4-1985

Lessons Learned from the CSIS [Centralized Storm Information System] (Appendix D)

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LESSONS LEARNED FROM THE CSIS

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1. INTRODUCTION

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

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

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

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

2. CSIS HARDWARE AND SOFTWARE

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

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

The three Harris /6 computers are identical, but each performs different functions. There is one data base manager (DBM) and two application processors (AP). These computers are linked by a high speed (10 mb/sec) line. The DBM handles all incoming and data lines. Its function is to bring in, preprocess, and store all of the data which is used by CSIS. The second computer is used as an AP for the operational support of CSIS. This AP is connected to two interactive terminals and performs all of the analysis and display functions requested by the forecasters. The third computer is used as an AP for research and development activities. It drives a single interactive terminal.

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

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

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

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

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

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

3. IMPACT OF THE CSIS

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

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

4. LESSONS LEARNED FROM THE CSIS

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

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

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

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

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

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

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

4.2 Scheduler function is crucial to any real time system

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

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

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

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

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

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

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

4.5 Forecasters generate a large peak load on computer resources.

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

4.6 Modular design of the terminal layout

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

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

5. SUMMARY

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

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

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

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

6. ACKNOWLEDGEMENTS

Many people have contributed to the development of CSIS. Dr. James Dodge (NASA), Mr. Fred Zbar (NWS), Mr. James Giraytys (NOAA), and Professor Verner Suomi (SSEC) have made major contributions. Angela Crowell, Christine Paurus, and Jody Edwards typed the manuscript. This effort has been funded by NASA Contract NASW-3476.

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