even the cores up to 64K are not too expensive; it's the peripherals that kill you.

In the RSX-11M you also have better protection from the students -- a not exactly trivial problem that hasn't been mentioned much today. Students can crash a system in a million different ways; if it can be done, they will do it. If they're anything like I was, if they don't do it by accident, they're going to figure out how to do it on purpose. One of the big differences between a batch system and a real-time system is that a batch system locks them out, because a batch system is simply a battle between brains: Can the guy who wrote the batch system do it well enough to keep the students out of it? It becomes a battle of wits. The real-time system is different; it's not a battle of wits anymore. I think it's just virtually impossible to prevent a student from crashing the system, so you just put inhibitions in there to slow them down a little bit and to keep the honest students from unintentionally doing it. But you are still vulnerable. I think in any real time system with students, you are going to crash the system regularly, and the RSX-11M provides much better protection against this with its password systems.

A second problem is to keep bad data from creeping into your analyses. We haven't solved that one; I don't think anyone has. I would like to spend just a minute or so on this problem at the end of my presentation.

Now let me present a few examples of what we produce at Penn State. Figure 8.8 is a pressure map, a very simple and smooth regression scheme with an rms standard error of about 0.5 mb. You can see a bit of an extrapolation problem near the edges. Figure 8.9 is a similar analysis of temperature with an rms error of about 3°F. These are not very good schemes because they are quite over-smoothed.

Our pride and joy, of course, are the cross-sections and soundings. Figure 8.10 is an example of a skew T log P diagram, with the temperature and dew point shown as solid lines. Since we don't have color, we use dotted lines for the background. (The rule of thumb that we use is: dash and dots for the background, and solid lines for data to keep things separated.) The solid lines are drawn faster, as you might have noticed on John Cahir's videotape this morning. It took much longer to draw the background than it did the soundings. Dotted lines take time; that might be unique to our system.

Figure 8.11 shows another sounding. Cross-sections like this show things like fronts quite nicely, and we can produce relatively smooth humidity cross-sections at the same time, using either regression or interpolation techniques. Figure 8.12.a shows another theta cross-section with a dramatic upper level front; Figure 8.12.b is the wind analysis that went with that theta cross-section.

Figure 8.13 is a Richardson number plot. The Richardson numbers look pretty big, but they do get as low as 0.25 or very near the cutoff for turbulence. These can be used to estimate clear air turbulence; you can draw several cross-sections, and block out areas where the Richardson number is very small and you are likely to get clear air turbulence.

In summary, we have worked mainly with cross-sections, but dealt a little bit with maps, and we've had some very interesting experiences dealing with computers. Some of those experiences have been quite frustrating. For example, computer manufacturers keep changing their software, and they always want to

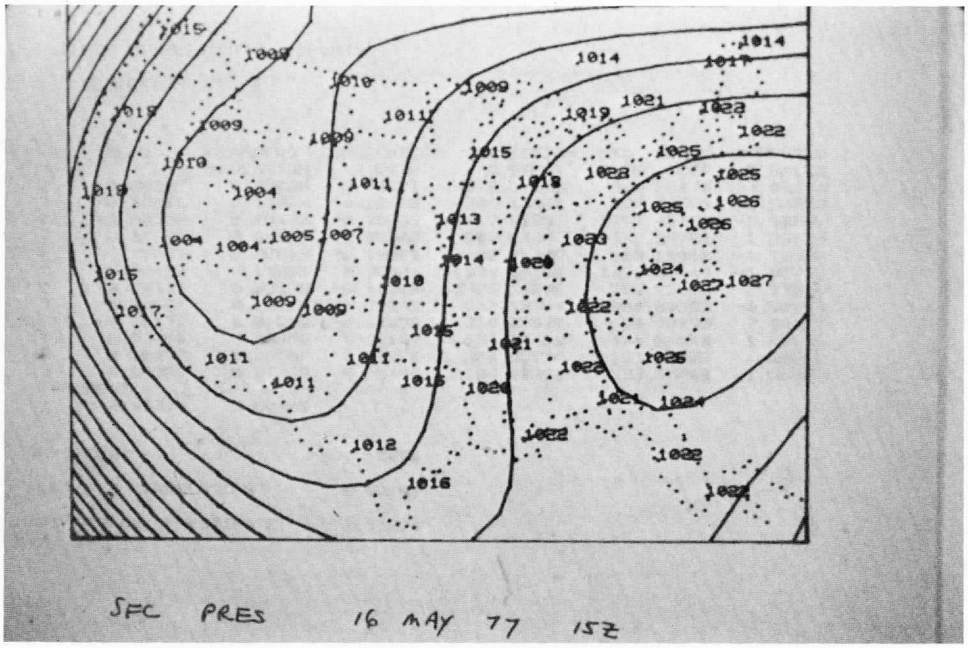


FIGURE 8.8

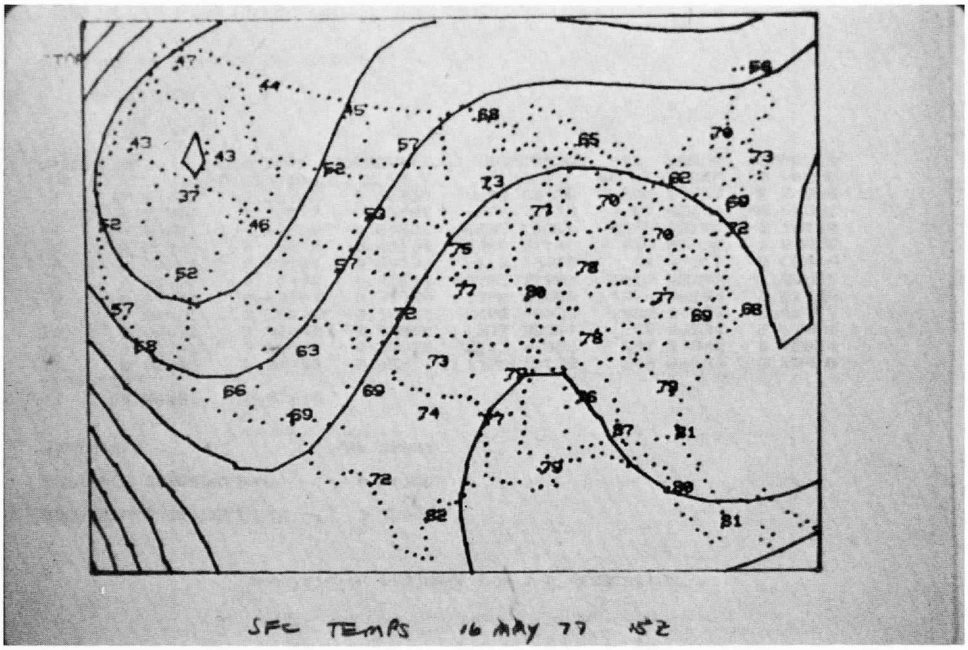


FIGURE 8.9

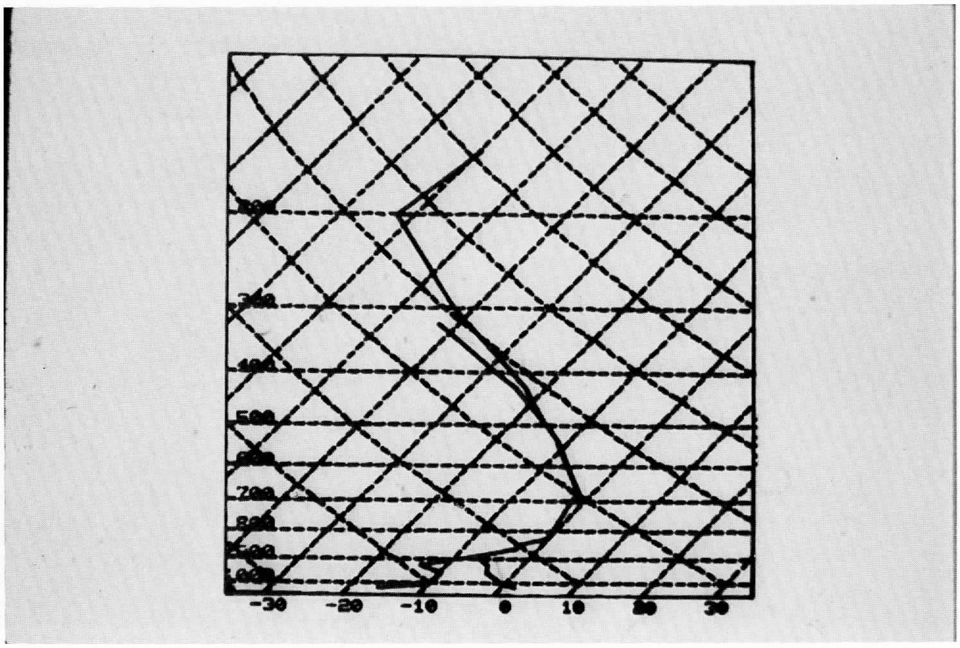


FIGURE 8.10

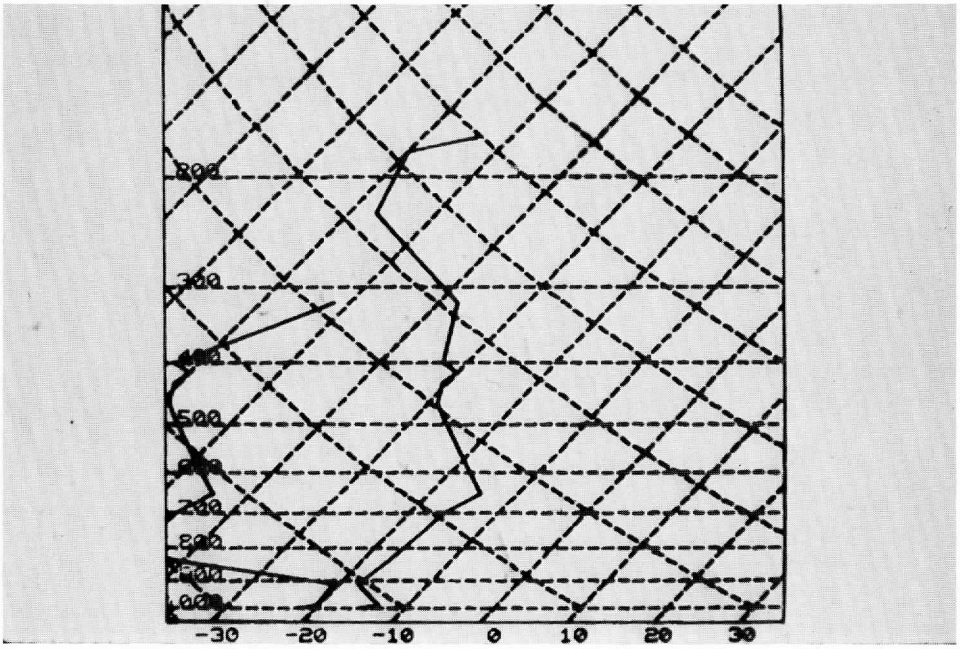


FIGURE 8.11

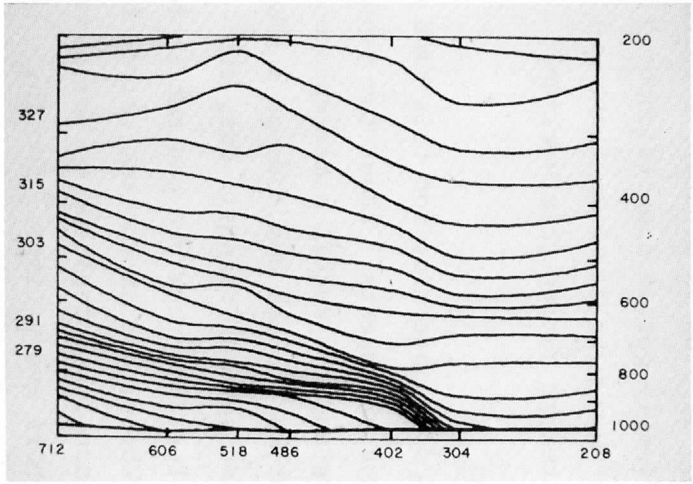


FIGURE 8.12.a

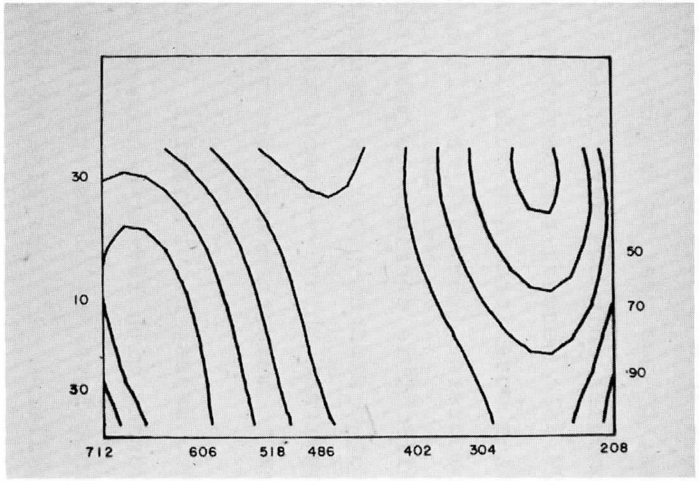


FIGURE 8.12.b

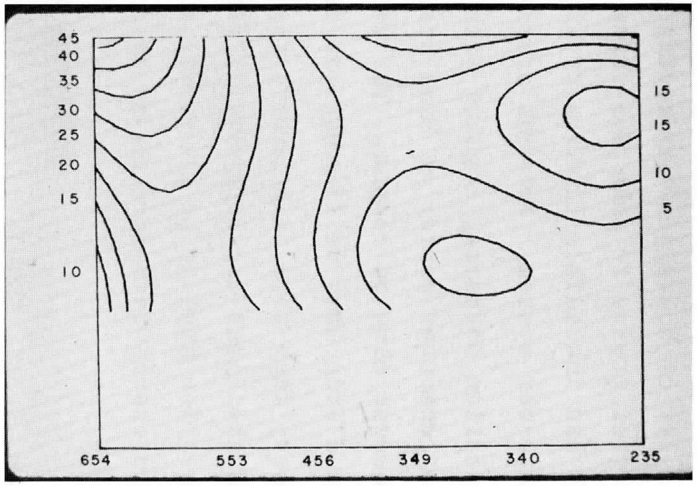


FIGURE 8.13

deliver the latest one to you, so every time you have a problem, you're updating it and changing your programs, trying to find glitches in the software. You spend a lot of hours just monkeying around, with zero scientific productivity. You're just trying to make the thing work.

We had incredible trouble trying to get a dotted map background program from NCAR into our system. We went around and around with tape labels and updated documentation software, arguing with NCAR and with our computer company, and with our computer center at Penn State. We even conned a file-transfer program from someone else on campus. The whole exercise took literally hundreds of man-hours and even when we finally got everything into the computer, we found that there were many more data points than we wanted. It took 20 minutes, I think, to draw the first map background, although we finally got it down to about 5 seconds. You have to be prepared, at times, to face problems like that, and maybe we should talk more about these types of things during this workshop.

QUESTIONS AND COMMENTS

C: [Dr. Suomi, SSEC]: I think this is a very fortunate time for this kind of talk, because many of the students are computer experts. About two years ago, I decided to learn all about computers and got myself a microprocessor. I was told I should consider a computer not as a black box, but as a glass box, to see what is inside. Well, I learned several things: One, the computer chip was very cheap (I bought it for $300; now you can get it for $29.75); second, the peripherals were not cheap, but expensive; third, it takes more intensive intellectual effort than I had realized to deal with computers (the machine will catch your errors every time); fourth, while it is possible to make things idiot-proof and fool-proof, making a system student-proof is impossible; and finally -- probably the most important thing -- computers can be much more powerful when you understand how to make them work for you.

C: [Dr. Evans, U. of Miami]: We are using an RT program, foreground and background, with 16+ asynchronous terminals coming into our machine, and we don't have any of the tape problems you mentioned. We have our own tape handlers. I'll be glad to talk with you about our system.

C: [unidentified speaker]: For those of us who might be considering facilities like yours, it's not just equipment cost, but also the cost of manpower needed to get the system going and keep it running efficiently that we need to consider.

R: [Response - Dr. Norman]: It's the trivial things that kill you. We've lost many man-hours of valuable research time, for example, wrestling with the air-conditioning system.

Q: What happens when someone crashes the system? How do you regenerate it?

A: We do all our regeneration from disk, and after a catastrophic failure, we can bring our operating system back up in a couple of minutes.

Q: Even if you lose your programming down on your disk -- your operating system -- you can bring it back up?

A: Yes. We always have a backup disk, so we can do that in a couple of minutes.

Q: Do you leave the RSX-11 in all the time, do you swap it back and forth, or do you leave RT-11 in all the time?

A: We use one or the other.

Q: Could you estimate (and maybe it would be helpful if the other speakers could too) how many and what kind of people it takes to keep your system viable? How many programmers? What kind of people do you need for hardware failures? What is the maintenance cost?

A: We have been trying to maintain a service contract. Unfortunately, the politics and economics at Penn State make that very difficult, so we have been moderately successful at mooching a service contract. The machine has operated for three years, about 8-10 hours a day, five days a week, and has failed twice. It's been an extraordinarily reliable piece of equipment. In terms of manpower, we have done a lot with graduate students, and quite a bit, also, with undergraduates, with guidance. It probably has been the equivalent of a half-time faculty member dedicated to guidance of students, and perhaps a half-time employee who keeps the disk heads clean, regenerates the system, and does a lot of the basic programming. It has taken a very minimal amount of manpower.

THE SOLID STATE COLOR IMAGE DISPLAY SYSTEM USED AT THE UNIVERSITY OF MIAMI

Dr. Robert Evans
University of Miami

For this section of the workshop I want to talk not about the evolution of our system, but about the fact that we desparately needed one. When we began to design our system, one of the places we came for help was here to the University of Wisconsin, to define features we wanted, to decide how to make the system responsive to our particular research activities, and how to assure that the system could be easily expanded. When you engage in an activity such as image display, new methods to display and analyze data suggest themselves, so we wanted our system to be responsive and to accommodate our present and future needs. Further, we wanted the system to be reliable and easily maintainable. Since our operation in Miami is small -- two scientists and two programmers -- we face a number of constraints. We have to develop, maintain, operate and extract science from the image display system while trying to assure that our time is well spent. As I mentioned this morning, our hardware is relatively new; while we have been involved in remote sensing for two years, our image display hardware has been operational for about six months.

Before I describe the hardware, I would like to address some of the typical aspects of satellite image processing and how they affected the decisions we made in designing our system. The procedure for processing satellite data -- VHRR and SR series from NOAA satellites, DMSP from the Air Force and GOES imagery -- is similar (Fig. 9.1). First we acquire the data; the source of the data depends on the system and the agency. Due to the number of satellite systems, the data (usually contained on nine-track tape) are encoded in a variety of formats. A flexible method must exist to input the data and convert it into a standard data base from which subsequent analysis and manipulation programs can operate.

Next the data is calibrated, via a process which depends on the satellite system. At present we are operating predominantly in the West Indian Ocean where there is no geosynchronous satellite data, and where, due to satellite failure, the DMSP operation has not been spectacularly successful. Most of the Western Indian Ocean data is provided by the NOAA VHRR and SR sensors. An example of the problems inherent in satellite image processing is provided

SATELLITE DATA PROCESSING PROCEDURE
(VHRR, RS, DMSP, GOES)

ACQUISITION:

Reformat from source media to internal file.

CALIBRATION:

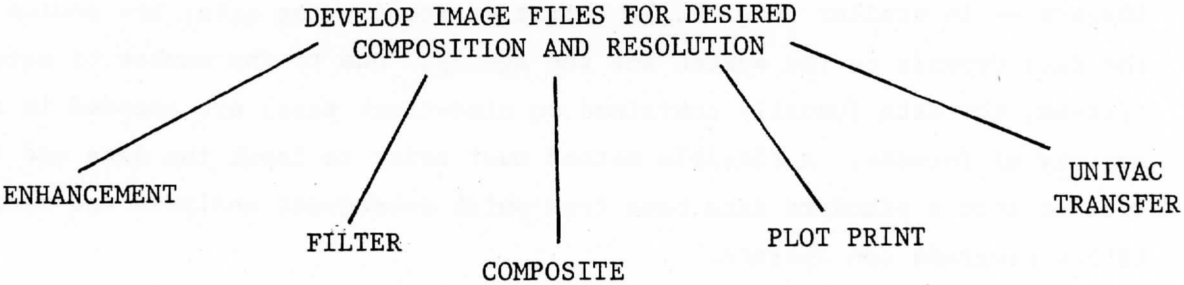
1. Preliminary validation
2. Sensor characteristics
3. Electronics characteristics

FIGURE 9.1

NAVIGATION/RECTIFICATION

1. Equal area projection
2. Co-ordinate conversion
3. Landmarks
4. Deskew image

DATA BASE COMPILATION



PARTIAL LISTING OF TASK INTERACTION WITH DATA BASE

FIGURE 9.2

by the VHRR data. There currently is no central repository for this form of data. Thus, one must go to one individual to determine which sensors are being used, to another to determine calibrations, to yet another to acquire orbital parameters, and to other groups to retrieve satellite data and assure their archiving. An essential requirement for satellite image processing is a well codified system containing basic information about satellite location, operation and data archiving. This is an important aspect of the GOES program, and much of its success is due in part to the work of people here at the University of Wisconsin.

Calibration includes removal of telemetry bias as well as sensor calibration. At this point, corrections can be introduced to reduce the effects of water vapor and other forms of contamination. These latter problems are currently treated through the introduction of ground truth data, although future sensing systems may alleviate this problem to some extent.

Since navigation and rectification (Fig. 9.2) have received considerable attention already, I will speak only briefly about this process. At Miami we include an additional step. Given the large time scales over which image data are taken, a significant degree of rotation can appear in the images; for this reason, the images must be deskewed. (Notice in Figs. 9.7.a and 9.7.b that the subsync lines of the VHRR images are slanted; features of Africa are geometrically corrected to give a better image than can be obtained from a raw VHRR facsimile picture.)

The real workhorse of the system is the data base compilation (Fig. 9.2). I want to stress that without a standard data format, programming efforts are extremely complicated. Operations that access the data base include enhancement, filtering, compositing and production of printer-plots, laser facsimiles and hard copy. After the significant information (space or time series) has been extracted, the satellite data is transferred to a larger computer for comparison with more conventional forms of oceanographic data.

Although some of the operations are computationally intensive, most are I/O (input/output) intensive; therefore, the time required to produce a useful product can be reduced dramatically if the number of times an image is swapped from disc is minimized. This requirement is met with a solid state system (Fig. 9.3), since the image memory acts as an extension of the computer.

Once an image is displayed, the computer can access the display memory and manipulate the image in a variety of ways without physically altering the data base.

Our computer, a PDP 11/10, was inherited from GATE and required extensive remedial maintenance due to its brief service as a shipboard computer. The initial machine complement included two small discs, magnetic tapes and unit record devices. A basic image display system was established through the addition of display hardware. Based on our research efforts during the last six months, our sponsors (principally the Office of Naval Research) have provided a virtual explosion of resources; a PDP 11/55 and a second tape system were added to speed processing and to ingest 1600 BPI tape images. Two electrostatic printer-plotters and a number of ancillary interfaces complete the system hardware. This system can support several extremely remote terminals, linked by geosynchronous communications satellites. These small portable terminals are based on the LSI microcomputer version of the PDP 11, and help provide more optimum use of limited ship resources.

Communications between the computer and image display (Fig. 9.4) are performed using high-rate bi-directional links operated at a direct memory access level. Loading an image requires less than a quarter of a second. Interactive capability is provided by an X-Y tablet instead of joy-sticks. This is a useful feature, since the satellite imagery is augmented by strip chart data. For example, tanker XBT tracks can be digitized; then, using navigation, these ground truth data can be compared with satellite data to provide information concerning satellite imaging systems, validity of XBT tracks and general experimental procedures. In addition to the color display, an ASCII terminal with limited plotting capability enhances operator communications. Histograms or other descriptions of image characteristics can be analyzed on the color monitor using overlay graphics (as with McIDAS), or with the plotting terminal itself.

Since this system is solid state, the display hardware is minimal and is contained on a rack 30 inches high and 19 inches wide. Each subsystem consists of a single printed circuit card, yielding a system that is small, easy to modify and reproduce, and relatively inexpensive. The color monitor, plotting terminal and X-Y tablet represent a major proportion of the total system cost of $23,000, exclusive of the computer. (Fig. 9.5 shows the operations console.) The color monitor is a Tektronix 6270A-1, which

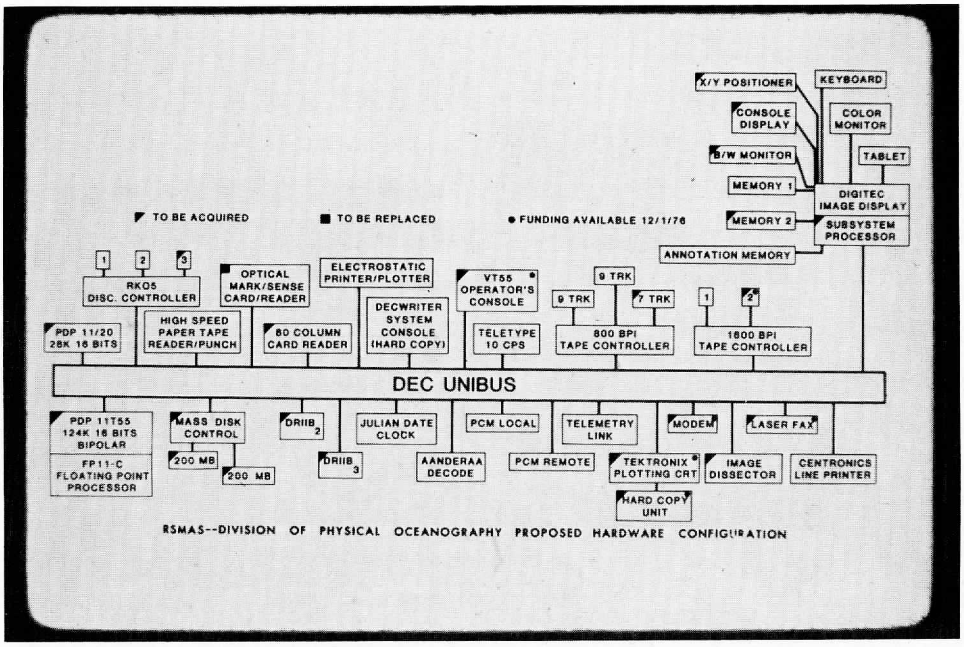


FIGURE 9.3

DISPLAY CONFIGURATION

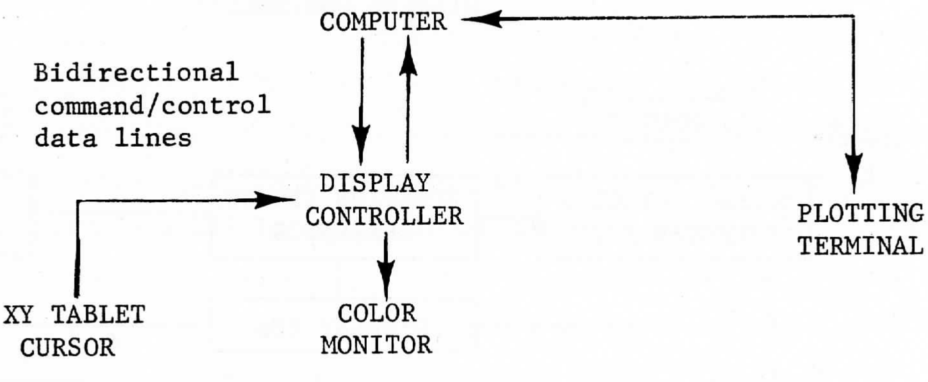


FIGURE 9.4

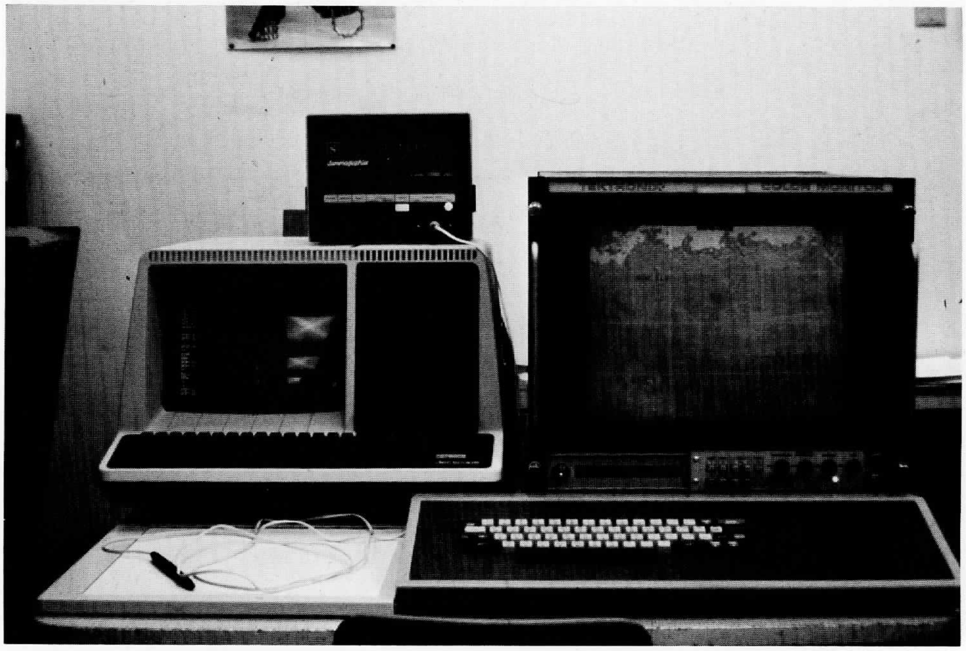


FIGURE 9.5

DISPLAY CONTROLLER

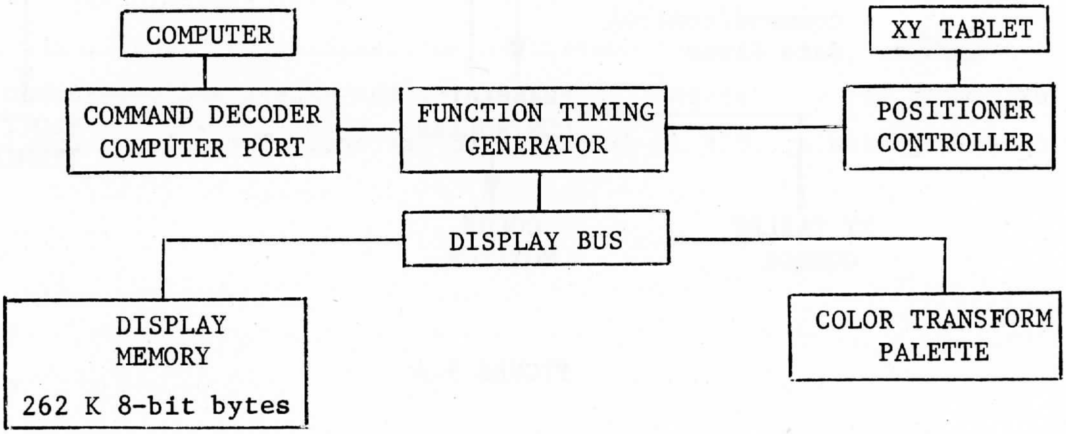


FIGURE 9.6

provides acceptable reproduction and stable intensity control. Mitsubishi manufactures a tube that provides 1029-line color format, and we will upgrade to that monitor in the future. In addition, there is a keyboard, plotting scope and laser facsimile device to generate image hard copy. (My slides today were shot directly from the color monitor using 35mm film.)

The display controller (Fig. 9.6) consists of several functional entities. One subsystem is a multichannel link to the computer, which includes two command and control links (simple 16-bit parallel interfaces), the data transfer DMA channel, and the command decoders.

This subsystem also includes the command decoders. Proper allocation of functions between hardware and software is fundamental to the system design process. Functions that control manipulation of the image would normally be realized in hardware to minimize data transfer. Alternately, maximum flexibility in combining functions is achieved with good software design which precludes frequent system reconfiguration. A function generator receives instructions from the command decoder, restructures the display, and controls memory addressing timing that permits an operator to translate or zoom an image. A positional controller can be connected to the X-Y tablet, joy-sticks, or other combinations of positional devices to allow an operator to interrogate, translate or modify an image. These subsystems are interfaced to a display bus. An image is refreshed from a 512x512x8-bit display memory; as pixels are strobed from the memory under control of the timing generator, they enter a transform palette that controls enhancement.

To illustrate one application of the display system, Fig. 9.7.a shows a VHRR image that has been navigated and calibrated; however, the image is extremely noisy. Information concerning the extent and development of the upwelling zone at 10^{O}N is difficult to extract. The intense upwelling region in the Gulf of Aden also is obscured. A 3x5 averaging filter was applied, producing Fig. 9.7.b, which more clearly shows the thermal structure. The noise was suppressed through averaging techniques, applied to the image as it resided in the display; we did not have to bring the image into the computer from disc, manipulate it and then reconstruct it. Image memory acts as either a word-addressable or a block-addressable device; thus, the display memory appears to be memory or a high speed, zero latency disc, transparent to the user. A user can reference image memory either through the display controller hardware, or treat it as a peripheral via standard read-write protocols.

SEE APPENDIX A

FOR FIGURES 9.7.a and 9.7.b

COLOR TRANSFORM PALETTE

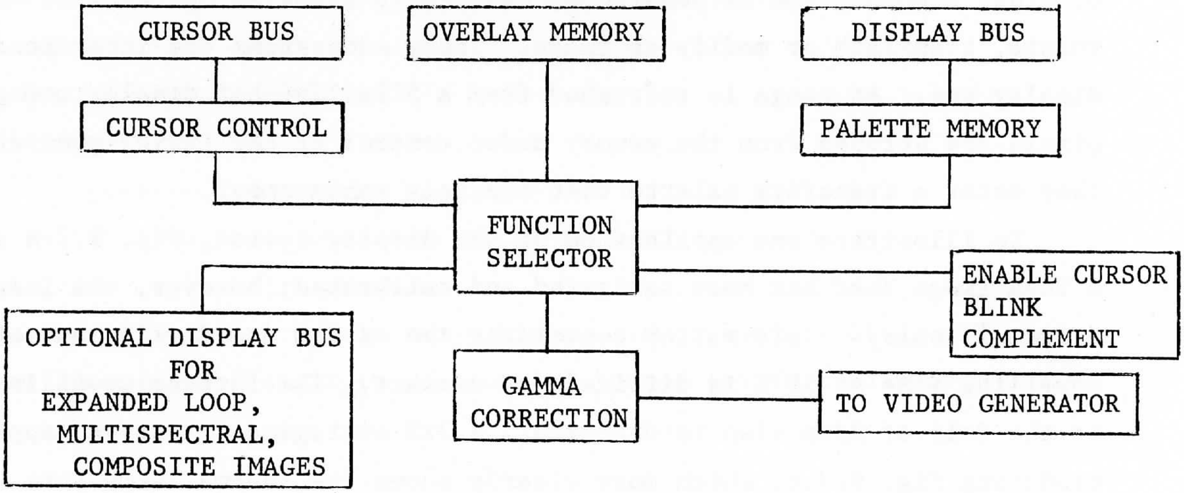


FIGURE 9.8

Flexibility of the system is derived from the transform palette (Fig. 9.8), which is divided into a series of subfunctions. Various displays operate under a priority system, in which the cursor is most important. Next, overlay graphics are displayed if present, and finally, the contents of the image memory are displayed. Cursor position and color are derived by the cursor control using input from the positioner controller. In the future a second display bus will be added to provide multispectral display, higher resolution or extended movie loops. Other functions include a blink mode and a palette complement mode. Blink mode provides an easy method to locate a small isoline contained in a field of 262,000 pixels. Complement mode yields a fast method to invert the color enhancement stretch function.

Each pixel is represented as an eight-bit data word in the display memory, which yields 256 possible states. During an earlier calibration phase, image measurement data are mapped onto the 256 states using a scaling transform appropriate to the data. After a pixel enters the palette, the eight-bit data representation addresses one of the 256 palette locations. The palette memory contains 16-bit words divided into three fields of five bits each, with one blink control mode bit. Each field is independently defined, providing total control of the enhancement. Further downstream a gamma correction section takes each five-bit field and expands it to an eight-bit representation to correct for the logarithmic phosphor transfer. This yields a perceived linear increase in brightness across 32 levels. From the gamma correction section, the image data then goes into the video generator.

I would like to describe the color enhancement procedure using a GATE image (Fig. 9.10.a and 9.10.b). A histogram of the image (Fig. 9.9) is first computed to determine the bands of interest, digitization interval and color sequence. In effect, a non-linear stretch technique is introduced in which everything below a certain value is coded black, everything above is white, separated by two intensities of each color. In Fig. 9.10.a, each gradation represents $0.5^{o}C$. Fig. 9.10.b presents the complement palette image that more clearly illustrates the gradient structure.

Fig. 9.11.a provides an idea of the perceptual and shading characteristics that result when three simple geometric figures -- a diamond, a square and a circle -- are composited using spatial convolution, a technique typical

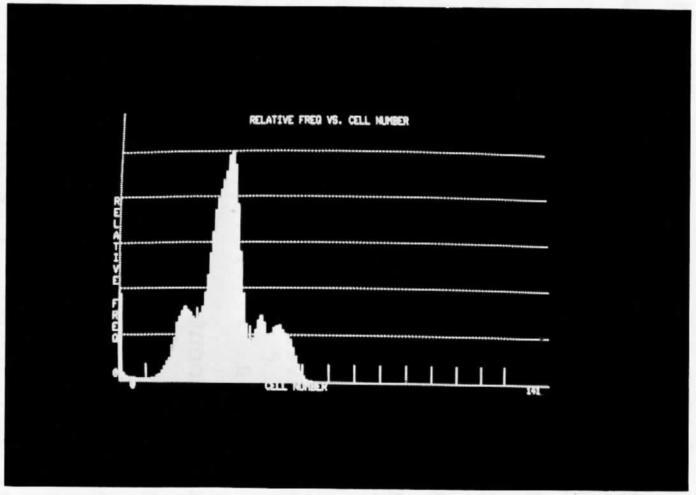


FIGURE 9.9

SEE APPENDIX A
FIGURES 9.10.a and 9.10.b

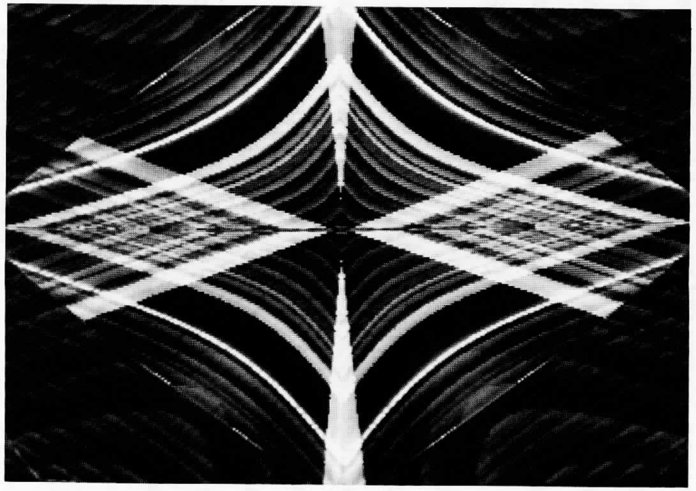


FIGURE 9.11.a

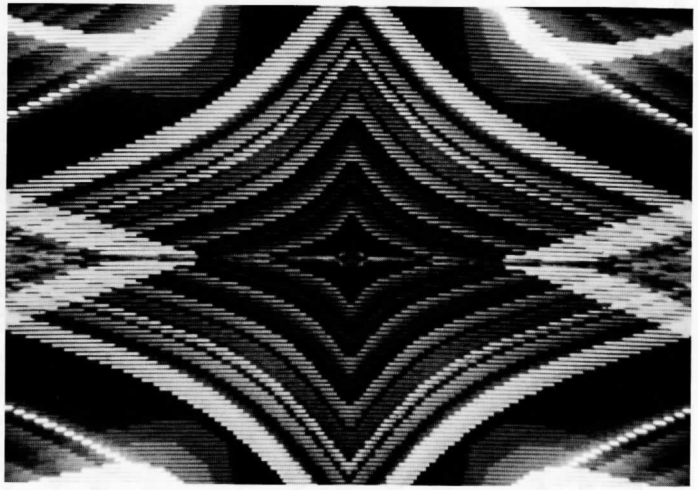


FIGURE 9.11.b

of image display. The image is then translated and magnified (Fig. 9.11.b) to present the image in more specific detail.

In summary, we have attempted to construct a system that is relatively small, inexpensive, easy to manipulate and predominantly self-maintaining, allowing us to devote as much time as possible to scientific applications of satellite remote sensing.

QUESTIONS AND COMMENTS

C: [Dr. Suomi:] I think this is a remarkable accomplishment in a short time--a very powerful and economical system which indicates that things do not have to be expensive if you understand the system (if I may use my earlier phrase) as a glass box rather than a black box.

Q: Are the plans for your system available, so we could build our own?

A: Certainly. There is nothing special about it; in fact, hardware has undergone quite a revolution in just the few months that we've had our system up, and there would be a few things about our system that I would change. I think you could safely and easily replicate our system for less money now. On the other hand, there are several companies (Comtol, for example) that are producing similar systems. They don't really have the flexibility, but the Comtol system comes closest to ours of any that I've seen, and the cost is reasonable.

Q: Do you have terminals in operation on ships? How do you communicate with those?

A: Yes. They are linked by synchronous communication satellites.

Q: You presumably run that whole system on RT-11 software. Do you have the kind of data that requires you to be reading and at the same time writing into the same file?

A: Yes. In fact probably the best example of this is our ship support efforts. Ships deploy autonomous buoy stations which are quite small, and those stations transmit to the ship via pulse code modulation (PCM). The ship acts as a data collector and also sends the data to Miami, where we process it and send it back to the investigator to use for dynamic control of his experiment. All of this happens in real time.

C: [Dr. Vonder Haar, Colorado State University:] Your comments about calibration are ones that we all must face. Whether we consider satellite data, radar data or other sources, we need good quantitative systems, where a red spot here means the same number as a red spot there. We want to know how many W/m^2/steradian that red spot represents, to compare with theoretical calculations. One of the things that the data collection platforms can do is provide real-time ground truth data to help overcome the difficulties of calibrating some of the satellite data. Have you experimented with that at all? Do you get anything back from your ships -- quick user verification or input that helps you do a more absolute job?

A: To some extent. Most of our work, as I said, is concentrated in the West Indian Ocean, and a lot of our data is collected by ships of opportunity (U.S. Navy and a lot of others). We also have an operational support base in Mombasa now. The point is that much of this is not real time data, so calibration is less important. For operations in other places -- the Atlantic or Pacific -- we do use fairly real time data.

NCAR DOPPLER RADAR DISPLAY SYSTEM:
HARDWARE DESCRIPTION/OFF-LINE DATA PROCESSING

Dr. Serafin

I want to talk first about our current real-time system used with our radars in the field, and then about an off-line system we are planning and developing.

The present system is actually very simple (Fig. 10.1). We have a radar with analog data rates on the order of 1MHz. We digitize those data (and maintain digital rates of about 1MHz), and feed them into a real-time digital processor which computes the parameters I talked about earlier -- the mean Doppler velocities, the reflectivities and the standard deviations of the Doppler spectrum. Through this process we are able to achieve data compressions on the order of 16:1 to 4000:1, typically about 100:1. Data are then sent to an interface controlled through a minicomputer and permanently recorded on a digital tape recorder. We have a display memory of 256 x 256 elements by four bits, so we can generate any one of 16 colors in real time. That memory is updated as the antenna is scanning in real time; we do the update during the vertical retrace on the color TV monitor, and then display any one of the 16 colors on the color TV monitor. We can play back from the digital tape through the interface; since the display system sees only the interface it does not know whether data are coming from the radar receiver or from the tape recorder and we can replay those portions of the storm that are of interest.

You want to know something about cost. The radar represents a $300,000 investment in components and salaries. The digital processor costs roughly $10,000; the mini-computer, digital tapes and interface cost around $30,000; the display system costs another $10,000. So it's about $50,000 for the processing package, and it's well worth the investment. The engineer and the technician who operate this system also designed and built it, and they currently are finishing a second version. We feel that with one more technician we'll be able to maintain both those systems and operate them in a variety of locations around the country.

We use a digital scan conversion process (Fig. 10.2). We deal with spherical or polar coordinates, and we can simply locate the radar anyplace in the memory which is 256 x 256 elements in extent, through a simple coordinate conversion process. The data are then read out in raster fashion onto the television monitor screen. Satellites produce large volumes of data, and so

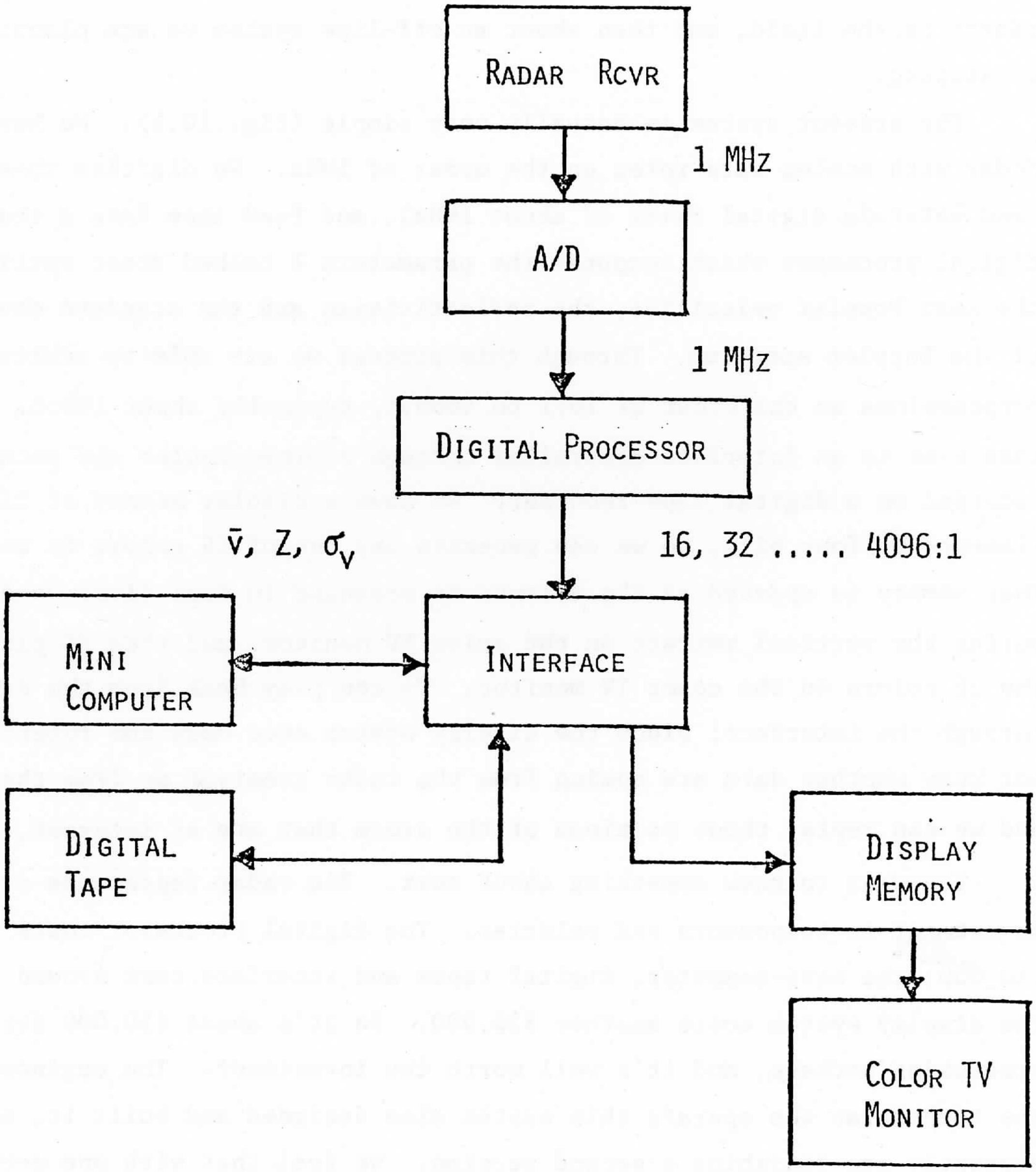
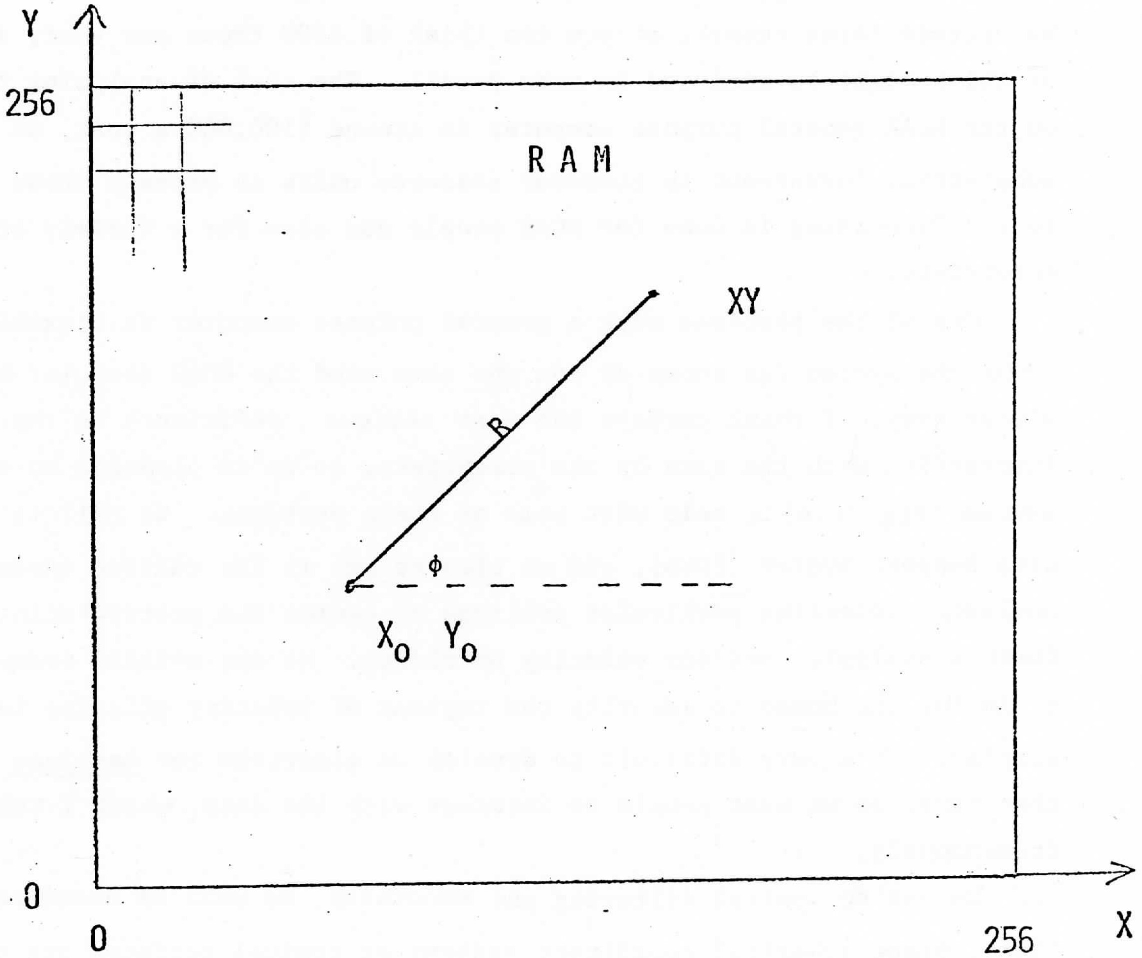

RADAR RCVR
1 MHz
A/D
1 MHz
DIGITAL PROCESSOR
v̄, Z, σ_V
16, 32 ..... 4096:1
MINI COMPUTER
INTERFACE
DIGITAL TAPE
DISPLAY MEMORY
COLOR TV MONITOR

FIGURE 10.1


DIGITAL SCAN CONVERSION

$$\left.\begin{array}{l}\bar{V}(R, \phi) \\ Z(R, \phi)\end{array}\right\rangle \longrightarrow \left\{\begin{array}{l} X = X_0 + R \cos\phi \\ Y = Y_0 + R \sin\phi \end{array}\right.$$

FIGURE 10.2

so do radars (Fig. 10.3). A complete digital tape takes about 26 minutes with a 100:1 data compression ratio; if we add another variable, it's 17 minutes per tape. With a single radar we generate something like 350 to 500 tapes per year. We operate three radars, so you can think of 1000 tapes per year, about a third of which might be analyzed in more detail. The cost of analyzing those tapes on the NCAR general purpose computer is around $100,000 a year, so there is a substantial investment in computer resource units to process these data every year. Processing is done for NCAR people and also for a variety of university scientists.

One of the problems with a general purpose computer is flexibility; getting onto the system (as those of you who have used the NCAR computer know) is not always easy. I think perhaps the most serious deficiency is the lack of real interaction with the data by the scientists, so we're planning an off-line system (Fig. 10.4) to help with some of these problems. We call it the Research Data Support System (RDSS), and we plan to use it for editing tapes, quick-look analysis, selecting particular portions of storms and precipitating systems for further analysis, and for velocity unfolding. We saw earlier today how simple it is for the human to identify the regions of velocity aliasing in the color display. It's very difficult to develop an algorithm for machines to accomplish that task, so we want people to interact with the data, which I think will help tremendously.

We can do spatial filtering and smoothing, as well as coordinate transformations, since spherical coordinate systems or conical surfaces are really very clumsy to handle. We need to get into rectangular systems to look at vertical and horizontal slices of the atmosphere. Overlay of displays is very important -- overlays of reflectivity factors onto velocity fields, overlays of reflectivity factors onto satellite-generated displays, and so forth. We can also do time-lapse displays.

So far we've talked only about single Doppler radar data, but we are also now putting together multiple Doppler radar data. Most studies of convective storms now require three or four Doppler radars in the field for generation of the complete three-dimensional motion fields. We need to spatially locate the radars, collect the data and put them all together to generate the three-

RADAR DATA VOLUME

- ONE 9-TRACK, 1600 CPI, 2400 FT. TAPE CAN HOLD
  - 2.5×10^8 BITS
  - 26 MIN OF 2-CHANNEL AVERAGED RADAR DATA
  - 17 MIN OF 3-CHANNEL DATA
- ONE RADAR IS EXPECTED TO GATHER DATA
  - 3 MO/YEAR IN FIELD
  - 150 HR/YEAR OPERATING (7%)
- ONE RADAR WILL GENERATE
  - 350 TAPES/YEAR, 2-CHANNEL DATA

FIGURE 10.3

OFF LINE PROCESSING

RESEARCH DATA SUPPORT SYSTEM

- EDITING
- QUICK-LOOK ANALYSIS, SELECTION
- VELOCITY UNFOLDING
- SPATIAL FILTERING
- COORDINATE TRANSFORMATION
- OVERLAID DISPLAYS
- TIME LAPSE DISPLAYS
- MULTIPLE DOPPLER RADAR ANALYSIS
- VIDEO TAPE
- FILM
- HARD COPY

FIGURE 10.4

dimensional fields. This can be a substantial task in view of the large volumes of data collected. Then, of course, we need some outputs - digital tape, video tape and film hard copy.

The RDSS is shown very simply in Fig. 10.5. It includes inputs from video tapes or digital tapes, control and feedback by the user, a variety of formats that can be selected by the user, and also a variety of user-selected outputs. Fig. 10.6 might represent a typical sequence in the analysis of a storm. First, a researcher would look at some time-lapse videotape generated by the system, either at our facility or perhaps on a video monitor in his laboratory. (We can generate a video tape and ship it to him.) Then, in response to his request, we could generate particular slices through that storm so he could look at it in more detail. Eventually we could develop a digital tape for his use, or, more likely, a variety of pictures.

Figs. 10.7 and 10.8 show what we call Phase I of the off-line system, which we are working on now. It includes two types of input: compressed digital data as I described earlier, processed in real time; and uncompressed raw data recorded on videotape. These two inputs are controlled by a Nova 1200 system, which we think is inadequate for the total task. We have a small disk now, but we plan to have a 300 megabyte disk within the next couple of years. These digital data then go to a video buffer memory. We're using a Comtal commercial display unit now; our people have reached the same conclusion that Bob Evans [Miami] mentioned. These are very cost-effective systems; you can buy a lot of hardware and software for a reasonable price. The video memories are 512 x 512 elements and 8 bits wide, so we can store two very high resolution pictures simultaneously with four bits for each of the two pictures. The data go to a coordinate converter, then into the display system, which has three memories, 512 x 512 by 8 bits. One is for the basic data and the other two are for overlays. We have a track-ball or joy-stick for moving the cursors around. We use direct red, green and blue modulation for the video display system; we don't modulate the intensity at all, just the red, green and blue guns. We feel this gives us the maximum in image resolution. We plan to use NTSC color encoder recording on conventional videotape; playback can be either on a video display system in our laboratory or on a monitor elsewhere. We expect to complete Phase I of this off-line program by about September 1977. We expect to be able to generate color displays of single

RDSS

RADAR DATA EDITING AND PRE-PROCESSING

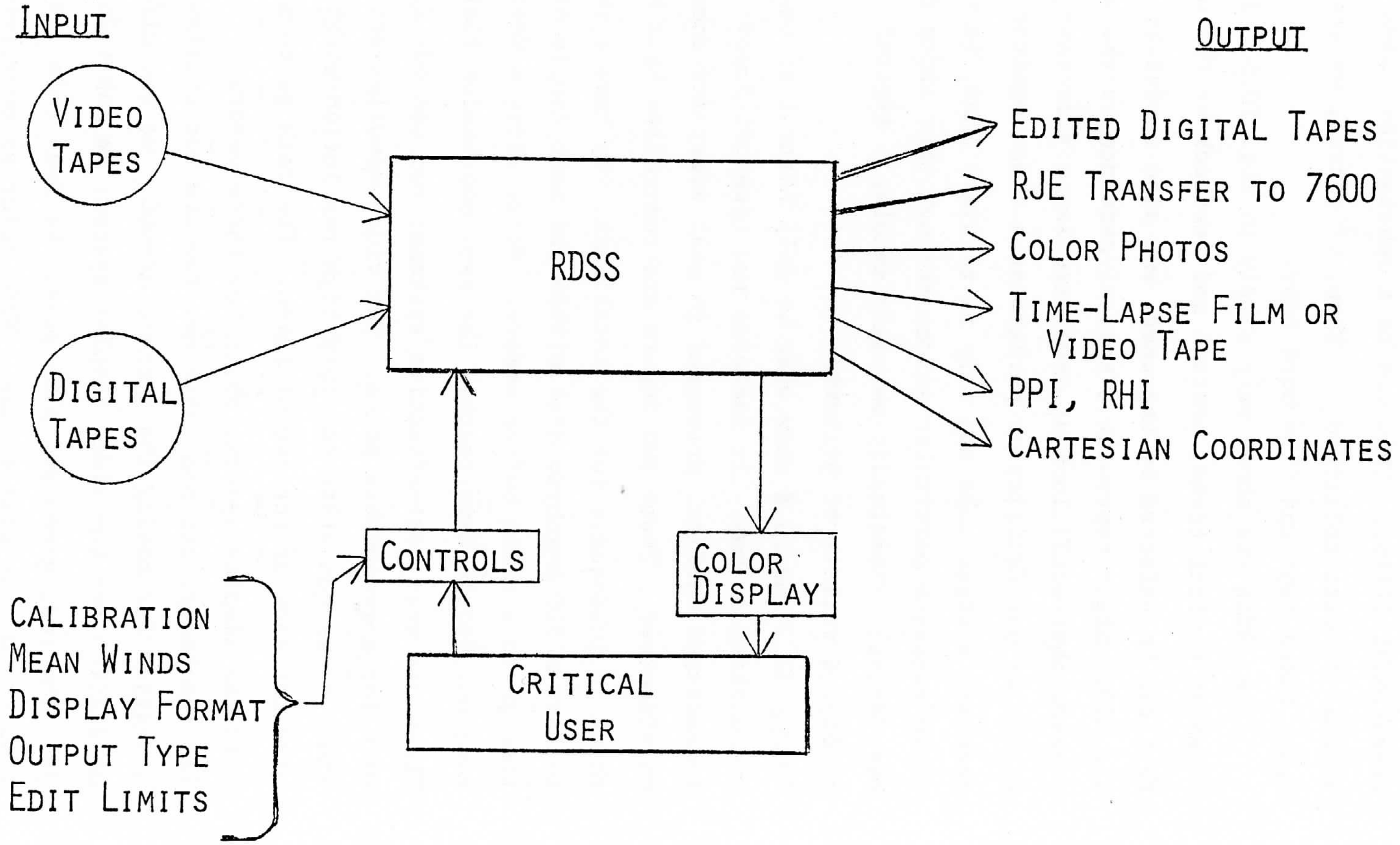


FIGURE 10.5

TYPICAL RDSS RADAR PROCESSING SEQUENCE

1. RDSS CONVERTS ONE DAY'S DATA TO A SINGLE TIME-LAPSE VIDEO TAPE, AS SCANNED, BOTH WITH INTENSITY AND DOPPLER VELOCITY, STANDARDIZED PROCESS.
2. SCIENTIST REVIEWS VIDEO TAPE, REQUESTS TIME-LAPSE OF CERTAIN PORTION IN GREATER DETAIL - EG. SLICES THROUGH CENTER OF STORM.
3. RDSS CONVERTS DATA TO SPECIALIZED TIME-LAPSE VIDEO TAPE AS REQUESTED.
4. SCIENTIST REVIEWS SPECIALIZED VIDEO TAPE, REQUESTS DIGITAL TAPE OF RAW DATA FROM CERTAIN TIME, SPACE.
5. RDSS PRODUCES DIGITAL TAPE, AS REQUESTED.

FIGURE 10.6

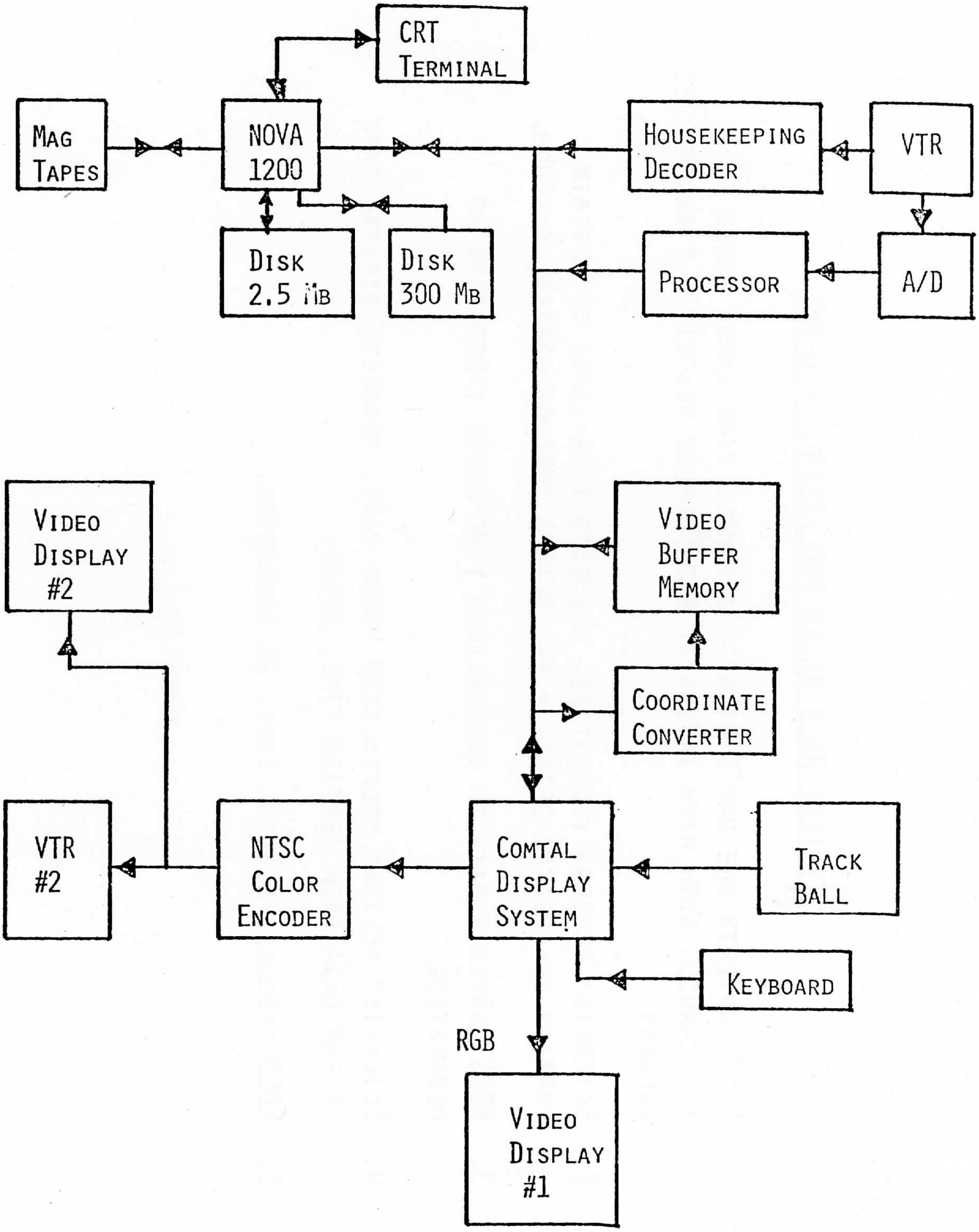

CRT TERMINAL
MAG TAPES
NOVA 1200
HOUSEKEEPING DECODER
VTR
DISK 2.5 MB
DISK 300 MB
PROCESSOR
A/D
VIDEO DISPLAY #2
VIDEO BUFFER MEMORY
COORDINATE CONVERTER
VTR #2
NTSC COLOR ENCODER
COMTAL DISPLAY SYSTEM
TRACK BALL
KEYBOARD
RGB
VIDEO DISPLAY #1

FIGURE 10.7

PHASE I

- PRODUCE COLOR DISPLAYS FROM DIGITAL DATA
- OVERLAY DISPLAY WITH TEXT
- PRODUCE TIME LAPSE VTR CASSETTES
- PRODUCE DIGITAL TAPES EDITED IN TIME AND SPACE
- SINGLE DOPPLER OPERATION

FIGURE 10.8

Doppler radar data, overlay those displays with alphanumerics and text, and to produce some time-lapse videotapes and digital tapes edited in time and space. As I mentioned earlier, we still will be restricted to single Doppler radar data with this system.

Phase II, about a year later (Fig. 10.9), will permit us to use a Cartesian coordinate system to look at vertical and horizontal slices of a storm, provide overlays for different types of data, and do some data smoothing. We will add some memory for additional image planes for rapid manipulation of the data, and provide some 35mm capability. Phase II will still operate on data from only one Doppler radar.

In Phase III (Fig. 10.10) we'll add another computer to finish the system. The raw Doppler radar input would be brought in, as well as the digital data, because in processing the data in real time, we can generate only three parameters; we don't have the raw data to look at again. But at times, one wants to look at the complete spectrum of the data, and this can only be done if one saves the raw data on tape. We expect to do that with videotape recordings in real time. Mass storage of data on digital discs makes the data much simpler to manipulate for computation of the Doppler spectra. We would add graphics at this stage, and get into multiple Doppler radar computations. With a 300 megabyte disc we could store three tapes of data from three radars on the disc at one time, which would make it quite simple to generate the vector field.

A final word about production processing. Much of the data processing on the general purpose computer would be done after Phase III has been completed.

QUESTIONS AND COMMENTS:

Q: Where will your Doppler radar processing facility be located?

A: In Boulder, Colorado, at the 30th Street laboratories of NCAR.

Q: To find water droplet size distribution, don't you need to use a couple of wavelengths in addition to what your system uses?

A: It depends on whether you are pointing the radar vertically or looking off to the side. In the vertical mode, one can compute drop-size distribution with a single Doppler radar by analyzing the complete Doppler spectrum. Looking off to the side, I think it's virtually impossible to determine drop-size distribution with one wavelength, or with two.

PHASE II

- PHASE I CAPABILITIES
- SELECTABLE "SLICES" OF STORMS
- PROVIDE OVERLAYS OF REFLECTIVITY ON DOPPLER VELOCITY
- LIMITED SMOOTHING CAPABILITY
- MORE IMAGE PLANES FOR DATA MANIPULATION
- PROVIDE MOVIE, 35 MM OR POLAROID HARDCOPY
- SINGLE DOPPLER OPERATION

FIGURE 10.9

PHASE III

- Phase I and II capabilities
- Radar data input from video cassettes
- Mass storage of data on digital disk
- More rapid image generation and data manipulation
- Computation of Doppler spectra
- Added graphics
- Multiple Doppler computations
- Production processing

FIGURE 10.10

Q: In discussing reflectivity factors earlier this morning, you used units of D^6. Shouldn't that also include the number of drops per unit volume?

A: Water droplet distribution is simply the sum of droplets within the sample volume. It is equal to that summation divided by the sample volume. The units are $mm^6/_{m}3$.

Q: What digital processor are you using?

A: It's a custom-made, special purpose unit, and it's very fast. We can do complex multiplications in 200 nanoseconds.

Q: How elaborate a CPU [central processor unit] will you need in Phase III?

A: Something like a PDP 11/70, and the cost of that system hardware will probably approach $250,000 to $300,000. I can't estimate the cost of software; we have two people working on it now, and I think they'll still be working on it three years from now. I'm not sure the software effort ever ends.

DIGITAL IMAGING SYSTEM AT
COLORADO STATE UNIVERSITY

Mr. Eric Smith
Department of Atmospheric Sciences

Our system (Fig. 11.1) is a relatively young system in which we have recently installed a digital refresh memory. It includes a Hewlett-Packard 2100-A minicomputer (Fig. 11.2), a digitizing system, and a digital eight-frame memory built by the Intel Corp. and designed at CSU by our department of electrical engineering. The console contains a video color monitor, a teletype, and a joy-stick panel. Fig. 11.3 shows the Intel solid-state refresh memory. It is an eight-frame 512x512 memory system with 64 interchangeable one-bit planes, eight interchangeable multiplex boards and a series of five look-up tables for the various outputs. We also have a digitizing camera system (Fig. 11.4 and 11.5) and a Canon cloud particle camera film ingest device (Fig. 11.6) used to read 35mm film for digitization and cloud particle selection.

The refresh memory system is very much like other systems you've seen today. We use an eight-bit memory to refresh the television set, driving memory outputs to a set of look-up tables and sending three inputs to a color TV monitor. We have the computer interfaced to look-up tables, which allows us to do false color enhancement.

Sequencing is illustrated in Figs. 11.7.a through 11.7.d. We can sequence at the video rate of one-thirtieth of a second, and we can mix visible and infrared data. Figs. 11.8.a through 11.9.c are all SMS-1 GOES images over the GATE region. Fig. 11.8.b is the September 17 cluster (very near the end of Phase III of the GATE), enhanced to indicate cloud masses and cold tops.

We also have a digital zoom capability which allows us to carry out higher resolution interpretation. Figs. 11.9.a through 11.9.c indicate a zoom or magnification sequence.

Fig. 11.10.a is a digitized photograph from SMS-1 indicating a cloud system on the day of the Big Thompson flood in Colorado. You can see the stagnant frontal line along which the thunderstorms developed. We enhanced the data (Fig. 11.10.b) and then used the cursor in the crop mode to examine a particular region in more detail (Fig. 11.10.c).

Another process provides the ability to mix signals from various bands of the spectrum as measured by satellite. Fig. 11.11.a is infrared data with enhancement; note the African continent and the double cloud cluster system

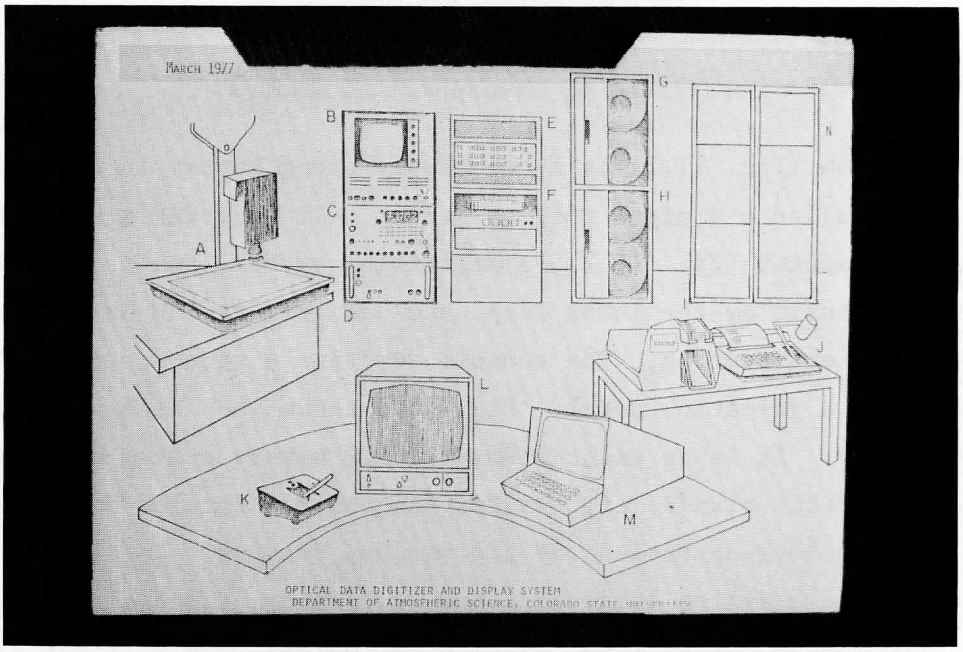


FIGURE 11.1

FIGURE 11.2

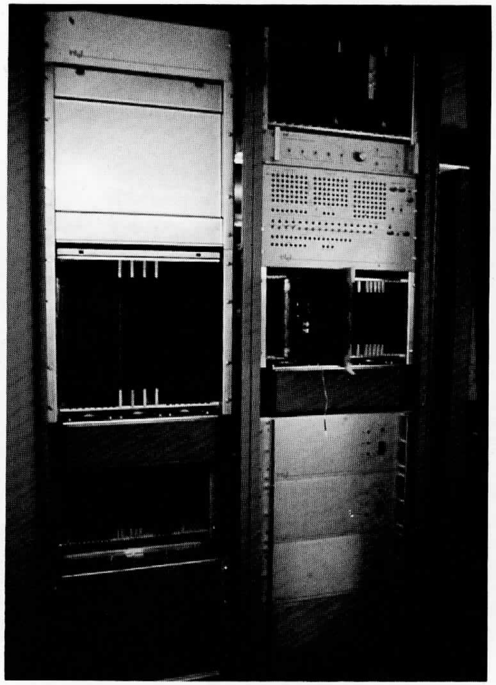


FIGURE 11.3

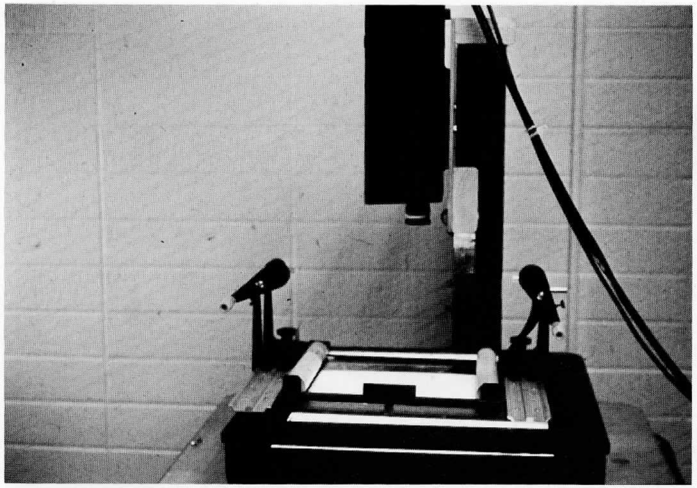


FIGURE 11.4

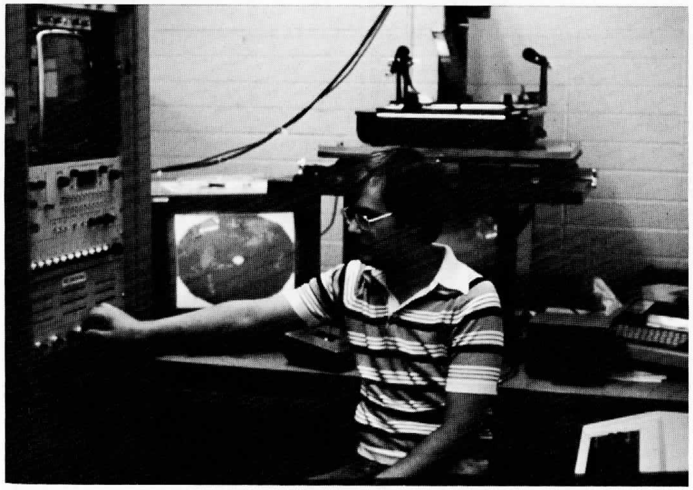


FIGURE 11.5

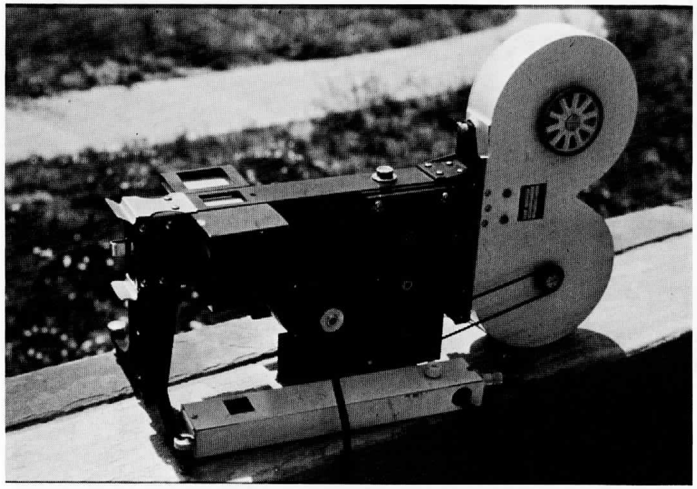


FIGURE 11.6

SEE APPENDIX A
FOR FIGURE 11.7.a

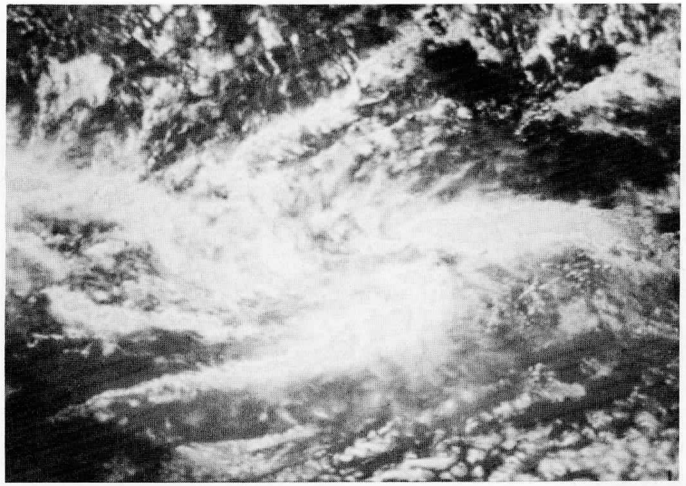


FIGURE 11.7.b

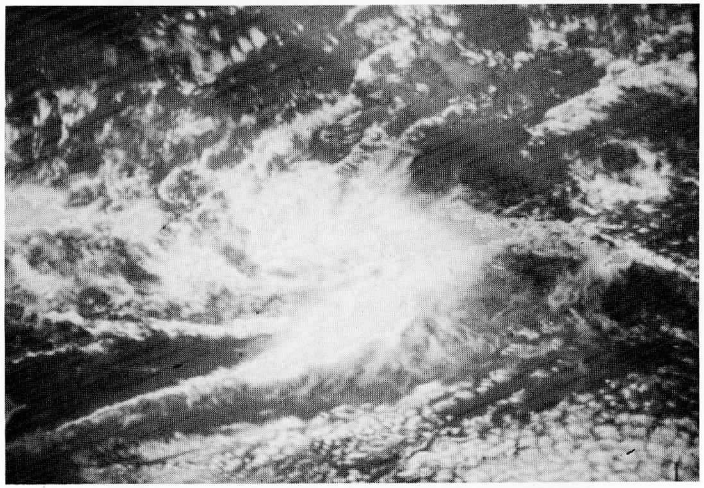


FIGURE 11.7.c

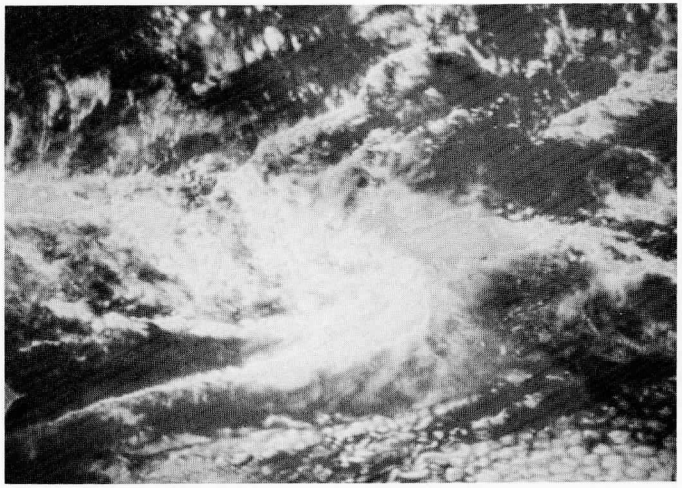


FIGURE 11.7.d

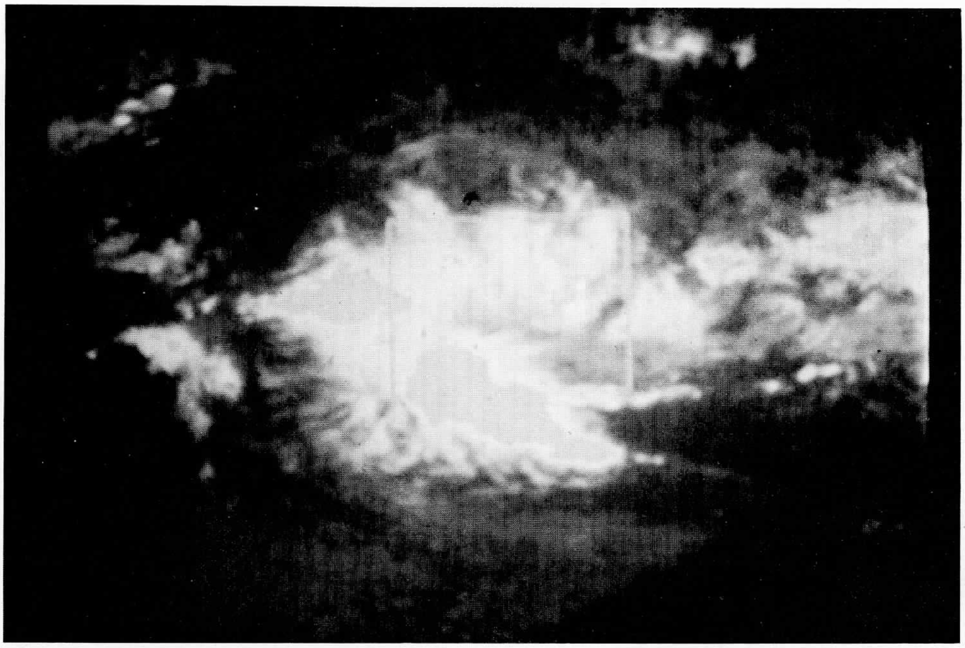


FIGURE 11.8.a

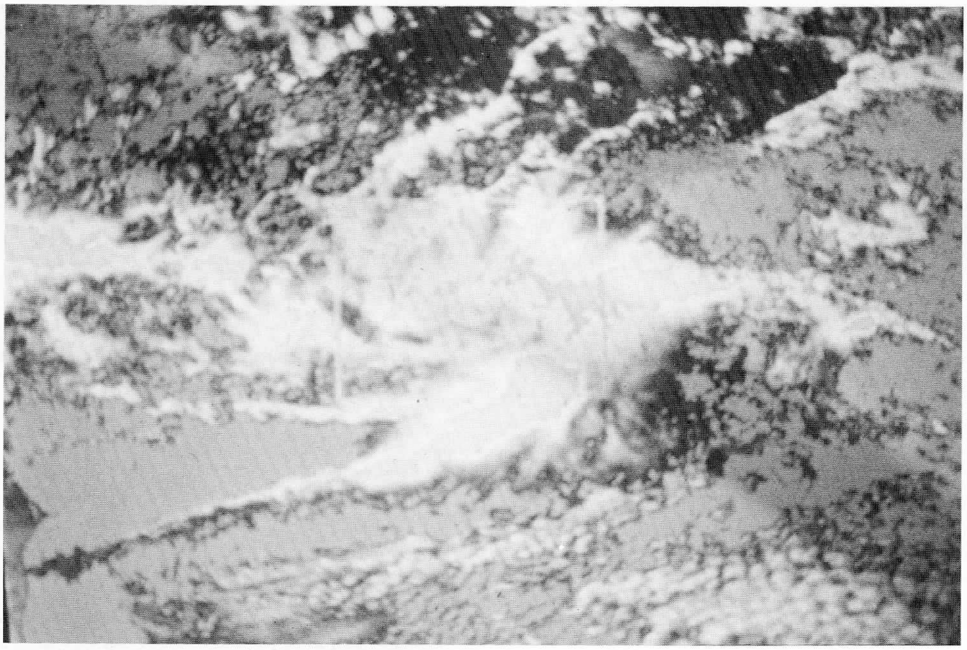


FIGURE 11.8.b

FIGURE 11.9.a

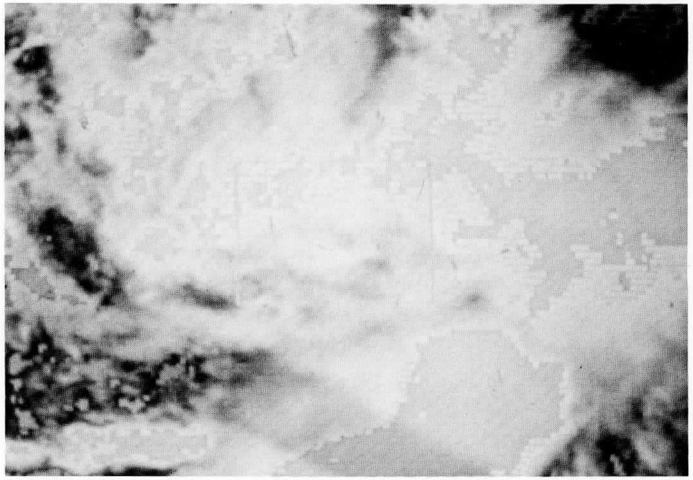


FIGURE 11.9.b

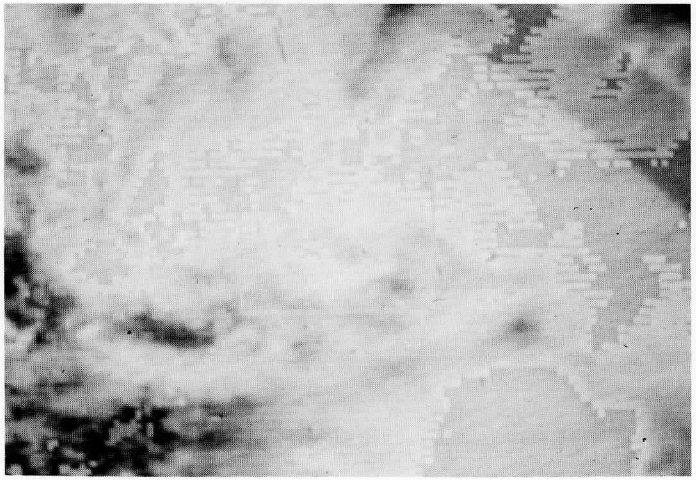


FIGURE 11.9.c

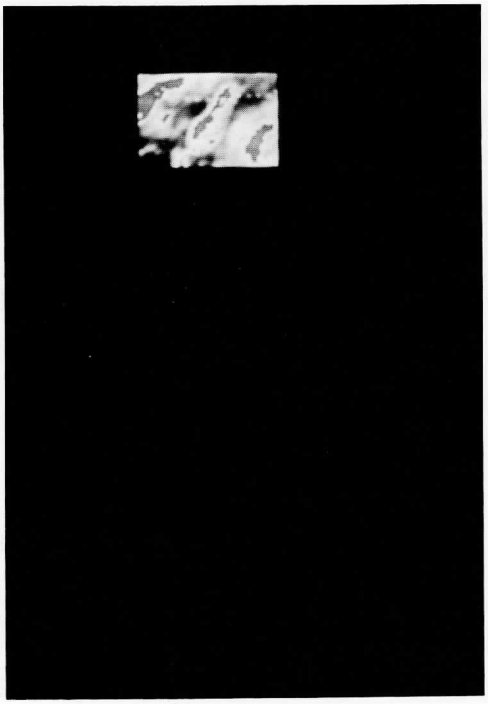


FIGURE 11.10.a

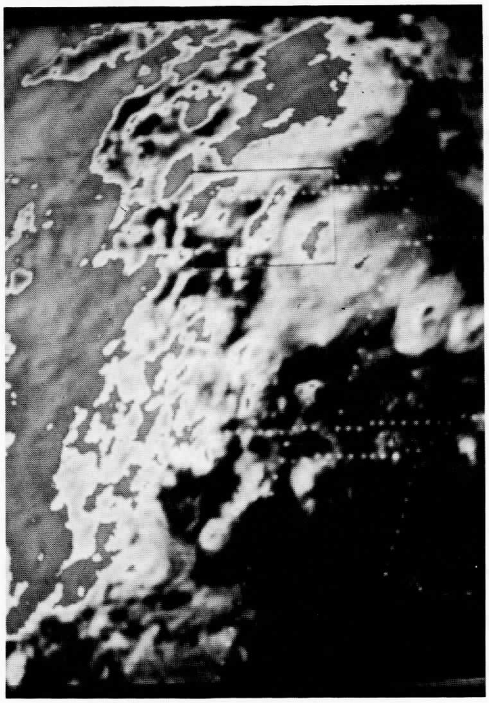


FIGURE 11.10.b

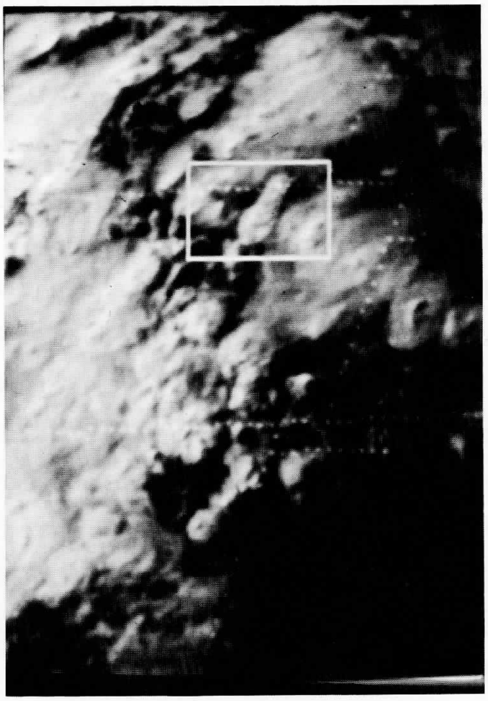


FIGURE 11.10.c

(again for September 17). If we mix in the visible data, we get a color signature for the various regimes of cloudiness; the pattern in Fig. 11.11.b was created by using separate signal inputs to the color monitor for the two images and mixing them to get a two-dimensional display.

In one of our projects we are trying to estimate rainfall using the passive microwave sensors on NIMBUS-5 and bringing in the SMS data to increase resolution within the ESMR-5 footprint. In the upper right corner of Fig. 11.12 is a radar scene from the Oceanographer, used to verify the satellite data technique. The left side of the graph shows the visible and infrared information, and the lower right corner indicates the ESMR-5 signal. Fig. 11.13.a is a full orbital swath through the tropical region; the white mass is Africa. Though the scale of the map is not correct, you can see a rain band going through the GATE region. Fig. 11.13.b is a finer resolution image of the same data, blown up over a ship position. We can look at the visible data (Fig. 11.14.a), the infrared information (Fig. 11.14.b), and the radar information (Fig. 11.14.c) for that day, and by using the various channels into the color monitor, we can mix visible and infrared and radar data for a color signature.

Fig. 11.15.a is the visible/IR combination which we saw this morning in Dr. Vonder Haar's presentation. Fig. 11.15.b combines the radar and IR data for the same area, and Fig. 11.15.c is a three-channel mix of visible, IR and radar data. This is a little difficult to interpret, because we don't have the necessary enhancement functions to properly contrast the three-dimensional color signature. In Fig. 11.15.d we mixed the radar and the microwave data; in doing so, we noticed a navigational error, so we used the coordinate translation capability of our digital system to realign the images.

Another area of concern is the calibration of satellite data; Figs. 11.16.a through 11.16.c suggest a technique for calibrating the SMS detector (which is really not calibrated in any true sense). We used a set of NOAA-2 scanning radiometer (SR) reference data to attempt a calibration of the VISSR. This data contains a photometric-to-radiometric calibration (if one can trust that relationship). We were able to reconstruct an image from the NOAA-2 scanning radiometer to align with an image from SMS-1, and by using regression techniques, we determined a cross-satellite calibration. Fig. 11.16.c is a two-signal mix of the NOAA-2 and the SMS-1 data; you can see some slight misalignment. That means we would have to recall a surface reconstruction of one of the data sets to more properly align it. Such a technique virtually requires

SEE APPENDIX A

FOR FIGURE 11.11.a

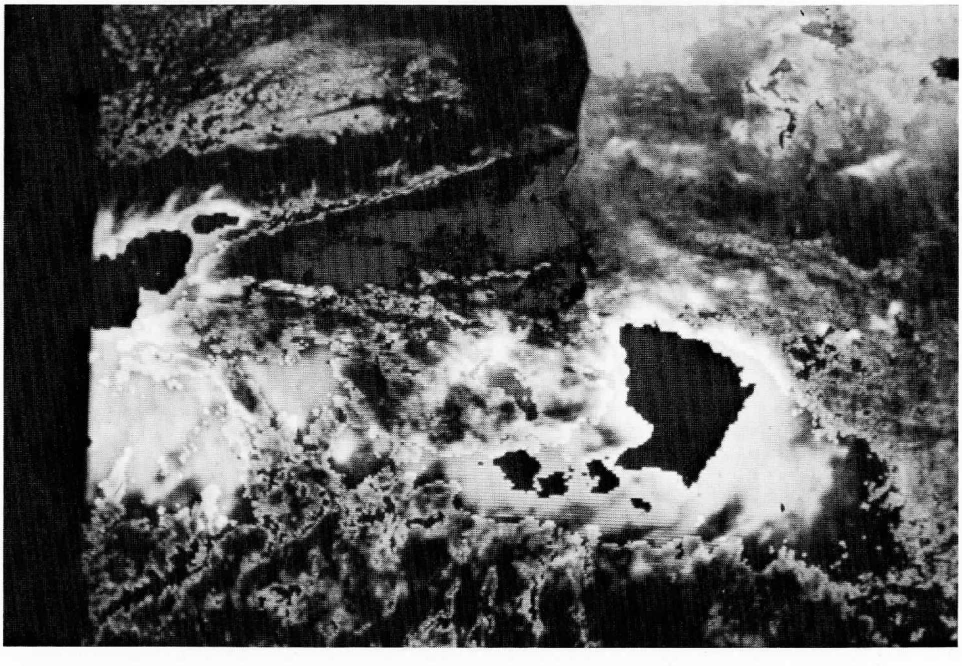
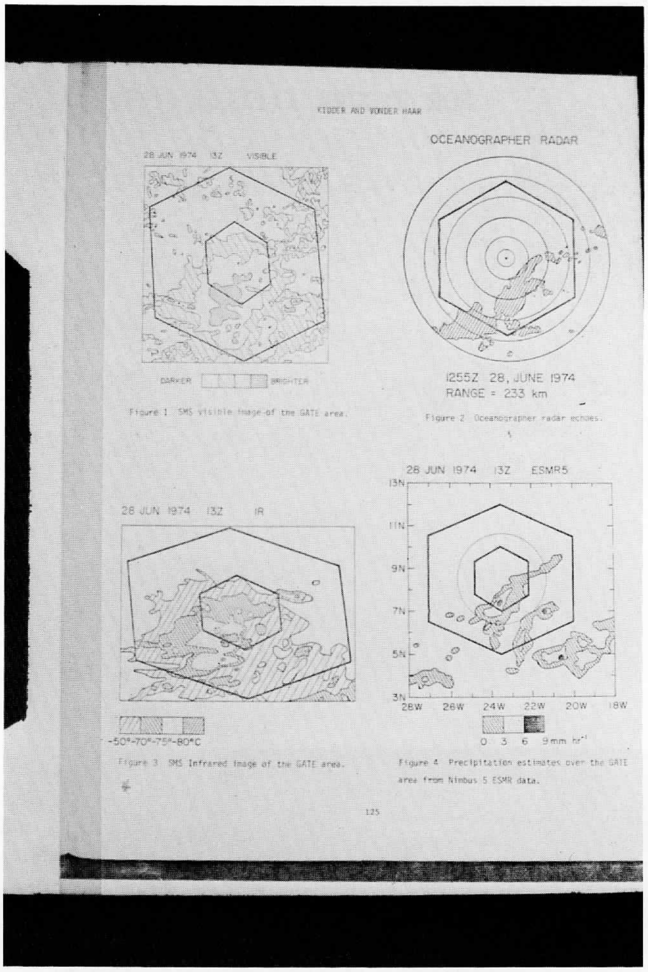


FIGURE 11.11.b



KIDDER AND VONDER HAAR

Figure 1 SMS visible image of the GATE area.

Figure 2 Oceanographer radar echoes.

Figure 3 SMS Infrared image of the GATE area.

Figure 4 Precipitation estimates over the GATE area from Nimbus 5 ESMR data.

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FIGURE 11.12

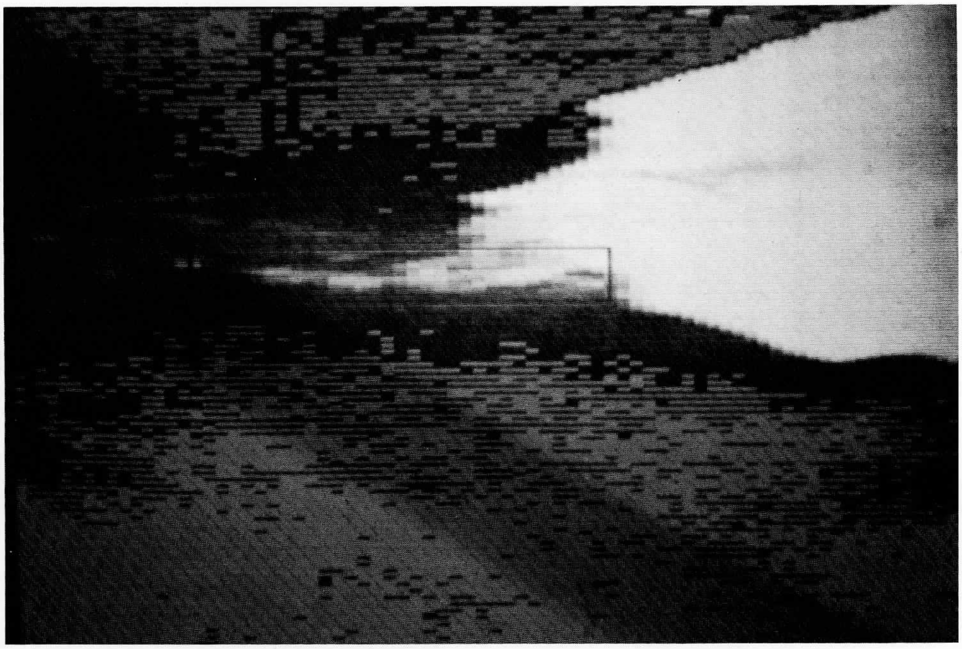


FIGURE 11.13.a

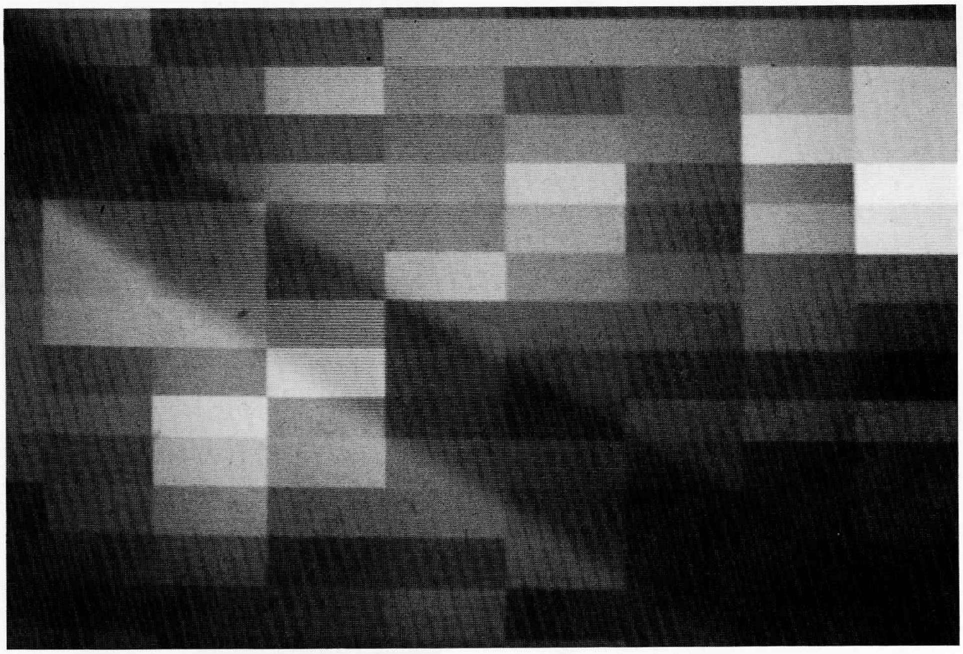


FIGURE 11.13.b

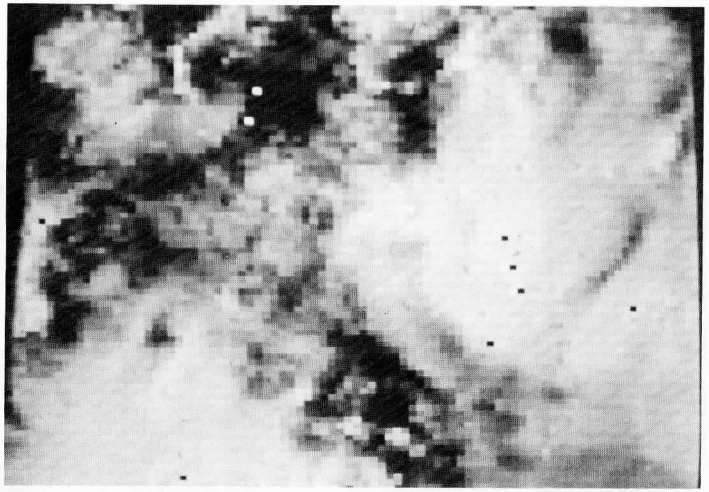


FIGURE 11.14.a

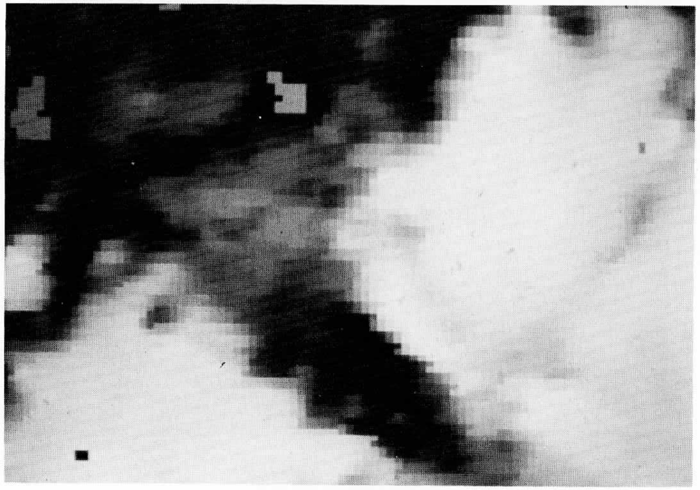


FIGURE 11.14.b

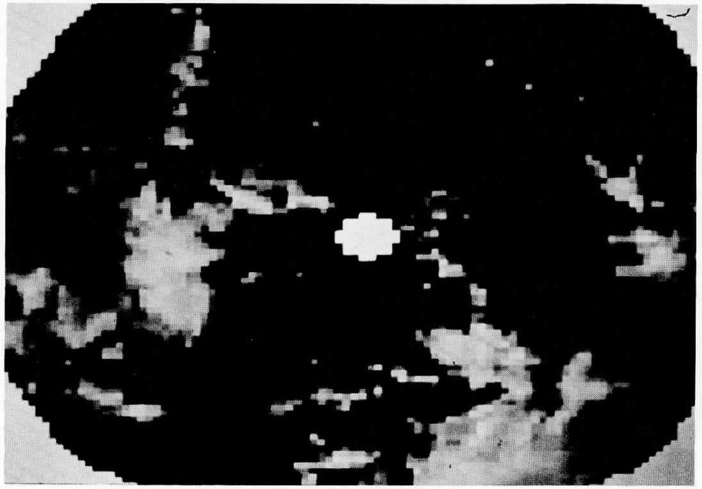


FIGURE 11.14.c

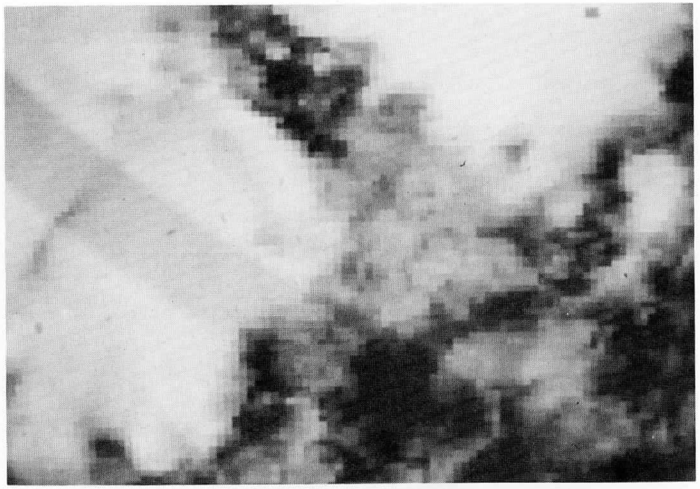


FIGURE 11.15.a

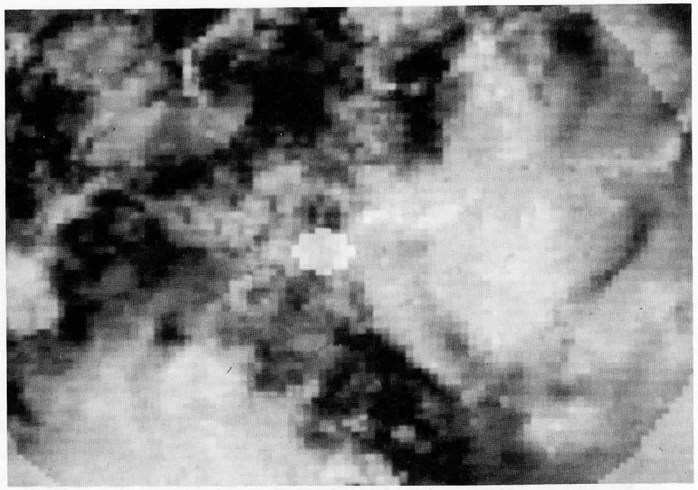


FIGURE 11.15.b

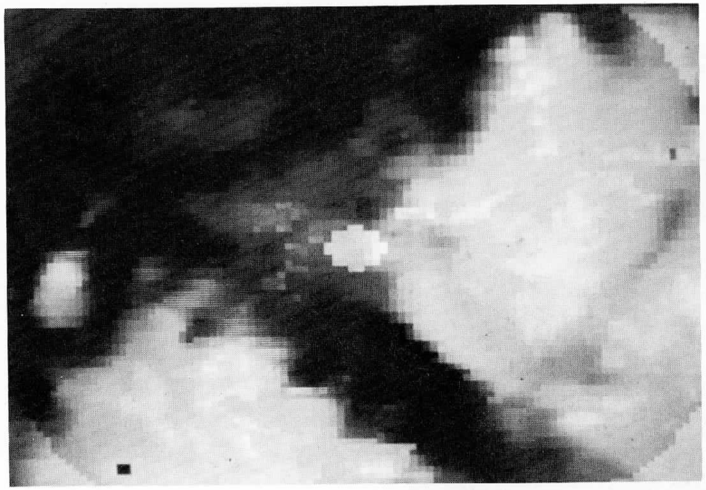


FIGURE 11.15.c

SEE APPENDIX A
FOR FIGURE 11.15.d

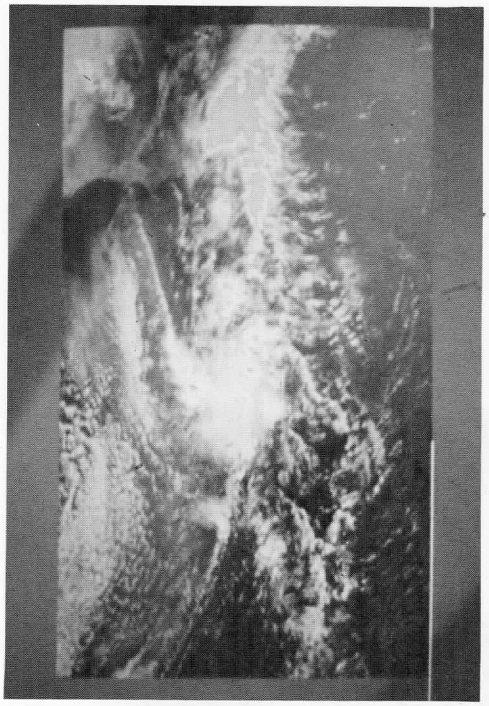


FIGURE 11.16.a

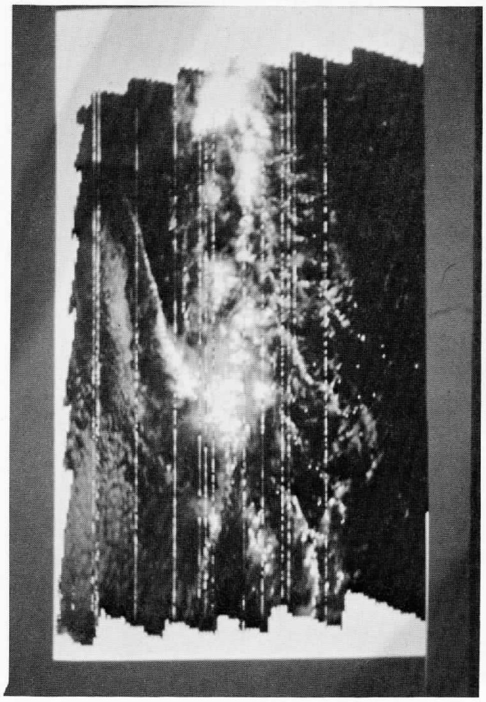


FIGURE 11.16.b

FIGURE 11,16,c

some kind of display device to properly align and adjust imagery which does not always come in an ideal format.

We are also concerned with the relationship between a satellite measurement and the flux emitted from a cloud or a background surface. Fig. 11.17.a shows our attempt to compare Sabreliner aircraft broadband flux measurements and SMS shortwave (.5 to .8 radiances) for the same area. You can see some differences in Fig. 11.17.a. If we look at the infrared channel (Fig. 11.17.b), we again see some very large differences. Some of this, of course, is due to narrow-band/broadband differences in the aircraft/satellite sensors, but it gives us something to think about. We ran a short experiment measuring the rise time of the infrared detector (Fig. 11.18). On the right is a sounding temperature through a convective cloud which started growing over Colorado. In the center column is a satellite-derived cloud-top temperature from the SMS-2 infrared sensor. Also to the right is a radar derived cloud height. We also measured the area of the cloud as an indicator of how the infrared detector was responding. You will notice a large discrepancy between the middle column and the far right column (Fig. 11.18) with respect to the cloud size, which gives you some idea of the response time of the detector. I would emphasize two points: without some type of imaging system, these are very hard measurements to make; and without some concept of the response of your detector, you really can't be sure what you're measuring via satellite.

We are also studying some of the interpretation problems related to the finite cloud problem. More specifically, you do not have an ideal infinite extent surface to reflect short-wave radiation (Fig. 11.19.a), so you get various stages of development of the brightness gradient over time. With some Monte Carlo parameterization, there may be a way to transform a raw measurement into a more accurate representation of what is actually coming from the cloud. Fig. 11.19.b is an attempt to draw an empirical relationship between the width of a cloud and the cloud brightness, using the SMS calibration technique to convert to a flux estimate.

Another problem area in which imaging and digital image refresh capability is absolutely essential is the study of time resolution requirements related to cloud growth rates. Fig. 11.20 shows (dashed line) a 30-minute derived cloud growth rate curve; the solid line shows what 5-minute higher resolution data has done to those same rate measurements. You see a lot more information, and you can estimate the severe weather time resolution agenda you might need for the satellite. Again, an imaging system is almost essential to

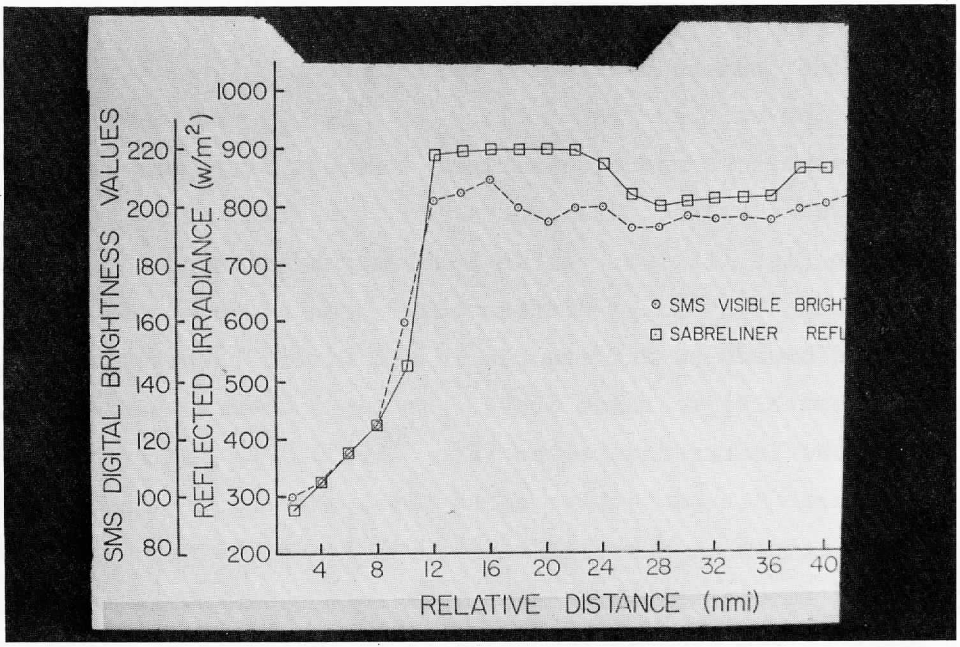


FIGURE 11.17.a

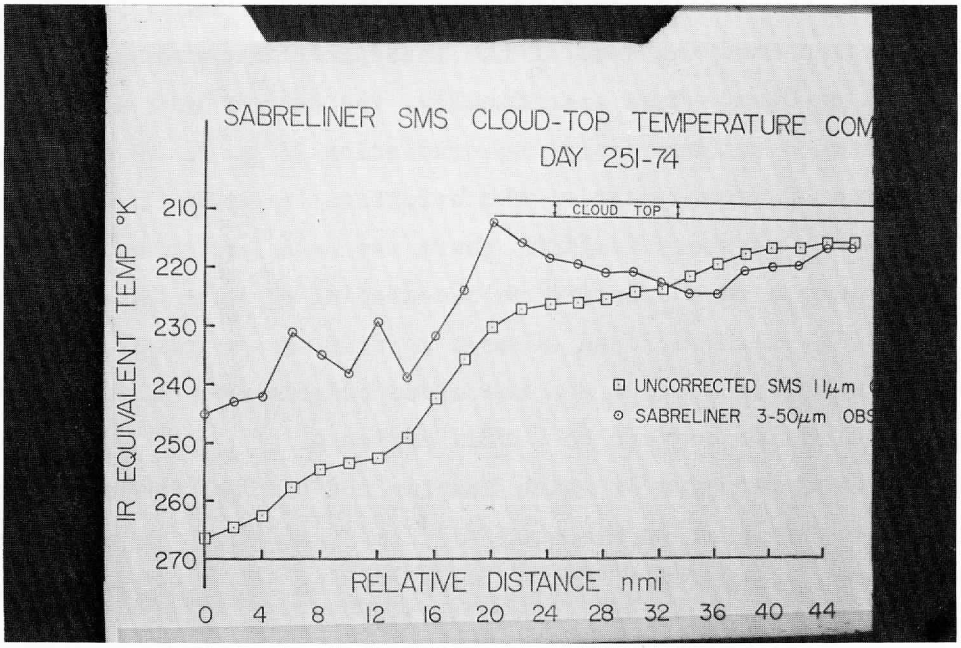


FIGURE 11.17.b

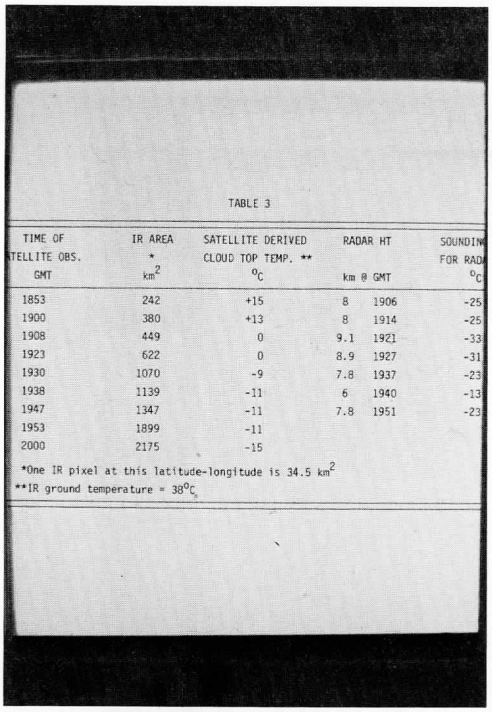


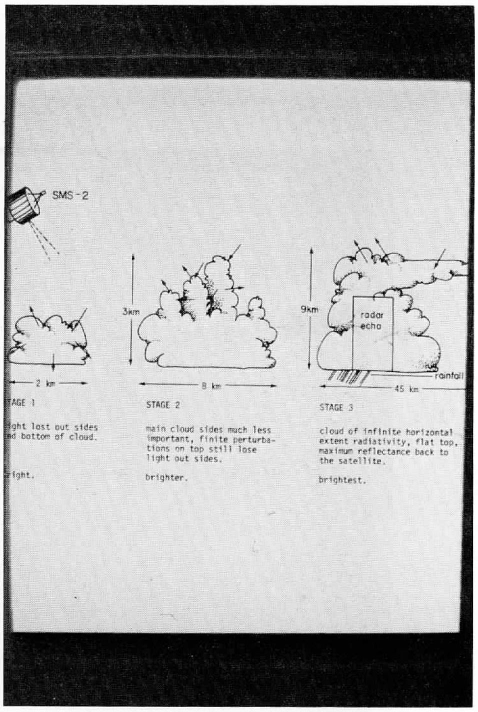
TABLE 3

TIME OF TELLITE OBS. GMT	IR AREA * km^2	SATELLITE DERIVED CLOUD TOP TEMP. ** ^oC	RADAR HT km @	GMT	SOUNDIN FOR RAD ^oC
1853	242	+15	8	1906	-25
1900	380	+13	8	1914	-25
1908	449	0	9.1	1921	-33
1923	622	0	8.9	1927	-31
1930	1070	-9	7.8	1937	-23
1938	1139	-11	6	1940	-13
1947	1347	-11	7.8	1951	-23
1953	1899	-11			
2000	2175	-15			

*One IR pixel at this latitude-longitude is 34.5 km^2

**IR ground temperature = 38^oC

FIGURE 11.18



TAGE 1

ight lost out sides
nd bottom of cloud.

right.

STAGE 2

main cloud sides much less important, finite perturbations on top still lose light out sides.

brighter.

STAGE 3

cloud of infinite horizontal extent radiativity, flat top, maximum reflectance back to the satellite.

brightest.

FIGURE 11.19.a

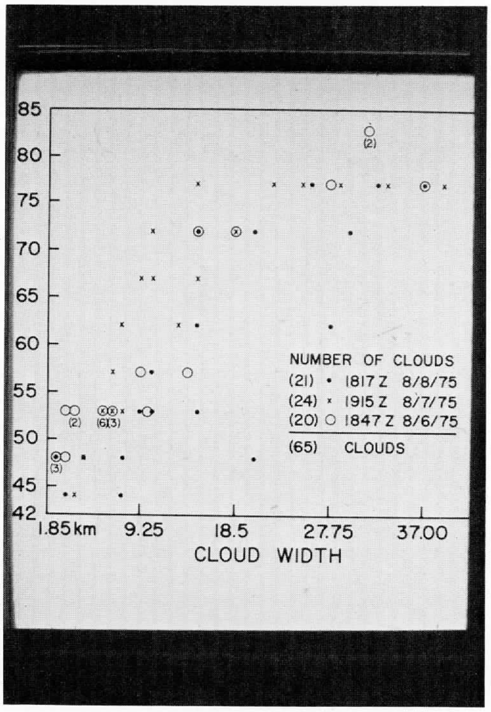


FIGURE 11.19.b

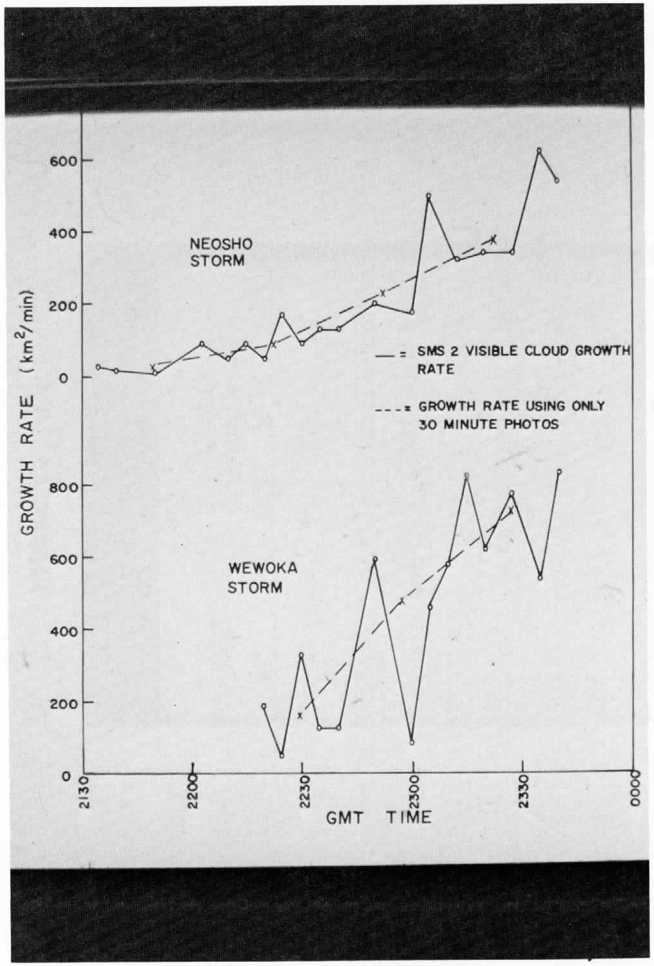


FIGURE 11.20

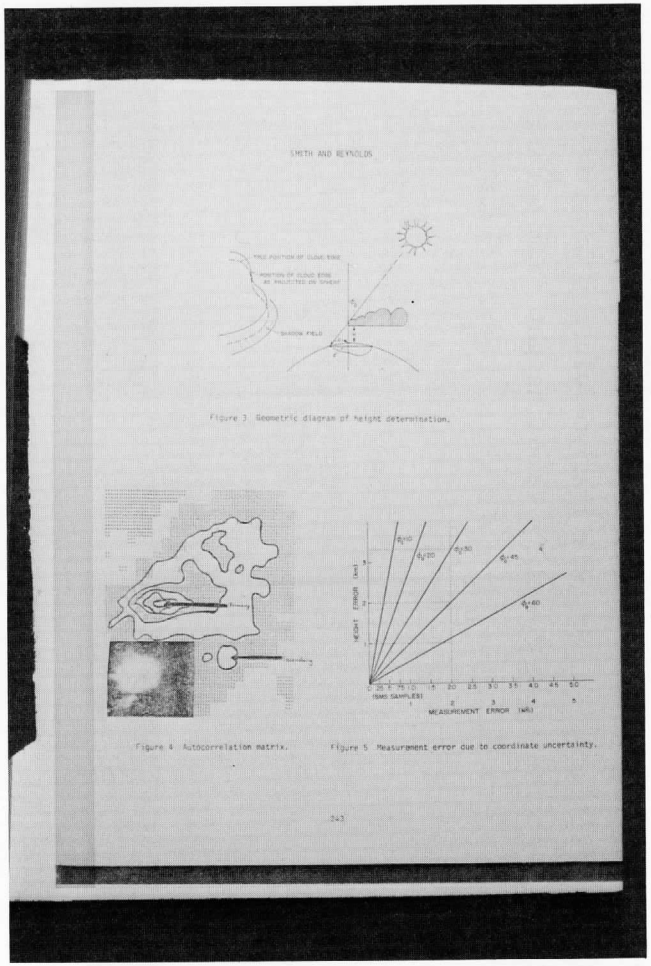

SMITH AND REYNOLDS

Figure 3 Geometric diagram of height determination.

Figure 4 Autocorrelation matrix.

Figure 5 Measurement error due to coordinate uncertainty.

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FIGURE 11.21

draw these kinds of conclusions.

We are also interested in alternative ways to measure cloud height. One scheme (which has not yet been transferred to our system) is a geometric method (Fig. 11.21) making use of a high resolution imaging system to detect shadow/cloud relationships to derive cloud height from satellite measurements.

We are also studying the use of the SMS satellite as a climate diagnostic system, realizing, of course, that we're making narrow-band radiance measurements though we're after flux-type information. Fig. 11.22 is an example of what we're working with -- spectral decomposition of a satellite picture, reconstructed at various levels of resolution using orthonormal functions. We prefer to do this with imagery, because we feel imagery gives us a little better handle on final output resolution. The top two sections of Fig. 11.22 show the difference between a 20-coefficient image reconstruction of an emitted flux field over the tropics and a 24-coefficient reconstruction. We are doing some prototype tests of this decomposition and reconstruction of a complete SMS data set, to see if there is a way to use SMS as a climate diagnostic tool, particularly because of its application to diurnal studies.

In closing, I would like to summarize my philosophy on video graphic systems (Fig. 11.23), acquainted as I am with the development of various systems around the country. I don't think it's important what type of data you're handling as long as it can be represented in some standard image format. This is one of the problem areas that we probably should discuss at this workshop. Let me list the image processing steps that I think are required to do careful studies. There is a calibration requirement, and some type of a normalization requirement, in order to bring various data sets together. There is certainly a navigational requirement; I don't think that needs to be discussed further. Very often there is a mapping requirement (to compare polar data with geosynchronous data and radar data). And of course, one would like to annotate. I think these are the areas we should dwell on in considering the exchange of software and ideas.

Let me go back for a moment to our TV data display. We wanted digital stability, so we went to an all-solid-state refresh system. The electrical engineering department at CSU under Dr. Brubaker and Dr. Andrews has been working on a means to dynamically translate, zoom, and rotate imagery at the video rate, controlling the process with a joy-stick or some type of analog

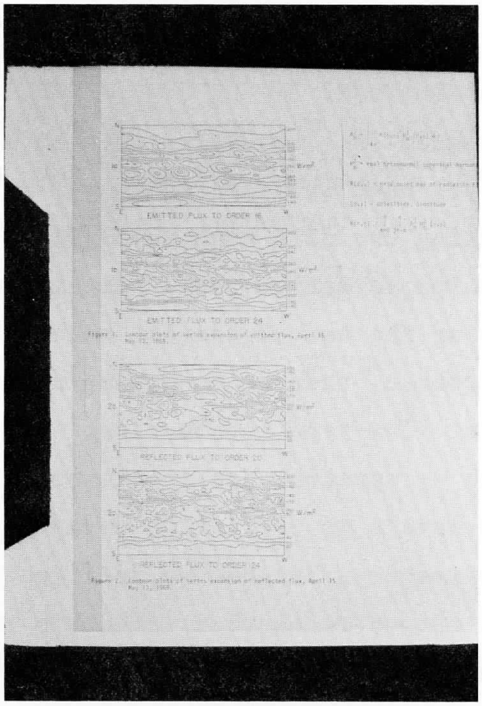


FIGURE 11.22

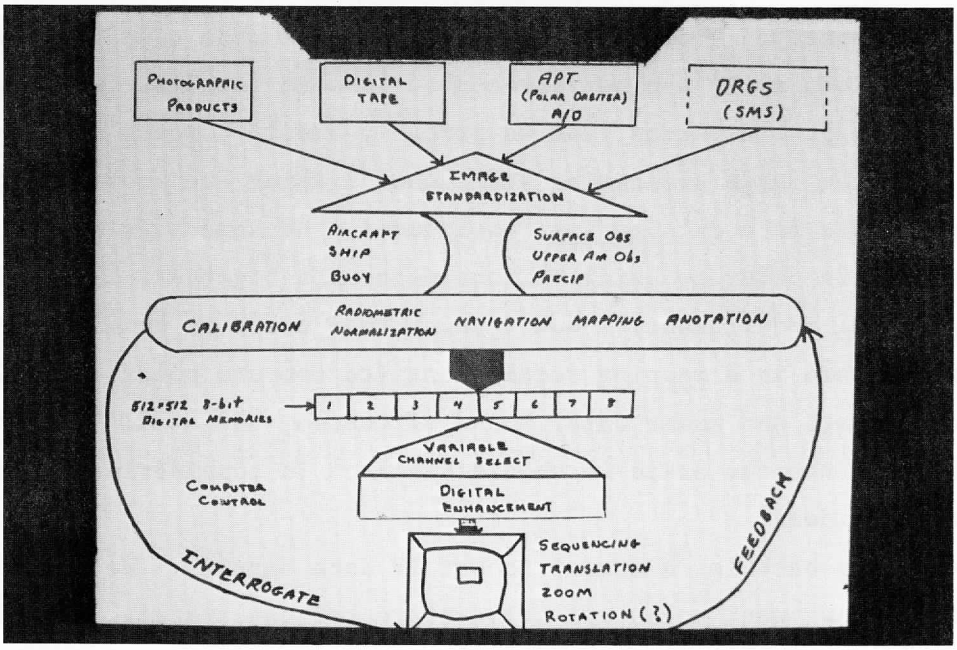


FIGURE 11.23

dial. There is also a requirement (and this may be a software problem) for a very rapid feedback mechanism in the system software, so that as you change the rules, you can feed that back into the system and maintain a permanent archive. You also need a very rapid interrogation control so that you need not wait and wonder what you're doing with the data.

QUESTIONS AND COMMENTS

Comment [Dr. Evans]:

One can become very concerned about the radiated properties from odd shaped clouds but, in some sense, gross column measurements may not be adversely affected.

Q: Could you describe the difference between a dynamic or solid state refresh and the older disc refresh? How much does it cost and where can you get them?

A [Mr. Smith]: We asked our electrical engineering department at CSU to design our solid state refresh system. We do not ask private corporations to design hardware, we only ask them to build hardware. We think Intel or some of the other chip manufacturers can put together digital semiconductor memory equipment, multiplexing, and the addressing and control system much better than graduate students can in a dirty, non-air-conditioned university laboratory. Regarding price, we spent $120,000 for that digital memory last November, and the same memory today is selling for less than $50,000. I believe that prices are coming down because groups like Miami and CSU and Space Science are showing an interest in digital refresh devices.

One comment on the dynamic controls in the memory. Since it is essentially a computer peripheral, one is allowed to randomly address and randomly repeat --which is all zoom and translation amount to--in the buffer stage. This allows you to translate and zoom imagery at the one-thirtieth of a second rate; you can change the rules every thirtieth of a second. The rotation, as our engineering department explains it, is done with beam deflection; and I don't think you can do it digitally. Evidently it has been done at the University of North Carolina with a very complex analog/digital system. But it also can be done strictly on a beam deflection basis, although it may not be quantitative in the sense that all these other processes are.

You find very quickly that many of the things you want to do with the data require a look-up table. You could double every data location, and use some kind of look-up table location which allows you to do just about anything because these memories are becoming very inexpensive.

The last point that I want to address is the personnel needed to build, maintain and operate the system. I believe that it requires one good design engineer, one good technician to maintain the equipment, and one good system programmer to make the systems that are delivered by the computer manufacturer work. The manufacturer's equipment will have to be modified to include your own ideas of operating system. You're also going to need a programmer for every scientist who wants to use the system, and our philosophy is simply this: we take a disc, we put a system on it, we hand it to a researcher and his programmer and let them go away and do whatever they want to do. They can come back, put their disc on the machine and do their own thing, so to speak.

Comment [Dr. Vonder Haar]:

I wonder if Dr. Suomi knows the answer to some of these questions about the evolution of technology, and equipment costs. The engineers predict that the costs go down by order of magnitude in about three years, and that's already started, as Eric says. Will prices really go down? Will we be able to get eight-bit 512 x 512 devices for $1000 in a few years? Should people count on that ?

A: (Dr. Suomi): I think that once the photomasks are made, the actual cost to manufacturers for a large memory system is comparable to the cost of making a small memory system. Two years ago I paid about $250 for my little computer with 1 kilobyte of memory. I just ordered one a few days ago that costs only $169 for 8 kilobytes of memory. So, I think actual memory cost will go down.

There is also a secondary consideration. Because you can pack so much memory into a small place, you need fewer cards, you need smaller power supplies, and so on, so I think that we can actually expect the cost to drop considerably. Not by a factor of ten, but certainly a factor of five, in the future. Some of the other peripherals may not go down in price, but with bubbles memories, and other techniques coming along, memory costs will tend to go down.

Comment [Mr. Smith]:

There is a new chip on the market with 16,000 bits per chip, so they can make a frame on a board now. We are paying about $1500 for half a million bits, and they tell us we can double that to 64,000 bits on a board if we want to pay for it; and the price might run to $3,000 per board.

Comment [Dr. Suomi]

In thinking for the future, we should realize that the memory aspects of the system--which are the probably the most expensive part--are definitely coming down in cost, while the capabilities of the computers themselves are at the same time going up. I think our colleagues from Miami very clearly indicated what you can do when you very carefully use the latest available technology.

THE McIDAS SYSTEM

Thomas Haig
Space Science and Engineering Center
University of Wisconsin-Madison

The McIDAS system I am going to talk about this afternoon is the old one; it isn't quite as old as either Dr. Suomi or myself, but in terms of electronics, it is indeed an old system. As you saw at noon, it sometimes doesn't function too well, and I want to tell you why. [Mr. Haig summarized a series of mechanical support-system problems that prevented the optimal operation of McIDAS during some earlier presentations.]

The new system that we'll also talk about tomorrow has many of the features of the newer digital refresh terminals. As a matter of fact, it is a more advanced version in some respects than the ones you just heard about, because the last person to build a system always has a chance to build it a little bit better than the person who did one earlier. In the new McIDAS we will have practically one full frame of data on each board. These boards were not available in November, but they are now, and six months from now the system that we're designing could probably be replaced with a better one. (If you want the perfect system, just wait forever and it'll be around.)

You've already heard a great deal about McIDAS, but I want to go through Fig. 12.1 block by block to explain the equipment that you will be seeing and working with tomorrow morning. This is not the kind of equipment that we would suggest you duplicate, because it is old. The updated McIDAS equipment and

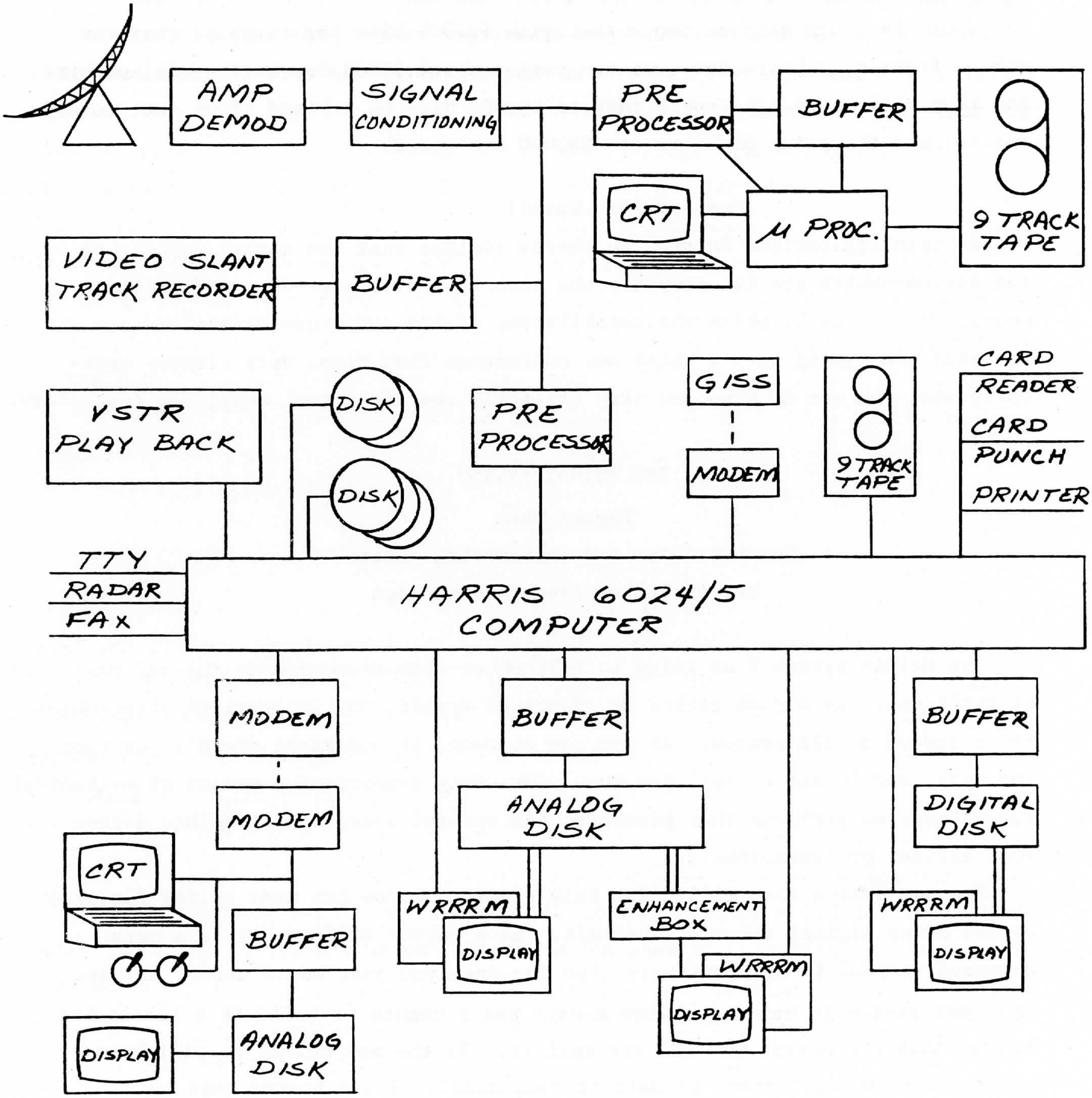

AMP DEMOD
SIGNAL CONDITIONING
PRE PROCESSOR
BUFFER
9 TRACK TAPE
CRT
μ PROC.
VIDEO SLANT TRACK RECORDER
BUFFER
VSTR PLAY BACK
DISK
DISK
PRE PROCESSOR
GISS
MODEM
9 TRACK TAPE
CARD READER
CARD PUNCH
PRINTER
TTY
RADAR
FAX
HARRIS 6024/5 COMPUTER
MODEM
MODEM
CRT
BUFFER
DISPLAY
ANALOG DISK
BUFFER
ANALOG DISK
WRRRM
DISPLAY
ENHANCEMENT BOX
WRRRM
DISPLAY
BUFFER
DIGITAL DISK
WRRRM
DISPLAY

FIGURE 12.1

software that you might be interested in will be described tomorrow afternoon. While the present McIDAS is not obsolete, some parts of it are five years old, although we've continually added new subsystems to it. For instance, the original CPU has been replaced by one that is faster and more flexible, and it provides improved capability at a lower cost.

The present McIDAS system consists, first of all, of a receiving system with antennaes on the roof supplied to us by NSF. We've just put up the second antenna and it should be operational soon. The first antenna--the one that is functioning now--was originally purchased by the National Environmental Satellite Service (NESS); it's exactly the same as the systems that they are using in Washington. It was put here so that we could conduct and support research at Wisconsin, but also so we could collect satellite data and supply it to other members of the scientific and university community. We are supplying this data to the extent that we are able to do so; the capability has gotten better as time goes on, and we hope to improve it in the next few months with our second antenna.

The system also includes an amplifier, a demodulator, and signal conditioning equipment--frame sync and bit sync. The signal from the satellite is supplied to several different systems. Dr. Suomi mentioned the Offline Data Ingest System earlier; this consists of a microprocesser which drives a preprocesser (we call it a "byte mangler") that determines the resolution of the data by averaging along lines and selecting between lines. It also compacts the data into 8-bit bytes and 24-bit words, which it then transfers through a buffer onto nine-track tape. The microprocesser can be programmed automatically to select any particular part of any image you want from that particular satellite during the next 24 hours (or until you run out of tape, whichever is earlier). It runs all by itself, so it's a rather efficient data collection system in terms of manpower. The system collects data for study by ourselves and also by people outside in other agencies.

We can bring that same signal down through a rather complex buffer system and put it on a converted video slant-track recorder, a standard television recorder using one-inch tape. On one reel of tape we can record 32 complete visible and IR images. This recorder system functions quite well, but it has a high maintenance and "tweaking" requirement. It's operating close to its limits, and so we would not advise people to duplicate that system. With good fortune we will soon have a much better system, which Dr. Suomi is developing right now, based on a Sony 3/4-inch cassette recorder.

We should have it defined and the engineering done within the next few weeks. We're having a little trouble reading things off the tape; we know we can get data on and off the tape, but we just haven't figured out exactly how to do it optimally. We're looking forward, with this cassette recorder approach, to providing very inexpensive data in good quantity to a large number of people. With that system, one cassette (a standard hour-long cassette, $20.00 retail) will hold ten complete visible and IR images. And since only about 90% of the tape space will be occupied, you can put surface and upper-air data for that same image data set on the same cassette. The playback unit would be relatively inexpensive--$2000 to $2500--so we're looking forward to a big improvement in the archival area.

The heart of McIDAS, a Harris 6024/5 CPU, has been replaced by a 6024/6 which runs almost twice as fast; it also has a RAM (random access memory) rather than core memory, which offers some advantages in cost and reliability. We went through a very thorough investigation of what was available five years ago before selecting the Harris, and we've had our selection pretty well confirmed by a recent article which I would recommend to anyone interested in acquiring a system. It is by D.J. Theis at the Aerospace Corporation on the West Coast, and it appeared in the February, 1977 issue of Datamation magazine. He examined the characteristics of the complete spectrum of computers now on the market, and categorized them into minicomputers, midicomputers and macrocomputers. He placed only three units in the midicomputer category, including the Harris CPU. He suggests that the midicomputer is practically an optimum CPU for the work which a McIDAS-type system does. I won't try here to duplicate his explanation, but if any of you are interested in the article, we'll provide copies tomorrow.

Inputs to the McIDAS computer can be from teletype, radar, and facsimile, of course, or from a slant-track recorder identical to the one in the archive system, which we can use as a playback or a mass-storage unit. This unit is computer-controlled, so it can access the particular image that one wants; it does it rather slowly, but it can access the image and read out the data at the same rate that it came from the satellite. It is a perfectly good archive, but it is a little slower than we would like. We also have five 10-megabyte discs on the system, operating through two controllers. There are many discs on the market now for about the same price that we paid for ours, but which offer much larger capacity. They are Control Data Corporation (CDC) type discs, and they operate quite well. We can also bring the data from a satellite through the byte-mangler or preprocessor into the computer. (The preprocessor incorporates one of a series of redesigns which are continued into the second generation McIDAS which we will describe tomorrow.)

We are starting to move input-output functions out of the central processor and into external modules. We're also making them smarter modules, by installing microprocessors to do a great deal of the thinking. This frees up the central processor so that it doesn't have so many things to do at once; it won't crash so often, and it can do more data analysis. We operate a modem to GISS (Goddard Institute for Space Studies) and to other outside 360-type computers for data transfer and some programs. There is a nine-track tape input, card reader, card punch and printer, all pretty standard peripherals.

We do have a variety of displays, some of which you will see tomorrow. One which you will not see is a remote terminal located in Milwaukee; Dr. Sikdar (in the audience) can describe that terminal if you're interested in more detail. It operates through a 9.6 kilobaud telephone line, through a buffer to an analog disc. Dr. Sikdar wanted a relatively large number of images available, so he chose an analog disc. It takes about four minutes to transmit one TV frame on the telephone line; he receives them, records them on the disc and has a large number of images available for the work and the teaching he wants to do. The nice thing about such an analog refresh disc is the availability of about 500 frames of data at any particular time. It would be prohibitive to provide 500 frames of digital refresh. Although the analog disc has been around quite a long time, it still offers some distinct advantages for certain applications. It is a good way to go for people who want quick access to a large number of frames, or who want to sequence 20, 30 or 40 frames at a time.

In Room 648 we have a video terminal and an Ann Arbor cathode ray alphanumeric terminal, and the video terminal has an overlay which we call a WRRRM--a write random, read raster memory. It is really a 4-bit digital refresh, and that's what was overlaying all the graphics on the pictures you saw earlier. The displays in this room are being operated in parallel to the terminal in Room 648. In Room 1039 is a similar terminal, identical in all respects except that it also has an enhancement box for using pseudo-color to treat IR and visible data (and other bi-spectral data sources) at the same time. Both terminals are refreshed from a single analog disc system; we read one side of the disc for one terminal, and the other side for the other terminal. There are two channels of data coming from each side of the disc, so we can read both visible and IR into each of these terminals and flip between them.

The fourth terminal operating on McIDAS now is the digital refresh disc terminal, with 12 frames of data available, but it may not be operating tomorrow. It operates over a bit serial link to the computer and that bit serial link is at the heart of our problem on the interrupt board. If we can find the mechanical fault and the bad chip on that board, it will be up and operating tomorrow.

QUESTIONS AND COMMENTS

Q: What are the other two candidates (besides the Harris) in the midicomputer category, and why is the midicomputer optimal?

A: First, let me suggest that you read the article by Theis. For our purposes, it's optimal because the word length is more than 16 bits. A 24-word bit allows us to do a great many computations without having to go to double precision. (That's actually a bigger advantage than the fact that you handle three bytes of data instead of two everytime you transfer). The operating system in the Harris is called a DMS (Disc Management System). It is based on the idea that most of your application software will be on a disc; you retain only what you absolutely need at the instant in core. Therefore, the system operates with a much larger apparent capability than if it had to retain much of the software in the core.

COMMENT [Dr. Suomi]:

We seem today to be shortchanging McIDAS's wind computation capability. Eric Smith (while at Wisconsin) developed much of the software for the wind system, and the computer which Tom Haig referred to has enough of a number-crunching capability to carry out these wind computations. For example, during the DST (Data Systems Test), a group here at UW-Madison supervised by Fred Mosher was able to gather 4000 winds per day, every day for four months, from satellite images of the Pacific. It's clearly not something you would do as a classroom exercise or even as a research exercise. (It was part of our work toward getting a data base for FGGE). But we were asking the system to do quite a bit more than what would be needed for some of the applications we're considering here today. It is unfortunate that none of us showed this wind-finding capability based on the drift of clouds; and you'll see this in the detail tomorrow. We're so used to it now, we've ignored telling you about it.

COMMENT [Haig]:

There's at least one more point on this issue of computer size. We're about to develop another computer system for VAS (VISSR Atmospheric Sounder), and in our evaluation we found again an overlap going from the microprocessors up to the macrocomputers. The capabilities of the macros tend to extend down into the midis, but the price range of the midis is about the same as the micros. So in that midi range you find many of the capabilities of the macrocomputers--their operating software, their design, their architecture--but you find that the midis are in the price range characteristic of the microprocessors or the smaller computers like PDP's and Eclipses. Again, Theis's article says it a lot better than I can.

Q: What is the error with which winds are estimated?

A: Several studies have been made of this; they range from about 1.5 to 2.5 meters per second RMS error, on cloud winds derived here or elsewhere. Anybody here want to argue with that?

COMMENT [Dr. Suomi]:

I would argue with it. The 1.5 - 2.5 figure is valid when you have an optimum cloud, but if I measure a gravity wave propagating, I'd get a completely erroneous wind. The greatest error now in the wind finding is the tracking of clouds, not in the displacement of the cloud. The greatest source of error is in the altitude of the clouds, because the wind shear enters through the thermal wind relationship. If you have a 10% error in cloud height, then you have a 10% error in derived temperature, too.

I think we've come a long way in tracking the displacement of clouds, but a man must be in the loop to select suitable tracking targets. In instances where you have many levels of clouds, it is not possible for any algorithm to separate them; a man must decide to follow this cloud or this cloud or this cloud....So, it depends how you answer the question. If it's a simple cloud and a good background, then I would guess that the actual displacement of the cloud can be measured almost to 1 meter per second or even less. But if the cloud is improperly chosen--if it is dissolving rapidly, or if the center of gravity is moving, or if it's in a strong wind shear and the front or top of the cloud is eroding while the bottom is being pushed in the opposite direction --then we have a problem. But this is really a problem in interpretation of the measurement, which must be considered in any case.

Q: What sort of storage device--analog or digital--do you need for very simple maps (like the state backgrounds) as opposed to the high density satellite pictures? Do you use different sorts of storage devices?

A: Yes, we do. We use the WRRRM, which is only 2 bits deep. Now that could be just one bit deep, and still hold the map backgrounds on it. We make it only 2 bits deep, which gives us four colors. What you're looking at is really three colors and erase. It'a a relatively inexpensive way of getting graphics as an overlay on image data. As you will see tomorrow in the design of the new McIDAS we've combined the WRRRM with the digital refresh on the same kinds of boards, because basically they're the same things. We'll be using a fast RAM accessible memory block, accessible to the computer in both directions, as the Miami system that Bob Evans described. In addition, it's reassignable so you can have images of different bit depth, or you can have more images with a great deal of flexibility.

VI. DEMONSTRATIONS OF THE McIDAS SYSTEM

During the morning of the second day of the Workshop, participants broke into groups of 15 to 20 to attend four demonstrations of specific applications of McIDAS to teaching and research. Presented below are brief summaries of those demonstration sessions, prepared by the UW-Madison personnel who conducted them.

Video Research Tools

J.T. Young and B. Auvine

McIDAS offers a wide variety of tools for research associated with imagery, particularly geostationary satellite imagery. McIDAS, as the name implies, is a data access system, not a data processing system. The researcher is the processor and McIDAS provides tools to assist in the research process. These tools can be divided into five categories: data display and simple access, auxiliary tools, data interrelationships, data modification and derived information.

I. Data Display and Simple Access

Data display and simple access make it possible to display images on a color TV monitor, view them, and sequence a series of pictures, so that one can appreciate the development of meteorological situations in the time domain. In addition to this qualitative access to the data, it is possible, with simple two-letter commands, to output the numerical brightness values of portions of images as a matrix, or to display portions of an image as a histogram showing frequency of occurence of these brightness values.

One can display x,y plots of brightness value along a horizontal image line, in which the y-axis represents the brightness value and the x-axis provides the horizontal position on a line. This type of quantitative information may be output to the user at his CRT, or it can go to a line printer for documentation of the situation of interest. One may also obtain three-dimensional graphical displays of the brightness field, in which the x,y axes provide the x,y position in the image and the z-axis represents the brightness.

II. Auxiliary Tools

Auxiliary tools are available to assist the researcher. These include a cursor under computer control. The joy-sticks may be used to control the cursor in a position joy-stick mode or a velocity joy-stick mode. The joy-sticks have a variety of functions in addition to these. The WRRRM (Write Random, Read Raster Memory) is a three-color transparent overlay on a TV monitor, with which one can superimpose grids, annotate with text various features on an image, or use a joy-stick to draw with varying degrees of smoothing.

Another auxiliary tool is the navigation system. By hitting the "E" key the operator can determine the earth location of the cursor, or position the cursor to a given earth location. In addition, a continental outline and state boundary file is available, which will, on request, superimpose a map grid on an image. We have developed techniques to grid and ingest the satellite pictures to the full half-mile resolution capability of the satellite, predictively, for 24 hours in advance.

General purpose curve-fitting algorithms are incorporated into McIDAS. These may be used interactively to access and edit points in a file and perform curve fits up to an eighth-degree polynomial, an eighth-degree polynomial plus sine, or an eighth-degree polynomial plus e^x.

To help in evaluating imagery, an interactive enhancement capability has been included, making it possible to control with the joy-sticks the complete grey scale domain of the image and convert it into any color pattern desired. There are 64^3 possible enhancement combinations that can be applied to an image.

III. Interrelationships between Data

Utilizing the conventional data, satellite data and the navigation tools, one can superimpose the conventional data over the satellite image in the satellite projection. One can compare IR and visible images, or, using the enhancement, add the two images; using this latter technique the detail of the visible data is still present, but color contouring is applied to the IR data to help infer the height of visible-image features. As noted earlier, x,y plots can present the brightness of one image on the x-axis and the brightness of a different image on the y-axis. This is very useful in comparing co-located images from different portions of the spectrum.

IV. Data Modification

Displayed images can be modified by several filtering techniques: band-pass, high-pass, low-pass filtering can be applied, shot noise can be removed, or minimum brightness can be obtained from a series of images. This last technique, for example, can generate an interesting "no-cloud" look at the Gulf Stream or other temperature anomalies in the ocean. Contrast stretch and non-uniform enhancement are also available.

V. Derived Information

Derived information in the form of cloud motions from satellite picture sequences has been produced frequently on McIDAS. Also available are techniques in area statistics, by which one simply draws a boundary around a feature of interest with the cursor to obtain the area of various contour values associated with this feature, or the total area contained within the drawn boundary. Statistics can be displayed as a histogram at the user's console, printed out or output to computer tape. The wind program can compute -- interactively, on real time or archive images -- the velocity of selected clouds from a series of pictures and attach to each vector the cloud height. As winds are computed, the vectors are displayed over the satellite pictures for comparison with the cloud motions. Erroneous winds are edited by placing the cursor over the vector and typing "X". The vector then is marked in error and erased from the screen.

The research tools presented represent approximately 15% of the inventory of the McIDAS. Only the user's imagination bounds the nature of the research which the McIDAS can support.

Teaching Applications

F. Sechrist and T. Whittaker

First, a 19-page handout was distributed giving examples of the hard-copy data lists and plots available for class use (see Appendix D). These lists and maps are prepared by using a reducing xerox to copy the original computer print-out page which comes directly from the DEC printer on the 14th floor. The station model used in plotting the charts was described and all the charts were identified.

Next, the current satellite image was displayed for the United States. As the morning progressed we were able to obtain additional images. So it was possible to loop through a series of images to observe the cloud development and movement. On this particular morning there was a dramatic thunderstorm complex in the area of Minnesota. During the morning the cirrus blow-off from this complex reached Madison and it could be observed both on the screen and out the window.

Since there was a good severe weather example on this particular day, it was decided to examine diagnostically the nature of the synoptic situation accompanying the thunderstorm. Wind barbs and weather symbols were superimposed on the satellite image to determine the nature of the activity. Next, streamlines were drawn on a United States base map. These streamlines showed marked confluence into the eastern half of South Dakota. Superimposed on the streamline was an analysis of the surface divergence field. This analysis indicated strong convergence, again in the area of convective activity.

To study the moisture distribution, a dewpoint analysis was displayed and low-level moisture flux was calculated and shown. Both of these analyses showed an abundant supply of moisture in the severe weather region. The dewpoint analysis could be animated by using a series of charts made for the same time each day for up to a week. Looping through this series would show the source of the moisture and its rate of influx into the area.

Later, to show the versatility of the system, displays were made to help determine whether the destabilization was brought on by cold advection aloft or by an influx of drier air which would contribute to the convective instability. To do this, soundings for St. Cloud and Huron were examined. The St. Cloud sounding showed a distinct dry layer while Huron was relatively wet. (Soundings can also be animated to illustrate significant moisture and temperature changes.)

Next, the use of the upper air data in the McIDAS system was demonstrated. Instead of simply showing plots of the data at each level, plots of 24-hour temperature change and 24-hour dewpoint change were made for the Midwest. The 850 mb dewpoint change chart showed the regions of drying, and the 500 mb temperature change chart showed no significant cooling. Thus, it was possible to conclude that there was little evidence of cooling aloft as a mechanism for the destabilization.

Following the demonstration of current weather, the participants were invited to request lists, plots or analyses of any station or region they wanted. In this way everyone was briefed on conditions in their home area.

It was generally felt that the demonstration was effective in showing how McIDAS can be used successfully as a diagnostic and instructional tool. There was a good deal of enthusiastic participation; almost everyone had a suggestion about which area analysis or chart would be most useful in diagnosing the storm system.

Meteorological Research Applications

F. Mosher and D. Suchman

The earliest scientific applications of McIDAS centered on satellite-derived cloud motion wind fields. At first, wind sets were mainly produced for distribution to other members of the GATE community. But as our experience grew, we saw other possible ways to study satellite data on McIDAS, such as measuring cloud growth using brightness data and estimating rainfall. In addition, we examined the quality of our winds to see whether they could be used for quantitative calculations.

We tested two sources of error: (1) operator error (which was rather small from person to person); and (2) the differences between the cloud tracer field and the "true" wind field (which were less than those often encountered between adjacent radiosondes). Hence, in some of the studies described below, cloud winds could be used to calculate divergence and vorticity fields, as well as vertical mass transport.

I. Movie - Cloud Clusters from BOMEX to GATE
   a. BOMEX: JULY 23-24 '69 (ATS-III): Earliest attempt at producing wind sets; a complete thermodynamic and dynamic analysis of this cloud system was performed.
   b. GATE: (1) DAY 261: 18 Sept. '74 (15-min. images) - First attempt to produce wind sets at three levels; there are three distinct levels of motion visible on the film. We also produced cloud maps using visible brightness data.
      (2) DAY 248: 5 Sept. '74 - very active double cluster - described later.
      (3) DAY 247 - Squall over GATE area, used for rainfall estimation.
      (4) Squall over Africa (Sept. 5).
      (5) Pre-Hurricane (July 15) that did not develop.

II. Short Movie

Sept. 5 GATE case with three time periods of winds superimposed on satellite images (cirrus-level winds on IR channel, cumulus-level winds on visible channel. Strong low-level convergence and strong upper level outflow are clearly seen. These wind fields were used to calculate vertical mass transports.

III. Rainfall Estimation

The ability of the McIDAS to extract limited, irregularly shaped data sets from satellite images has been utilized to develop techniques for estimating rainfall amounts by studying the expansion of the cirrus shield. McIDAS was used to develop the relationship between the stage of growth of the expanding anvil and rainfall measured with rain-gauge calibrated radar. The operator would roughly outline the anvil of a convective cell over a series of images. The McIDAS then would obtain the digital data from inside the outline and perform statistical analysis on the area covered by different brightness levels. This information was used to develop a relationship between the area of cloud growth in relation to its maximum size and rainfall amount. Examples of images with cloud outlines were shown, as were examples of the ground truth radar remapped into satellite coordinates and overlayed on the cloud images.

IV. Gravity Wave Studies

The use of McIDAS by Mike Pecnick to study gravity waves was illustrated. A gravity wave had to be observed on barograph traces from the Midwest. The satellite images showed stratus clouds in the vicinity of the gravity wave passage. Using a high-pass filter on the image data, the passage of the gravity wave through the cloud deck was observed and tracked. Analysis showed the gravity wave to have a structure that tilted with height.

Another gravity wave study showed lee waves from the Appalachian mountains. Using satellite images taken every three minutes, the clouds could be seen going into the wave pattern, dissipating, and then growing again as the air moved through the stationary wave structure.

V. Lidar Study of the Boundary Layer

A lidar operated in an RHI (range-height indicator) mode has been used by Prof. James Weinman and Ken Kunkel to investigate the turbulent structure of the sub-cloud boundary layer. The McIDAS was used to display series of RHI scans. Reflections from sub-visible particles in the boundary layer showed the turbulent, convective nature of the boundary layer, as well as the roots of small cumulus clouds. The McIDAS was used to display and track the turbulent eddies to obtain wind measurements in the boundary layer.

VI. Mid-Latitude Studies of Severe Weather

This season we have been archiving satellite images from the "three-minute rapid scan" satellite days. (On days when severe weather is expected to occur, the satellite takes images every three minutes from 17Z-01Z.) Data from two of these days was shown:

(1) 4 April: A tornado struck Birmingham, Alabama. Fifteen-minute images were shown, including overlays of conventional data. A transformation of the images to a LaGrangian coordinate system clearly showed the rotation of the storms.

(2) 5 May: A tornado outbreak in Oklahoma and Texas. We showed a 30-hr. IR sequence, 12 hrs. of 30-min. visible images, and a 3-hour part of the 3 minute data. On the last of these, the changing texture of the anvil, the rapid growth and collapse of turrets, and wave motions were all visible. The location of tornadoes was also shown on blow-ups of the satellite images. A longer more complete videotape of this day is now being made, at the request of several of the participants.

Other McIDAS Capabilities and Applications

R. Petersen and G. Chatters

The purpose of this discussion was to present further examples of the diverse research applications possible using an interactive video graphics system.

I. Snow Mapping/Clear Sky Simulation

Knowledge of the depth and area of snow cover and rate of snow melt is of vital importance to water resource management in the Southwest. Operationally, snow mapping has been performed manually from once-daily polar orbiter images. Ron Gird, a visiting NOAA graduate student, at UW-Madison recently applied McIDAS-processed GOES images to this problem.

Comparing images obtained over two water-shed areas of Arizona during January 1977 with images obtained on a day known to be free of any snow-cover, he used the McIDAS "area statistics" programs to quickly and accurately compute the snow-cover percentages during a two week period.

Since geosynchronous images were used in this study, it was also possible to demonstrate clear sky (cloud-free) simulations by merging the darkest features from a series of images. Transient cloud features are thus eliminated, while stationary features (in this case, snow-cover) remain. Applications of this technique, originally developed by Fred Mosher for oceanographic current studies and albedo variability studies, were also demonstrated.

II. Soil Moisture

It has been shown that, independent of vegetation type, nocturnal surface temperature changes are related directly to mean soil moisture. Barry Hinton (SSEC) is currently using GOES-IR images taken over the central plains states, to test the feasibility of remotely measuring root-level soil moisture. By subtracting the digital IR data from a late afternoon and an early morning image, the various fields of temperature change can be readily observed, especially if black-and-white-to-color enhancement procedures are used.

III. Rooftop Thermal Scanning

Thermal scanning is a technique for remotely sensing building heat loss. Bob Madding (IES) has made use of such photographic measurements to evaluate energy loss in Beloit, Wisconsin. Since the images produced by the thermal scanner are normally calibrated on a black-to-white gray scale, McIDAS's variable color enhancement capabilities were used to help differentiate various sources and degrees of energy waste.

IV. Nimbus-6 Sounder Studies

The thermal sounder Nimbus-6 research satellite measures microwave and infrared radiances in several wavelength bands. These measurements are combined (using objective testing procedures) to obtain equivalent cloud-free radiances and then derived vertical temperature soundings. Ralph Petersen and Lyle Horn (Meteorology) in cooperation with SSEC and NESS are currently using the video imaging capabilities of McIDAS to make visual intercomparisons of data from various infrared channels to see if man-computer interaction could improve the current retrieval processing techniques.

V. Display of Output from Larger Computers

The video capabilities of McIDAS need not be restricted to computations performed on the system's own computer. For example, Louis Uccellini (Meteorology) has used McIDAS video sequencing to display various results from a hybrid isentropic primitive equation model. His model results, obtained using the UW-Madison Univac 1110 computer, were originally displayed only at three- or six-hour intervals on hard copy. To get a fuller appreciation of the time evolution of the model results, the gridded forecast fields were read from tape into McIDAS at one hour intervals, analyzed and displayed. Loops of various fields were then available for a 36 hour period, and could be viewed at any speed and overlayed at will.

VI. Studies of the Atmosphere of Venus

McIDAS has been used to analyze fly-by spacecraft images of the atmospheric dynamics of the planet Venus. Using the same navigation, enhancement, displacement analysis and coordinate-transform techniques used to study earth satellite images, McIDAS aided in the study of cloud formation and movement over the planets, including the polar regions.

VII. PANEL DISCUSSION

Chair - Ronald Taylor (NSF)

Robert Evans (Miami)	David Houghton (Meteorology)
John Cahir (Penn State)	William Klein (NWS/AFOS)
Thomas Vonder Haar (Colorado State)	Frank Sechrist (Meteorology)
Verner Suomi (SSEC)	Robert Serafin (NCAR)

This panel discussion examined two major questions: What should be the future directions of interactive video systems? and What user needs remain to be addressed? Following brief statements from members of the panel, the session was thrown open to questions and comments from the panel and from the audience.

Dr. Robert Serafin:

We've seen some facilities here that are extremely impressive, but as Dr. Suomi has said, it's not just the hardware that's important. The most impressive aspect of the facilities here at the University of Wisconsin, I believe, involves the dedication of the staff and what they've been able to achieve through imaginative use of software. This is where the real payoff is. I feel that if you can raise the money, you can put together hardware that will do the job. But you've got to find the people to put together the software package, and at Wisconsin that task has taken some five years of effort. Given that premise, then, how can universities or others who haven't yet begun in this field take advantage of video graphics technology? Is it best for them to develop their own system piecemeal, or should they somehow share facilities such as these at the University of Wisconsin? That's the principal question I see at this workshop.

Dr. Frank Sechrist:

I would like to say three things about a system like McIDAS. First, I'm very frustrated because I do not see it growing into something that other people -- particularly small schools -- can use.

The second thing -- something that really turns me on -- is using such systems to study the whole question of climate and food supply. I see future systems as new dream machines. I see systems that can tell me when it last rained in Tokyo, how the crops are doing in Ethiopia, how accurate our worldwide rain and temperature forecasts are. The potential for understanding the weather and the implications of weather change is very exciting to me.

My third comment concerns the use of video graphics systems in forecasting. I think the only time that I've seen a few sparks fly is when we've discussed the usefulness of these systems in the forecast problem. I think we all have to face these questions: Am I spending all my time looking at and diagnosing storm systems, but forgetting about forecasts? Should I treat all this stuff as a black box research tool and say to forecasters, "Don't look at this."? We need to use video graphics to get a better understanding of how the atmosphere behaves, so that we can improve our models and our forecasts.

But there is another side of the problem. I can't make students understand the weather, and make them necessarily good forecasters. Now, maybe I should say to my students, "Don't worry about all the data in this black box; just shake it up and see what comes out, then make your forecast." But we all know what would happen. The forecasts would all say "... 50% chance of rain and variable cloudiness," without saying anything about the <u>weather</u>. So that's a problem I see, striking that balance between pure research and oversimplified forecasting with video graphics systems.

<u>Dr. William Klein</u>:

I'm not sure exactly what Frank meant, but I guess he was vaguely attacking the concept of machine forecasts in a general way. I don't think there's any conflict, necessarily, between having improved numerical guidance coming out of a central office and the kind of diagnostic work he was showing us here this morning. The forecaster should understand as much as he can about the weather and about the current situation, in order to use the guidance intelligently. But, on the other hand, I don't think he should throw away the guidance just because he has this wonderful McIDAS system. You still have to use numerical guidance to forecast for tomorrow. I'd say that's the biggest single deficiency of the system we've seen here today; it does not incorporate any of the prognostic chart material which comes to us from <u>NMC</u> every day -- material which you must have to be able to forecast for more than a few hours in advance. What we need in the future is a <u>combination</u> of these two different kinds of systems.

Now, let me present some of my own thoughts about the future needs and future direction of interactive video systems. It seems to me that what we have so far, practically everywhere, are wonderful request/reply systems. The forecaster asks for certain information and the machine replies and gives it to him, but I don't think these are truly interactive systems yet. In the future I think they will be.

What we have to do is give the forecaster the ability to modify what appears on his screen. (Even with AFOS, we're a long way from doing that.) He has to be able to change the graphics, or perform his own analysis, or do his own contour analysis and put that directly on the scope, or even on the national distribution circuit sometimes. He should be able to throw out certain data that he may not like, and then maybe let the machine do another analysis. He still may not like the machine's analysis; then he should be allowed to do his own analysis. I don't think we've worked out a way to do that yet.

So I think that's one problem I see in the future, coupled with the problem of bringing all the prognostic data into the system (which AFOS is planning to handle). I might mention that AFOS is sponsoring a contract with Penn State University called Interactive Forecasting Systems, but I'm not sure that even that system is truly interactive. I think it's mostly a request/reply system like practically everything developed so far.

Dr. John Cahir:

It depends on what you mean by "interactive." If a forecaster is sitting at a console, changing the analysis that appears before him, what really happens once he's changed it? Does he just take a picture of it and put it in his pocket and bring it home? I don't think that's the way to go with an interactive system; the interaction ought to change the forecast, not the data fields from which it was drawn. We are trying at Penn State to develop some schemes where he can check the forecast or the conclusions on the basis of data. As you all know, the data go through a very long cycle before they start producing actual forecasts, and it's possible to conceive of an AFOS system which will generate forecasts without any forecaster there. We're saying that, at some point, it might be a good idea to appeal back to the data. In that sense, it's interactive. Instead of just looking at the observations as a check, we look at the product.

Dr. Verner Suomi:

In helping develop and teach about satellites, I have learned several important things. One is that a satellite is less useful in an area that is meteorologically speaking, already data rich. There's nothing wrong with barometers, conventional measurements or wind instruments, and in some instances, they are even better tools than satellites. But a satellite can help in two ways. First, it can aid the study of large-scale motion because it can produce winds or soundings all over the globe. We think it can be of great help for GARP, but we cannot comment about it quite yet; we have to wait until 1979 and 1980 during the First GARP Global Experiment (FGGE) to see if it really helps. Some preliminary experiments seem to indicate it may not help at all. The answer to that question is confused, however, because we don't know if our initial specification of the atmosphere was satisfactory, or if the model on which we're making a judgement about the initial specification is satisfactory. In other words, the model has weaknesses as does our observing system.

Let me suggest that it is pointless to use a satellite over the United States to study large air motion when our radiosonde system does it very well. On the other hand, even over the U.S., study of the mesoscale weather is very limited, because we are "data poor" regarding mesoscale parameters. We have a very good description of the large-scale weather twice a day, but even that requires an intermediate scale. So, it would seem to me that we could develop a better kind of interaction and a possible forecast modification by addressing the question: How do you use the synthetic data being created by the model?

The synthetic data tells us what the next hour's or the next day's weather will be. These data may or may not be real, but it is important to society to know when they are real and when not, because society takes action based on our forecasts. We have failed to make this clear earlier, but let me say that one of the very valuable inputs to McIDAS or any system is synthetic data. Then the forecaster can quickly compare the synthetic data with the real data and revise his forecast if necessary.

The inclusion of synthetic data could also be very useful in the educational exercise, even if the data flow is not in real time. There are now model forecasts being made at NCAR, GISS, NOAA and UCLA, for example, including synthetic data for a specific time, and for some specific initial conditions. I think that for educational purposes we need a combination of the synthetic data and the real data. This will help increase confidence in the forecast when the forecast is progressing honestly and well. And if the forecast model is not working well, we will automatically be able to identify scientific problems for research to improve the model. The synthetic data cannot come from one place; that is too large an effort. It requires interaction among researchers. I would like to see future efforts aimed at the inclusion of synthetic data of the very highest quality.

Dr. William Klein:

I think that the concept that Dr. Suomi has suggested is one that the forecasters at NFC have used for many years, called the "model of the day." Researchers compare the numerical forecast to the weather that's been observed up until the time of the forecast and try to correct the model accordingly.

Dr. Verner Suomi:

That's what I have in mind, except that in a McIDAS-type system, it would be much more rapid and thorough.

Dr. William Klein:

But even with a McIDAS system it doesn't always work out; although the model has been going too slowly up to a certain point, it may not continue to do that for the next 24 hours. Nature can accelerate and change, and the errors are not always linearly extrapolated. And so it's a very complex and difficult problem.

Dr. Thomas Vonder Haar:

I'd like to talk a bit about the research aspects of these new tools. We've seen fantastic displays of the McIDAS system, and we've heard from Miami people, Penn State and CSU (and I think there are other groups who are doing such things). To me, this research means as much to atmospheric science as the electron microscope did to many of the other sciences. I think we can now look in a quantitative way at things such as mesoscale features that we just began to see qualitatively a few years ago. But how do we really capitalize on this? Many scientists need to use an electron microscope once or twice a year; others need to use it every day. I think that when we all go home from this conference we'll find that we won't choose research topics just because McIDAS is available, or because a computer is here or there. By and large, we follow our lines of inquiry and our hypotheses and our areas of interest pretty much as we had them laid out before we came here -- perhaps with some adjustments. So again we'll fall into groups who need access to this new tool twice a year or ten times a year, or every day.

How can we get this technology for our research? We have national centers for atmospheric research (NCAR), and they should have the best tools available, I think, especially for people who only need to use them infrequently. So I see this as a communications problem. Frank Sechrist noted the difficulty in making video systems available to smaller organizations for teaching purposes, and I think we may have that same difficulty, to a lesser extent, in research. I think satellite communications is the way to go. Our national weather service has four communication satellites in orbit today -- I think two of them are active, and two of them are stored. And I think it's time to think of a meteorological/atmospheric science communications net to transcend the land-lines for which we pay such high rates. I pose that as a challenge, perhaps at the national level.

Many of our research plans for the near future involve field programs. We saw today some analysis of the GATE experiment, and we know that despite the satellite data available at takeoff time, many GATE aircraft did not go into the most ideal cloud system, despite our best efforts. I don't think we can afford that anymore. I think we need to develop a field version of McIDAS or AFOS, or whatever, that can sit in a trailer in Vail, Colorado, or in a C-130 aircraft. That should challenge the engineers, but I think we need this capability at our fingertips to use our resources in the most efficient manner.

I'd like to close with one other thought. Research results must be transferrable; you've got to be able to communicate your research. So I would ask the audience to consider how we can best share the software and the other aspects of these new systems. Is this information really transferrable from one group to another? If it's not, it may always lie in the potential category, rather than in the real category. But if it's transferrable -- if there's enough commanality, if we can share it, use it, exchange it, publish it -- then indeed we may perhaps come to view research on video-linked computer systems as an important area of atmospheric science research by itself, at least for the next few years.

Dr. John Cahir:

I'd like to first address the impact on classroom instruction of a system like McIDAS. I think all of us teaching in universities have to come to decide how to expose our students to these systems. As you know, we've done something about it at Penn State, but I think we need to do more. There are questions I think that we really need to address. Perhpas there ought to be a kind of national distribution system for some of the products we saw this morning, rather than having the same things reinvented at a number of universities. I think that even a very modest system like the one we have at Penn State can be very useful if just on an interim basis, because a real time system of any kind can be a strong motivating factor for students in meteorology.

Video graphics systems are also very effective tools in communications. We do a television program at Penn State every day (as we have for years), and though we haven't heard very much here about IVAM (Innovative Video Applications in Meteorology), I think the link-up of systems like McIDAS with broadcast television represents some marvelous opportunities in improved communication.

But the principal thing, as Dr. Suomi said yesterday, is that McIDAS is a very powerful research tool. Most of us can't have that research tool over the near term, so I think we might all start thinking about some sort of system for people to visit Wisconsin and actually use this tool. On an interim basis, that may be the most practical solution to the access problem.

Dr. Suomi's comment about synthetic data certainly is an important one, but there's so much to do with McIDAS, you wonder how many things we can ask the system to do. Further, it's not clear whether there is really a need for more expenditure in this area. That's a very difficult problem, and I've thought a little bit about it. I've often told my students that the most valuable guy in the weather office is the guy who notices that it's snowing in Bluefield and knows that I didn't expect it to. It is very hard to code up judgemental decisions, to know when the model of the day is sour, and to know when you've gotta really do something about your forecast. That's a very big problem, and I just don't think that one national system would be able to deal with all those problems.

Dr. Robert Serafin:

First, with regard to Tom Vonder Haar's comments on real-time data needs in field programs, I don't think he meant that you need a McIDAS system, but that you need the McIDAS capability, and that's where the communications link comes in. My second comment relates to John Cahir's comments about the state of usage of McIDAS now. I learned this morning that the system is used from 8:00 a.m. until about midnight, so a single system like McIDAS could not serve the entire community of atmospheric science.

Dr. William Klein:

Concerning John Cahir's last comments, in AFOS we are planning to monitor the official aviation terminal forecasts and compare them to the latest hourly observations. This will be done automatically by the computer, and if a discrepancy is noted, an alarm will sound to bring the discrepancy to the attention of the forecaster. This is a step toward the special-area forecasts he talked about, except that we have to extend the system to cover all of our forecasts--not just aviation forecasts, but all public and severe storm forecasts, marine forecasts, agricultural forecasts and the like. This will come in the future, but we're starting out with the aviation forecast because they have to be amended by law when a weather emergency arises.

Dr. John Cahir:

Even that is tough, because it's very hard to "tune" the system to know where the weather's going sour. You don't want alarm after alarm from all the stations you're supposed to be taking care of, yet if you make it too insensitive, it isn't going to pick up important changes.

Dr. Robert Evans:

Though the applications of video graphics to oceanography may be a bit different from meteorology, the same basic performance requirements are there. One of the basic things I think we need to do is to educate ourselves and the community about the existence of these systems and about the ways they can be used to advance the progress of research and education.

There are also several technical points that I'd like to see addressed. One is the cost of data acquisition; the acquisition of satellite images is not a trivial expense. Second, how does one calibrate and navigate satellite data in such a way that everybody's working with a standardized data product? And third, how can these systems be made available? There are applications for reasonably capable centralized systems, but there is also a real need for much less expensive systems than we have now.

Dr. David Houghton:

As one of the resident users of the McIDAS System I can attest to the difficulty that we scientists have keeping up with the McIDAS engineers and development people. And if it is hard for us here to keep up, I really wonder how someone who's not in-house with a system like this can keep up with all the new potentials that it offers. I think in a general sense we should not confuse our desires with our needs. Many scientific exercises need not be real time, for example. Further, interaction with the computer is very difficult for me; I'm a traditional scientist who needs time to think. I'm used to putting something into a regular computer, waiting a few hours or a day for turn-around, then thinking about what the computer has said before the next go-around. This interactive mode sometimes just boggles my mind. I hope that future research is more of a technical interactive and not a scientific interactive nature, even if that might sound like heresy.

I also think that sometimes McIDAS actually presents too much data; in a sense, too much data can confuse the picture, at least for those of us interested in concepts and overall understanding of the weather. So, I make these comments as a continuing challenge from those of us who want to pursue scientific research with the system.

Dr. Owen Thompson:

University of Maryland

We are discussing the future of interactive video display, but there are a lot of us here who don't even have a present. It seems to me that the first thing we should to is to get a system that we can afford, that will do something for all of us--for example, some way to get on the AFOS System would be a good start.

Dr. William Klein:

I think you're absolutely right.

Q: Are there any plans to allow university students to go to AFOS installations to learn how to work with the AFOS system? How does the weather service plan to prepare students to work with AFOS? NWS is talking as though it's the universities' responsibility to educate people to work on the weather service system, but I think that's the weather service's responsibility.

A [Dr. Klein]: We don't regard it as a very serious training problem. We're planning to train our own forecasters with a one-week on-site training program; we don't think it takes more than a week or two to teach a trained forecaster how to make a forecast with the new system, or how to make the transition from the old system to the new system. But we certainly don't have any plans for teaching university students; our big problem is to teach our own people. We have a team of a half-dozen instructors who will tour the country, going into a station a month or two after the equipment goes in, to give the on-site training courses. This will occur over a four-year period, starting in January, 1978. But we hadn't thought about the university problem at all up until this minute.

Dr. Thomas Vonder Haar:

As the head of a department at CSU, faced with questions from students about jobs in the National Weather Service, I've made some inquiries with NWS regional directors and others. I've been told the same thing that Bill Klein just explained: "we train our own people." Their policy is to bring in the meteorologist intern and teach them the system: how to make the measurements, how to make the forecast on the new apparatus. I get the distinct impression that NWS really would just like us at the universities to give students the right number of credits in Synoptics and Dynamics and a few other things, and that's all. Just give students the basics, and let NWS do the training later. And when I approached the Air Weather Service with the same suggestion (that they provide their version of AFOS to universities with contingents of Air Force students, just to familiarize the graduate students with the new system) again I was told this was counter to their training policies. So, we're not going to get anywhere along that line unless we talk to the people at NOAA involved with training procedures, and that would be a major policy change.

Dr. Richard J. Reed:

University of Washington-Seattle

I think there's an extra dimension here that we've missed. Sure, NWS thinks they can train new personnel in a week with a good training program. The question is, how are we going to train people accustomed to using the more conventional forecasting tools and techniques? I think we all realize that something's going to change when AFOS comes, but we may not realize how much is going to change. The rug will be pulled out from under us, and unless we're supplied with some new, modern type of training, we're going to be in trouble.

Q: Will the AFOS system cause a reduction in NWS personnel?

A [Dr. Vonder Haar]: The Air Weather Service said they were going to reduce their staff. I don't know what NOAA is saying. Will there be a reduction in manpower?

Dr. William Klein:

When the AFOS program was sold to the federal Office of Management and Budget, we promised to save about 100-200 communicators, and that is all. That's the only manpower loss that will occur, and those people have already been swallowed up by new demands and requests for utilization, in NOAA weather radio for example. And because the number of electronics technicians to maintain the new system keeps going up all the time, we'll end up, I think, with no net change in the overall manpower in the National Weather Service.

There hasn't been any in the last five or ten years, and we don't anticipate any in the future. There may be a slight change in the personnel composition, in the mix, but that's all.

Dr. Verner Suomi:

MCIDAS was created through grants and contracts from NASA, NSF and NOAA, and the accountants at those agencies insist that a program like this pay for itself; that is, those who use it must pay for it. Let me ask the audience for comments and questions about their willingness to come to Madison to use McIDAS under some kind of user fee system.

Q: I'm curious about using the system to study space physics, which also generates a significant amount of data to describe three-dimensional dynamic systems. Could I use McIDAS to study things like auroral imagery and surface magnetometer measurements, used to derive the horizontal current in the ionosphere?

A [Suomi]: If your data is in digital tape form, there is no problem (unless you have seven-track instead of nine-track tape). If you have photographs, we do not have now a facility for digitizing that data, though that is a fairly straightforward process. We plan to set up such a facility later, however, because much of the meteorological archive of the past is in photographic form.

The McIDAS display is quite flexible. For example, the pictures you saw yesterday of Venus were from an 800-line, rather than a 525-line camera format. You may also have seen displays of the "black holes" in space; several of these displays were prepared by the UW physics and astronomy group using the McIDAS system.

Q: Would you at SSEC allow me to use McIDAS for space physics studies?

A [Suomi]: Yes.

Q: Should we come here with digital data, or should we work from the digital data and an objective analysis to prepare instructions for drawing contours (as NCAR suggests)? Can the contours be drawn right on the screen from the digital data, saving us three or four steps of preparation?

A [Tom Whittaker]: We could do it either way; it really depends on what you want to get out of the system. We could, in fact, go all the way back to the raw observations.

Q: But what would be the most efficient way to present the data, so that we don't use any more of the computer resources than we have to?

A [Whittaker]: If you are happy with our analysis approach (picture drawing, not interpolation of the grid) that produces single-line or shaded contours, I'd suggest that you stick with a grid-point pattern. On the other hand, there is nothing to prevent you from writing pen motions on a nine-track tape; we could move the pen around on the screen and draw the pictures for you that way.

If you use the uniform grids, however, you have a lot more flexibility in ordering your displays. You can change the contour intervals and calculate derived parameters from the uniform grids, and display those as well. If you use just a pen-motion system, it is very hard to back-track and reconstruct the original data set.

Q: I see in the development of AFOS a national meteorological communications network which apparently is not going to serve as a communications network for one of the two mesoscale observational tools we have--the GOES satellite data. Is that correct?

A [Dr. Klein]: That is correct; it will not. Later on, if we can digitize the satellite pictures and get the most important information from them into the system, then we'll be able to transmit the digitized information. But not the raw satellite picture, no.

Q: So if I, in a small institution, want quasi-real time data and prognostic data, I need to go to an AFOS-type facility, then to a GOES facility for the real-time satellite data, and then (if I want an interactive capability for research and instructional purposes) to a small McIDAS-like system. What bothers me here is that I'm talking about three systems, all of which I can't individually afford. It looks like we've got to come up with something that is affordable and versatile for the smaller institutions, or with a communication network that gives us access to this capability.

Dr. Verner Suomi:

The best communication network that I know of is called "a graduate student with a tape under his arm going across the street;" no wideband system beats that. But in a more serious vein, some of the things you saw today can be put on a video cassette. It's very clear that somewhere along the line, you're going to need a display system. (It could even be a movie screen, but movie film is very expensive, even though the projectors are cheaper.) The most useful system is the one that is the most flexible, and in my view at the moment anyway, that is the video tape cassette system, because the initial cost, the replacement cost, and the improvement with time are likely to be the greatest. If you ever get a system, you're going to need a video-type display anyway, so depending on your priorities, you can get some of the early benefits right away by obtaining a good video display system.

Mr. Arthur Hansen:

NWS/AFOS

I would like to clarify what may be a misconception about AFOS. I emphasized the communications, data-sort and data retrieval aspects of AFOS yesterday, and did not go into the interactive capabilities. But the types of computations done by McIDAS are possible within AFOS; the big difference is the lack of satellite imagery in the AFOS system. AFOS can, however, do the contouring and the computations that McIDAS can do. Of course, AFOS will not have a color capability.

Q: Can it access NMC's data base and the National Climatic Center's data base?

A [Dr. Klein]: Yes, absolutely. You'll have all the alphanumerics you saw with McIDAS: the station plots and the graphic plots. The only problem is that AFOS will not superimpose the satellite picture on the video screen the way McIDAS does. So that basic question remains unanswered. The person who asked that earlier question may be right; you may need three systems.

Q: I think there is a more basic question. How will people outside the weather service access AFOS?

A [Dr. Klein]: Many different possibilities are being investigated.

Q: If AFOS is going to replace the teletyping and facsimile circuits, there is no excuse for NWS not having a policy on how that new system would go public.

A [Dr. Klein]: We expect a final report on this in the fall. We've had a contractor studying external user questions, and there is one report already available. There are many options, and the final decision just hasn't been made yet. We do guarantee continued service to present users, with no deterioration of teletype and facsimile services.

Mr. Eric Smith:

Colorado State University

Let me offer my observations on the future of image processing. I think the next step must combine image display systems, and surface/upper air and satellite data systems to start constructing three-dimensional (3-D) images of the weather, so we can start putting together true analyses of such things as severe weather events. Presently we have all four dimensions available to us, but we can only look at a two-dimensional flat projection in sequence. If we're going to address the future of image processing, I think we face this problem of increasing the dimensionality. We've gotten a quasi-three-dimensional system working in a number of places, and research will go on, but if we want to expand image processing rather than just stop and work with what we have now, I think we need to face this problem of another dimensionality.

Dr. Verner Suomi:

I think Charlie Bristor (NESS) has already done some work in simulating three-dimensional image processing. He took an infra-red image and made a false stereo, which made it look as though the clouds had real depth. If you wish to wear special glasses when looking at the screen, I'm certain that it would be possible to change the polarization of two images in sequence, with sufficient speed that you could see three dimensions, too. I think there probably are also interferometer or hologram schemes that could do the same thing. It seems to me, though, that before we go to 3-D, we would have to justify it's utility; as soon as the need arises, ingenuity will find a way to meet it. We mustn't have a solution looking for a problem; we need a problem looking for a solution. I think that we need to identify what needs would be served by such a capability.

Mr. Eric Smith:

I think we already do have a problem. McIDAS has combined a satellite view of the atmosphere with a surface view of the atmosphere. We see superimposed images, but we have a hard time interpreting them. Dave Suchman [SSEC] showed some good videotapes today in one of the demonstrations on some of the GATE double-cluster data. There's a lot going on there, and a lot to understand about momentum exchange and other convective processes.

There's a lot of data from GATE ships, from satellites, and from aircraft, and you cannot reconstruct the atmosphere from this flat view of things. There has to be some mechanism for putting the data into a truly three-dimensional plan, because that is how you like to take your observation.

Dr. David Houghton:

You want to see what's going on, but in order to understand it, you have to reduce it to simpler presentations. I would use the three-dimensional approach for a first look, but to get down to the real science, I would say that other ways of presentation would be better.

Mr. Eric Smith:

Well, you may want to finalize your results in a bar graph, but image processing came about as an intermediate tool for discovering what the problem was before you could make a bar graph. We miss a lot of weather phenomena with the present system because we have different projections of the data and we cannot reconstruct them into what we want.

Mr. Thomas Haig:

I've had a bit of experience with three-dimensional systems. The government has in the past spent a great deal of money on 3-D systems for a variety of purposes. I know of three systems: the least expensive cost about $21 million, the most expensive cost in excess of $250 million. All of these systems have been abandoned, not because they didn't work, not because they didn't give good three-dimensional presentations, but because people were unable to make decisions easily in using a 3-D display. It made no difference whether this was a decision for the extraction of data, or simply deciding to push a button or respond with a yes/no choice. You want a display so you can interact and make decisions, but they have found that it was almost impossible to quantify that third dimension.

On a two-dimensional display you can make some kind of graph; you can include numbers and understand and appreciate that in your brain. But when you put the third dimension on there, interpretation becomes extremely difficult. They found that it was much more effective to present two two-dimensional displays, then move these planes through the three-dimensional space. The complexity of the display and the inability to include quantified information on it defeated the 3-D systems.

Dr. George Freier:

University of Minnesota

It's not clear to me what we all consider meteorological education to be. Are we talking about training people to work for the Weather Service, or are we also talking about the hundreds of thousands of liberal arts students who have to fulfill a science requirement so take just one quarter of meteorology? How vital is a video graphic system to them?

Dr. David Houghton:

I'll speak for the Wisconsin experience. We have meteorology courses at all levels, and one is at the survey level for the liberal arts student. Dr. Sechrist has used the McIDAS system at this basic level just to present what the weather looks like, but also for undergraduate meteorology majors, and of course for our graduate level programs. We have also tried to use the system in our synoptic meteorology course in a way that is relevant to the operations of the National Weather Service.

Dr. Richard Reed:

I hope we're interested in all levels, from survey courses right up through graduate courses. We're not trying to teach students what the Weather Service techniques are, but we must show them that the Weather Service provides the only source of information that we have at present--very good information for our purposes. Frank Sechrist has shown us how a McIDAS-like system can enhance our teaching methods so we can do a better job.

Dr. Frank Sechrist:

I don't envision using the system to accommodate Meteorology 100; I envision the system as a training tool for the synoptic lab and also as a research tool--to study the structure of the atmosphere and to show students how to look at it and how to prepare an analyses. Just because it's there, it's awfully nice to use part of it for the 100-level course, but I wouldn't set up a system just for that survey course level.

Dr. K. Jayaweera:

University of Alaska-Fairbanks

Most of the systems that were discussed are meant for real-time studies of satellite imagery. One of the problems that I have faced is how to use the satellite data collected over the last five or ten years to do climate-related studies. Is there any system I can use to get the stratus-cloud cover distribution or thunderstorm distribution within a state, for example?

Dr. Verner Suomi:

In principle, it would be possible to address that kind of question with McIDAS. We saw an elementary example in the snow-cover study by Ron Gird (NESS). We can emphasize short-range as well as long-range weather features. One of my former students, Jack Kornfield, took single pictures of the tropics, every day for two months, and analyzed them using McIDAS. The images jumped around a lot, but they did show the waves in the tropics. It would be perfectly possible to look at things in a longer time frame; it isn't necessary to do it minute by minute. We've already published data on two-week average cloudiness, for example. The system can do these things, but it takes individuals sitting in front of the machine to actually ask the questions.

Mr. Robert F. Myers:

AFGL - Bedford, Mass.

I happen to have the only other live McIDAS system outside Wisconsin at the moment, and about three years ago, I was in the position that many of you are in now. I had many of these same qualms that you're having, and many of the same questions. And all your questions are right. With a system like McIDAS, it's going to be a lot harder, and it's going to be a lot easier at the same time. So much depends on individuals and on resources. We have McIDAS hardware and software, and we are adding a terminal to it, and we've found that it's useful at all levels. I've had public groups coming in to see what weather looks like--even more elementary than Meteorology 100. People are amazed: Wow, the weather does look like that! The clouds do move! On the research level, let me describe the very first real payoff we had on McIDAS. People were getting tapes from NOAA and NESS, cramming them through the 6600, and then looking at the print-out and trying to decide why it didn't say what they thought it should say. When we put the tapes on McIDAS, we found there were holes right in the middle of the area we were processing. We just had no idea there were areas of mismatch or noise; we had a lot of bad data and we didn't know it. So just a trivial quality control program on McIDAS--punch up DF, you're on the screen, and yeah, that's a good picture--saved untold hours of heartache.

System time -- particularly data acquisition time -- is at a premium. You can send a graduate student, your secretary or another staff member to do something for you on McIDAS, and they can do it. You write out a series of five commands for them, and they can run the job for you. But there's a danger in doing that, because you lose the interactive benefits of seeing things for yourself. The thing you thought was going on, wasn't really going on, or you look at the screen and see something else you didn't realize was there before.

Please, remember that you need to run the system yourself, at least to feel what it's like. You know, you can read about love all you want to, but it's the experience that counts, and I must say that I have something of a love affair with McIDAS. I get mad at it sometimes, and at times we almost get divorced, but on the whole it's a very good and a very worthwhile system.

VIII. FUTURE VIDEO DISPLAY SYSTEMS

INTRODUCTORY REMARKS

Mr. Thomas Haig

I would like to discuss how we at the University of Wisconsin view our opportunities and responsibilities in disseminating the information we hold. We are the custodians of information which has been paid for by the public, and we clearly see our obligation to make this information as broadly available and useful as possible to the university and government community and others.

Research programs generally proceed as in Fig. 13.1. Somebody has an idea, writes a proposal and gets a research contract (if he's lucky). He then does some work and prepares a report, which is almost always followed by another proposal for development of some prototype hardware. In some cases there is even another proposal for a final development phase, to put the information and hardware into the hands of people who can make use of it.

We who work with McIDAS are about half-way down that road; we have done some transferring of McIDAS technology outside of the Madison campus--to Milwaukee, and also to AFGL--but we are planning to do much more. We are now building two units to be installed at the National Environmental Satellite Service (NESS), so they can navigate and grid the GOES sectors with good accuracy; we are building another system to be used here in support of FGGE; we are building an abbreviated system to be used on a study sponsored by NASA; and we anticipate building a display system for Prof. Weinman here at UW (which will be installed in a van, incidentally) as a half-way van-mobile kind of interactive system. This latter system will serve mainly to display data as he collects it, rather than as an interactive system, but it has the capability to become interactive. So, we are taking this relatively mature video graphic system and putting it into several forms (such as kits and procurement specs, for example) for dissemination.

We'll have four presentations this afternoon. Dr. Richard Daly, will tell us about software and our plans for transferring it to interested parties in the relatively near future. Bob Norton--our engineer in charge of the second generation McIDAS development program--will tell us what's

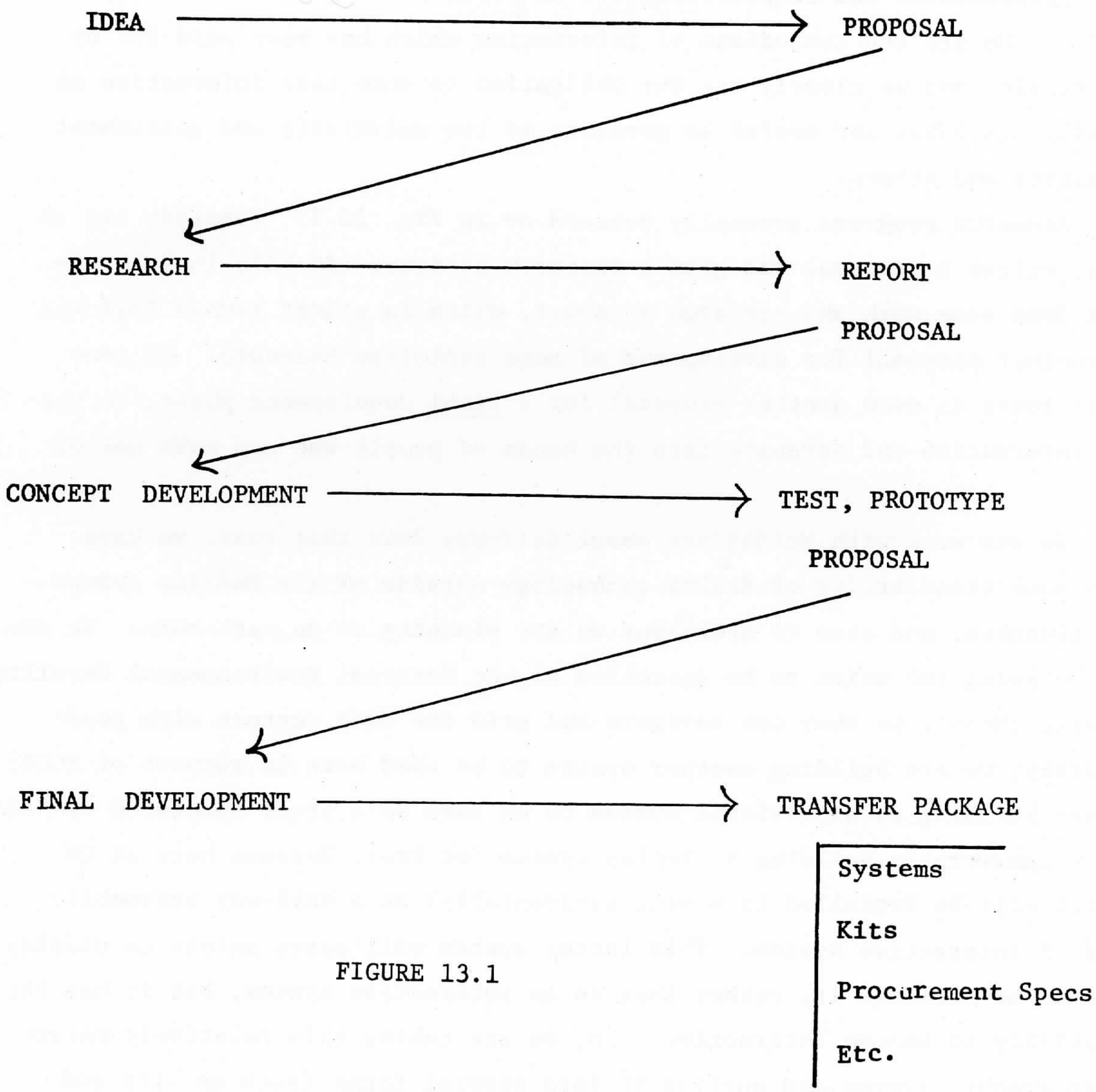

IDEA
PROPOSAL
RESEARCH
REPORT
PROPOSAL
CONCEPT DEVELOPMENT
TEST, PROTOTYPE
PROPOSAL
FINAL DEVELOPMENT
TRANSFER PACKAGE
Systems
Kits
Procurement Specs
Etc.

FIGURE 13.1

different about the McIDAS_2 system. Gary Banta will discuss what we call the "kit approach" as one way to transfer information about McIDAS at the least cost and greatest efficiency. Then I'll talk about costs (somebody has to!) and about the opportunities at SSEC for outside investigators to make use of McIDAS. We've accommodated quite a few researchers in this way, and we are willing to continue to do so.

I also have a questionnaire (Appendix C) which is a very important part of this workshop. This is a feedback mechanism to NSF, and is your opportunity to tell NSF about your intentions, or your plans or feelings toward computer interactive systems, so that NSF can formulate some plans about how best to use their resources to support the university community and the scientific institutions who may want such systems.

McIDAS SOFTWARE STATUS AND AVAILABILITY

Dr. Richard Daly

We have a large body of software, some of which you've seen demonstrated today, and we are very interested in making this available to other members of the research community. I'll talk first briefly about the operating environment necessary for running most of our software, and also about the McIDAS control environment -- the specialized software modules that operate at a level just below the operating system. Then I'll talk at more length about the application subsystems operating on McIDAS, and finally (an unpopular topic with programmers and a popular topic with everyone else) about documentation.

The operating environment (Fig. 14.1) requires a real-time executive system that is able to respond rapidly to interrupts, to listen to teletype wires (if you want to gather that data) and to ingest large volumes of satellite data as it's received, taking care of other tasks when time is available.

Multi-tasking capability is also probably required. To a certain extent this can be avoided, though the interactive capability of the system degrades considerably without it. By multi-tasking I mean something different than the usual time-sharing capabilities of most computer systems. Multi-tasking allows us to start a processor running from a terminal (for example, to ask that a satellite image be displayed) and then, while the computer is running that program, use the same terminal to ask for another program to be started. This second program will also start up and compete with the first one for system resources. This means, for example, that you can have a map being drawn on the screen from a map file by one processor, and have contour data being drawn at the same time, by a different program, on the same screen.

A system common -- a dedicated block of core -- must be available for communication between independently running programs. Much of our application software makes use of system common intercommunication.

To load programs rapidly for real-time execution you must also have a fairly sophisticated file management system.

If you're running in a small or middle size computer, as we are, it's necessary to have a link-cataloger which can make overlays; that is, to

REQUIRED OPERATING ENVIRONMENT

REAL TIME EXECUTIVE

MULTITASKING

SYSTEM COMMON

FILE MANAGEMENT SECTION

LINK CATALOGER WITH OVERLAY

FORTRAN

FIGURE 14.1

produce programs which can be loaded and executed in parts. Generally, our applications software occupies less than 16 K of core, but for the larger modules like WINDCO, thirteen or fourteen segments come in one after another to actually carry out the computation.

Finally, as in most systems, our software is almost all written in FORTRAN. We use a version of FORTRAN prepared by the Harris Computer Corp.; it's fairly close to the standard FORTRAN-4, with two minor differences. One is a logical shift operation to pack and unpack bytes and words quickly (which can be done just as well with multiplies and divides by powers of two, if you don't have the logical shift). We also use the ENCODE function, at least in some of the older software. We've tended to get away from it more recently. ENCODE allows you to make internal core transfers of data and to re-format with FORTRAN format statements.

The McIDAS control software is, I feel, a beautifully simple structure. At its highest level it consists of three core resident modules: video control, terminal communications, and task dispatcher (Figure 14.2).

The video control module checks the SYSCOM block to see if any applications task has changed some control parameter. If so, video control makes the appropriate change in the video system hardware. This module becomes active at video retrace rates, so it is generally not very busy.

The terminal communications module accepts input from the terminal and activates the appropriate decoding task to handle it. In addition, in our present configuration, this module also accepts character input from the circuit 604 data wire and activates the decoding task when a block of text has been accumulated.

Tasking is implemented via a task message queue. When any active task requires that another task be started up, it places a message for that task in the queue. The dispatcher will then take the steps necessary to activate the new task so that it can retrieve its message from the queue and carry out its function. This dispatcher is part of the third -- and by far the largest -- core resident module: the Harris DMS operating system. DMS occupies about 14,000 words, while the other two resident modules require approximately 6000 words.

Our applications software is shown in Figs. 14.3.a and 14.3.b. This looks like a fairly neat structure, but it doesn't necessarily reflect the

McIDAS CONTROL SOFTWARE

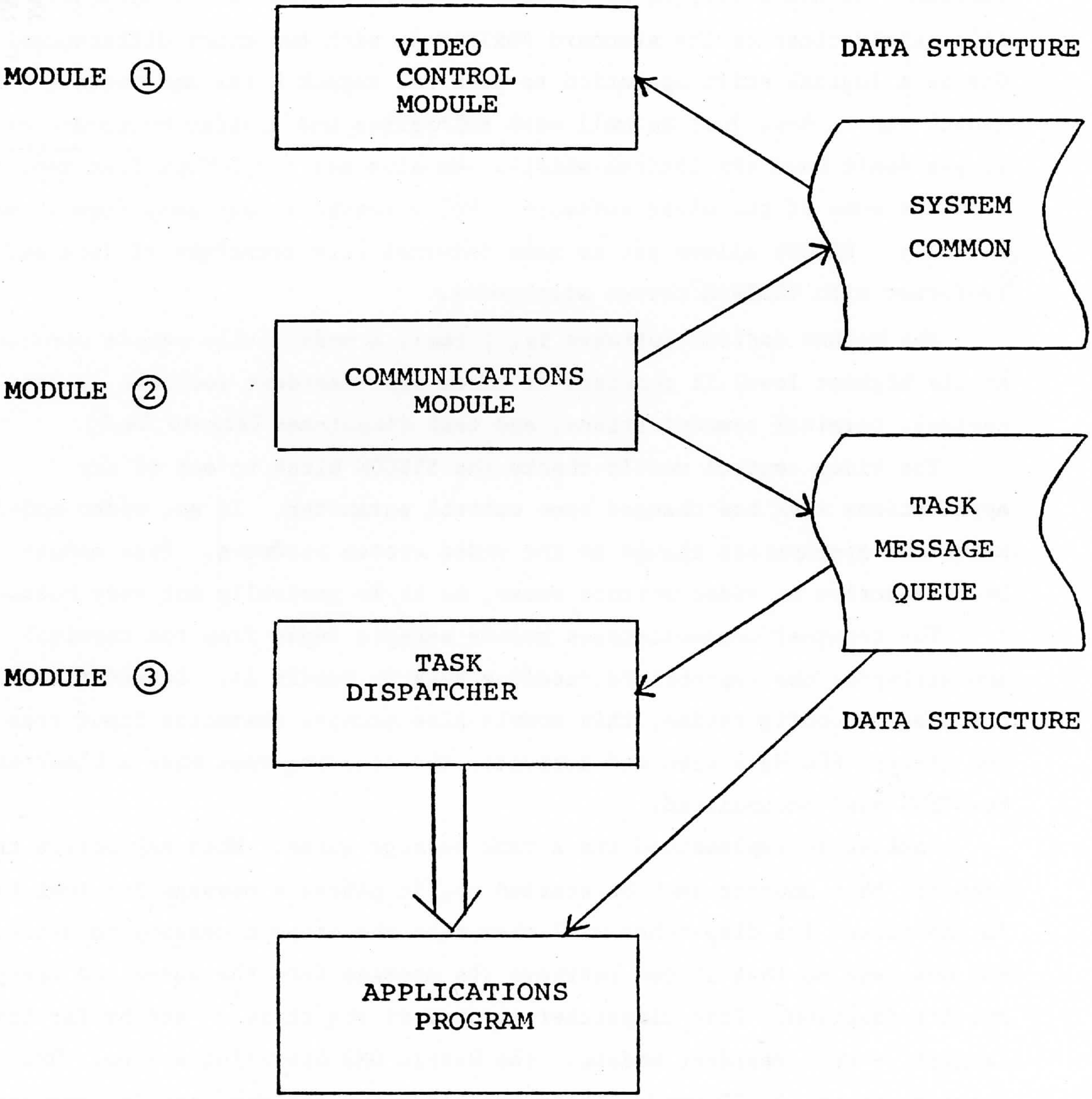


FIGURE 14.2

APPLICATIONS SOFTWARE SUB-SYSTEMS

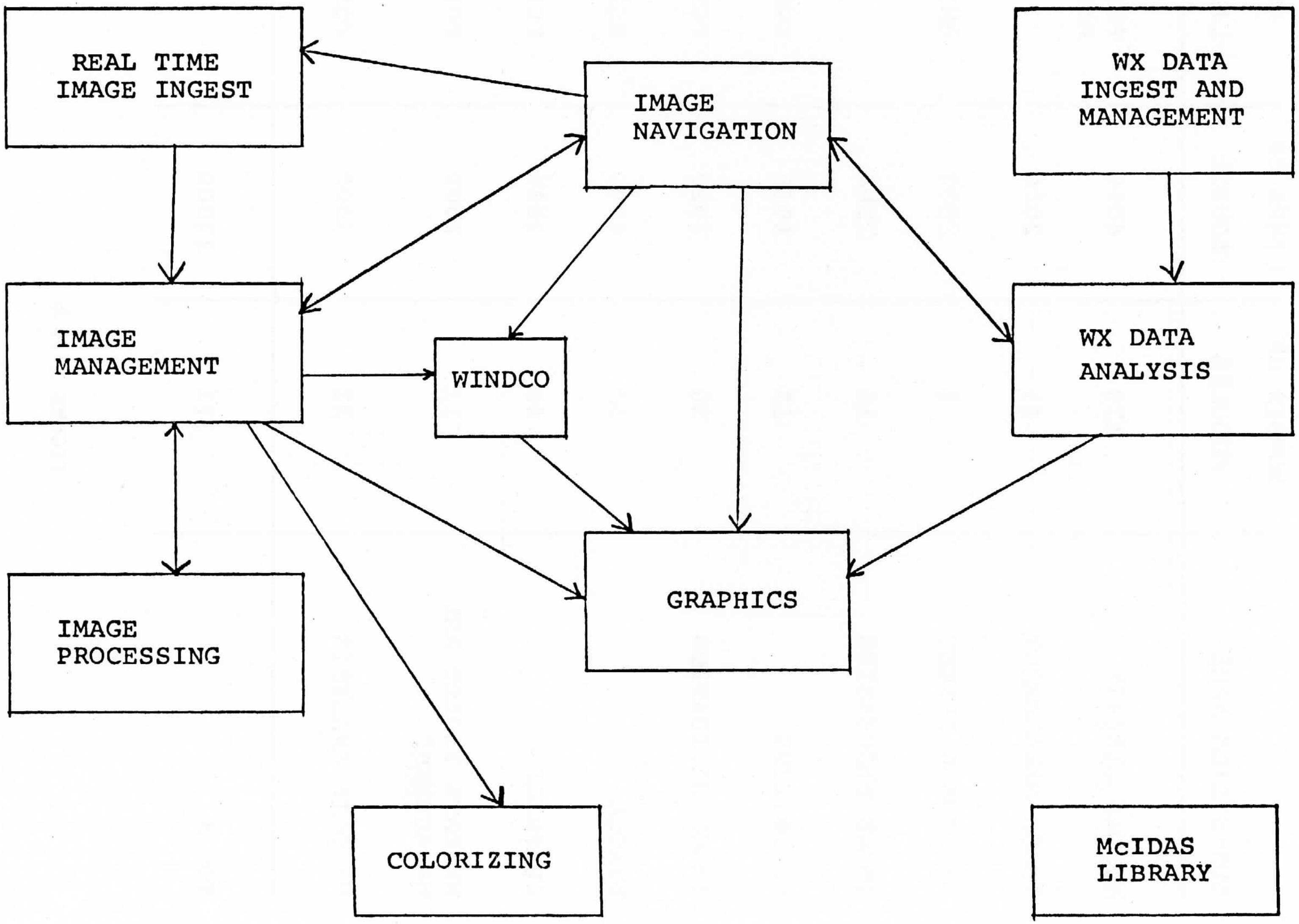


FIGURE 14.3.a

SUB-SYSTEM NAME	NUMBER OF MODULES	LINES OF SOURCE	CODING LANGUAGE
McIDAS LIBRARY	128	4000	FORTRAN & ASSEMBLY
IMAGE MANAGEMENT	41	2000	
R-T IMAGE INGEST	2	2000	ASSEMBLY
IMAGE PROCESSING	15	2500	
COLORIZING	11	1000	FORTRAN
IMAGE NAVIGATION	50	3000	FORTRAN
WINDCO	50	4500	FORTRAN
GRAPHICS	40	3000	FORTRAN
WX DATA INGEST AND MANAGEMENT	12	2000	FORTRAN
WX DATA ANALYSIS	22	3000	FORTRAN
TOTAL	371	27000	

FIGURE 14.3.b

real system exactly. The McIDAS software has been growing steadily for about four years, and the growth has been quite rapid recently. Some of it, particularly the navigation software, goes back to 1968; it originally started out on the UNIVAC system here at UW. The software we are using began originally with the image management system, which allows us to read nine-track tapes of images, to display them on the screen, to change the scale of the displays (to blow them up or down), to change the resolution of the digital data itself, to move the cursor, and so forth. I am not including in that set of programs, however, any of those that work on image brightnesses. We have another set of programs for filtering, smoothing the data, and normalizing brightnesses according to various schemes; they occupy a different family of programs. Then we have the colorizing programs, a relatively small family somewhat independent of the others and dependent on specialized hardware.

I should point out that the arrows in Fig. 14.2 do not indicate control flow, but rather data flow. The control flow in McIDAS is always through the user sitting at a terminal, making a key-in request. The arrows rather indicate data flow. Each of these subsystems have data structures associated with them, and the arrows indicate which subsystems need access to data structures generated and maintained by another subsystem. Control flow on McIDAS is almost always through the user at a terminal, since most applications programs run in less than 60 seconds (and often in much less time).

WINDCO, probably the oldest real applications subsystem on the system, constitutes a large number of programs developed somewhat early in the McIDAS program; it is still one of our most useful packages. It obviously needs images, and it also needs navigation information to align the images. To a certain extent it also makes use of graphics programs for displaying vectors on the screen.

Largely independent of that whole body of programs are the circuit 604 programs that ingest the data and manage the data base. These programs were developed somewhat recently by Tom Whittaker [SSEC]. Associated with them are a collection of programs (you saw many of them operating this morning) for analyzing that data, some it directly, without any interaction with the satellite images, and some of it in combination with the satellite images.

Finally, we have a very large number of modules which constitute the McIDAS library. Some of the subroutines in the library -- the lower level handlers for the hardware such as the enhancement box handlers -- are in assembly language. But by and large, most of the programs are in FORTRAN.

There are now about 371 modules. Two hundred of them are associated with key-ins (the two-letter keyboard entries that constitute our basic command structure); the others are specialized libraries. For example, a lot of the graphics programs are subroutines for doing vector plotting, or higher level subroutines for doing whole graphs. There are also subroutines for doing three-dimensional isometric displays and the like. I'm including in this total both independently running processors and also subrouting modules. Altogether we have about 20,000 lines of code developed over the past several years, almost all of which is in FORTRAN.

What sort of documentation is available? Documentation (Fig. 14.4), as you might expect, was a problem, since our system grew in response to requests. Somebody would say, "I really need a subroutine to read the ERTS tapes; could you write something like that?" Well, the program gets written, but it doesn't get documented. The person who wrote it and the person who asked for it both know about it, but nobody else knows about it. When we began to realize what a treasure we had in the McIDAS software, our documentation efforts also began to increase.

The documentation is broken down into two types. For the software that was already running, the only existing documentation was the key-in list in the user manual. It seemed, then, that the most useful thing to do first would be to produce an annotated program directory. We gathered the names of every module on the system, made up a short description of what the module did, and arranged this list in alphabetical order. So if you wanted to know what a certain program did -- or where to look in this huge file of cards to find it -- you could consult the directory. We've used a single-line entry format, with the name of the program, the programmer, when it was done, what subsystem it's in, and a short description of what the module does. Just this entry system alone has made programming a lot easier.

Another high priority effort was data structure documentation. It's very hard to figure out what old programs do if you don't know what kind of data structure they're working on, so we spent a lot of effort defining the file structure involved: what units were involved in the data; how the data was packed in the file; what tape formats were used. We also spent a lot of time documenting the system common, listing the function of each of the words in

SOFTWARE DOCUMENTATION

A. SYSTEM-WIDE DOCUMENTATION

1. ANNOTATED PROGRAM DIRECTORY
2. DATA STRUCTURES DOCUMENTATION

B. INDIVIDUAL PROGRAM DOCUMENTATION

1. COVER SHEET
2. USER'S MANUAL PAGE
3. DOCUMENTATION LISTING

FIGURE 14.4

McIDAS DATA STRUCTURE DOCUMENTATION

Type Disk File
(Disk File, Savetape, COMMON Block, etc.)

Name FRAMED
(if applicable)

Documenter J. Benson Date 2/2/77

Description of Structure:

McIDAS Frame Logging and Image Coordinate Transformations

The Frame directory is a disk file containing a 14-word integer record for each video frame in the system. The file is arranged so that there is a continuous block of records for each video system, and the absolute location of the record is determined by the frame number.

The contents of this frame record are as follows:

1. SSYYDDD
2. HHMMSS
3. IMAGE LINE
4. IMAGE ELEMENT
5. TV LINE CONTAINING (3)
6. TV PIXEL CONTAINING (4)
7. MAGNIFICATION, AREA LINE RES, AREA ELEMENT RES as 3 8-bit bytes
8. Creation YYDDD of area
9. Creation HHMMSS of area
10. Creation YYDDD of frame
11. Creation HHMMSS of frame
12.
13. Unused
14. Project permitted to write on this frame. (ZERO indicates unrestricted).

The contents of this frame record are updated by the "DF" processor, all except word 14, which is left unchanged. Word 14 may be modified by "RF", the restrict-frame function.

FIGURE 14.5

the different routines. All the documentation for the data structure are now collected in a single loose-leaf binder, easily accessible to anyone who wants to refer to the data structures.

Figure 14.5 represents a short example -- a rather crucial one -- in our system. It documents the frame directory, noting the kind of data structure, the actual file name, who did the documentation and when, and the kind of items in that file. The frame directory is a disc file that keeps track of what image is on each frame of the display system at any time.

Then we turn to individual program documentation (see pages 315, 316 and 317 in Appendix D). We produce a cover sheet which gives the basic identification information about the program -- when it was written, who wrote it, what it was supposed to do, what language it's in, where you can find the source and where you can find the object code of that program on our system. Included with each program documentation is the user manual page that goes with that program. The user page contains information about what the program is supposed to do and what the input parameters mean, so it's very handy to have it filed with the program listing itself.

Finally, we include a standard documentation listing (with whatever comments we can cajole the programmer into placing in the code), plus the compiler-produced tables at the end of the listing to tell you what external subroutines are referenced and have to be considered when using or modifying that piece of software. All three of these items are filed together in a single binder. We have broken our documentation down into the subsystems that I showed you earlier. Each subsystem of programs then is bound in a single loose-leaf binder in alphabetical order, with a directory at the beginning of the binder so that you can find the program quickly. We also include a system-wide directory which lists all the programs on the system in alphabetical order so you can locate the binder you need.

We are very anxious to make this software available to anyone who can use it. It's all running now on the Harris machine here at SSEC, and some of it (the navigation software, for example) is now running on other machines at other places. We are currently engaged in a cooperative project with the German Space Operation Center, outside Munich, to transfer all of the McIDAS software -- the control programs, as well as all the applications software -- to an Amdahl computer, which is an IBM 370 look-alike. Our system programmer

(John Benson, SSEC) is in Germany right now, working on the operating system; he took with him an IBM-readable tape which contains all the source programs on our system. We will be intimately involved in the conversion of all the software to the IBM operating environment, and we expect that to be a very interesting undertaking.

QUESTIONS AND COMMENTS

Q: In what form do you make the software available?

A: We would like to deliver software in punch-card form. We keep all our software in punch cards and update it on punch cards, so that's the easiest way for us to deliver it. If we were to provide it on tape, we would provide the images of the punch cards with our control cards embedded.

Q: If I were interested in getting software on tape (because I can't read cards), could I get a nine-track binary unlabelled tape?

A: Yes, you could, but you probably would want an ASCII tape rather than a binary tape.

Q: Is the Data General Eclipse computer big enough to handle the computer functions you described?

A: I don't know; I think parts of it are. But rather than try to answer that kind of a question right now, we would rather try to help you go through an analysis of your system. We can talk to you directly about your operating system and its capabilities versus our software requirements.

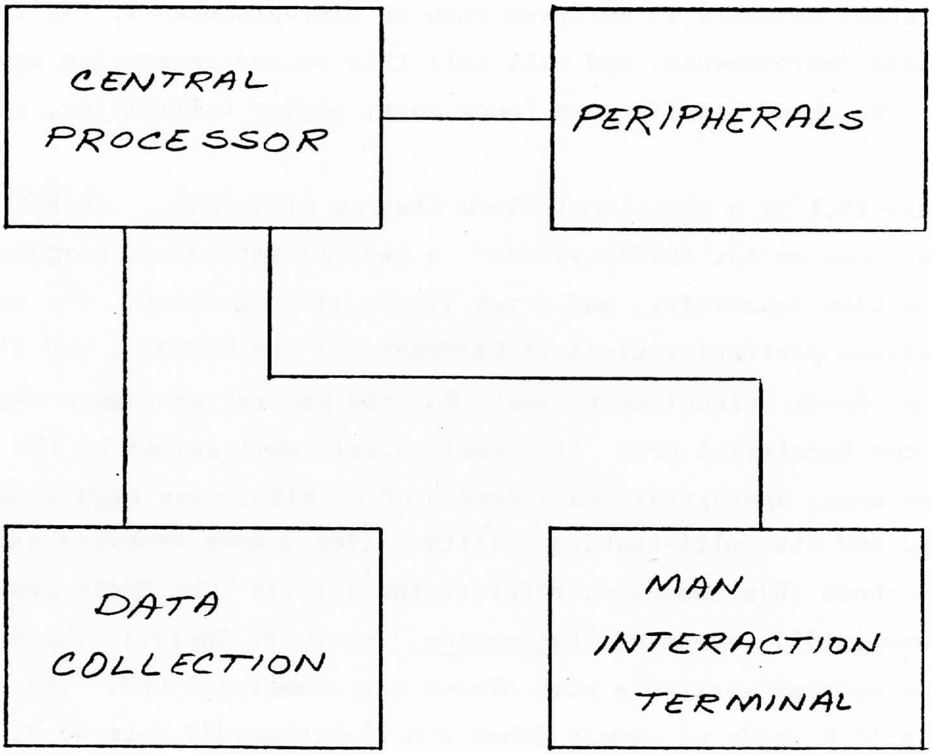
THE SECOND-GENERATION McIDAS APPROACH

Robert Norton

The working hardware system you have seen is McIDAS. Looking back, it's easy to see where several improvements might be made, especially in view of recent advances in hardware such as microprocessors. We're now making these improvements, and will call this second-generation system McIDAS$_2$. The chief benefits are lower cost, higher reliability, and greater capacity.

Figure 15.1 is a functional block diagram of McIDAS$_2$. It has the same basic functions as the McIDAS system: a central processor, peripherals, data collection capability, and a man interaction terminal. For each function we have chosen particular kinds of hardware for the McIDAS$_2$, and I'll describe now some of those selections to you. For the central processor block (Fig. 15.2) we chose the Harris/6-2 CPU. It's particularly well suited to the task because of its low cost, appropriate word length of 24 bits, very high input/output (I/O) bandwidth, and its multi-tasking ability. (For a more complete explanation of why we chose this computer, refer to the article "The Midi-computer," in the February, 1977, issue of "Datamation," by D. J. Theis.) There is a wide variety of options available with almost any commercial CPU. The Harris CPU comes with 16 K words of memory (that's a 24-bit word/3 byte word, MOS memory), expandable to 128 K words, real-time clock, and eight priority interrupts. We always add at least one 16 K-word memory module to that. If there will be a lot of arithmetic processing required, we also add an arithmetic unit. The present Harris/5 unit does not have floating point hardware, but it still can do quite a bit. It is estimated that it could go about thirty times faster with floating point hardware, which would speed up some of the processing-intensive operations. The Harris/6 has a number of different I/O channels. We use the universal block channel (that's for DMA-ing out large records) and a program input/output channel for handling key-ins and single byte transfers.

The second block in the system is the peripherals (Fig. 15.3). We are considering several different kinds of digital discs, like the 5, 10 and 300 megabyte CDC disc; the nine-track magnetic tape by Pertec (which is going to be dual density on the new models that we're building); a Centronics line printer



FUNCTIONAL BLOCK DIAGRAM

FIGURE 15.1

CENTRAL PROCESSOR

1) Harris L6-2 CPU
    - 16 K words MOS memory expandable to 128 K words
    - real time clock
    - 8 priority interrupts
2) 16 K word MOS memory increment block
3) Operators Console
4) Arithmetic Unit
    - floating point hardware package
5) I/O Channels
    - Universal Block Channel for block transfer
    - Program Input Output Channel for single transfers

FIGURE 15.2

COMPUTER PERIPHERALS

1) DIGITAL DISK
    - 10, 50, 300 MBYTE CDC
2) 9 TRACK MAGNETIC TAPE DRIVE
    - DUAL DENSITY PERTEC
3) LINE PRINTER
    - CENTRONICS
4) CARD READER
    - DOCUMATION
5) HARRIS/SERIAL INTERFACE
    - SSEC CUSTOM

FIGURE 15.3

and a Documation card reader. We're also going to be implementing a special 4-channel serial interface (Fig. 15.4) to drive terminals and to collect data from other sources. This special serial interface handles the exchange of information over single-pair lines, bringing the data in at rates up to 640 kilobaud to the Harris I/O channel. It does this without degrading system response time or processing time even when supporting a number of high speed terminals. We like the serial access route, because it's easy to electrically isolate the peripherals from the CPU; also, the cabling is cheap, and it has adequate bandwidth for all of the tasks which we'll be doing. Furthermore, if you decide to make a terminal remote from the CPU, it's simple to reduce the bandwidth of the serial line to what a phone line or a coaxial cable can handle. For instance, Dr. Sikdar has a terminal in Milwaukee running over a 9600-baud phone line.

Another important block of the system is the data collection block (Fig. 15.5). Currently we have four methods of collecting data. First, we have an asynchronous line that brings in conventional weather data. We are also making a facsimile ingest module which digitizes the facsimile pictures available from radar or GOES sectors, and makes those kinds of images available to the display system in McIDAS.

Figure 15.6 is a very simplified block diagram of how the facsimile ingest module is assembled. It has some special facsimile hardware to acquire the signal, convert it and strip out the line start information and the documentation. It's under micro-processor control, regulating the way the feed-back loop operates to maintain very precise timing; there is a slight drift, and you have to stay locked on to it. The data is presented in serial format to the CPU, so this unit can be fairly remote from the CPU. The unit is also electrically isolated. If you have a large system (like McIDAS) with many modules distributed over a great distance, it's easy to have electrical problems caused by grounding. Common ground and serial lines help you to get away from that.

Some of the other data sources are the antenna system to bring in the real-time syncronous satellite data, and the off-line data ingest system (ODIS). From the ODIS (Fig. 15.7) you get tapes that you can save for later use, or

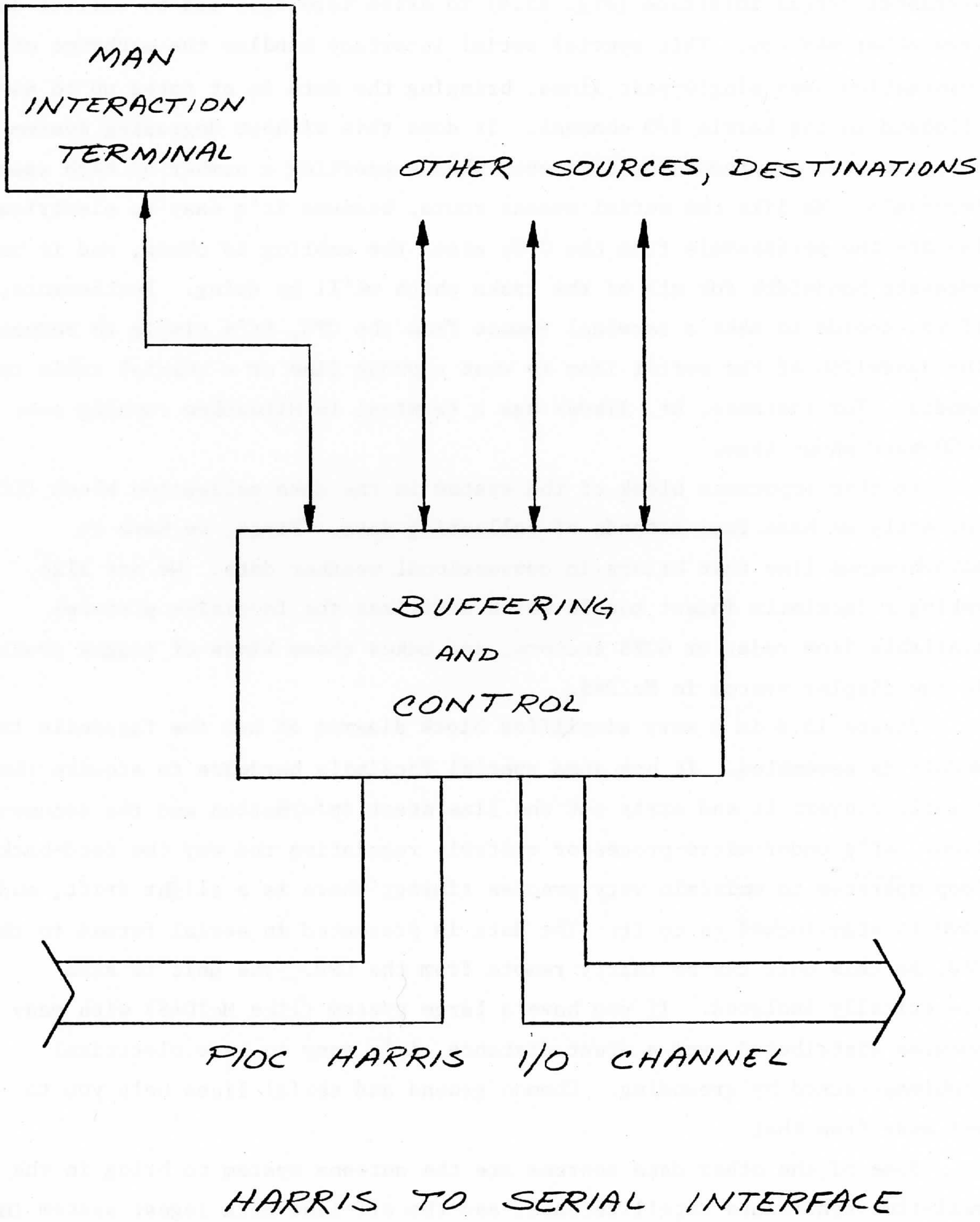

MAN INTERACTION TERMINAL
OTHER SOURCES, DESTINATIONS
BUFFERING AND CONTROL
PIOC HARRIS I/O CHANNEL
HARRIS TO SERIAL INTERFACE

FIGURE 15.4

DATA COLLECTION

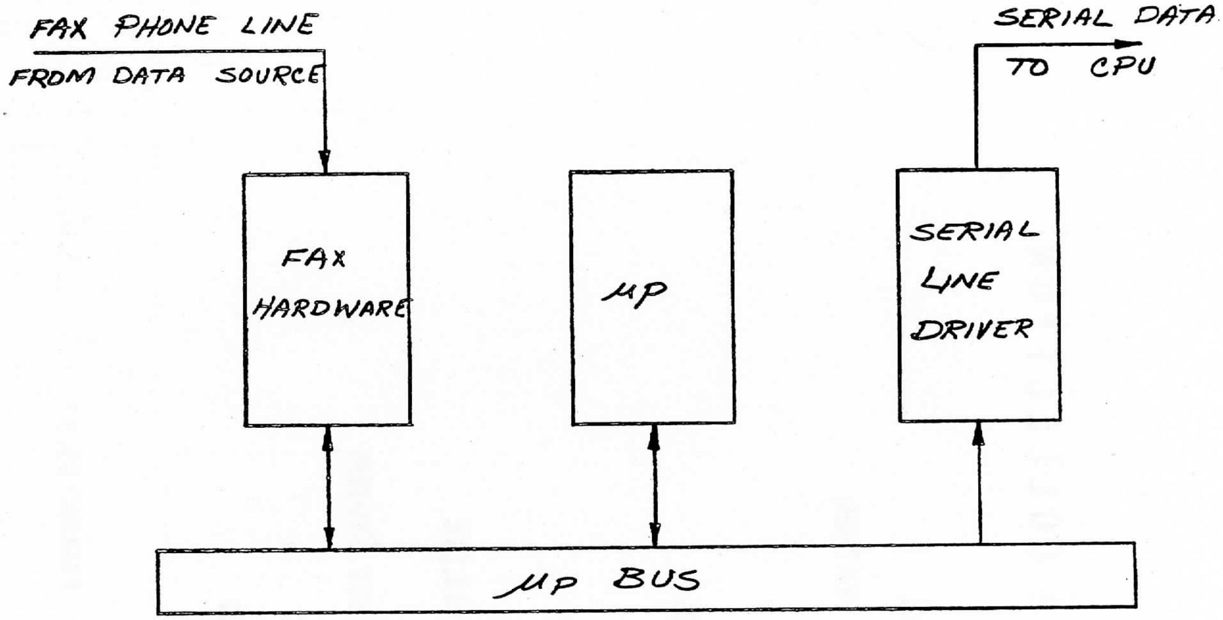
1) ASYNCHRONOUS LINE
    - CONVENTIONAL WEATHER

2) FAX LINE
    - RADAR PICTURES
    - GOES SECTORS

3) ANTENNA SYSTEM
    - REAL TIME SATELLITE

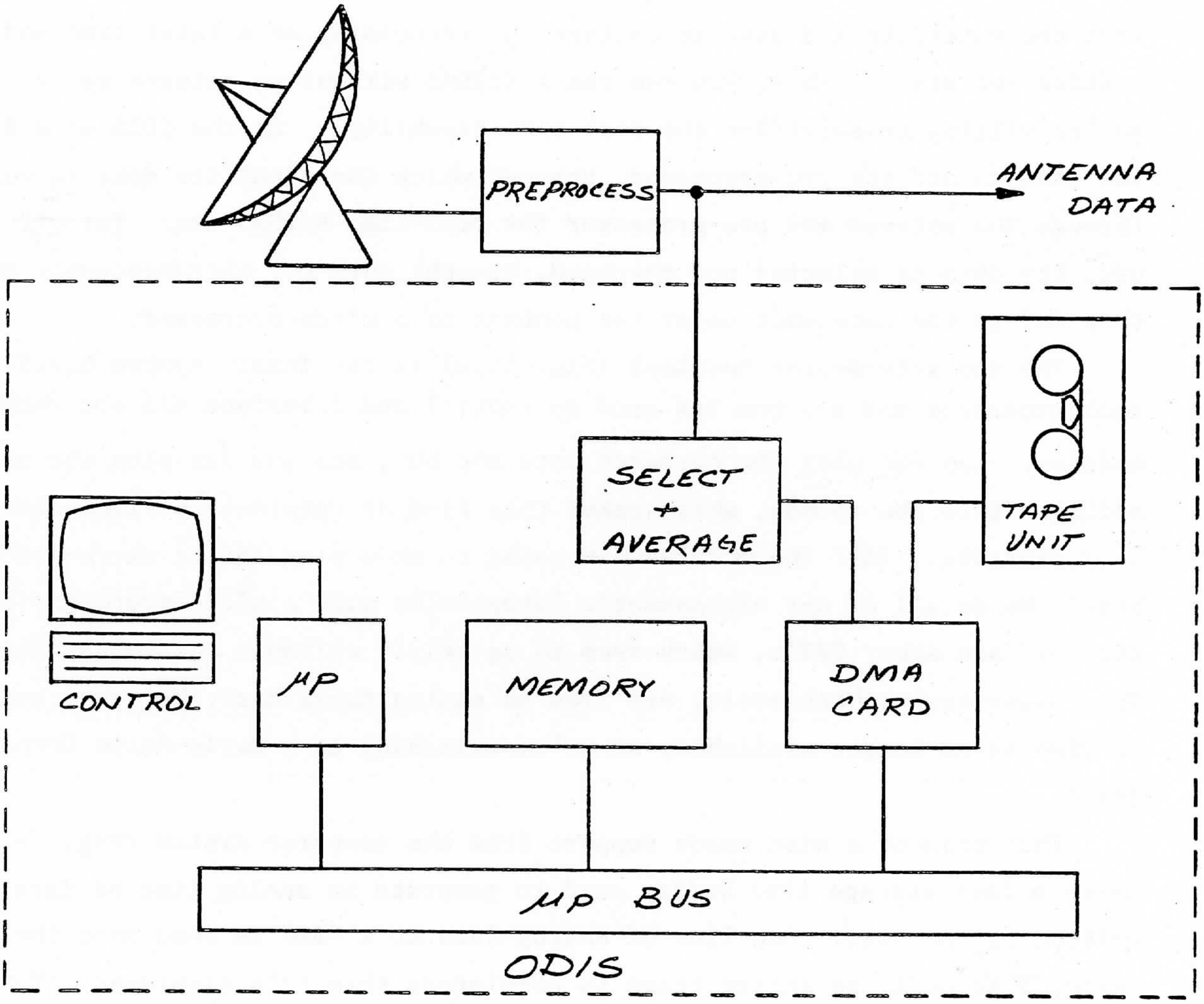
4) OFFLINE DATA INGEST SYSTEM
    - SAVE TAPES
    - SHIPPING TAPES

FIGURE 15.5



FAX INGEST MODULE

FIGURE 15.6



OFFLINE DATA INGEST SYSTEM (ODIS)

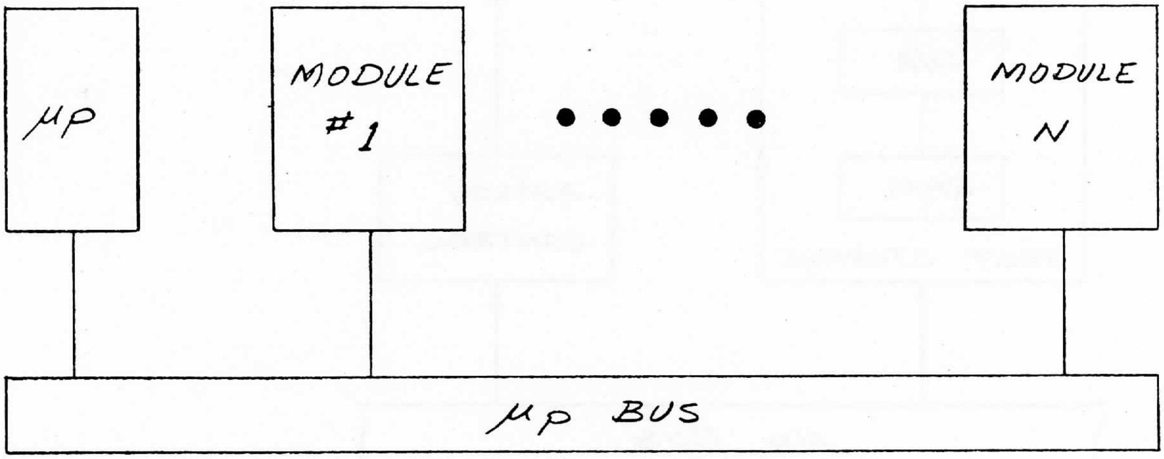
FIGURE 15.7

compile into a library. You can also place an ODIS system near an antenna, ingest data on a pre-selected table (write in what days you want, what areas you want, what resolution you want) and it will automatically ingest that data from the satellite and save it on tape for processing at a later time and in a different place. Thus, you can run a McIDAS without an antenna system if you're willing to sacrifice the real-time capability. At the ODIS site is the antenna and the pre-processor, through which the satellite data is collected through the antenna and pre-processor for real-time McIDAS use. For off-line use, the data is selected and averaged, brought into the microprocessor memory, then fed to the tape unit under the control of a micro-processor.

The man-interactive terminal (Fig. 15.8) is the fourth system block. The microprocessor and its bus are used to control and interface all the hardware modules. You can plug the hardware into the bus, and you can plug the new software into the rounds, which makes this kind of terminal configuration very flexible. (All the modules I'm going to show plug into a micro-processor bus.) We do all of our alphanumeric interaction with a micro-processor through standard Ann Arbor CRT's, which seem to be fairly reliable and competitive. The images you've been seeing are from an analog Ampex disc, but that type of disc is no longer available, so we're switching to a Davis-Smith Corporation disc.

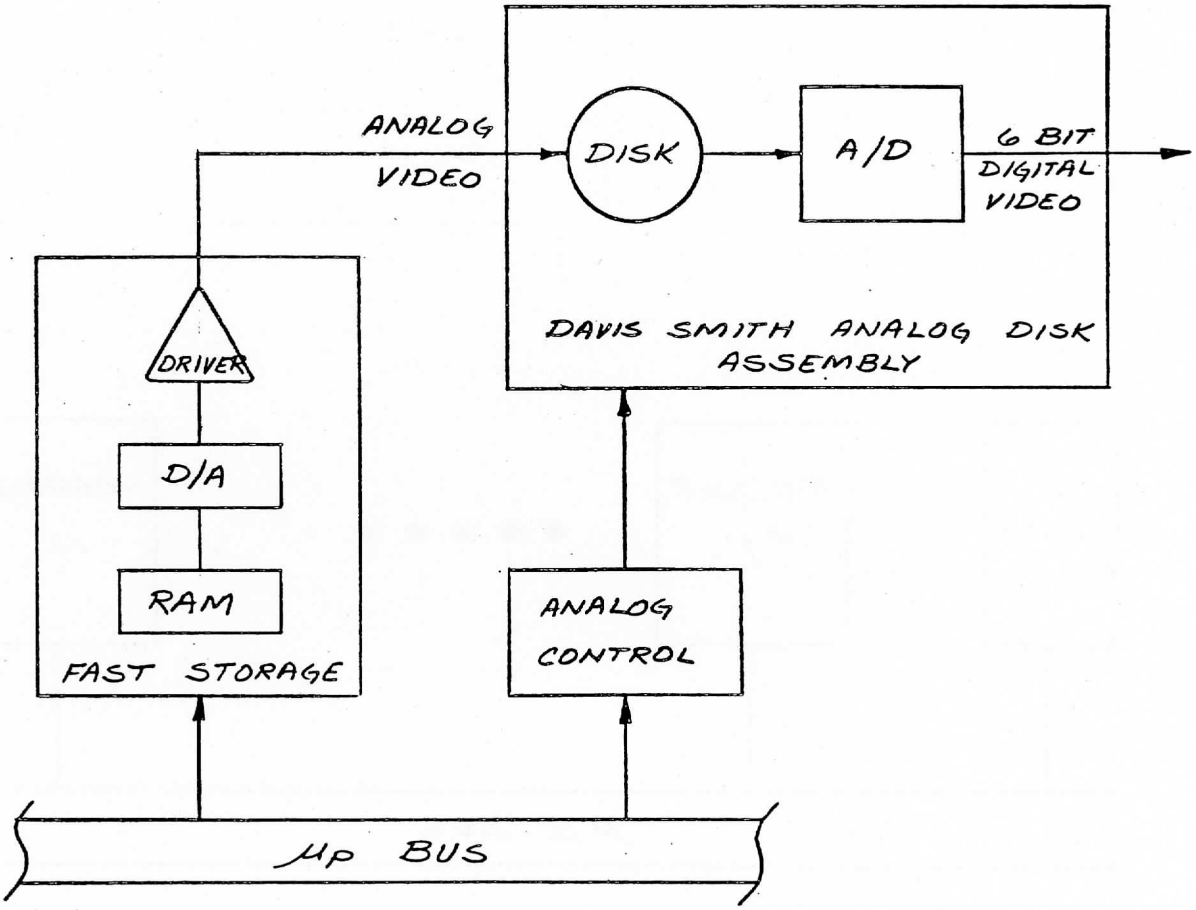
That kind of a disc needs support from the computer system (Fig. 15.9). It needs a fast storage line buffer card to generate an analog line of data to be written on the disc. One line of analog data at a time is read onto the analog disc until an entire frame is completed; then it's displayed. You also need some RAM storage capable of operating at video rates, to feed that frame, one line at a time, on to the disc. To operate the steppers which move the analog heads in and out on the disc (and to control the other disc functions, such as which head is being looked at) you need a card to supply those control signals to the analog disc. The net result is a six-bit digital video output stream from the analog system.

An alternative which we're developing for the NESS systems which we're building is an all-digital RAM image refresh (Fig. 15.10). This system works functionally in just the same way. You load information from the terminal bus into the RAM memory; it is then continuously read out of that memory to create a four-bit digital video



GENERALIZED
MAN INTERACTION TERMINAL

FIGURE 15.8



FAST STORE LINE BUFFER, ANALOG CONTROL
AND
DAVIS SMITH DISK ASSEMBLY

FIGURE 15.9

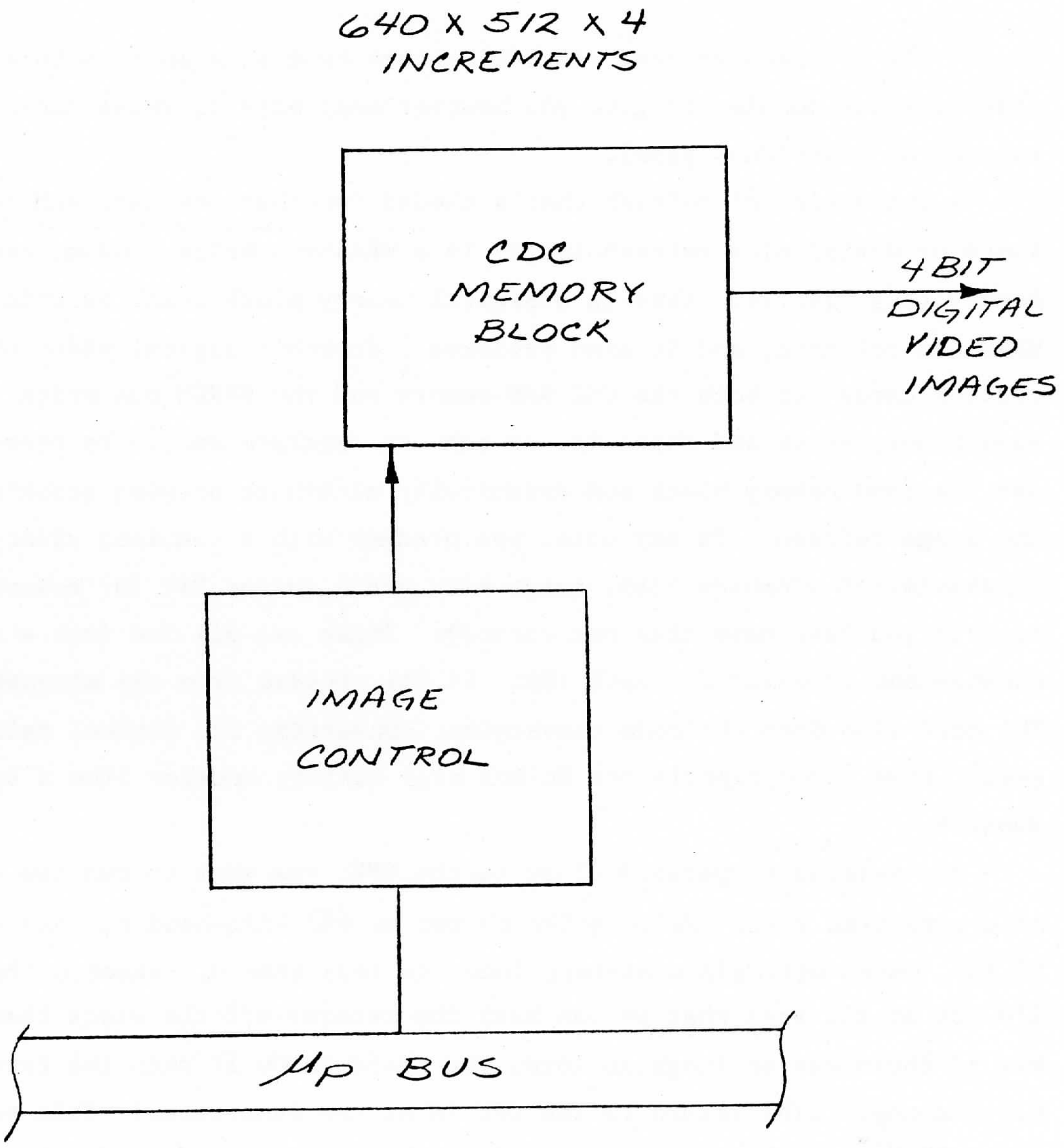


IMAGE REFRESH MEMORY
AND
IMAGE CONTROL CARD

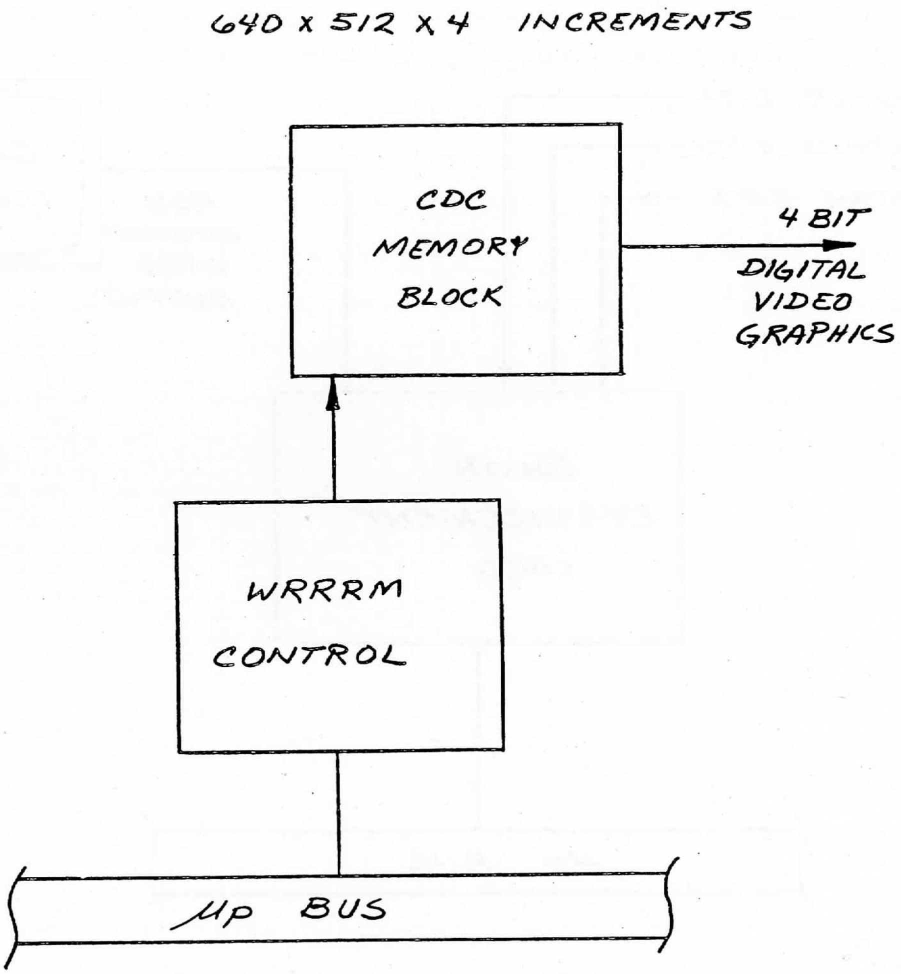
FIGURE 15.10

image. If you need greater resolution than four-bits on a picture, you just cascade these modules to give you however many bits of resolution that you want on an individual pixel.

A third kind of refresh that's needed (whether you have RAM refresh image or analog disc refresh image) is a WRRRM--a write random, read raster memory (Fig. 15.11). This is a digital memory block which is written into by a WRRM control card, and it also produces a four-bit digital video output. The control cards for both the CDC RAM memory and the WRRRM can write into the same memory block and share it, or can use separate ones. In fact, you can use the same memory block and dynamically alternate between graphics refresh and image refresh. In any case, you produce with a combined video stream, consisting of graphics bits, image bits and a cursor bit (or several cursor bits if you have more than one cursor). These are all fed into a color enhancement or colorizer card (Fig. 15.12), loaded from the microprocessor bus. The card also does the code conversion, converting the digital values into red, green, blue video signals for an RGB high quality monitor like a Ball Brothers monitor.

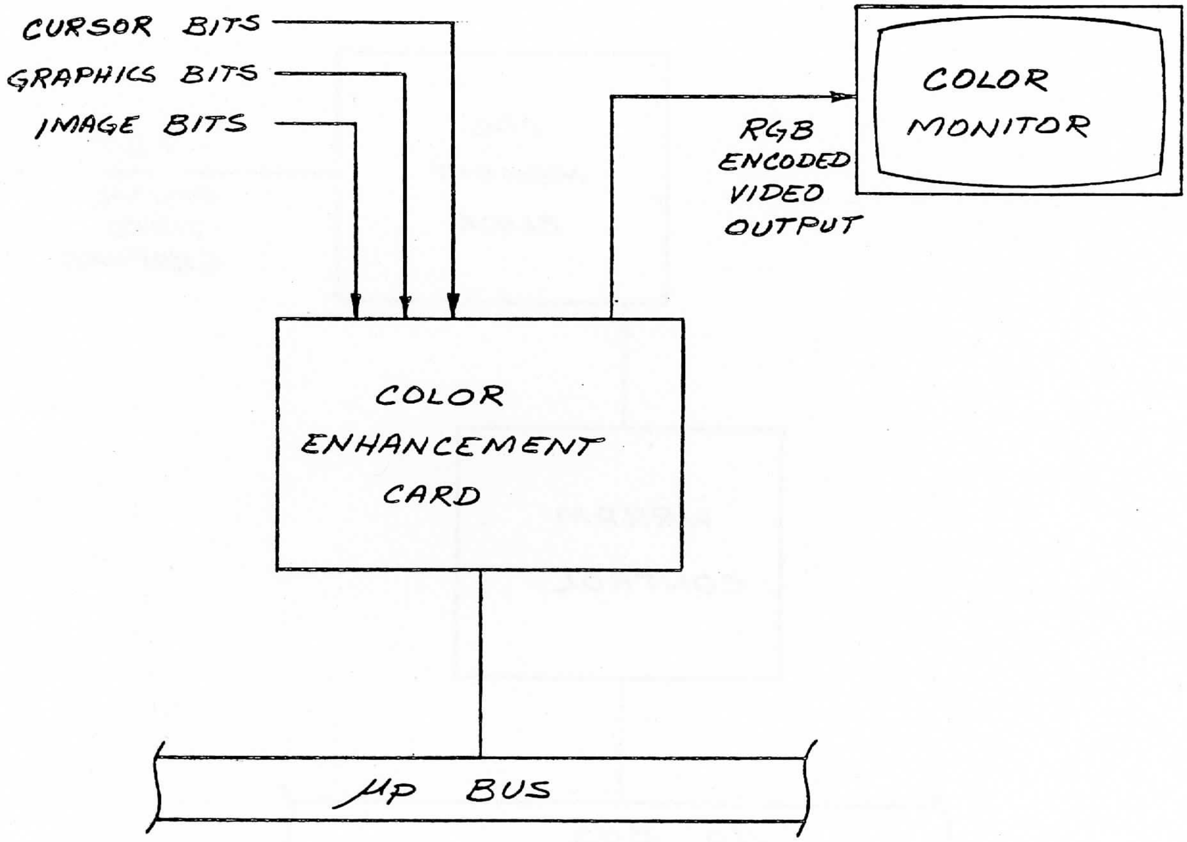
For terminals operated close to the CPU, you want to run the serial line at a very high rate. We're going to run at 640 kilo-baud for our transfers (Fig. 15.13), which will allow picture loads in less than 0.5 seconds from stored data. I'm not at all sure that we can haul the records off the discs that fast, but if there was an image in core, you could throw it onto the terminal in 0.5 seconds. (The return to the CPU is at the same rate.) This permits virtually instantaneous transfers (on a human time scale) of all requests and small packages of documentation.

Another small module essential to the function of a terminal is the joystick module (Fig. 15.14). It's actually a pair of functionally separate modules -- a joystick section which makes available to the terminal and then to the CPU the position of the joysticks; and a cursor generator module, into which is loaded the desired position of the cursor. Usually the computer just echoes what the joy-stick says and places the cursor where the joysticks indicate, but for certain programs you want the computer to assume direct control. In those cases, the computer disregards the joy-stick section and



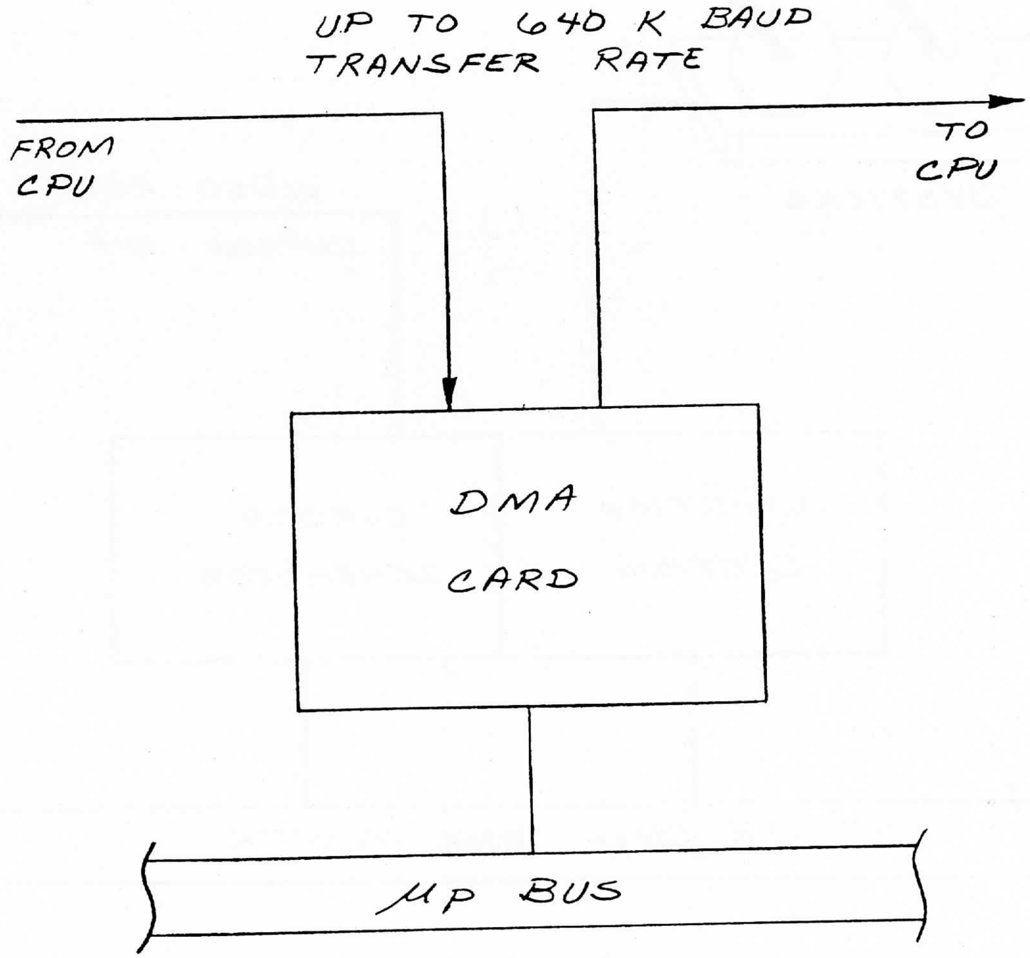
GRAPHICS REFRESH MEMORY AND
WRITE RANDOM READ RASTER CONTROL (WRRRM) CARD

FIGURE 15.11



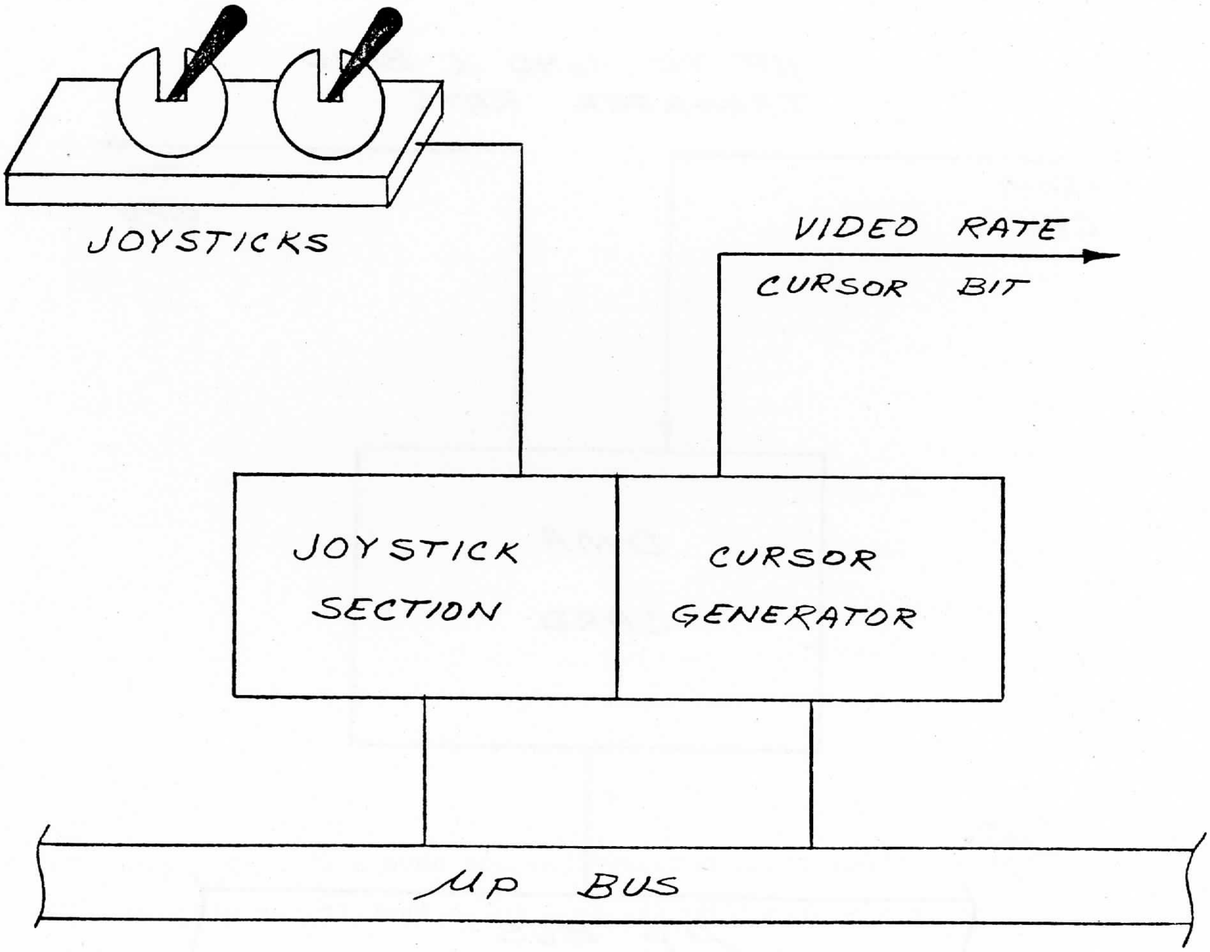
COLORIZER CARD AND MONITOR

FIGURE 15.12



DIRECT MEMORY ACCESS CARD

FIGURE 15.13



JOYSTICK/CURSOR CARD

FIGURE 15.14

loads the cursor generator independently. This card lets you use a variety of cursor types, depending on your application.

Other modules are available to plug into this micro-processor back plane. It's a standard Intel SPC back plane, commonly used for industrial control systems. We feel that this type of system will be adaptable, reliable and fairly quickly available, offering a lot of performance at reasonable cost.

QUESTIONS AND COMMENTS

Q: Are you going to have one controller and several discs, or are you going to actually have two disc controllers, so that more than one terminal will not restrict the operation of the system?

A: We've looked at Ball Brother discs, where you can put eight discs on one controller. They support overlapping seeks, so you can actually have several accesses in progress at once. We're also looking into using CCD refresh discs, which have an access time two orders of magnitude better than moving-head discs.

Q: What will McIDAS_2 cost and when will it be ready?

A: Tom Haig will talk about that later this afternoon. I can tell you that we have contracts in-house to deliver these things this year, based on pieces of this system.

Q: The article from "Datamation" makes a case for the Harris machine on the basis that the sixteen bits is just not adequate. I was quite surprised about that, because they now have a floating point processor on that very system. So it seems to me that if, we had a machine with sixteen bits, maybe we could use it (if we could get your software and somehow convert it). It seems that a 16-bit machine would be adequate, particularly if it already had a floating point processor.

A: Well McIDAS is not primarily a number-smashing system. The thing which really places the greatest demand on McIDAS is the extremely rapid context switching; having lots of different tasks in core at the same time; and the 6 MHz I/O bandwidth requirement.

Q: Wouldn't those programs which don't require a lot of number-crunching be speeded up considerably if there were floating point hardware?

A: The only program on McIDAS that can be extended to use the floating point are the navigation programs. Everything else is written with integer arithmetic.

Q: If we have a 16-bit computer and can solve around the problem of gridding your software to run in our machine, would we have any problems doing that?

A: Word length is not the only thing that determines what you can or can't do. The operating software, the amount of memory core available and several other factors come into play. We'd be glad to speak to you individually about the system you suggest, rather than try to answer the question right now. In that same vein, each of you will have specific questions about software transfer, so please approach us tomorrow on an individual basis. To try to answer your questions all at once this afternoon will just be too difficult.

THE "DO IT YOURSELF" McIDAS KIT SYSTEM

Gary Banta

I was a little bit hesitant to talk about some of the real mundane, down-to-earth aspects of a technology transfer like this, but it's very encouraging to see that those are the kinds of things you're all worried about.

I'm going to talk about the kit approach, in which, quite simply, we'll supply the design and you'll supply the labor. This approach offers several advantages. First, the experience you gain in building your own system can be of great help in maintaining the system later; maintenance on a system as complex as McIDAS is very important. Second, as universities, you all have student labor available at low cost to build a system and offer an excellent educational opportunity as well.

Let me make clear at this point that, as yet, we have no fixed and firm programs concerning the kit approach, because we need to know more about your needs as users--how many of you want a McIDAS kit system, how many of you do not, how many of you would like something else. In this regard, those questionnaires Tom Haig distributed will be very important to us, as well as to NSF.

The first step in the kit approach (or in any other approach) to building a McIDAS system is coming up with a system configuration. As Bob Norton illustrated, there are many modules in the system, and a lot more modules that could be designed to meet individual user needs. They can be added and subtracted pretty much at will, so you do have a great deal of flexibility in establishing a system configuration. (Remember, too, that some of these modules can even be used in other applications.)

There are several questions you face when configuring a system. Do you need a lot of frames or only a few? Are you going to be doing research or teaching? Are you concerned with real-time data? All these kinds of things must be considered when it comes time to do system configuration.

Next, you can talk about acquiring the system. The system can really be broken down into two types of assemblies. One type comprises major assemblies produced by other equipment manufacturers -- things like computers, monitors and CRT terminals. There are many kinds of equipment available, but we can suggest what we consider good choices and provide you with a specification list so you can purchase them yourself.

The second kind of modules are those designed and provided in some form by SSEC. If any of you have had experience building up large hardware systems from modules, you know that one of the most expensive and time-consuming tasks is wiring. You can use wire-wrap technology, in which integrated circuits plug into one side of the board, pins stick up on the other side and you use a wire-wrap gun to make the pin connections. But this takes a lot of time, and presents a great chance of error. One alternative I'm sure you're all familiar with is the printed circuit board. This would greatly reduce the wire-wrap task. This kind of circuit-board technology, by the way, is only really suited for low-to-medium-density applications. When your chips are packed on the board very tightly, you need things like computer programs to figure out how to map from point to point. Sometimes you'll have to go to multi-layer boards, which is not a very desirable solution either.

One board technology which permits high density circuit design is the Multi-wire^R board. This is the kind of board that you would get for the WRRM control and the control for the solid state refresh memory. This Multi-wire^R board, produced by computer, is made by Photocircuits in Glen Cove, New York. I'm emphasizing board technology because this is a major part of the kit approach. The manufacturer starts with a photo-etch process to lay down your power and ground plane. He puts a layer of epoxy on top of that, then with a numerical control machine he writes the wire onto the surface, puts the holes through, and plates them. Then he trims the board and you've got your finished product.

We have microprocessors scattered throughout the system, and you know they've got to have programs. These programs will get to you via PROM's (Programmable Read-Only Memories). The PROM's, which fit into sockets on the board, comprise the actual software. (The software does not go away when you shut down the machine.) E-PROM's (Erasable PROM's) are also used as functional components in a few places in the system, already programmed. Of course, you would have the documentation to reflect what's on the PROM's.

SSEC would also provide quantity purchase items, like cable that you can only buy in 500 or 1000 foot rolls. In a kind of catch-all category, we would provide certain special parts, such as joysticks. (We actually make joysticks out of fish-floats that we buy at a discount store.)

You would also receive schematics and blueprints of the circuitry, including a set of reproducible schematics. You'll need to maintain those reproducible documents, so that any modifications made to your system are reflected on the schematics.

If we decide to provide complete kits, another question needs to be answered. How easily can you get parts? We may not provide complete kits, but only the items which would be difficult for you to get. We will, in any case, provide parts lists; if we provide partial kits, the parts lists will reflect what you will need to buy as well as what is included.

You will also receive a theory-of-operation manual, describing the operation of individual modules and of the whole system. And last but not least, you will receive an assembly manual with each module, which describes how to put the thing together.

There are also questions about labs, facilities and personnel. McIDAS is a complex system, and you should not try to cut corners to try to economize; it could end up costing you much more in the end. To supervise the production of a McIDAS system, you will need a supervisor--an engineer or a highly skilled technician with experience in modern digital logic, computers, micro-processors and video. This person could possibly do all the assembly, or could supervise a staff of technicians or students. It would be also desirable to make this supervisor responsible for system maintenance after you have your system installed. You should have lab facilities and a minimal shop facility. (We can supply a list of tools and other equipment you would need for a shop.) One piece of test equipment you'll need is a high-speed oscilloscope. We use a Tektronix 485 and we're very very happy with it. It's not inexpensive, but it certainly does help when you're knee-deep in some very complex problem; it provides a good window into the system.

Another important consideration is the system environment. You're going to have to worry about air-conditioning, humidity control, electrical interference, and primary power at the installation site. You'll need spare parts. (If we supply the complete kits, you'll also get a spare parts kit.)

Let me discuss the nature of the support SSEC might provide after your system is set up. It would be real nice if we could have some people sitting by a telephone waiting for your call, but we haven't considered any mechanisms for handling lots of phone calls. We've thought about on-site service, and I think we're going to have to consider that on an individual basis. We can really think more seriously about a "board-swap" service; you could disconnect an individual module, and ship it to us. We would check it out and send it back to you when it's repaired.

QUESTIONS AND COMMENTS

Q: Could you supply the necessary drawings so we could make our own boards?

A: I really wonder why you would want to do that. The boards are really the cheapest part of the system. One plated-through circuit board would cost about \$40-\$50, and I don't think you can make it for that price if you start from the drawings. But if you did want the drawings, we could supply them.

Q: Do you have any estimates of how long it would take your shop to assemble a kit system?

A: It would really depend upon the system that you wanted.

COSTS AND OTHER SYSTEM CONSIDERATIONS

Thomas O. Haig

I want to provide some approximations of cost and availability for the McIDAS_2 system, but first let me comment briefly about some system considerations. The system is really made up of three different things: concepts, software, and hardware (Fig. 16.1).

Concepts are very expensive, because they require invention, and invention is always expensive. It's hard to put a cost on these things because they are generally distributed rather broadly, so people are unaware of the total cost of this kind of work. Concepts, however, are very durable; they persist through changes in software and hardware. Many of the concepts on which McIDAS is based are derived directly from things we did with hard copy, analog correlations with jitter machines, and the like.

Software has a very long lifetime, also. Some of the software we're using is between seven and nine years old. It comes from the 1108 and from the 1110, and is now in the Harris machine. The cost of software is very high compared to the hardware.

Though the cost of the hardware is relatively low, hardware is the part that most people concentrate on when they talk about a system. The emphasis should be placed on concepts and software, where the costs are much higher and lifetimes much longer than for the hardware. Of these three parts of the system, the hardware is by far the shortest-lived section. When you plan a system, bear in mind that the hardware is a transient in your system; the software will be there long after the hardware is gone.

What kind of a system (Fig. 16.2) are we talking about? It's made up of data sources and inputs, some kind of computer or CPU, peripherals, display controls; some kind of output, and software. Of all these items, the cheapest one by far is the CPU. But the CPU goes a long way toward determining how much money you have to put out for software. So we are trying to present a system in which you have immediate access (providing you can transfer it into your CPU) to a software set which is several years old, very large, mature and expensive. The cost of a CPU, compared to the value of the software, is very small.

Let's talk about how to get the GOES satellite images as input (Fig. 16.3). You can set up your own receiving system, and I'll explain what that could cost.

Lifetime		Cost
Very durable	CONCEPTS	Very high
Long	SOFTWARE	High
Short	HARDWARE	Relatively low

FIGURE 16.1

WHAT IS A SYSTEM?

Data sources and inputs

Computer

Peripherals

Displays and controls

Results output

Software

FIGURE 16.2

GOES Satellite Images:

Your own receiving system
NESS Central Data Distribution System (Sectors)
EDS Archive (Asheville, NC)
NASA Archive (GSFC)
SSEC Archive
ODIS

FIGURE 16.3

if you take the route we took. You can also get such data through the NESS Central Data Distribution System (CDDS), which produces the sectors. Tapping onto that line will give you whatever is being transmitted over that line in the area where you have access. This is not a bad service at all, and it's going to get better in the future. These two input sources are the only ones that can give you real-time data; they're the only two practical ways of getting GOES data in real-time that I know of. You can get recorded data from the Environmental Data Service archive in Ashville (very little GOES data is actually stored there at the present time) or from the NASA archive at Goddard, where getting information out is difficult (simply because of the design of the archive, not because the people aren't willing to try to serve). But there is, at the present time -- I think it's very safe to say -- no suitable archive of GOES data anywhere.

We have an archive here on one-inch tape, but not a complete archive at all. We have data sets from particular times when we were funded to record data. We also can supply data to users with an Off-Line Data Ingest System (ODIS). The one which we have at SSEC is owned by the Department of Meteorology, and we operate it to provide data to the department. We are building another ODIS which will be an SSEC unit. If anyone is interested in acquiring data that way, we certainly could consider building another ODIS; it costs about $21,000 to reproduce that stand-alone system. If someone wanted to fund that, they could position it here or at some other place where there was a receiving antenna, and gather data that way. This is not a real-time source, however. I'd be glad to discuss this with anyone on a one-to-one basis.

Shown in Fig. 16.4 are some cost figures reflecting the erection of our antenna system (not including engineering costs). The reflector is purchased from RF Systems; the feed and feed assembly are locally manufactured. The pre-amplifier we're using is a surplus piece of equipment from the Air Force that's no longer available, but the price shown in Fig. 16.4 is for a new solid-state pre-amplifier from Watkins-Johnson, Incorporated. The cables were locally produced and, including assembly, freight and so forth, everything on top of the building runs about $66,000, including the antenna and reflector. The cost of the mounts and drives is relatively high. We built a mount which looks like a Maginot Line tank trap, because we have had

GOES RECEIVING SYSTEM:

ANTENNA:			
REFLECTOR (RF SYSTEMS)		17,500	
FEED SUPPORT (LOCAL)		1,220	
FEED ASSEMBLY (LOCAL)		5,960	
PREAMPLIFIER ( )		6,000	
CABLES (LOCAL)		950	
ASSEMBLY, FREIGHT, ETC.		3,300	
			34,930
MOUNT AND DRIVES:			
FABRICATION (LOCAL)		22,000	
BUILDING MODIFICATION (LOCAL)		5,000	
ELECTRICAL MODIFICATION (LOCAL)		1,000	
ERECTION LABOR (LOCAL)		3,500	
			31,500
ELECTRONICS:			
PSK DEMODULATOR BIT SYNCHRONIZERS (TWO)	(EMR)	13,300	
FRAME SYNCHRONIZER	(EMR)	24,000	
POSITION CONTROL (LOCAL)		5,500	
INSTALLATION, RACKS, CABLES, ETC.		3,500	
			46,300
		SYSTEM TOTAL:	112,730

FIGURE 16.4

our antenna damaged twice when it was supported by an insufficient mount. But I think we may have over corrected. It should be possible -- if you don't have to put yours 17 stories high in Madison, Wisconsin -- to get by with a somewhat less expensive mount. The building modification cost figure is a typical estimate, reflecting actual local erection labor costs.

In estimating the cost of the electronics, I've listed the price of a purchased unit, rather than to promote the system which we are building for ourselves. It is easier for you to buy the commercially available unit, and the difference in price between that and ours is uncertain; ours isn't up and operating yet. A position controller is not too hard to make, and we can supply the drawing for that. Installation, racks and cables round out the total cost of the system at about $110,000 to $120,000. That's an expensive installation, but then you're on your own; you have your own access to the satellite, and you can get as much data as you want, in real time.

Concerning display systems, you really have two choices (Fig. 16.5). An analog disc refresh system is characterized by a large number of frames, multiple outputs (depending on how many heads you put on it), and something of a reduction in Z-axis precision (depending on how much attention you pay to the electronics for input and output). It is not as precise as a solid-state refresh system, and failures can be expensive; when one of those heads crashes on the disk, you may have to replace a large portion of the whole analog disk drive. You have to keep it up and clean it, with specialized maintenance capability required. But it is by far the least-cost way to get several hundred frames of data available to you, because you can't afford to put that kind of capability into solid-state. So an analog disk refresh has special characteristics which sometimes dictate its use despite some of its handicaps.

Solid-state refresh -- such as any one of the three that have been talked about here in the Workshop -- gives you very good Z-axis precision (amplitude data) and greater image manipulation flexibility. It's expensive, but the price is coming down. Also you have to be careful when you design the interfacing input-output circuitry. There is no standard solid-state refresh system on the market (that we know of) that is as good as the one you can make with just a little ingenuity and some careful design of your own, but there are some good

DISPLAYS

ANALOG DISC REFRESH-

- **Large number of frames**
- **Multiple outputs ...**
- **Loss of Z axis precision**
- **Failures can be expensive**
- **Specialized maintenance required**

DIGITAL DISC REFRESH

- **Not a preferred route now**

SOLID STATE REFRESH

- **Z axis precision**
- **Greater image manipulation flexibility**
- **Expensive per frame, but decreasing**
- **Good design required**

FIGURE 16.5

memory boards available.

Based on the $McIDAS_2$ design that Bob Norton presented, what are the cost differences for a fully assembled system, a full kit, or a bare kit (which doesn't have all the parts in it)? The basic McIDAS is largely a purchased system, comprised of manufactured items. We have tried to eliminate special-design parts as much as possible, using standard equipment available on the market. So Figure 16.6 shows book prices, for the most part, plus or minus 10 percent. The disc and controller comprise about $8000 worth of disc and about $9200 worth of controller. These are all outright purchased items. It is possible to build your own controller for less (we built our own), but we are not really volunteering to go into production on controllers. We could not give you very good service, maintenance or a guarantee; you could do much better by buying one from the manufacturer.

The colorizer, facsimile ingest module and analog disk controller are units which you can't get on the market, and the prices shown reflect what they would cost in a stripped-down and in an all-parts-supplied kit. The other modules in Figure 16.6 are just about the minimum needed for a McIDAS which will bring in satellite images, generate graphics and overlay graphics on satellite images. $61,000-65,000 is about the minimum price you'll pay to get this kind of capability. But that represents a basic system; you can increase its capability by adding other modules (Fig. 16.7). Again, there are other modules available -- some based on our design, and others which you could buy. They're based on our experience and our preference for the manufacturers, which is somewhat arbitrary.

We didn't talk about the cost of transferring the software. We tried to estimate a typical price for transfer of software, assuming that no two sets of software would be identical, because they wouldn't be prepared at exactly the same time (our software package is constantly changing). Figure 16.8 shows the cost of duplicating the documentation, the cost of making the card deck or tape, and the cost of checking the documentation, the card deck and the tape to make sure they're error-free.

BASIC McIDAS$_2$

MODULE	ASSEMBLED	FULL KIT	BARE KIT
HARRIS 6024/6-2 CPU WITH 32K WORD MEMORY	26,000		
UNIVERSAL CHANNEL	3,300		
10MB DISC & CONTROL	17,200		
DECWRITER PRINTER	1,700		
DAVIS/SMITH ANALOG DISK	8,000		
COLOR MONITOR	3,000		
SBC MOUNTING RACK	1,500		
SERIAL INTERFACE (HARRIS)	3,160	1,910	130
ANALOG DISK CONTROLLER	425	225	85
SIX BIT COLORIZER	1,565	1,165	200
FACSIMILE INGEST	4,300	2,800	100
BASIC McIDAS	70,150	66,600	61,215

FIGURE 16.6

McIDAS$_2$: OTHER MODULES

MODULE	ASSEMBLED	FULL KIT	BARE KIT
DUAL CHANNEL PRE PROCESSOR	3,110	1910	130
WRRRM CONTROL, RACK & VIDEO CARD	6,770	6370	160
RAM CONTROL, RACK & VIDEO CARD	6,510	6210	70
JOYSTICK - CURSOR	560	460	220
SERIAL INTERFACE (SBC)	550	250	110
FAST STORE BUFFER (SBC)	565	365	65
HARRIS PROGRAMMER'S PANEL	1,000		
ANN ARBOR TERMINAL	1,500		
PERTEC DUAL-DENSITY TAPE DRIVE	6,300		
DUAL-DENSITY TAPE CONTROL	6,500		
CDC RAM VIDEO CARD	3,700		

FIGURE 16.7

SOFTWARE TRANSFER COSTS:

CARD DECK OR TAPE AND DOCUMENTATION

LABOR	770
MATERIALS	240
	$1,010

FIGURE 16.8

QUESTIONS AND COMMENTS

Q: Are the software costs shown in Fig. 16.8 for individual programs?

A: No. This is the whole set, everything that Dick Daly was talking about when he described the software. We can't do it for any less than that, we don't think, and even that price depends upon how much adaptation is necessary in order to suit whatever machine you're going to put it on. The cost could be quite a bit higher if there's a lot of rework on the operating system. For instance, the cost of transferring our software onto the West German equivalent of a 360 -- including travel -- is about $65,000. That's very expensive, but they consider it the biggest bargain they ever had, because they're tapping in on a software package that would cost about $2 to $2.5 million in programmer time to duplicate.

IX. FINAL QUESTIONS AND COMMENTS

Q: In describing the cost of the antenna for the GOES system (Fig. 16.4), does the $6000 figure for the preamplifier include the whole receiver package -- the pre-amp, the mixer, the local oscillator and the line drive?

A: [Thomas O. Haig, UW-Madison]: Yes. Watkins-Johnson,Inc. is the major supplier.

Q: I have a question for the people from Miami and Colorado State. We have a PDP/1155 like you do, and we have a Hewlett-Packard 2100 like Colorado State. Could we get together with you and try to convert the McIDAS software to the kinds of systems we have?

A: [Robert Evans, Miami]: You're certainly welcome to talk to us and try. We have picked up a lot of the McIDAS software, and there's a lot more of it we'd like to use.

Q: Would you use all of the McIDAS software if you could get it onto your system?

A: [Evans]: I think we'd use as much of it that is consistent with our needs. [Neither Dr. Vonder Haar nor Dr. Smith from Colorado were available to respond to the question.]

Q: Will the PDP 11 package support McIDAS without requiring great expenditure for software?

A: [Mr. Haig]: There is another source of some of the McIDAS software in PDP form at GSFC (if you can get to it). We did a transfer of this whole software package to Goddard over a year ago, and at relatively high expense they hired an outside contractor to repackage it for their PDP/1175. So we can say that they have some of it operating there, with difficulty. There are some things which PDP does much more slowly than our Harris machine.

Q: Where is that software available?

A: [Mr. Haig]: At Goddard Space Flight Center (GSFC), Greenbelt, MD. A gentleman named Billingsley is in charge of that facility.

Q: I know you people at SSEC don't like machines like the PDP/11, but some of us have to use them. Our cheapest alternative is to use student labor to do the software conversion. We can't afford to pay the prices you're talking about, so how can we get a system like McIDAS without spending a lot of money?

A: [Robert Myers, AFGL]: May I comment on that? I have a system programmer who was a PDP 11 lover before he came with us. The only problem is PDP 11 won't do this job. He's convinced that the architectural structure, the software and the operating system of the Harris is so different that to get it on a PDP 11 would be very difficult and very expensive in man-hours. Student man-hours might be cheaper, but students often don't stay long enough to finish the job, which is another problem.

I sympathize with you. If it was possible to get McIDAS software on a PDP 11, my programmer would have done it long ago because we had access to a whole roomful of PDP 11's. But after he got into the system and saw how it worked, he said, "This is hopeless. It's not a PDP 11 type job." (And he has run RT 11 software and some of the other operating systems.) All I can do is reinforce Tom Haig's warning: "Beware."

Q: Are you suggesting that PDP equipment is not applicable to real time video display systems?

A: [Tom Haig]: We really are not trying to shoot down PDP. We have a PDP 1140 operating in our IVAM system, and we also have four LSI-11 single-board computers of the PDP type. So we are very much involved with PDP technology. We have RSX 11M software running in IVAM (modified to make it do something more useful) because the IVAM system is a production system with absolutely zero man interface; no operator interaction at all. For a production system designed to use a multi-processor production line doing highly rigid, totally predetermined and pre-defined jobs, a PDP is fine. You can afford to design the system to do that kind of grunt work on a production basis.

The McIDAS is a different kind of beast. It's a flexible, interactive system. If that's what you want, our experience says that you might consider not doing it on a PDP (even if you own one) as a least cost route. We just suggest that you consider it; we're not saying that's the only way to go.

Q: [Robert Myers]: Isn't it the file structure that gives you the trouble? It seems that the DMS operating system on the Harris CPU is much better than the PDP 11 for handling files and getting data in and out.

A: [Tom Haig]: I would agree, but I might add that I have a very selfish interest in this. I don't own any stock in Harris, but I would love to see several universities all use the same kind of basic CPU's with the same kind of software, so we can do software exchanges and expand this total software package much more rapidly than if all the development is being done in just one place.

Q: I didn't see a summary of cost statistics in your presentation.

A: [Tom Haig]: For people who would like to have further discussions about cost, software or the transfer of data, we can arrange for you to see me, Bob Norton, Dick Daly or Gary Banta tomorrow. We'll be available all day tomorrow as late as necessary.

I'd like to point out that the prices presented for the McIDAS$_2$ basic system and modules are book prices. We are buying these now at the OEM price, which represents a 15% reduction which we could pass on to you. But I'm not sure we are legally authorized to quote those prices yet.

Q: I would expect that in the future, a heavy burden on this sort of system would be in obtaining meteorological data. Would the data transfer itself be in a form other than the nine-track tape? Would it go on videotape?

A: [T.O. Haig]: Dr. Suomi is working very hard on a 3/4 inch cassette tape recorder system that may well revolutionize this whole business of archiving, simply because of the costs involved. The cost of the cassettes are low, the amount of data that they can hold is relatively high, the cost of the playback unit is very low, and its reliability should be very high. It should make accessing things from an archive much easier. (Now that's only for new data because none of the past data is in that tape format.) But certainly we can put surface data, upper-air data, and the satellite pictures all on one tape, and have that available as a data set for study.

Q: Assuming that cassette system works, are you planning to distribute that kind of data to other people?

A: [T.O. Haig]: Yes. Right now, within our capability, we are perfectly willing to record data, at cost, for people. We do this for Scripps Oceanographic Institute, for the Naval Postgraduate School at Monterey, and for others. One reason we have the antenna is to help people get access to the satellite data. We're really hoping that, with the second antenna and with the cassette recorders, we can provide the kind of service to the university community that we would really like to provide. We're quite confident we will have that capability by this fall.

Q: I didn't see anything on your cost list about the color monitor; could you say a bit more about that?

A: [T.O. Haig]: I think we're planning to use a Japanese monitor very much like the one we have downstairs. It's not a Conrac; it's a Ball Brothers monitor.

X. CLOSING REMARKS

Dr. Ronald Taylor (NSF)

I can say with confidence that the National Science Foundation is pleased to have sponsored this workshop, speaking on behalf of Dr. Allen Grobecker, Dr. Gene Bierly, and Dr. Frank Eden, as well as myself. I'm very impressed with how it was arranged; the fact that we've been on time throughout is absolutely staggering. I think the success of the Workshop depends on its participants, and on the subsequent use you make of this experience. I think that the meteorological community in some way has to assume some leadership on this very broad question.

I have two further remarks to make, one involving a little bit of history and the second involving the question: Will the NSF buy one for me? I think it's worth remembering that the essence of the scientific method is abstraction -- a cogent selection of the relevant, if you please. And in that process more or bigger is not always better. If you look at the history of meteorology, you see that the conceptualization of meteorological phenomena has played a relatively large role in the history of science. Theory has been less important and has not guided meteorology in any conspicuous way until relatively modern times. What one sees over the last two centuries are collections of observations, first listed in books and papers, and then organized in some way. An early and successful way was the weather map. The first synoptic charts were analyzed by Brandis in 1810, using data from the 18th Century. Even before that, Luke Howard organized a conceptual view of cloud classification. And I think one can also see a parallel in the developments of synoptic analysis and other concepts in meteorology.

I think if the McIDAS and similar systems are successful, they will evolve in a similar way, helping us to conceptualize certain atmospheric events, or indeed pointing out things that we did not suspect were there. I think if such a system is not a part of that evolution, future researchers will look back and see it only as an interesting collection of clever people and machines. For myself, I am quite optimistic. I think how we organize the use of video systems is a practical problem of tactics.

Now, the second question: "Will NSF buy a video graphic system for me?" I can say with decisive clarity "maybe." The NSF is interested in an investment of this kind of system, but will all members of UCAR, for example, get one? Probably not, because not everyone needs one. I think the decisions about who and where and how many must come in some measure from the participants here and others throughout the atmospheric sciences community. I think you have to decide what your needs are, and how best these might be met.

I think the NSF is prepared to make some kind of investment, but neither I nor anyone else is prepared now to say how much or when. But I think that the National Science Foundation is certainly going to play some role, and I think that the questionnaires you've filled out will give us some very useful information on some very specific questions. But this is an ongoing discussion; I think everyone has to go back home and think about it. I know I certainly will try to reach some judgement, and that this will have to be expressed as some kind of collective judgement at some later time. And I am also hopeful about that future judgement.

I have no other remarks, except to say that I appreciate the opportunity to make these comments, I'm very impressed with the conference, and I hope everyone will depart with a renewed sense of vision.

[The entire final day of the Workshop was devoted to interaction with McIDAS by the participants, in order to answer individual questions about operation, applications and costs. Two McIDAS terminals were available for use, and personnel from SSEC and Meteorology were on hand to provide information.]

XI. LIST OF FIGURES AND CAPTIONS

1.1 The operator can interact with McIDAS to convert a high volume/low information density data flow to a low volume/high information density data flow.

1.2 The McIDAS software is composed of quite visible applications software and a great deal of less obvious system software.

1.3 Examples of McIDAS system and applications software.

1.4 The functions performed by McIDAS.

1.5 McIDAS allows the user to explore a third (z) dimension in addition to the usual x-y dimensions presented in maps or photographs. The z dimension could be wavelength, image intensity or cloud height, for example.

1.6 Access to McIDAS is through a display terminal, comprised of cursor-control joy-sticks, a keyboard, an alphanumeric screen and an image/graphics TV monitor screen.

1.7 Brief schematic of the McIDAS hardware components.

1.8 Typical weather service facsimile chart.

1.9 Satellite image of weather patterns displayed on McIdas.

1.10 McIDAS display overlaying map outlines and isothermal contours on a satellite image.

1.11 Antenna at SSEC for receiving satellite data, mounted atop a 17-story building.

1.12 Analog disc for storage of digital data for display by McIDAS.

1.13 McIDAS interactive display terminal.

1.14 Full-disc navigated satellite image displayed on McIdas.

1.15 Blow-up of one section of a navigated satellite image displayed on McIDAS.

1.16 Conventional weather data is received over NWS circuit 604 and transferred directly to McIDAS.

1.17 McIDAS TV monitor for image and overlay display (right) and alphanumeric CRT terminal for operator communication and data listing.

1.18.a CRT listing for a single hourly observation from Madison, Wisconsin.

1.18.b CRT listing for consecutive hourly observations reported for Madison, Wisconsin.

1.18.c CRT listing for all stations reporting light snow showers at a particular hour of interest.

1.18.d CRT plot of reported observations in a particular region of interest.

1.19 SSEC DECwriter terminal for generating printed hard copy of McIDAS data.

1.20.a Printer plot of equivalent potential surface temperatures for every weather station in the continental U.S.

1.20.b Printer plot of temperatures in the U.S. Southwest.

1.20.c Printer plot of 24-hour pressure change data.

1.20.d Printer plot of data interpolated to grid points.

1.20.e Weather data contoured on the printer plotter.

1.21.a Surface streamline data displayed by McIDAS, overlaid on map outlines.

1.21.b Surface streamlines plus isotachs overlaid on map outlines.

1.21.c Temperature invection (a derived parameter) plus streamlines, overlaid on map outlines.

1.22.a Overlay of surface temperatures and map boundaries on a satellite image.

1.22.b Overlay of surface winds and weather symbols, plus map outlines, on a regional satellite image.

2.1 A large storm system (center) may still be difficult to study in a large-scale satellite image.

2.2 High resolution image of Madison taken by the Earth Resources Technology Satellite (ERTS).

2.3 A resolution chart used to define the number of discrete picture elements (pixels) in an image.

2.4.a In this ATS-1 image, Baja, California, was at the edge of the satellite field of view, so image resolution is quite poor.

2.4.b In this SMS image of Baja, the satellite was more directly overhead, so resolution is very good.

2.5 High resolution allows one to distinguish between clouds (right) and snowfields (left) in a satellite image.

2.6 Even when resolution is degraded (compare the three top images), useful information can still be extracted from an image.

2.7 In the left image, a false dynamic range has been created by introducing small-scale noise in the large-scale image. This makes the extraction of information easier.

2.8 The satellite camera that took this image was sensitive enough to show city lights, but its dynamic range was relatively poor; note the washed out cloud areas.

2.9.a - 2.9.c	By manipulating the dynamic range (as McIDAS can do), the brightness variations in these very flat pictures of Mars were expanded to make structural details stand out.
2.10	An image of the Martian surface, enhanced by expanding its dynamic range. Note the wave structure in the clouds behind the large crater.
2.11.a	ATS image of clouds over the eastern Atlantic.
2.11.b	A non-linear enhancement of the same ATS image, bringing out more clearly the dimmest and the brightest areas of the picture.
2.12.a	Images taken by a Nimbus polar orbiter in the $6\mu m$ water vapor band, showing shallow (dark) and high (light) moisture areas as well as clouds.
2.12.b	Unenhanced Nimbus water vapor channel image.
2.12.c	Enhanced Nimbus water vapor channel image.
2.12.d	Winds measured from water vapor images, superimposed on winds measured from cloud images. Agreement between the two was found to be quite good.
2.13.a	Deliberate reduction of resolution in an image exhibiting a very wide range of brightness.
2.13.b	Use of contours to facilitate the interpretation of an image with a very wide range of brightness.
2.13.c	Use of color to represent different brightness levels as an aid in image interpretation.
2.14.a	Note the enormous dynamic range (from white clouds to black shadows) in this image of clouds over the sun-glint region of the ocean.
2.14.b	Images like this sequence of clouds over the sun-glint region of the ocean can be used to determine surface wind speeds.
2.15.a	In this visible wavelength image of Wisconsin, the clouds are barely visible.
2.15.b	In this infrared image of Wisconsin, the clouds stand out more clearly, but resolution is degraded somewhat.
2.16.a	High Resolution Infrared Sounder (HRIS) image used to measure the brightness of part of the visible image shown in Fig. 2.16.b. The sounder deduces the amount of cloud cover from the brightness, then corrects its sounding measurements as necessary.
2.16.b	Visible wavelength image of the cloud cover described in Fig. 2.16.a.

3.1 The Penn State video display system includes a PDP 11/10 computer, a tape drive, a DECwriter, a Tektronix CRT display and a hard copy device.

3.2 An atmospheric cross-section generated by the Penn State system. Note the pronounced front, the stable stratosphere and the mixed and windy troposphere below the front.

3.3.a Upper air chart for 19 April 1963.

3.3.b Surface chart for 19 April 1963.

3.3.c Cross-section chart for 19 April 1963.

3.3.d Cross-section of winds for 19 April 1963, looking north. Plus 100-knot winds from the south are at the right, as are the warmer temperatures. The cold air is in the middle, at zero wind speed.

3.4.a Cross-section from Lander to San Diego showing the mesoscale nature of the hyperbaroclinic zone.

3.4.b Cross-section from Lander to San Diego showing associated wind speeds and temperatures.

3.5 Analysis of Richardson Numbers for the same cross-section as Fig. 3.4.b.

4.1 Image display categories for the video graphics system at the University of Miami, Department of Meteorology and Physical Oceanography.

4.2 Satellite image programs at the University of Miami.

4.3 Uses of the graphics portion of the University of Miami system.

4.4 Uses of the color contouring portion of the Miami system.

4.5 Uses of the auxiliary computer memory of the Miami system.

4.6 The University of Miami experimental program in the West Indian Ocean.

4.7 The University of Miami research program concerning the Somali Current.

4.8 Reasons for the use of satellite sensing in the Somali Current study.

4.9 Satellite image of the East African coast and the Gulf of Aden. The Somali Current forms along the coast of East Africa. Sea surface temperature code: white is warmest, green intermediate, blue coldest. The lower half of the image indicates the confidence level for each pixel temperature value; bright red indicates the highest confidence.

4.10 Sequence of color enhanced satellite images. Note the enlarging blue area, indicative of cooling. The Somali Current appears as a thin green band along the East African coast.

4.11 - 4.18 Sequential images taken every eight days, showing changes in sea surface temperature in the West Indian Ocean. Note again the enlarging blue area, indicative of cooling.

4.19 High resolution IR scan of the same area as in Figs. 4.11 - 4.19. White is warm, clouds are blue and darker areas are cool. Note the upwellings at 5°N and 10°N, the Somali Current and the great whorl below 10°N.

4.20 Summary of a study (based on navigated satellite images) of sea surface temperature structure in the 5°N upwelling region. Results compare favorably with empirical data from moored and drifting instrumentation.

4.21 Schematic description of the cloud removal technique used by Miami researchers (developed by Mosher, SSEC) to analyze GATE satellite images.

4.22 Factors in preparing composite GOES images for the GATE area.

4.23 Infrared satellite data for the GATE region, coded so that each color represents a 0.5°C temperature variation. Note the absence of speckling, which tends to lend confidence to the technique.

5.1 Schematic of pertinent parameters in Doppler radar imaging.

5.2 One of NCAR's Doppler radars (12 feet in diameter) is housed in this radome. Transmitter, receiver and processing electronics are installed in the van to the left.

5.3 Two color codes are used on a radar display. One identifies Doppler velocities (right) and the other identifies reflectivity factor. Receding velocities show as gray through violet, approaching velocities as gray through red.

5.4.a Conical scan of precipitation right over the radar; magnification factor is 1:1.

5.4.b Same as Fig. 5.4.a, but with magnification factor 4:1.

5.5.a Continuous velocity azimuth display with range markers at 20 and 40 km, elevation angle 7°. Wind velocity at the 20 km range (about 2.5 km altitude) is approximately 21 m-sec^{-1}.

5.5.b Reflectivity image corresponding to Fig. 5.5.a. Note the precipitation generators trailing down from the tops of the clouds. The bright band indicates the melting level.

5.6 Horizontal scan (0° elevation) showing the passage of a front. To the east, winds are blowing from the southwest; to the west of the radar, winds are from the northwest.

5.7 Radar pattern produced by a flock of birds 80 km away.

5.8.a Reflectivity display (10^{o} elevation) for a super-cell storm that dropped four inches of hail on northeast Colorado in June 1976. Note the hook, the weak echo vault and the heavy precipitation behind it. (Black picture elements indicate areas where the reflectivity scale was exceeded.)

5.8.b Simultaneous Doppler velocity display corresponding to Fig. 5.9.a. Note the strong approaching velocities on the outside of the hook, and the lower velocities in both the updraft of the weak echo vault and in the precipitation region.

5.8.c Same storm as Fig. 5.8.b, but at an elevation angle of 16.5^{o}. Note that the weak echo vault is no longer apparent.

5.8.d Same storm as Fig. 5.8.b, at a higher elevation angle. Note the persistence of the cyclonic signature.

5.9.a Doppler velocity scan (0^{o} elevation) of a severe tornado-producing storm near Norman, Oklahoma in May 1977. Note the strong receding velocities, indicative of a circulating storm system.

5.9.b Reflectivity display corresponding to Fig. 5.10.a (0^{o} elevation). Note that there is no indication of rotation.

5.9.c Doppler velocity display, same storm as Fig. 5.10.a, but at a 3^{o} elevation angle. Note the persistence of the cyclonic signature.

5.9.d Reflectivity display corresponding to Fig. 5.10.c (3^{o} elevation). Note that there is still no indication of rotation or circulation.

5.10.a Doppler velocity display at the time chaff was dropped from an NCAR aircraft.

5.10.b Doppler velocity display 25 minutes after chaff drop. Note the variations in the velocity field and fluctuations in radial velocity patterns.

5.11 Doppler velocity display produced by echoes from a cloud of insects. Insects can be used to measure wind speed using Doppler radar.

6.1 Recent meteorology field programs at Colorado State University.

6.2 Actions necessary to meet the science objectives of field programs.

6.3 Data collection platforms at Colorado State University that transmit to the GOES west satellite.

6.4 Wintertime radar cloud research station at Colorado State.

6.5 Air quality experiment in Vail Valley conducted by Colorado State.

6.6 Colorado State video graphic display of cloud systems over the GATE region.

6.7 CSU composite display of radar data and satellite data over the GATE region. Radar data is in red, satellite data (visible wavelength) in blue. White portions indicate agreement between radar and satellite concerning areas of precipitation.

6.8 Computer graphic image of an ice crystal captured by NCAR sailplane for use in study of cloud physics and atmospheric aerosol chemistry.

6.9 Satellite visible image of a severe storm over the Midwest on 24 April 1975.

6.10 Low-level wind vectors obtained for 24 April 1975 by CSU students using the NASA AOIPS system (similar to McIDAS and the CSU systems). (See Fig. 6.11 for vector scale.)

6.11 Smoothed objective wind analysis performed about three hours before the severe weather of Fig. 6.9 occurred. (A vector 1^o long corresponds to $u = 17$ m-s^{-1}, $v = 22$ m-s^{-1}.)

6.12 Contoured low-level divergence, $v \cdot v$, 10^{-5} sec^{-1}. Only negative values (convergence) are contoured.

6.13 Combination of a) satellite derived low-level wind field, V, at 1800Z, and b) NOAA sounder moisture data, ρ, at 1600Z. Moisture divergence fields like this are under study as possible indicators of incipient severe weather. (Units are 10^{-5} cm H_2O sec^{-1}.)

7.1 National Distribution Circuit linking NWS Weather Service Forecast Offices. Observed or derived data enters the circuit at any point and travels in both directions until it reaches a point where it has been received from both directions; then it is extinguished.

7.2 Typical regional communication network linking a central NWS station with up to 12 WSFO's and other users.

7.3 Typical AFOS work station incorporating modular equipment design.

7.4 The AFOS alphanumeric terminal with standard keyboard input and display screen.

7.5 Block diagram of a Weather Service Office with a single minicomputer. The system checks all incoming messages for accuracy before retransmission to the next station.

7.6 Typical AFOS work station showing a stand-alone alphanumeric terminal, a two-bay terminal and a printer-plotter.

7.7 Close-up view of AFOS graphics display terminal, with 800-line format and 50-frame-per-second refresh rate.

7.8 Graphic display of a map background with two overlays, one solid and one dashed. A third (dotted) overlay could also be displayed.

7.9 Using the display control panel the AFOS operator can select the texture and intensity of each overlay, manipulate the cursor, select zoom ratios and display another area of interest without changing the zoom ratio.

7.10 A blow-up or zoom image with wind barbs and surface observations displayed.

7.11.a - 7.11.c Images can be displayed in sequence to aid in the study of weather development.

9.7.a	A calibrated and navigated VHRR image that is too noisy for detailed study of sea surface temperatures in the Gulf of Aden.
9.7.b	Same image as Fig. 9.7.a, with noise eliminated by averaging techniques, performed while the image resided in the image display.
9.8	Functional schematic of the color transform palette in the University of Miami video system.
9.9	The first step in color enhancement is the construction of a digital frequency histogram from the image of interest.
9.10.a	Each color enhancement gradation in this GATE image of sea surface temperature represents 0.5°C.
9.10.b	The University of Miami system can also display the complements of any color originally displayed. (Same image as in Fig. 9.10.a.)
9.11.a	Three simple geometric forms -- circle, square and diamond -- processed through a common spatial convolution technique, then colorized.
9.11.b	A magnified and translated version of a section of Fig. 9.12.a.
10.1	Schematic of the NCAR meteorological Doppler radar system.
10.2	Digital scan conversion process used in analyzing Doppler radar data.
10.3	Volume of data generated by the NCAR Doppler radar system.
10.4	Functions of the off-line data processing system (Research Data Support System) to be added to the NCAR Doppler radar system.
10.5	Schematic of the Research Data Support System (RDSS).
10.6	Typical RDSS radar data processing sequence.
10.7	Schematic of the Phase I RDSS now under development by NCAR (to be completed about September 1977).
10.8	Capabilities of the Phase I RDSS.
10.9	Capabilities of the Phase II RDSS (to be completed about September 1978).
10.10	Capabilities of the final Phase III RDSS.

11.1	The Colorado State University (CSU) video graphic system (see text for description).
11.2	Hewlett-Packard 2100-A minicomputer used in the CSU system.
11.3	Intel solid-state refresh memory used in the CSU system.
11.4	Digitizing camera system.
11.5	Control panel for the CSU digitizer.
11.6	Canon cloud particle camera for reading 35mm film for digitization and cloud particle selection.
11.7.a - 11. 7.d	Presentation of sequential images, which can be done on the CSU system at the video rate of one-thirtieth of a second.
11.8.a	Mixed SMS-1 infrared images of a cloud cluster in the GATE region (September 17 day).
11.8.b	Enhancement of Fig. 11.8.a to indicate land masses and cold tops of clouds.
11.9.a - 11.9.c	Sequence illustrating the digital zoom capability of the CSU system.
11.10.a	Digitized SMS-1 image of the cloud system responsible for the rainfall that caused the Big Thompson River flood in Colorado in 1976.
11.10.b	Enhancement of Fig. 11.10.a.
11.10.c	The cursor on the CSU system can be used to select an image area for enlargement and more detailed study.
11.11.a	Infrared image of a double cloud cluster system in the GATE area (September 17), enhanced to make the African continent and the clouds more visible.
11.11.b	Addition of visible data to the IR data of Fig. 11.11.a, creating a color function for areas of different cloudiness.
11.12	Estimation of rainfall from passive microwave sensors on NIMBUS-5, using SMS data to increase resolution within the ESMR-5 footprint. Upper right: radar data from a survey ship to verify the technique. Upper left: visible SMS data for the GATE region. Lower left: Infrared SMS data for the GATE region. Lower right: ESMR-5 signal for the GATE region.
11.13.a	A full orbital swath image across the coast of Africa (white area). Cursor outlines a rain band that covers part of the GATE region.
11.13.b	The same cursor area as Fig. 11.13.a, but at finer resolution, blown up over a ship position.

11.14.a Visible data for the same area and time as Fig. 11.13.b.

11.14.b Infrared data for the same area and time as Fig. 11.13.b.

11.14.c Radar data for the same area and time as Fig. 11.13.b.

11.15.a Mix of visible and IR data for the same area and time as Fig. 11.13.b.

11.15.b Mix of radar and IR data for the same area and time as Fig. 11.13.b.

11.15.c Three-signal mix of visible, radar and IR data for the same area and time as in Fig. 11.13.b.

11.15.d Mix of radar and microwave data for the same time and area as in Fig. 11.13.b.

11.16.a - 11.16.c A suggested technique for calibrating the SMS detector.

11.16.a The SMS VISSR detector image.

11.16.b Reconstructed NOAA-2 data for the same area as Fig. 11.16.a.

11.16.c Two-signal mix of the NOAA-2 and the SMS VISSR image data.

11.17.a An attempt to relate the broadband flux measurements taken by a Sabreliner with the visible brightness shortwave radiances (0.5-0.8) measured by the SMS satellite sensor for the same area.

11.17.b An attempt to relate the broadband IR measurements taken by a Sabreliner with the narrow-band IR measurements taken by the SMS satellite sensor for the same area.

11.18 Examination of rise-time performance of the satellite IR detector. Note the discrepancy between the center column and the right column regarding cloud size. Lack of knowledge about the rise-time of the satellite IR detector can lead to erroneous measurements of cloud size.

11.19.a Illustration of the finite cloud problem. The real cloud surface is not an ideal infinite surface for reflecting shortwave radiation, so variations and gradients of cloud brightness can complicate image interpretation.

11.19.b An emperical examination of the relationship between cloud width and cloud brightness, using a theoretical calibration scheme to convert brightness to a flux estimate.

11.20 A study of time resolution requirements necessary in the examination of cloud growth rates. Dashed lines are based on a 30-minute observation interval, solid lines for a higher resolution 5-minute observation interval.

11.21 A proposed geometric technique for the derivation of cloud height from shadow-cloud relationships observed in satellite images.

11.22 The use of the SMS as a climate diagnostic tool. A satellite image could be broken down into its spectral components then reconstructed to achieve the desired level of resolution using orthogonal coefficients. Top two figures illustrate the difference between a 16 and a 24 coefficient reconstruction of an emitted flux field over the tropics. Bottom two figures show a 20 to 24 coefficient comparison.

11.23 Schematic of the required image processing techniques suggested by E. Smith (CSU) for comprehensive image analyses that can be exchanged among various investigators.

12.1 Block diagram of the current McIDAS system.

13.1 Schematic description of research, development and transfer of technology.

14.1 Required operating environment for McIDAS.

14.2 Schematic of McIDAS control software.

14.3.a Schematic of McIDAS applications software subsystems.

14.3.b Listing of applications software subsystems for McIDAS.

14.4 McIDAS software documentation.

14.5 An example of McIDAS software documentation: a disc file that keeps track of what image appears on each frame of the display system at any given time.

15.1 McIDAS$_2$ functional block diagram.

15.2 Components of the McIDAS$_2$ central processor unit.

15.3 McIDAS$_2$ computer peripherals.

15.4 Four-channel serial interface for the McIDAS$_2$ to bring in data to the Harris CPU at a 640-kilobaud rate.

15.5 McIDAS$_2$ data collection options.

15.6 Facsimile ingest module to digitize facsimile pictures for input to the McIDAS$_2$.

15.7 Off-line data ingest system (ODIS) for selecting and taping satellite data (collected by an antenna) for later study. Note that real time data ingestion is impossible with an ODIS.

APPENDIX A

SELECTED COLOR FIGURES

(See Section XI. for captions)

(To keep printing costs within budget limits, only the following selected pictures have been reproduced in full color.)

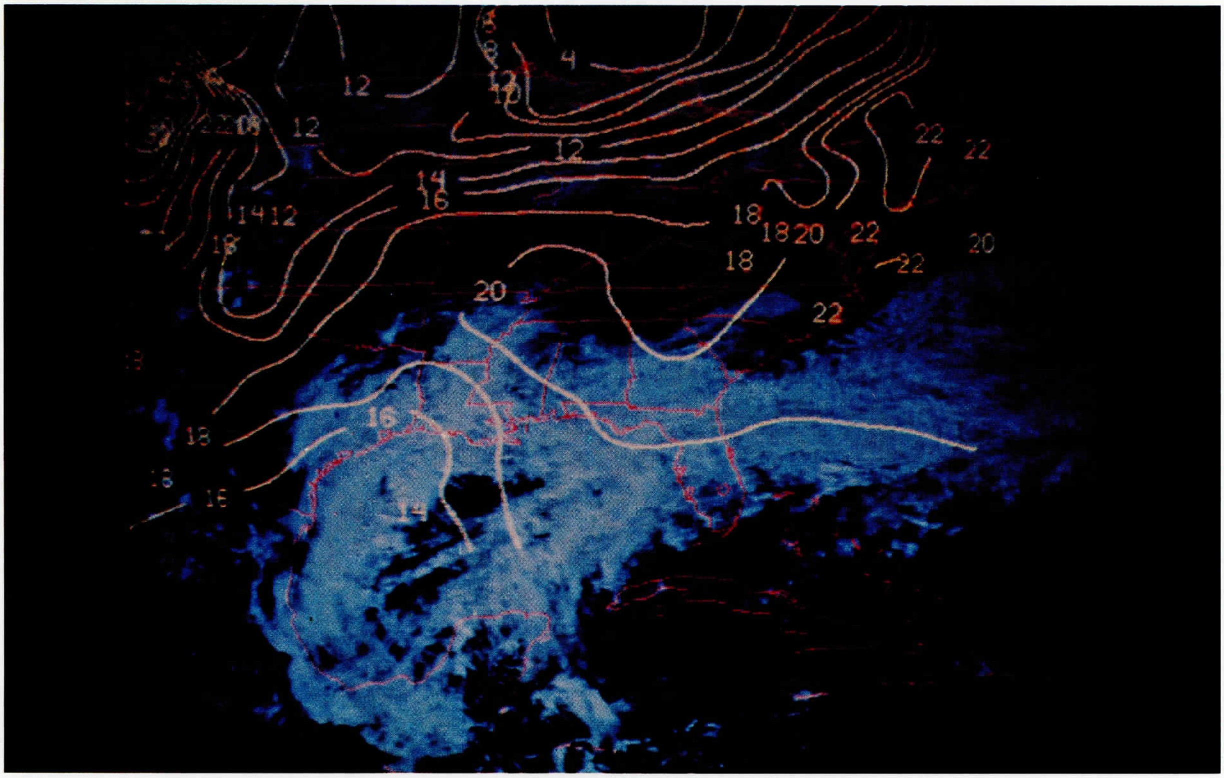


FIGURE 1.10

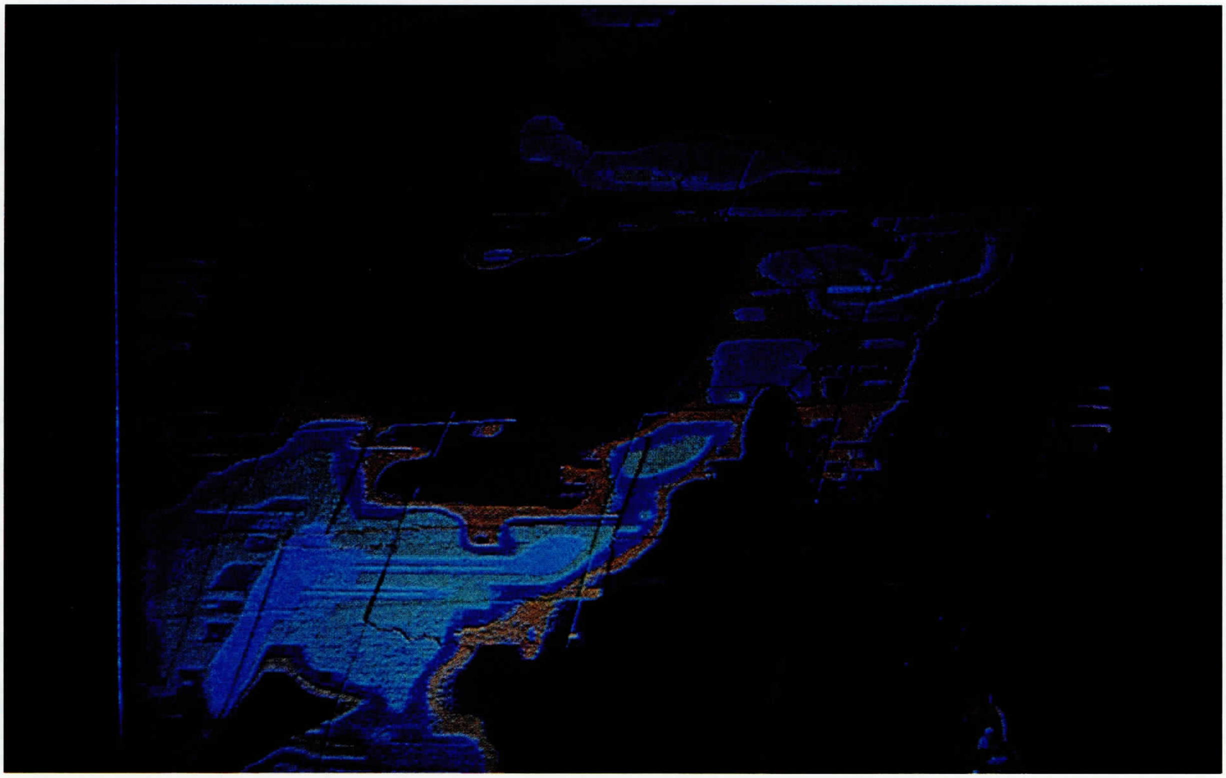


FIGURE 2.13.c

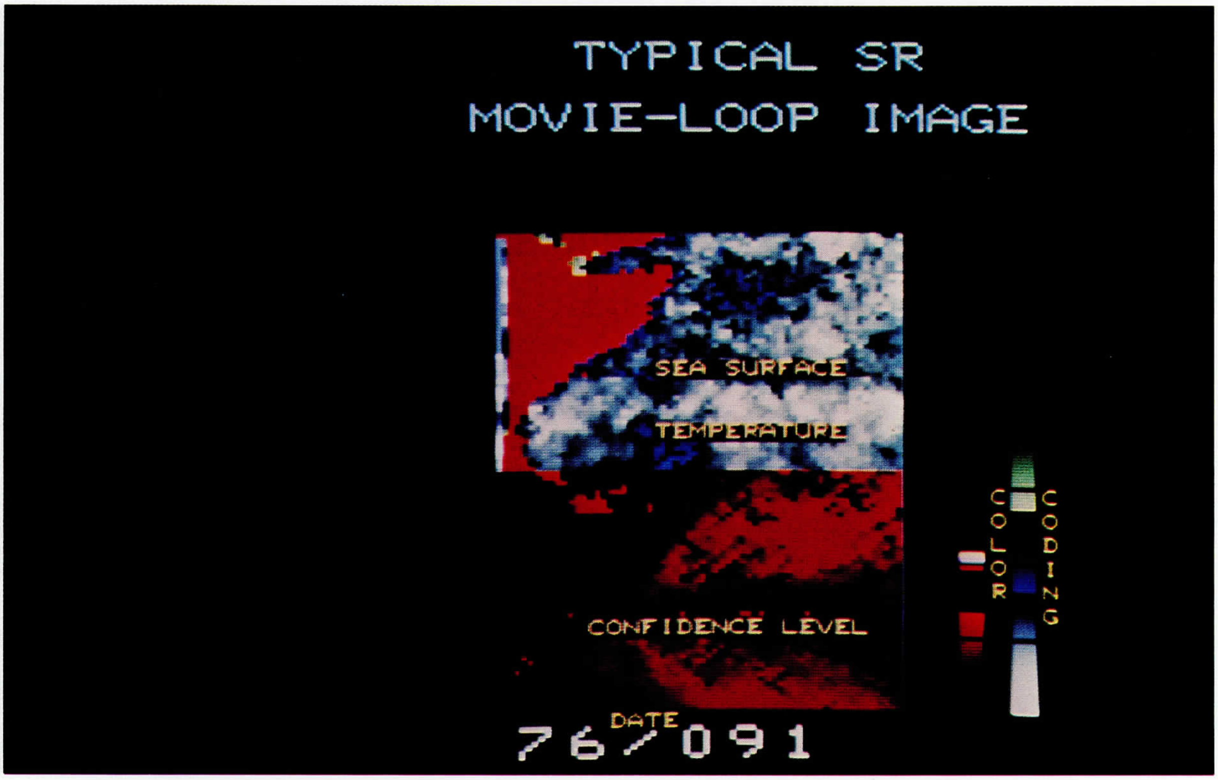


FIGURE 4.9

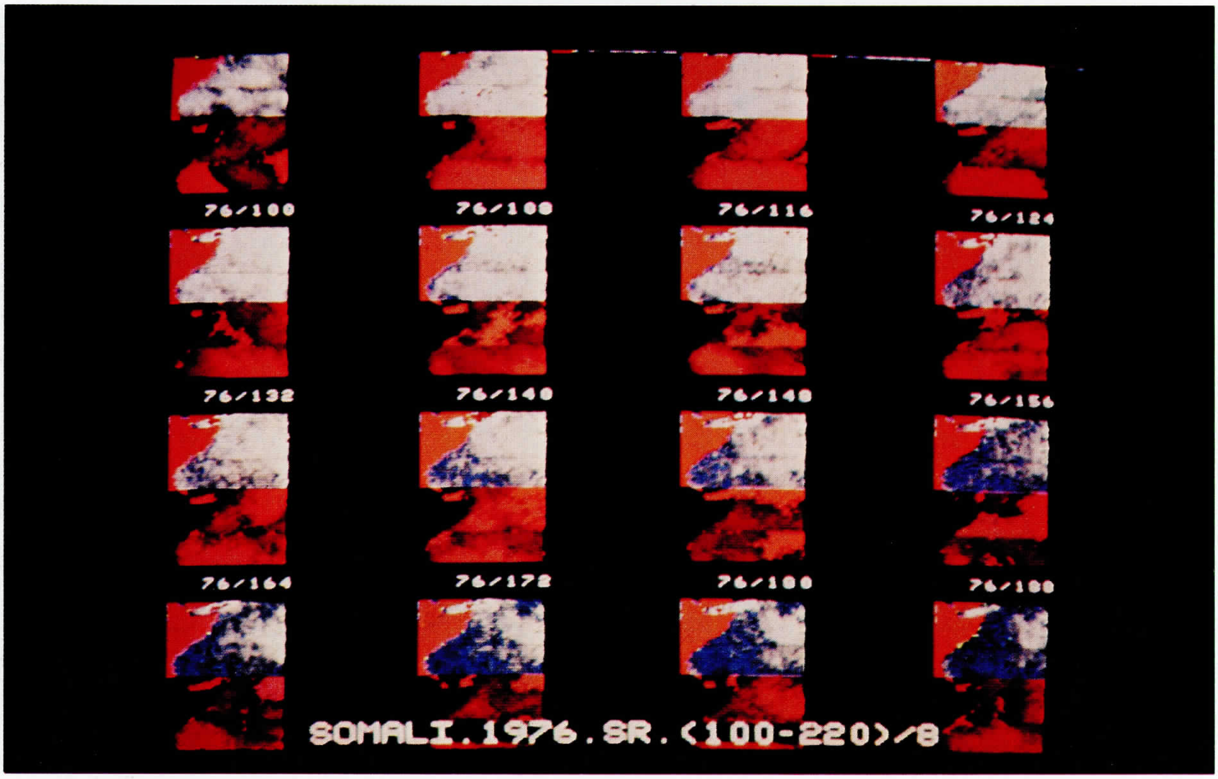


FIGURE 4.10

FIGURE 4.19

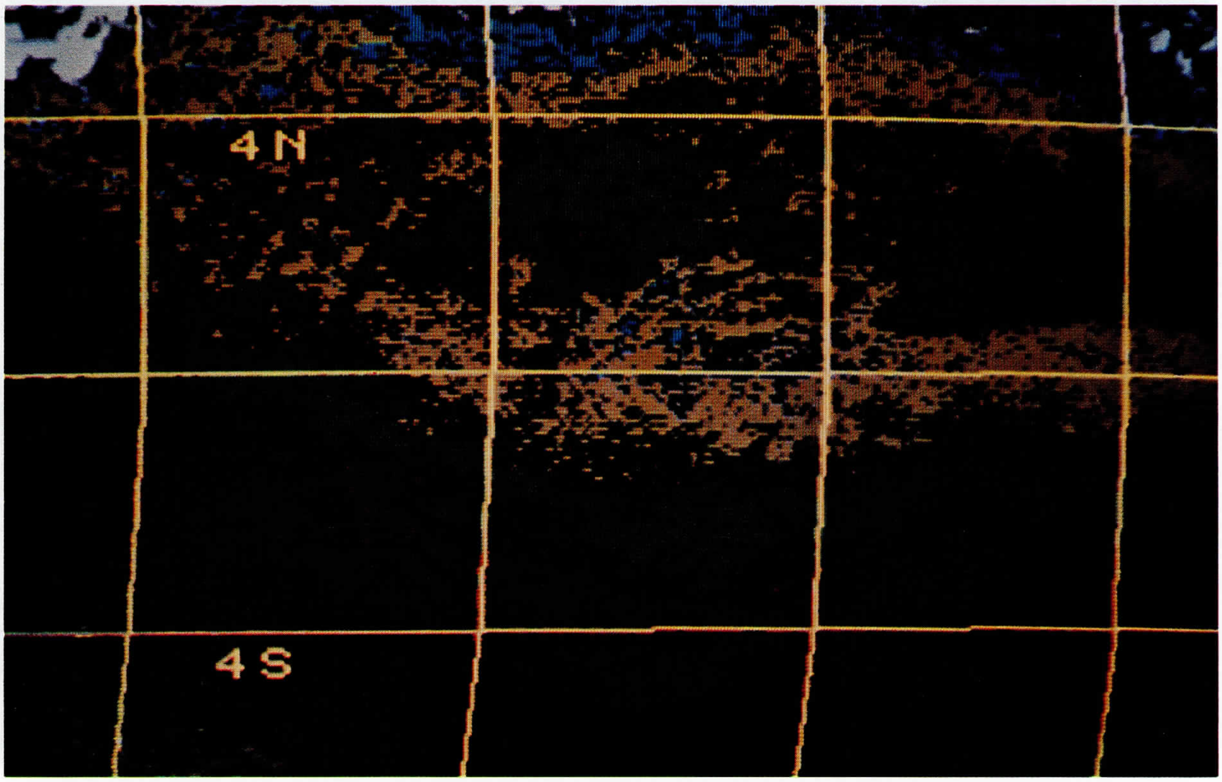


FIGURE 4.23

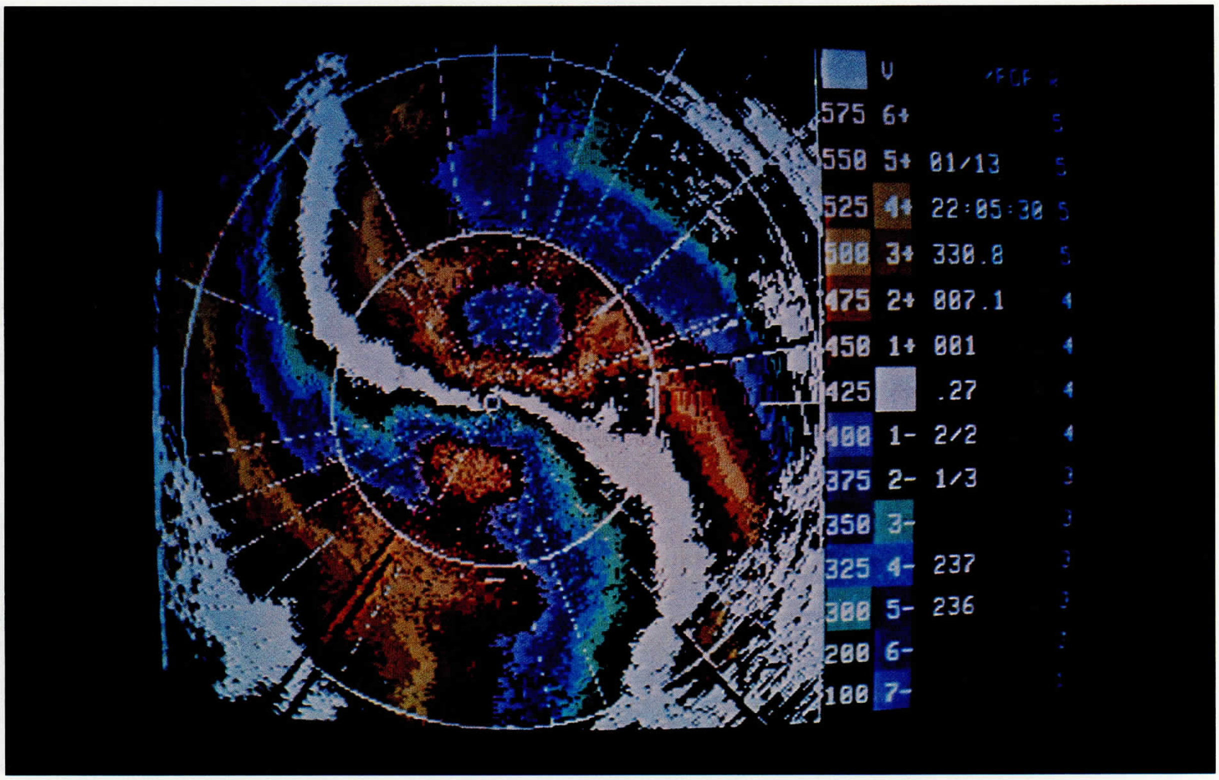


FIGURE 5.5.a

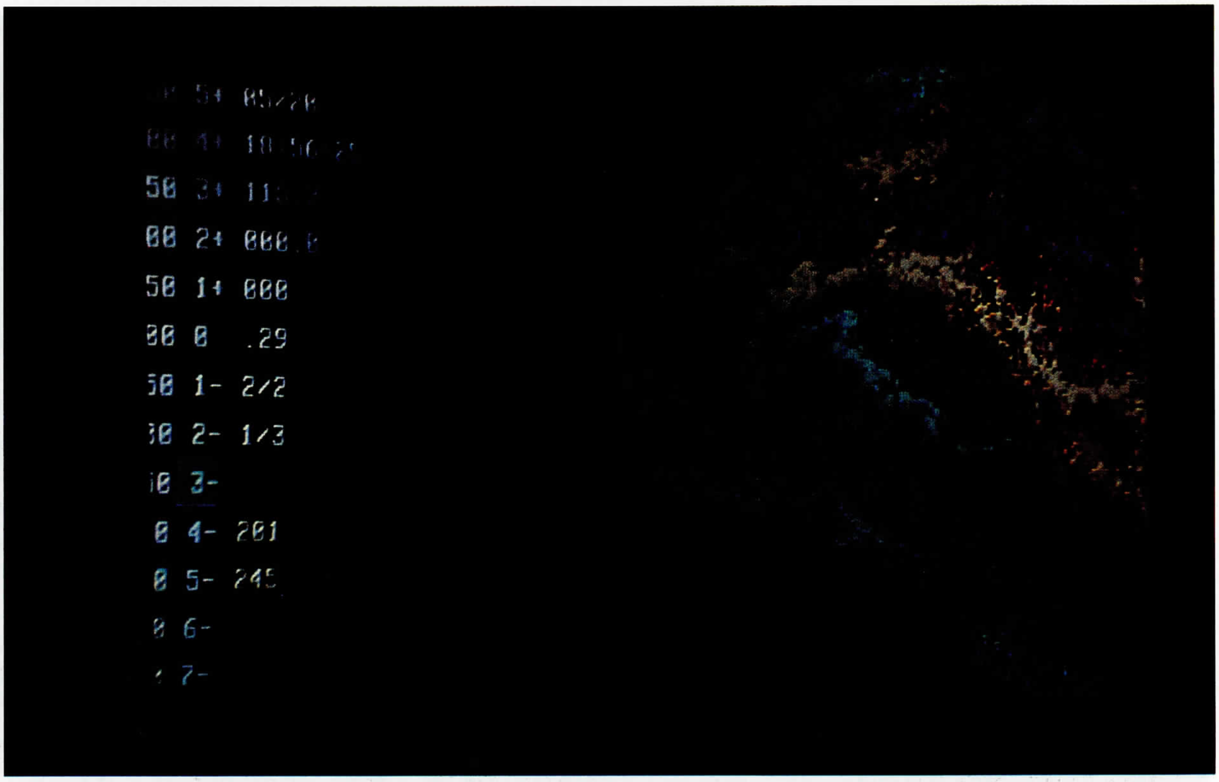


FIGURE 5.9.c

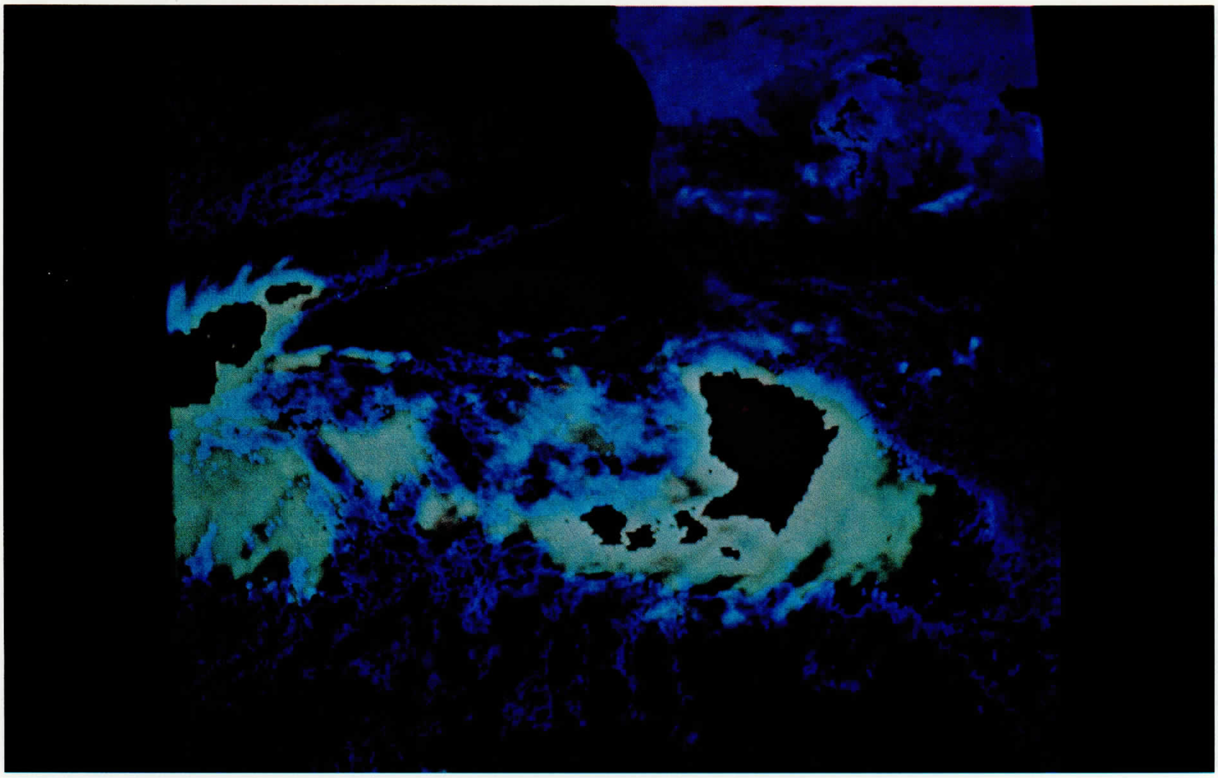


FIGURE 6.6

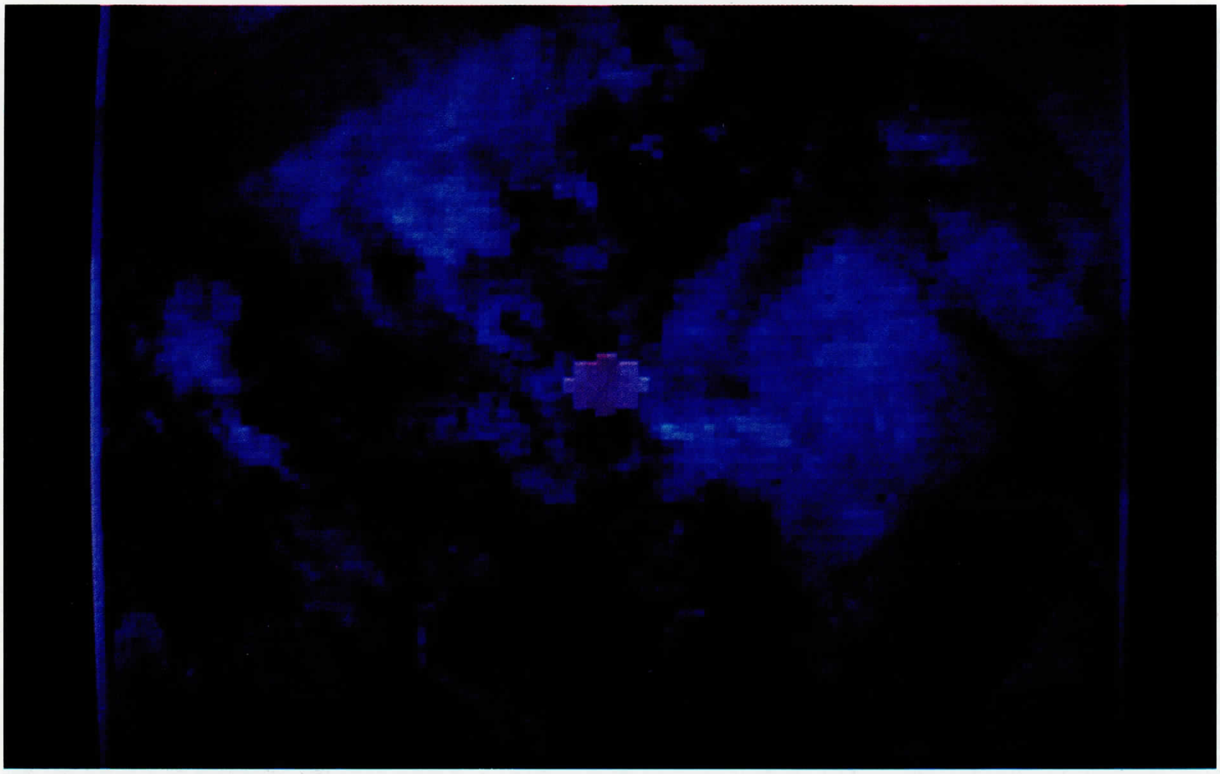


FIGURE 6.7

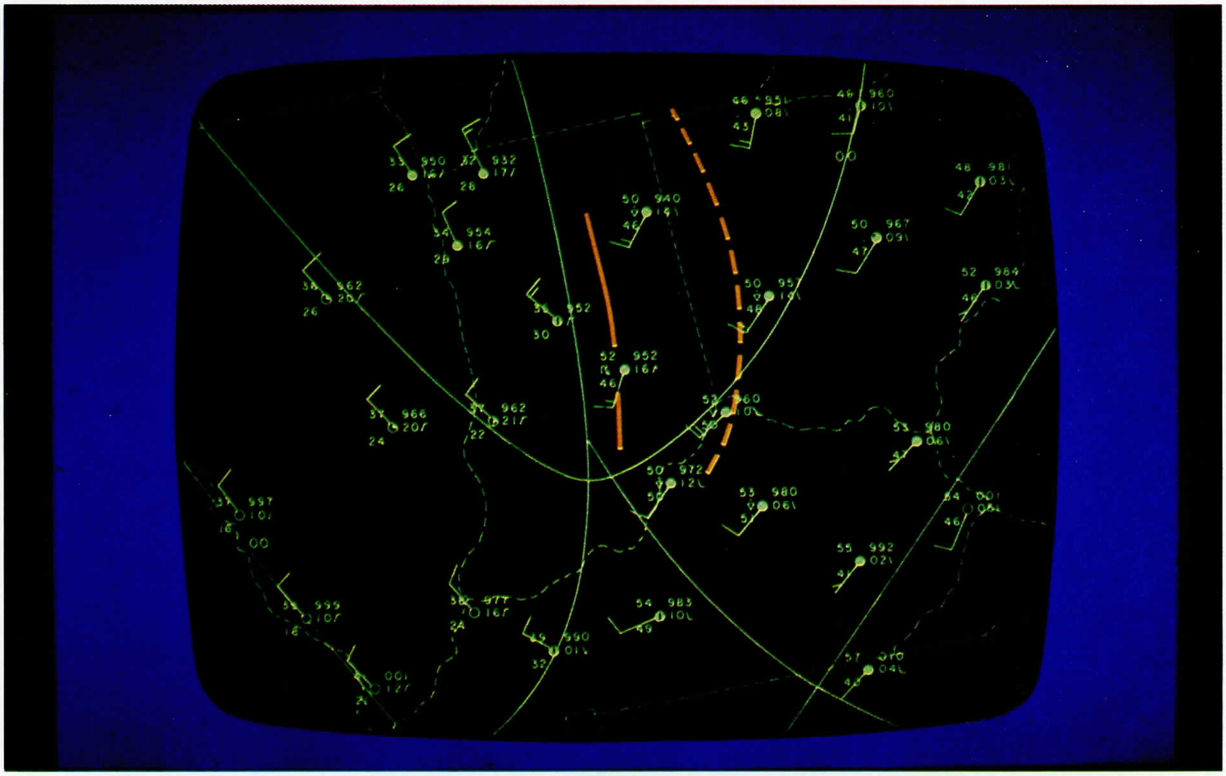


FIGURE 7.10

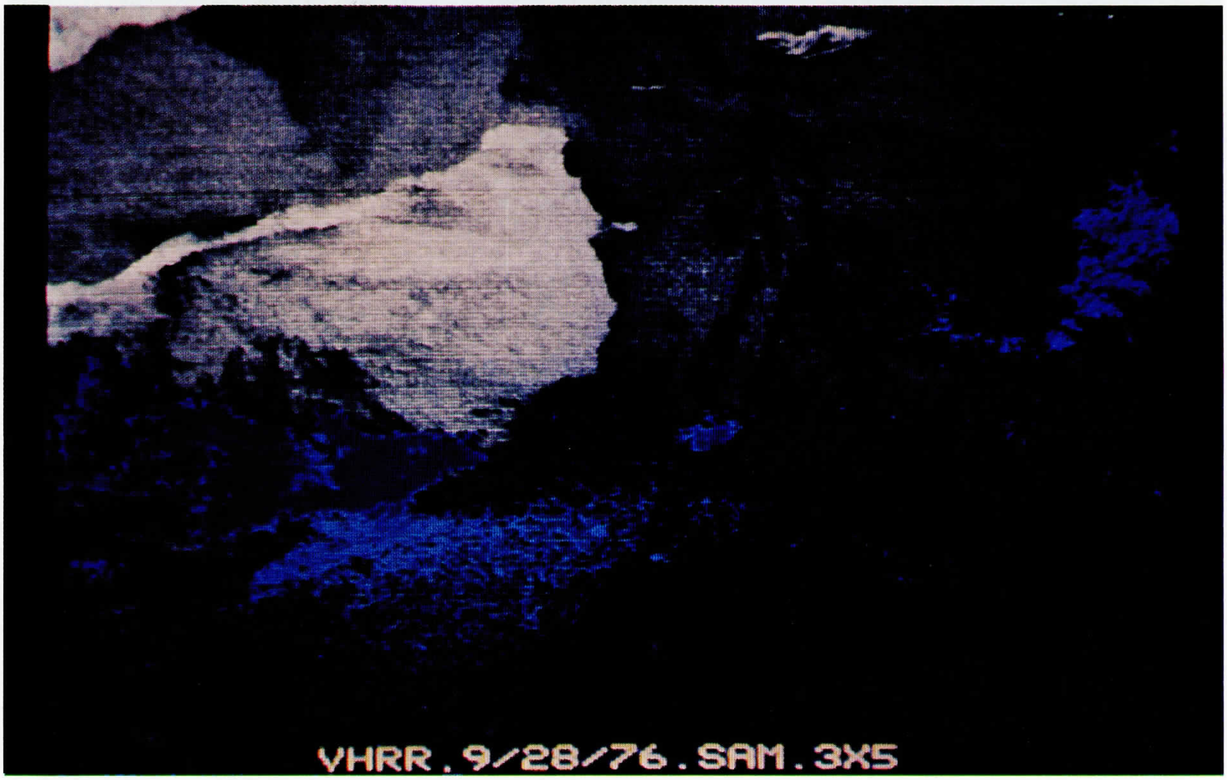


FIGURE 9.7.a

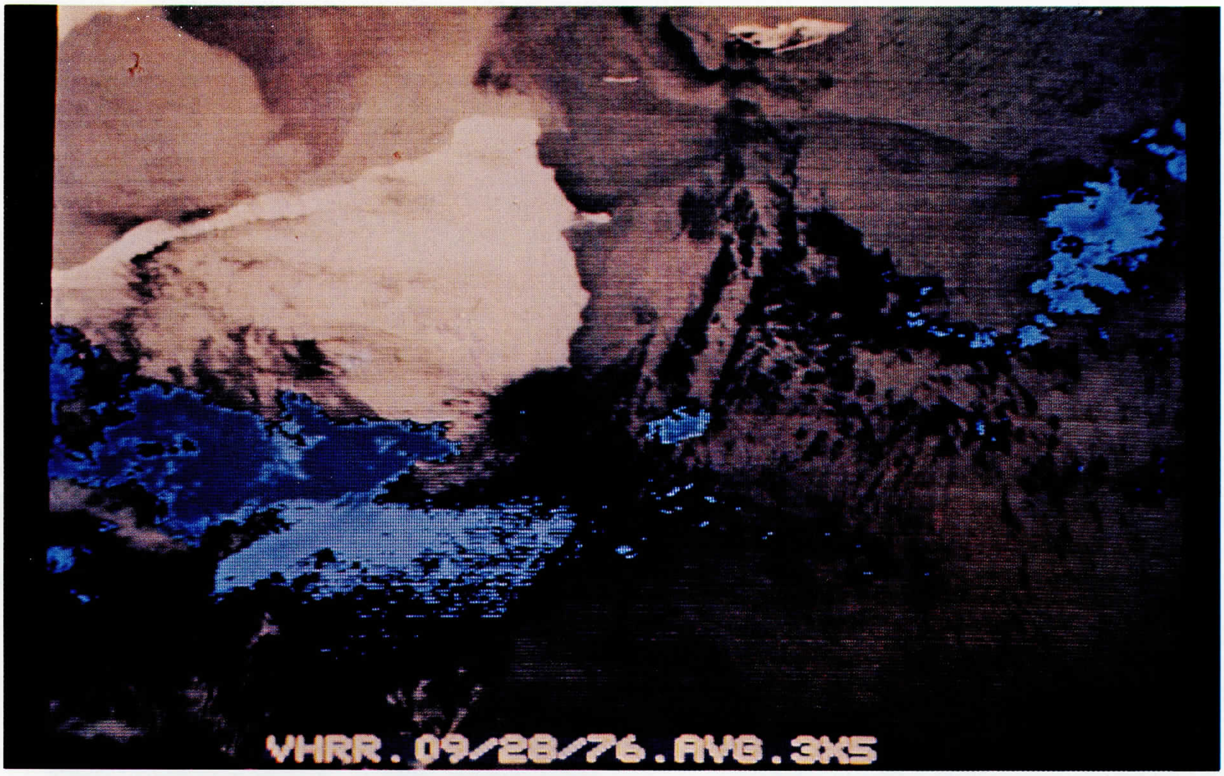


FIGURE 9.7.b

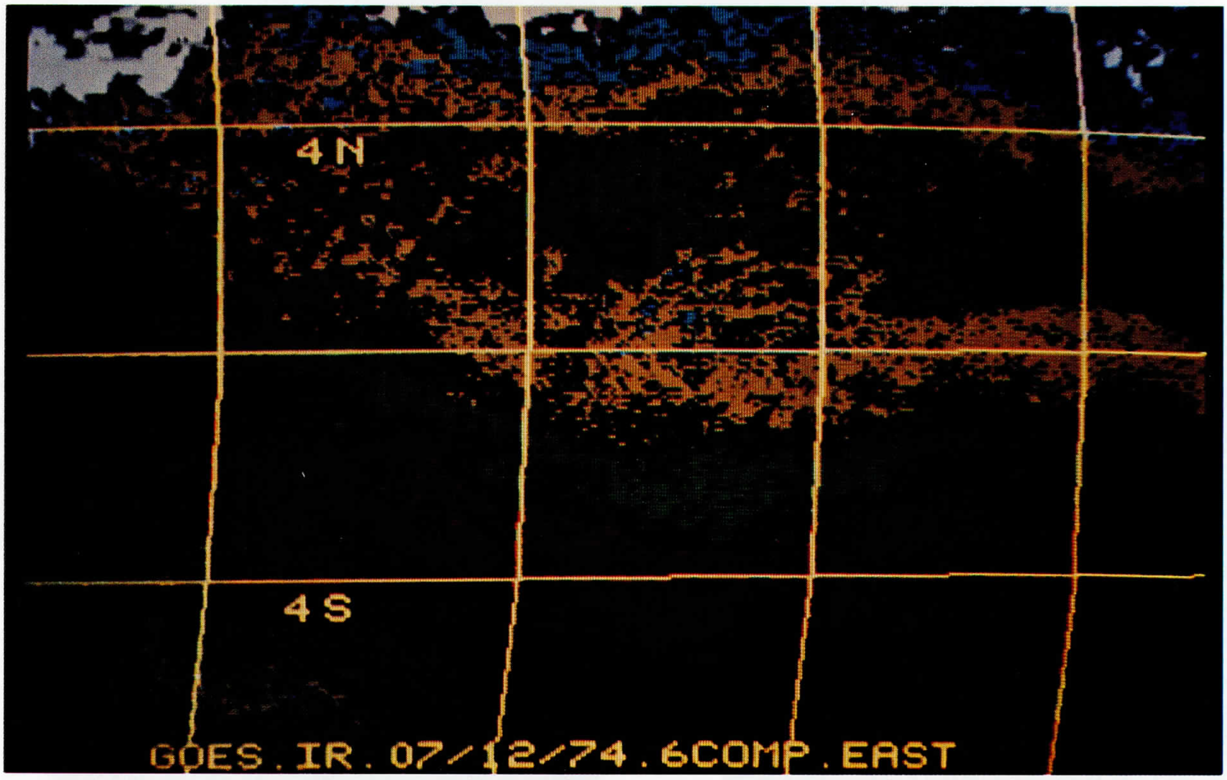


FIGURE 9.10.a

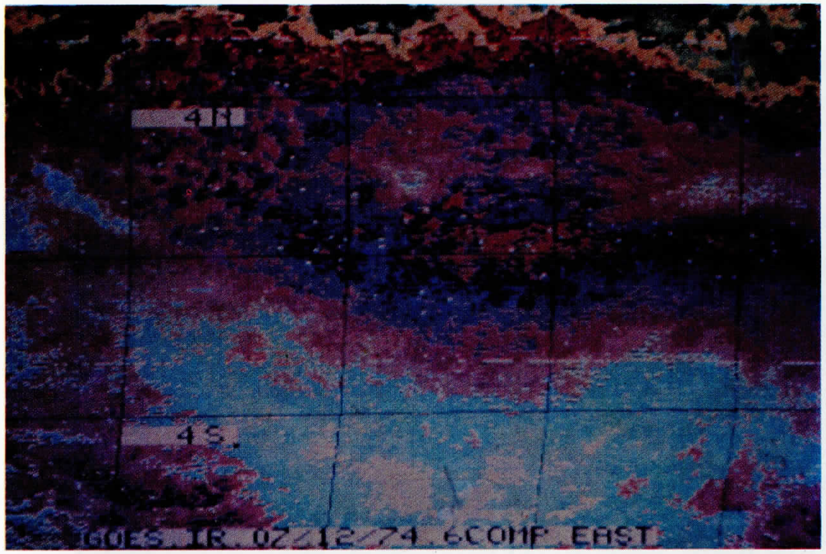


FIGURE 9.10.b

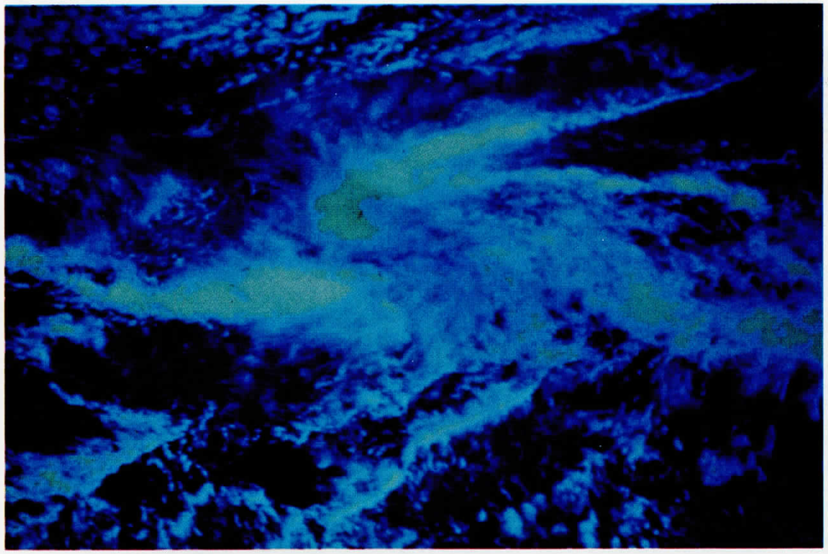


FIGURE 11.7.a

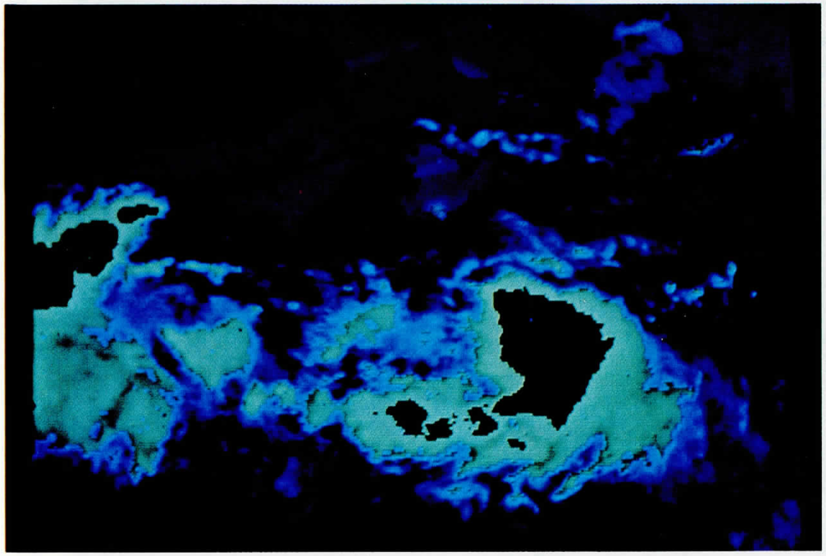


FIGURE 11.11.a

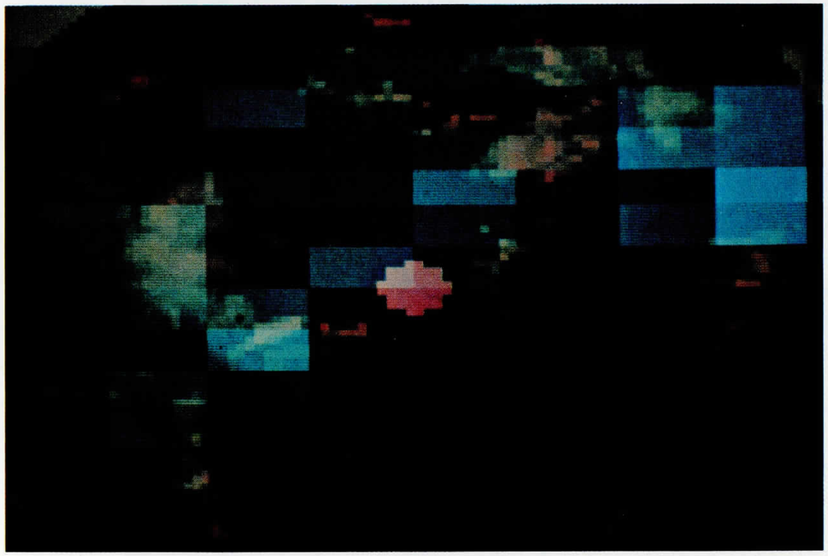


FIGURE 11.15.d

APPENDIX B:

LIST OF ATTENDEES

(* indicates those who gave presentations at the Workshop)

UNIVERSITY OF WISCONSIN-MADISON

Space Science and Engineering Center

* Verner Suomi, Director
* Thomas Haig, Executive Director
Brian Auvine
* Gary Banta
Gary Chatters
* Richard Daly
Ralph Dedecker
* Fred Mosher
* Robert Norton
* David Suchman
* J. T. Young

Department of Meteorology

* David Houghton, Chairman
* Donald Johnson
* Ralph Petersen
* Frank Sechrist
* Tom Whittaker

UNIVERSITY COMMUNITY

Dr. Hugh R. Anderson
Department of Atmospheric Science
Rice University

Dr. Elford G. Astling
Department of Meteorology
University of Utah

Prof. David A. Barber
Department of Atmospheric Science
Oregon State University

Prof. Fred Bartman
Division of Atmospheric & Ocean Sciences
University of Michigan

Dr. Lance F. Bosart
Department of Atmospheric Science
State University of New York-Albany

* Dr. John Cahir
Department of Meteorology
Pennsylvania State University

Prof. Han-Ru Cho
Department of Physics
University of Toronto

Mr. John H. Coleman
P.O. Box 8739
University of Hawaii

Dr. Grant Darkow
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University of Arizona

Prof. C. R. Holmes
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Dr. K.O.L.F. Jayaweera
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University of Alaska

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EDS/CEDDA
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Woods Hole, MA

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Dr. William Klein
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* Dr. Ronald Taylor
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Prof. Forrest R. Williams
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Oceanography
Naval Postgraduate School
Monterey, CA

APPENDIX C:

QUESTIONNAIRE DISTRIBUTED TO WORKSHOP ATTENDEES

SUMMARY

To provide planning information to the National Science Foundation, all workshop attendees were requested to fill out a questionnaire, a copy of which follows this summary. Representatives of five universities did not return questionnaires; a total of 41 were included in the summary which follows. Return from representatives of NCAR, Woods Hole Oceanographic Institution, and the Naval Postgraduate School were included with the university group. Returns from 6 representatives of government agencies were excluded. Responses are summarized, where possible to do so, for each question:

5. If your institution has an interactive computer/video data processing facility at this time, please describe it briefly:

negative response	20
no response	7
Existing systems	14, of which 6 used PDP computers, 1 Interdata, 1 Prime 400, 1 HP 9825, 2 Nova and 3 unspecified.

6. Are there needs which your present system cannot meet?

negative response	1
positive response	20
no response	20, which corresponded to the negative responses to Question 5.

7. Does your institution plan to add to a present system, or to acquire a a new one?

Yes, acquire a new one	20
Yes, add to present one	4
negative response	9
no response or noncommital	8

8.

For Research?	28	
Teaching?	28	
Other?	6	(Public service)
no response	5	

10. The Government is interested in having its investment in McIDAS and the other systems reviewed at this workshop, extended to benefit other institutions. Are you interested in acquiring or duplicating any of these systems? Please explain:

Positive response	25
negative response	5
no response, or noncommital	12

Many responses were tentative because institutional plans were not clearly drawn. Several indicated here or under Question 14 below that an interactive display system was inevitable and that all meteorology departments would have to acquire them soon. Several also indicated misgivings about costs involved.

11. Would your institution be interested in acquiring:

a complete system?	9
part of a system?	18
kits to make a system?	12
no response	10

12. Do you have the facilities to assemble kits?

positive response	27
negative response	6
no response	8

13. Would your institution be able to buy the system from internal funding?

8 responses indicated partial funding would be available. 26 said "no."

Would Federal Government assistance be required?

34 said "yes." No one said "no." 7 did not respond.

QUESTIONNAIRE

Please fill this out completely and return to T. O. Haig, SSEC,
1225 W. Dayton Street, Madison, WI 53706.

The National Science Foundation wants this information as a basis for planning future programs and grants.

1. Your name and title: ______________________________

2. Your institution and department: ______________________________

3. Phone: ______________________________

4. Mailing Address: ______________________________

5. If your institution has an interactive computer/video data processing facility at this time, please describe it briefly:

6. Are there needs which your present system cannot meet?

7. Does your institution plan to add to a present system, or to acquire a new one? ______________________________

8. For Research? _____, Teaching? _____, Other? ______________

9. Please discuss your plans briefly: ______________________________

10. The Government is interested in having its investment in McIDAS, and the other systems reviewed at this workshop, extended to benefit other institutions. Are you interested in acquiring or duplicating any of these systems? Please explain: ______________________________

11. Would your institution be interested in acquiring:

a complete system? ______________________________

part of a system? ______________________________

kits to make a system? ______________________________

12. Do you have the facilities to assemble kits? ______________

13. Would your institution be able to buy the system from internal funding? ______________ Would Federal Government assistance be required? _____.

14. Any further comments? ______________________________

APPENDIX D:

TEACHING MATERIALS PREPARED BY McIDAS

```
 23900204
  SA   GREAT LAKES STATES  311604
CMX
MQT E120 BKN 200 OVC 30 100/65/47/2310/982!MQT&3/14
SSM
PLN E70 BKN 250 OVC 30 114/71/53/1505/986/ UA /OV PLN180070 1537
/TP BE35 /TB LGT /RM RW- N HIGGINS LK TO W+SWPLN&5/8
APN 120 SCT E200 OVC 15 131/66/52/1012/991/!APN&4/1 4/7 5/6
TVC -X E45 OVC 6RW-H 114/64/52/1805/986/RWB24 H3
AUW E10 BKN 40 OVC 10 087/61/58/E0305/979
EAU E8 BKN 20 OVC 4F 086/61/59/2511/979/RE40!EAU&5/12
LSE E15 BKN 30 BKN 15 100/65/59/2712/982/RE10
GRB SP 8 SCT E20 BKN 80 OVC 4TRW-F 088/56/55/0710/978/ TE22B48 OVHD
MOVG E OCNL LTGIC PRESFR!GRB&5/8 5/9
HTL E60 OVC 8RW- 126/60/50/1405/990/RB22
MBS E80 BKN 100 BKN 250 OVC 7 125/68/51/2510/990
FNT 100 SCT E250 OVC 14 109/72/43.1209/986
MKG E55 BKN 5H 084/65/62/1113/978/RE20 TCU ALQDS
MKE 4 SCT 10 SCT E60 BKN 087/68/62/0905/979!MKE&4/73 4/74 4/83 5/27
MSN M16 BKN 25 OVC 4HK 093/66/59/2305/981
LNR 60 SCT 250 -SCT 8 70/58/2806/ TCU W
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AZO 100 SCT 5H 73/57/0610/984
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DTW 250 -OVC 7 115/79/56/1511/988
DET 25 -KN 6HK 77/54/1209/988/ !DET 5/20 SVM DME OTS&3/7 3/27 5/18
IMT SA 1542 E 18 OVC 10R- 54/52/0105/985
IWD SA 1548 15 SCT E40 BKN 150 OVC 7 60/58/1903/977
MBL SA 1549 E50 OVC 20 59/58/1108/984
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ESC SA 1550 E50 BKN 150 OVC 7 62/52/1505/984
JVL SA 1548 E40 BKN 4H 73/64/2812/980
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OSH M6V OVC 3F 60/58/0910/979/ CIG 5V7!OSH&5/3
MWC M6 BKN 12 OVC 3F 64/64/0906/981/OCNL RW-
YIP E200 BKN 7 75/55/1310/988/ !YIP&5/1
JXN M50 OVC 6H 110/78/61/1710/986/DARK NW-N!JXN&5/6
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...END OF TEXT...
* * * TERMINAL  AVAILABLE * * *
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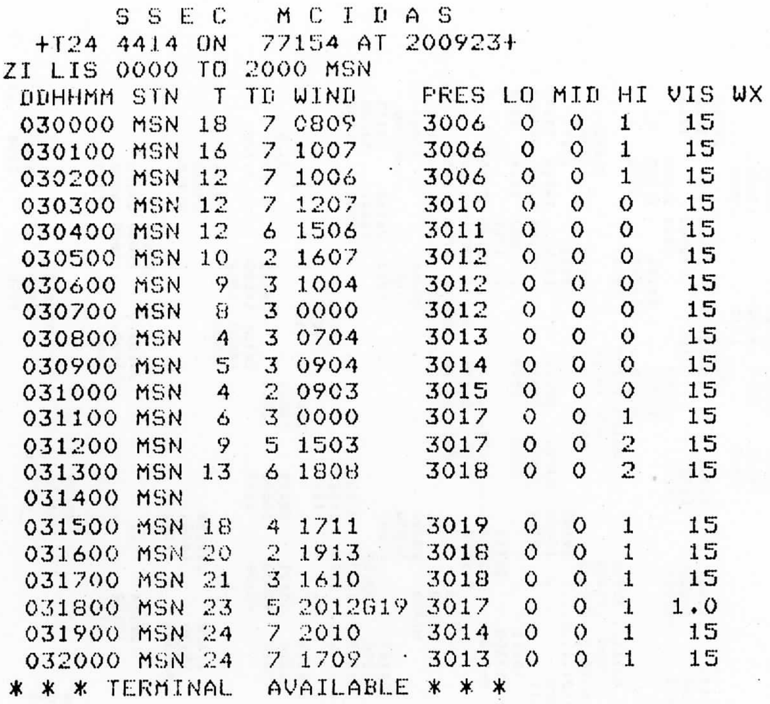

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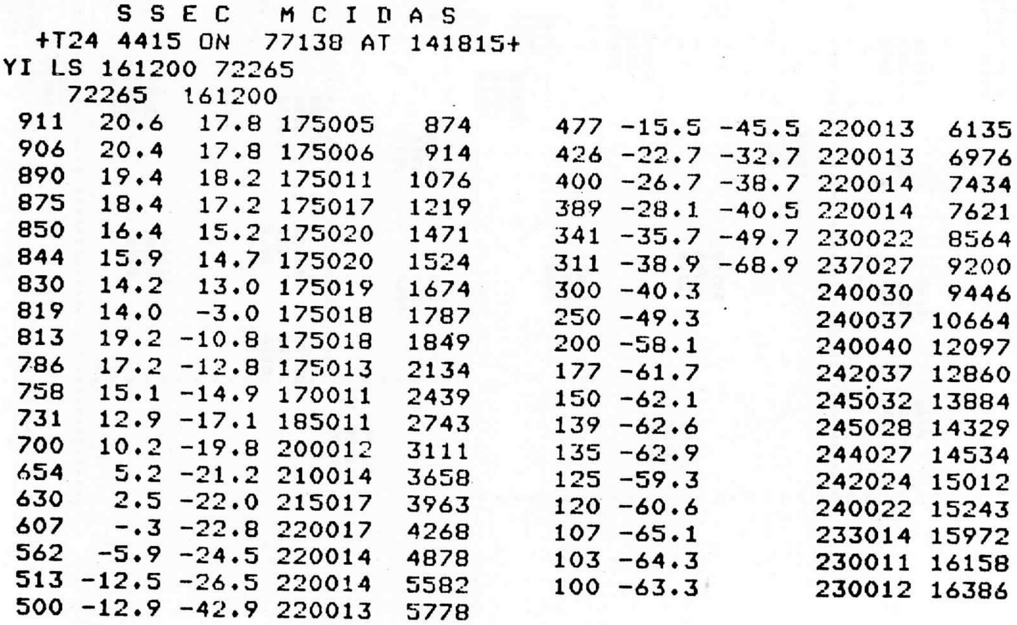

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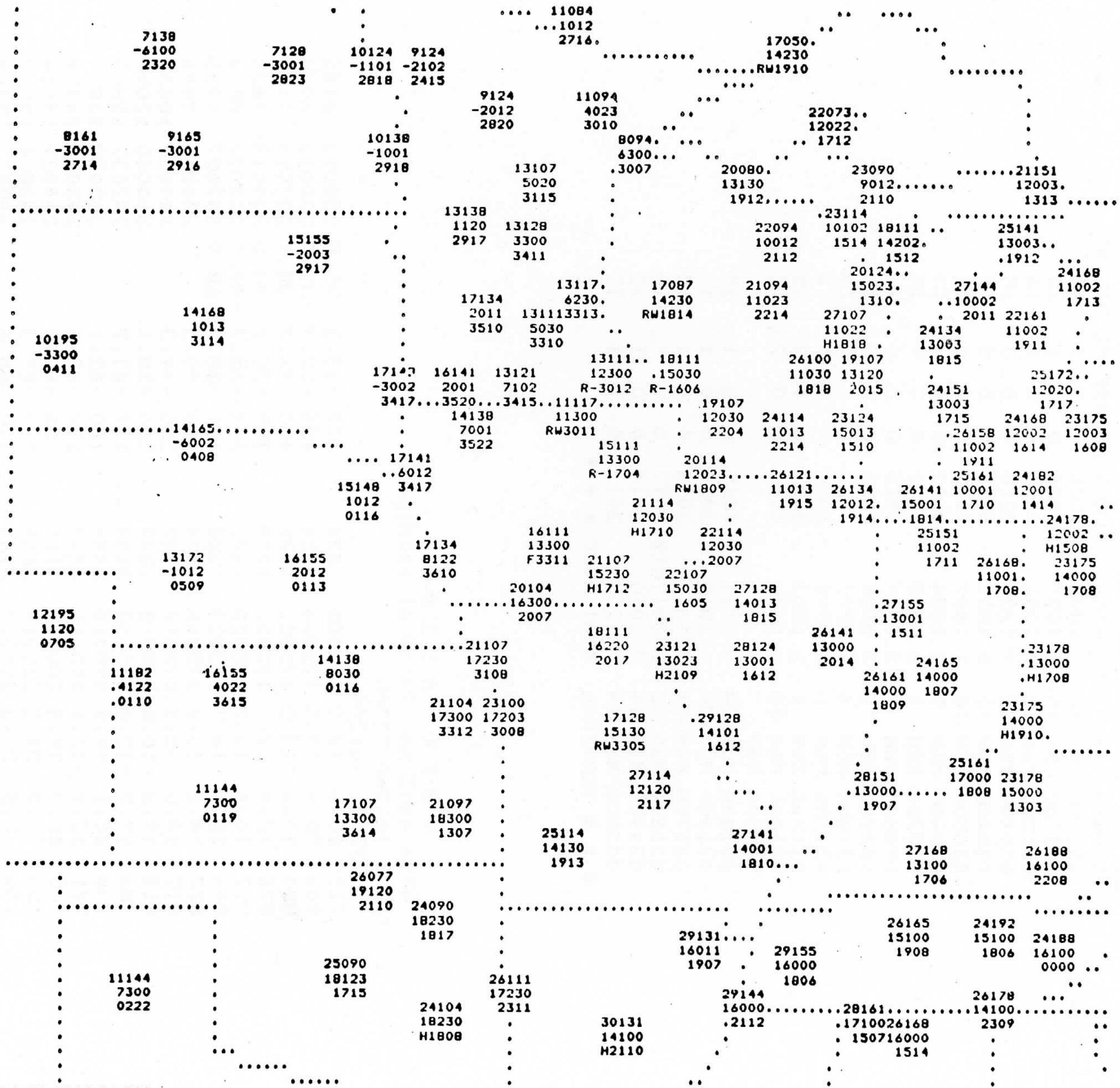

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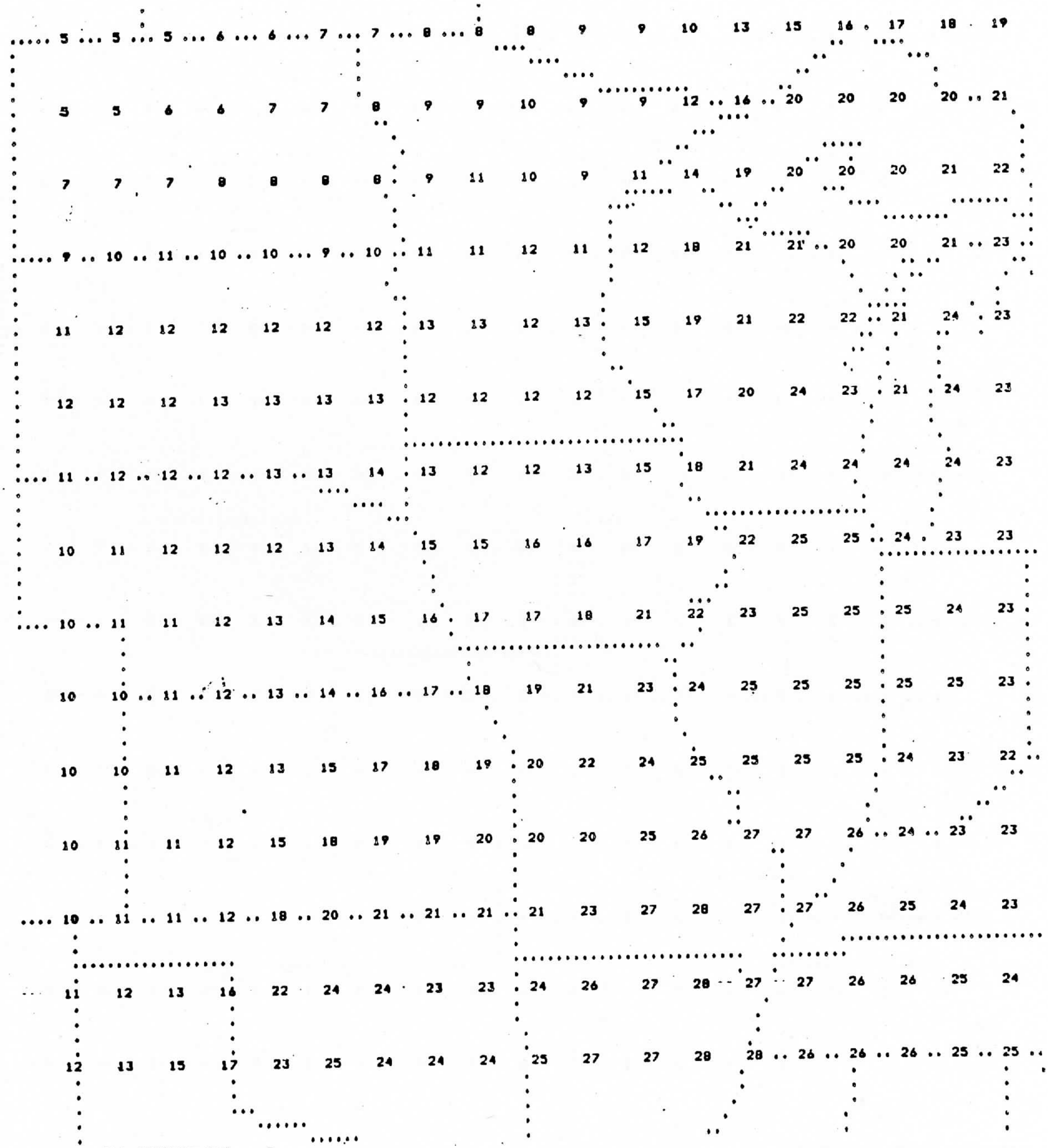

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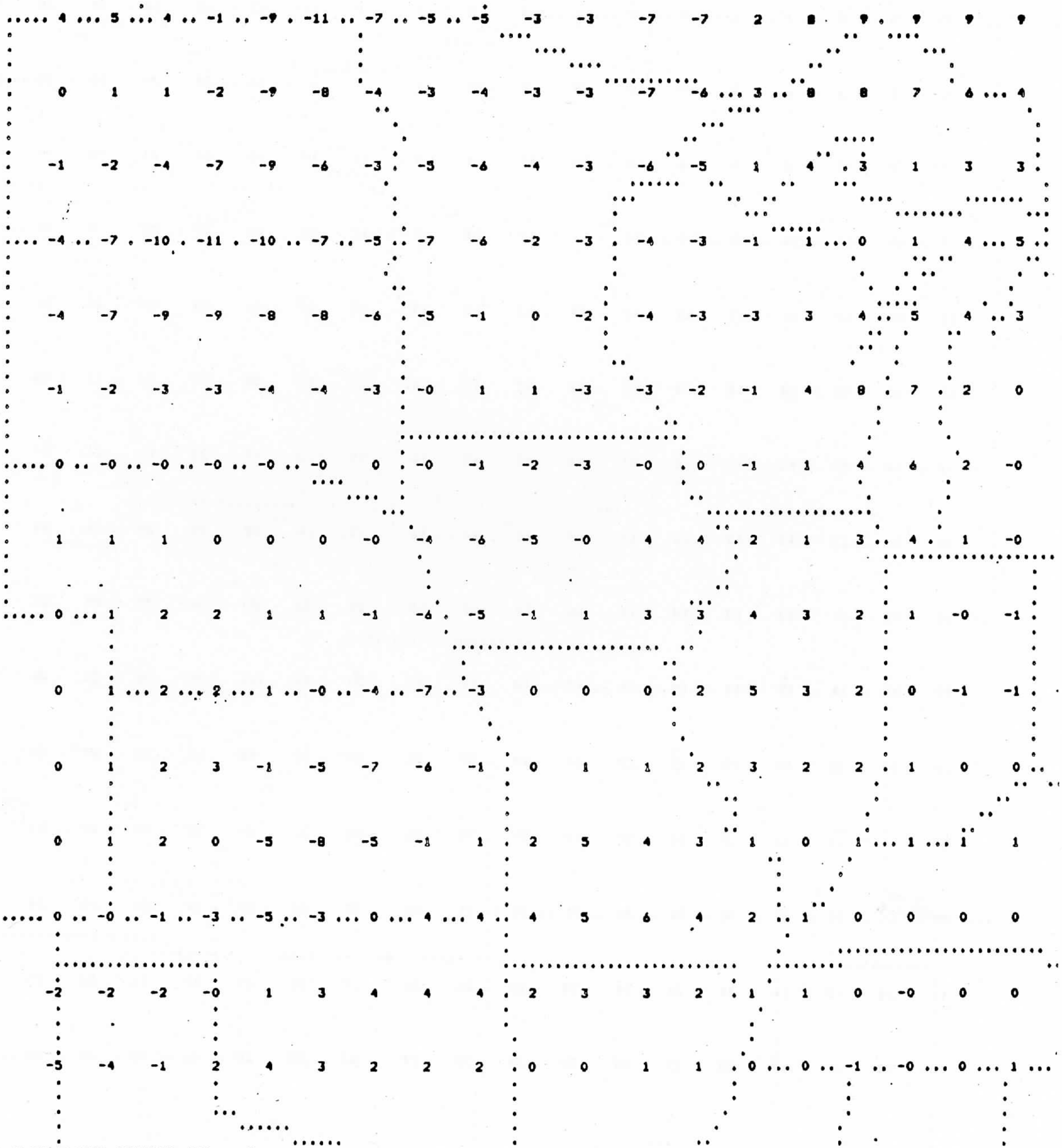

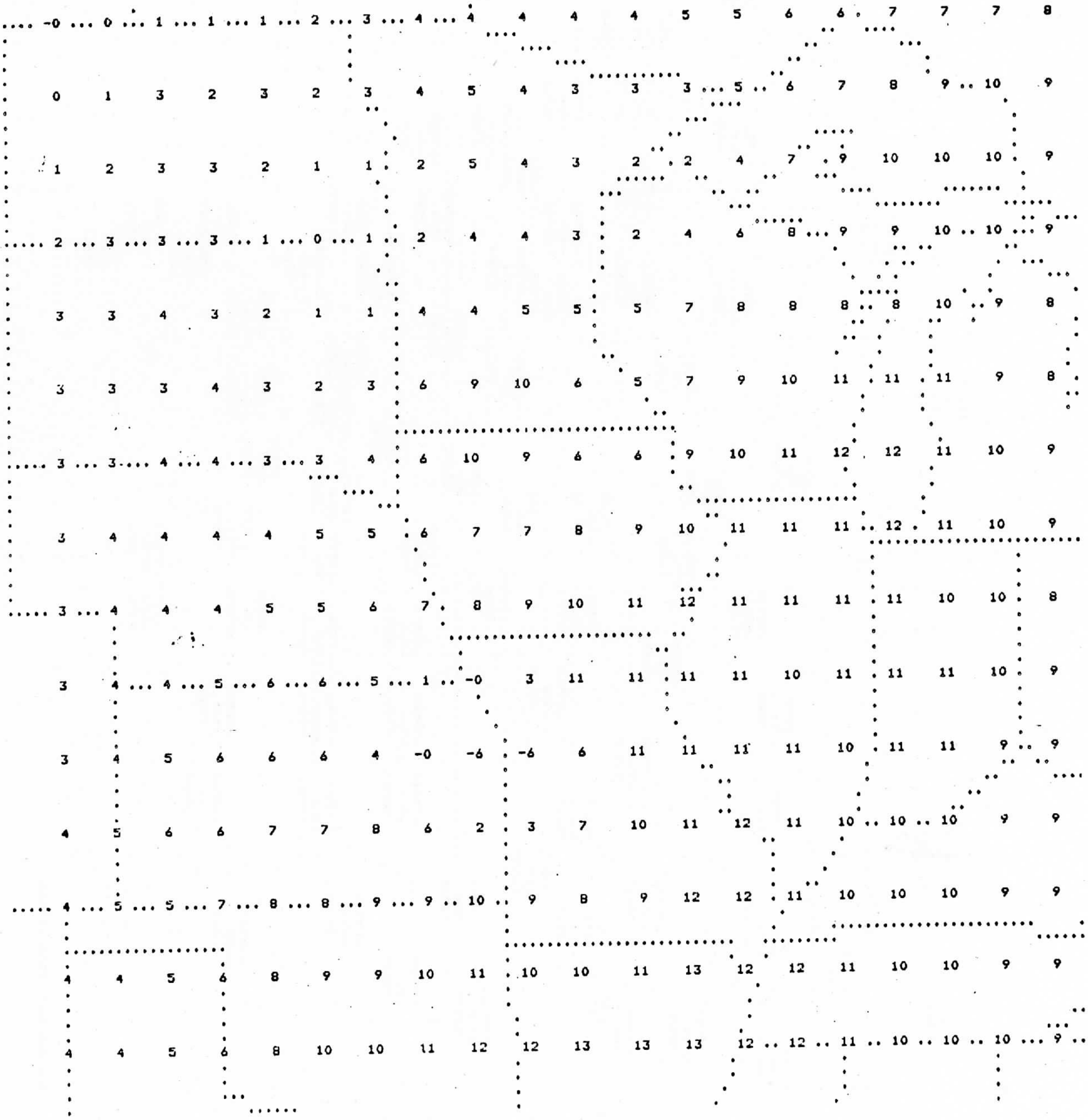
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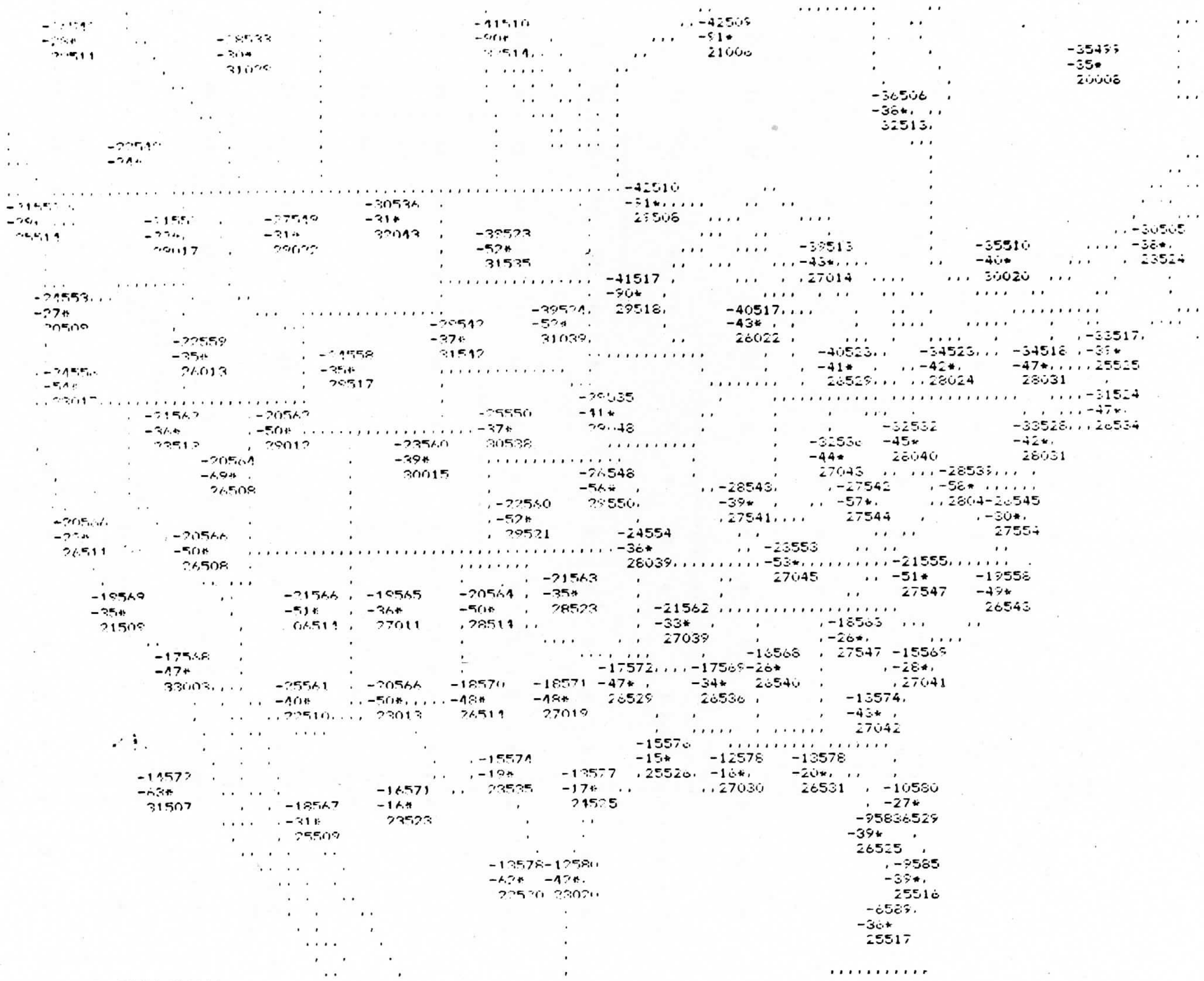

PLO 500 DATO FROM 120000

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FOR THE PERIOD 032100 TO 040900
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PARA X
BLUE
VALID 2100Z TO 0600Z
MAX TOPS 500
MIC 05 PCT...TAA 40 PCT
VALID 0600Z TO 0900Z
TS AS IN PARA S
PARA U
GREEN
VALID 2100Z TO 0600Z
MAX TOPS 500
MIC 04 PCT...TAA 30 PCT
VALID 0600Z TO 0900Z
TS AS IN PARA S
PARA Z
GREEN
VALID 2100Z TO 0300Z
MAX TOPS 420
MIC 04 PCT...TAA 30 PCT
VALID 0300Z TO 0600Z
TS AS IN PARA T
PARA A
ORANGE
VALID 2100Z TO 0300Z
MAX TOPS 450
MIC 03 PCT...TAA 25 PCT
PARA S
ORANGE
VALID ENTIRE PERIOD
MAX TOPS 400
MIC 02 PCT...TAA 10 PCT
PARA T
ORANGE
VALID 2100Z TO 0600Z
MAX TOPS 350
MIC 02 PCT...TAA 10 PCT
S                                                                     N
MWA NR 03G FOR                         ...............
032100 TO 040900                  .....   . ...      ....
4                               ..                       ...
5                            ...                             ...
6                         ....                                  ...
7                         .                                        ....
8                         .                                          ..
9                       TTT                                         ...
10                    TT. TTTTT                                      .
11                   TT       TTTT                                   ..
12                  ZZZZZZZZZ     TTT                                .
13                 Z.        ZZZZ    TTT                            .
14                ZZ             ZZZ   TTT                         ..
15                Z.               ZZZ   TTT                       .
16               ZZ.         Z       ZZ     TT                    ..
17               ZZZ                  Z      TT                   .
18                TZZZZZZZT         ZZT       TT                 ..
19                T.      ZZZZZZZZZZ           TT                .
20              TT..TTOOOOOO                    TT              ..
S1            OOOOOOOO     OOOOOT                TT             .     N
22         SSSO                  OOOOO             TT           .
23        S.  OO                XXXXXXXXXX     T    TT         ..
24        SS.  OO         O    XX        XXX         TT        .
25         S.   OO             X           XXX         T       .
26         S.    OO            X             XX        TT      .
27      SSS.      OOO          X              XX         TT    .
28    .SS           OOO        XXXX            XX          TTT .
29....  S             OOO        OXXX           TX           TT.
30      SS              OOO         OXXX           XX        T..
31       SS               OOS          XXX          XX       T.
32....    SS                OOO          XX           XX      T
33     ..  SSS                  OOO        XX         X XXXX  T
34      ..   SS                   SOOOOOOOOOOXX            XXXX.
35       ..   SS                        S     XXS            XX
36        ..   SS                                XX          X.
37         ..   SS                                 XX     .  X
38          .    SS                         S       XXX  ....X
39         ..     SSS            SSSSSS               XXXX. XX
40          .       SSS       SSSS    SSSS               XXXX ..
41         .            SSSSSS           SS                .S   .
42         .                               SS   ......... . S  ..
S3         ....                             SSS    .... ...S  .       N
44         ... .                            SS...    ...SS...
45             ..                             SS        SS.
46              .                              SS   ...SS .
47           AAA.                              ...SSSSS   .
48          AA AAA                             .......... .
49         AA  ..AA                            ....    ....
50       AA     .  AA                           ....   ..
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53   AAA   ....         A                              . ..
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56    ..      ...        AA....            .....             ..
57   ..      ..          AA     ...       .......              ..
58   .......        AAAAA        .....................          ........
59              AAAA               ....               .                .
60AAAAA     AAAA                                       ...........  ....
61      AAAAA                                           ...      .. .
62                                                                 ..
S3                                                                     N
```

```
* * * TERMINAL  AVAILABLE * * *
* * * TERMINAL  AVAILABLE * * *
  T24 4414 ON  76266 AT 202104
ZC T 1700 TO 2000 MN
   SVCA - DAY 22 USED
   SVCA - DAY 22 USED
```

```
***    S S E C   M C I D A S     ***     PROGRAM: SAKNTR     TERMINAL: 024  PROJECT:    4414  DATE:   76266  TIME:  202151
```

```
* * * TERMINAL  AVAILABLE * * *
  T24 4414 ON  76266 AT 202454
ZP PLOT 2000 MID
   SVCA - DAY 22 USED
```

Service A Processing List of Parameters

This is a list of parameter keys used by all SVC-A processing programs, except as noted.

KEY	PARAMETER	PROGRAMS (if not all)
T	Temperature	-
TD	Dew Point	-
PRE	Pressure	-
WIND	Wind Data	-
LO,MID,HI	Cloud Data	only ZI
CLD	Composite Cloud Date	all but ZI
THA	Potential Temperature	
THE	Equivalent Potential Temperature	1
Q	Mixing Ratio	
WX	Current Weather	all but ZK, ZC
DIV	Divergence	ZC, ZK
VOR	Vorticity	ZC, ZK
DSH	Deformation - Shear	ZC, ZK
DST	Deformation - Stretching	ZC, ZK
TAD	Temperature Advection	ZC, ZK
DAD	Dew Point Advection	ZC, ZK
QAD	Mixing Ratio Advection	ZC, ZK
AAD	Potential Temperature Advection	ZC, ZK
EAD	Equivalent Potential Temperature Advection	ZC, ZK
PAD	Pressure Advection	ZC, ZK
TDI	Temperature Divergence	ZC, ZK
DDI	Dew Point Divergence	ZC, ZK
QDI	Mixing Ratio Divergence	ZC, ZK
ADI	Potential Temperature Divergence	ZC, ZK
EDI	Equivalent Potential Temperature Divergence	ZC, ZK
PDI	Pressure Divergence	
LAB	Implies all parameters	ZI only
PLOT	Implies all parameters	ZP only

Note on "time." When a "time" is required by one of the SVC-A processing programs, it may generally be in the form DDHHOO or simply HHOO. DD is day of month, HH is hour (GMT) and OO is two zeros. If the day (DD) is omitted, the most recent day is used.

COMMAND: SVC-A Information Retrieval

KEY IN: ZI

PROGRAMMER: T. Whittaker

DATE: 9 Sept. 76 /JAN 77./ 9 APR 77

CHAPTER: 9

ZI ^ STAT	Causes the status of the decoding program to be printed.
ZI ^ HOUR ^ hour	Lists all days with data available for "hour" (in the form: HH00).
ZI ^ HOUR ^ ALL	Lists all data periods available.
ZI ^ AVAIL ^ time	Lists the number and percent of stations with data for the time (in the forms: DDHH00 or HH00). If the keyword LIST appears after the time, the station identifiers are listed.
ZI ^ MISS ^ time	Same as AVAIL except for missing data.
ZI ^ LIST ^ time ^ $id_1 \ldots id_n$	List the data for the stations named ($id_1 \ldots id_n$) for the time indicated.
ZI ^ LIST ^ $time_1$ ^ TO ^ $time_2$ ^ id	List the data for the single station named (id) for each hour between $time_1$ and $time_2$.
ZI ^ LIST ^ time ^ param ^ op ^ value	For the time specified, list all stations where the indicated parameter (param) satisfies the relational condition stated. "op" is EQ (equal), NE (not equal), GT (greater than) or LT (less than). "value" is the test value to be used.
ZI ^ COR ^ time ^ id ^ param ^ new-value	For the observation at the station named (id) at the time specified, change the indicated parameter (param) to the new-value given. To delete an observation set T (temperature) to -100.
ZI ^ LOC ^ iii	Print the latitude and longitude (degrees and minutes) of the station "iii"

COMMAND: Contouring SVC-A Data   KEY IN: ZK/ZC

PROGRAMMER: T. Whittaker   DATE: August 1975 /JAN 77

FUNCTION DESCRIPTION: CHAPTER 9

Normal

Z_C^K ‸ param ‸ time ‸ map

param = T, TD, WIN, PRE, THE, THA, STR (not available in ZC), TAD, PAD, VOR, DIV, EAD, EIV, AAD, ADI, DST (stretch), DSH (shear), Q, QAD, QDI
time = HHMM or DDHHMM
- Time interpolation is done if MM ≠ 00 except on quantities using winds.

map = MID or WIS, or "post office" abbreviation

Change Charts

Z_C^K ‸ param ‸ time 1 ‸ TO ‸ time 2 ‸ map

param = as above
time 1 = as above
time 2 = as above
map = as above

NO TIME INTERPOLATION DONE

Different Contour Interval

Z_C^K ‸ param ‸ time ‸ cont ‸ map

Z_C^K ‸ param ‸ time 1 ‸ TD ‸ time 2 ‸ cont ‸ map

cont is desired contour interval (trailing zeroes are dropped in labels) as a two digit value. A digit preceding this two digit value selects color (ZK0, or type of output (ZC).

Different Map Area

Change "map" to LTLNNW ‸ LTLNSE

LTLNNW = lat and long (whole degrees) of N.W. corner of map
LTLNSE = lat and long (whole degrees) of S.E. corner of map
form AALLL: AA-lat, LLL-long
ex: 55115 35085
55N, 115W - 35N, 85W
Note zero in second group.

Different Output Device Eunits

insert after "map", ‸ LLBLLE ‸ NNBNNE

LLB = begin line
LLE = end line
NNB = begin element (column)
NNE = end element (column)

ex: MID ‸ 10440 ‸ 10640   line beg = 10   line end = 440
element beg = 10   element end = 640

APPENDIX E:

ABBREVIATIONS AND ACRONYMS

ADCCP	Advanced Data Communications Control Procedures (NWS)
AFGL	Air Force Geophysics Laboratory (Bedford, MA)
AFOS	Automation of Field Operations and Services (NWS)
ATS	Applications Technology Satellite
BOMEX	Barbados Oceanographic and Meteorological Experiment
CDC	Control Data Corporation
CDDS	Central Data Distribution Service (NESS)
CEDDA	Center for Experiment Design and Data Analysis (EDS)
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSU	Colorado State University
DEC	Digital Equipment Company
DMA	Direct Memory Access
DMSP	Defense Meteorological Satellite Program
EDS	Environmental Data Service
EPROM	Erasable Programmable Read Only Memory
ERTS	Earth Resources Technology Satellite
FAA	Federal Aviation Administration
FAX	Facsimile
FGGE	First GARP Global Experiment
GARP	Global Atmospheric Research Project
GATE	GARP Atlantic Tropical Experiment
GISS	Goddard Institute for Space Studies (New York City, NY)
GOES	Geosynchronous Operational Environmental Satellite
GSFC	Goddard Space Flight Center (Greenbelt, MD)
HRIS	High Resolution Infrared Sounder
INDEX	Indian Ocean Experiment
I/O	Input/Output
IR	Infrared
IVAM	Innovative Video Applications in Meteorology (SSEC)
LIDAR	Light Detection and Ranging (Lasar Radar)
M-RDOS	A software system created by Data General Corporation
McIDAS	Man-computer Interactive Data Access System (SSEC)
MONEX	Monsoon Experiment
NASA	National Aeronautics and Space Administration

NCAR	National Center for Atmospheric Research
NCC	National Climatic Center
NESS	National Environmental Satellite Service
NMC	National Meteorological Center
NOAA	National Oceanographic and Atmospheric Administration
NSF	National Science Foundation
NSSL	National Severe Storms Laboratory
NTSC	National Television Standards Code
NWS	National Weather Service
ODIS	Off-line Data Ingest System
PCM	Pulse Code Modulation
PROM	Programmable Read Only Memory
PSU	Pennsylvania State University
RAM	Random Access Memory
RDOS	A software system created by Data General Corporation
RDSS	Research Data Support System (NCAR)
RGB	Red/Green/Blue
RHI	Range-Height Indicator
ROM	Read Only Memory
RSMAS	Rosenstiel School of Marine and Atmospheric Science (University of Miami)
SMS	Synchronous Meteorological Satellite
SR	Scanning Radiometer
SSEC	Space Science and Engineering Center (UW-Madison, Wisconsin)
STRATEX	Stratoform Cloudiness Experiment
TTY	Teletype
VAD	Velocity/Azimuth Display
VAS	VISSR Atmospheric Sounder
VHRR	Very High Resolution Radar
VIMHEX	Venezuelan International Meteorology and Hydrology Experiment
VISSR	Visible/Infrared Spin Scan Radiometer
VSTR	Video Slant Track Recorder
WPL	Wave Propagation Laboratory (NOAA)
WRRRM	Write Random, Read Raster Memory
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
XBT	Expendable Bathythermograph