Satellite & Computer Applications

REALTIME PROCESSING AND TRANSMISSION OF DIGITAL SATELLITE IMAGERY FOR USE AT A REMOTE FORECASTING FACILITY

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1. INTRODUCTION

At Colorado State University (CSU), the Departments of Atmospheric Science and Electrical Engineering are engaged in operation and development of CSU's Direct Readout Education and Training Earthstation. This facility provides realtime recording of satellite imagery and remote surface data which is transmitted through NOAA's Geostationary Operational Environmental Satellites (GOES-East and GOES-West). During five months of 1980, CSU operated a communications link from the Earthstation and ADVISAR on the Fort Collins campus to the Denver FWS Forecast Office. In this pilot study, "digital" images of a local or statewide forecast region from GOES satellites were sent to and displayed in the WSFO using a minicomputer network. During this period image-and-graphics products were received and interpreted nearly in realtime by NWS forecast personnel in the course of their normal duties. The satellite image products were designed to present the information available in geostationary satellite imagery to the mesoscale forecaster for rapid analysis and more precise prediction. CSU installed and operated the Mobile Display Unit (MDU) at the Denver WSFO by remote control from the CSU ADVISAR from April to September, 1980. The processing and display via this system functioned successfully in test and operational modes during days of significant convective activity until September.

2. THE EARTHSTATION, IMAGE PROCESSOR AND COMPUTER LINK

Figure 1 represents in block diagram from the configuration of the CSU Direct Readout Education and Training Earthstation/ADVISAR Communications Network which supported the image production and data link to the MDU. Using two independent receiving systems, satellite telemetry of radiance signals can be accepted from either of two dish antennae located at the Atmospheric Sciences Research Center (see Figure 2). Data streams coming from the GOES satellite at more than 1 million bits per second are routed through an EMR frame synchronizer/sectorizer which formats the image data from a pre-programmed earth sector into a file that is stored on a 300 Mbyte disk or 1/2-inch magnetic tape. Control of this process is accomplished by a Digital Equipment Corporation (DEC) PDP-11/34 minicomputer which accesses systems utilities as well as extensive specialized software. Although full-earth, full-resolution images can be collected, users (such as the WSFO forecasters) are generally interested in smaller sectors. The system configuration allows disk buffering of many images during a given data collection period and permits immediate availability of recent imagery for display processing and transmission to the remote user site.

Image manipulation and interpretation occurs on the ADVISAR via interactive TTY terminals and a joystick/keyboard panel interfaced to a DEC PDP-11/60 minicomputer (1). ADVISAR uses dynamic random access memories (RAMs) for image storage. It was designed by CSU engineers and built by INTEL. This system contains 64 512 x 512 1-bit planes configured as eight frames with eight 1-bit planes per frame (Figure 3). Thus, eight 512 x 512 - pixel image sectors can be stored simultaneously at eight-bit digital resolution. Time lapse loops of computer generated images of weather sequences may be displayed on the ADVISAR, although in the pilot study only single frames were sent to Denver.

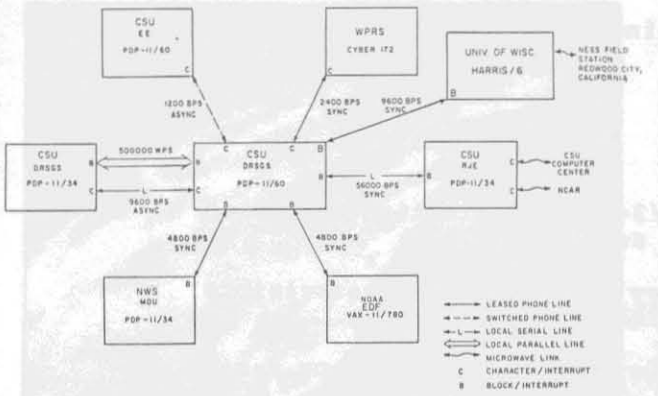

Figure 1. CSU Data Communications Network

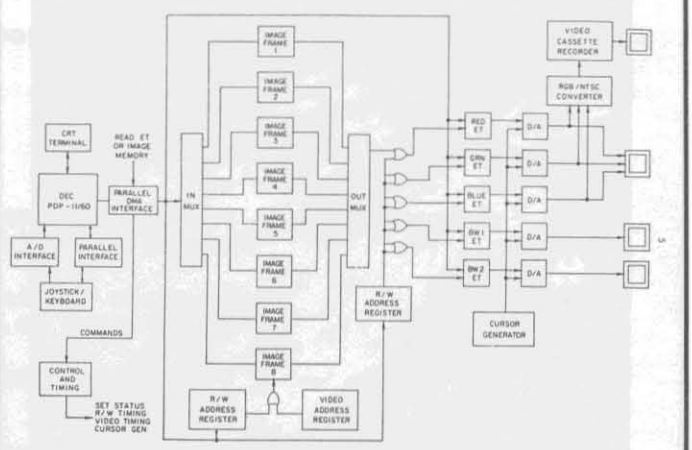

Figure 3. All-Digital Video Imaging System for Atmospheric Research (ADVISAR)

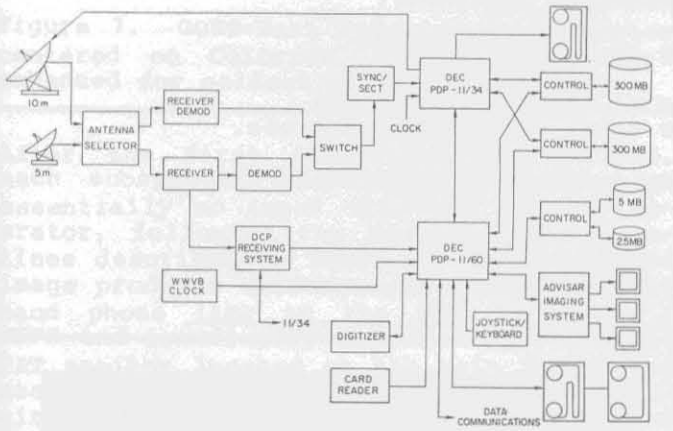

Figure 2. Direct Readout Education and Training Earthstation

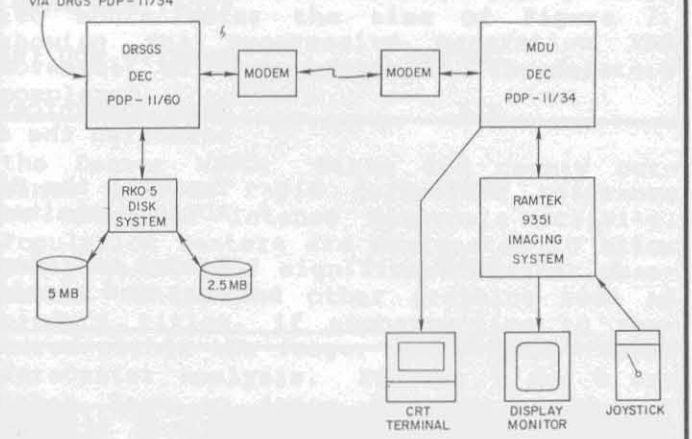

Figure 4. CSU Mobile Display Unit

Image products developed for use at the MDU in the Denver WSFO combined several processing techniques such as grayscale and pseudocolor enhancement, graphic overlays of geopolitical landmarks and boundaries, and simultaneous display of more than one image. A large set of Fortran and assembly-level software was written in order to support product generation at CSU and remote operation of the MDU. Engineers at CSU designed the systems programs to carry out these functions with very little human input necessary. The first satellite image taken on a given day was used in an initialization routine which acted to:

(1) Retrieve the image from the PDP-11/34 disk, display it on the ADVISAR using a routine on the PDP-11/60 and prompt the operator to locate a landmark for image navigation (2) on the PDP-11/60.

(2) Create a navigation directory to be used for all imagery taken during that day.

(3) Prompt the operator for the tropopause temperature obtained from the latest Denver sounding (communicated to CSU by the Denver forecaster).

(4) Initialize the color enhancement table, using T_{trop} as a reference level. This table was used to create an enhancement color bar indicator to be superimposed at the top of each image.

Table 1

MDU Image Processing Procedure

Procedure	Description
TAKEDATA	Program the PDP-11/34 data collection system to record PROFS image sector.
NAVIG	Navigate the imagery and display either visible or infrared on ADVISAR.
REMAP	Default to satellite image projection, or remap to Mercator.
NVPLOT	Plot graphic overlay of states, Colorado counties, cities, highways.
COLOR	Color-enhance infrared images relative to tropopause temperature.
GBAR	Title the image product with time, date, image type; and show enhancement indicator.
DSKTAP	Archive MDU imagery on magnetic tape.
TLK	Open communications to the MDU RAMTEK and establish the color enhancement table for use.
SEND	Transmit the display image as it appears on the ADVISAR monitor.
STAT	Record and display the transmission time, blocks sent and received, the number of line errors.

Figure 5. In-field components of the Mobile Display Unit located at the Denver WSFO during summer 1980. The image-and-graphics color display monitor is controlled by a PDP-11/34 mini-computer (shown below the monitor) from the interactive terminal (to the left of the monitor) and from the remote host computer at the CSU Earthstation.

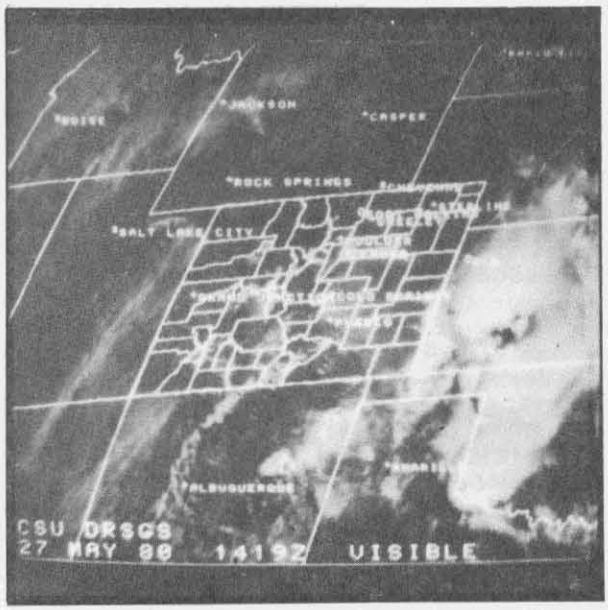

Figure 6. Unenhanced digital image product showing a GOES-East visible satellite photo with a graphic overlay of the image label and geopolitical references.

Figure 7. GOES-East infrared image sector centered on Colorado, selectively color-enhanced for coldest cloud temperatures.

Figure 8. Enhanced infrared imagery taken two hours after the time of Figure 7, showing the progressive generation and movement of late-afternoon thunderstorm complexes.

After the first image set was defined, each subsequent image was processed with essentially no input from the standby operator, following the sequence of subroutines described in Table 1. The generated image products were transmitted via a 4800 baud phone link to the MDU in Denver's WSFO and immediately appeared on the color CRT monitor located at the main forecaster station. During normal operations the digital satellite image products reached Denver and were displayed before they were more than 20 minutes old.

The Mobile Display Unit at the remote site represents a remote extension of the Earthstation/ADVISAR processing system (see Figure 4). Since no tape or disk drives are used at the MDU, all user and systems software are downloaded from the PDP-11/60 disk files on power up. The MDU 11/34 contains 64K words of memory for this software, which controls the CRT, joystick cursor box, and display monitor of the RAMTEK single-frame imaging system (shown in Figure 5). As part of the image processing routine, CSU-resident programs sent display instructions to the MDU computer. Additional manipulation at the MDU after transmission is possible on this type of remote unit and is only constrained by memory space and the hardware configuration of the imaging system in use.

3. EXAMPLES OF THE SPECIAL SATELLITE IMAGE PRODUCTS

Figure 6 is typical of the image products transmitted to and displayed on the MDU at the Denver WSFO. State and county outlines provide rapid forecaster reference to areas of intense mesoscale activity. Population centers are designated to allow early warning of significant weather phenomena. These and other graphics such as product titles, if unobstructive to features within the image, simplify and speed forecaster analysis. Figures 7 and 8 are taken from an image sequence which was used at the MDU to forecast events during a severe thunderstorm and flood threat. The enhanced infrared imagery identifies cells exhibiting strong convective growth, and river basin outlines were used in pinpointing areas of expected heavy rainfall along the Colorado Front Range.

MDU operations at the WSFO demonstrated several types of image products which could be used as input to mesoscale analysis and forecasting. Time sequences of high-resolution visible imagery (Figures 9 and 10) reveal the generation and growth of cumulus congestus, the presence of overshooting updrafts, and the propagation of thunderstorm complexes. Image remapping to Mercator projection allowed direct comparison of the satellite-observed cloud distribution (Figure 11) to radar scans taken by the local Weather Service radar. Image composites such as Figure 12 present the time evolution of both the visible and infrared radiance patterns. Synoptic-scale image products were also transmitted to the MDU in order to aid prediction for the 3-12 hour time frame (see Figure 13).

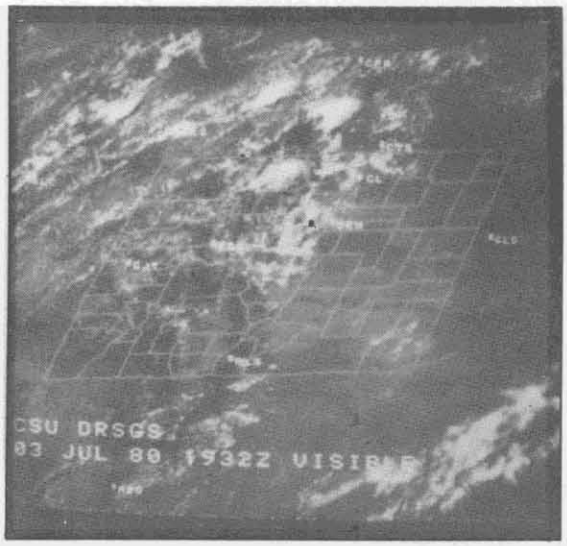

Figure 9. One-kilometer resolution visible image taken at the beginning of a convectively active period over the Front Range of the Colorado Rockies.

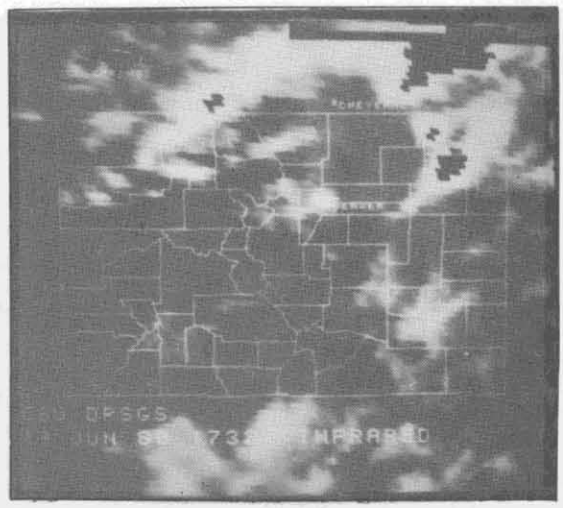

Figure 11. Infrared image and graphic overlay of Colorado county boundaries, both remapped from the GOES-East satellite viewing perspective to a Lambert conformal projection.

Figure 10. Visible imagery recorded and displayed subsequent to Figure 9, in which Cb's have developed into heavy thunderstorms moving rapidly past Denver and Fort Collins.

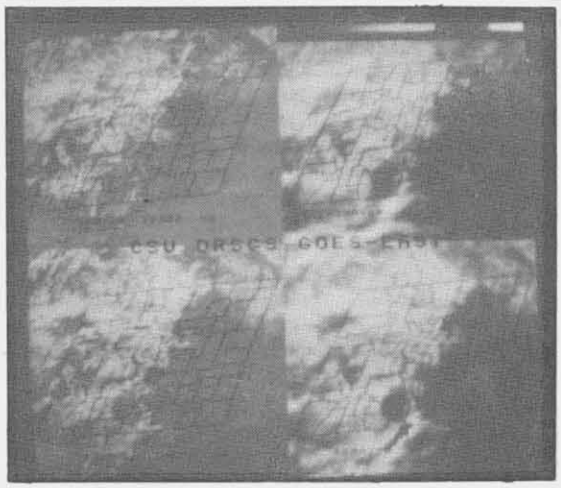

Figure 12. Display composite of time-sequenced visible and color-enhanced infrared images over Colorado and the surrounding region.

Other image products such as radar/satellite composites, motion and vorticity fields, and rainfall contours which are created as single-frame imagery on the host computer can be displayed at the MDU in its stated configuration. More advanced design of such a display unit can be achieved by upgrading the components or processing tasks at either end of the communications network, depending on user needs.

4. SUMMARY

The satellite data product transmission 60 miles from CSU to the WSFO in Denver was a successful demonstration of remote image display capabilities in realtime from a regional reception and processing site. Participant evaluation of the pilot study was favorable and emphasized to contribution of timely image products to mesoscale analysis and prediction. The CSU Departments of Atmospheric Science and Electri-

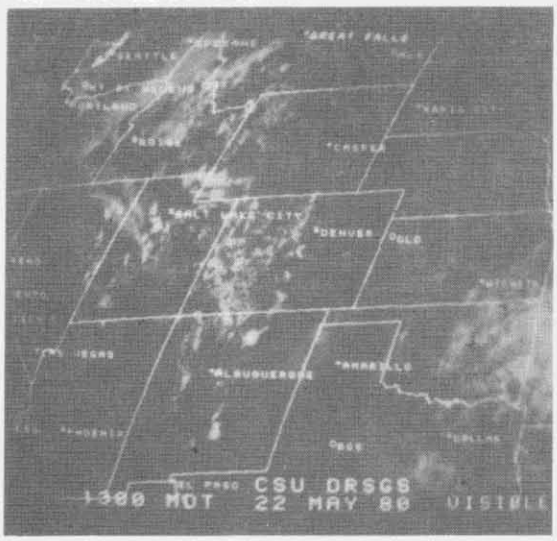

Figure 13. Synoptic coverage of visible radiance patterns which indicate regions of convection to the south and west of Colorado.

cal Engineering continue to support the PROFS Program through development and testing of image-and-graphic combinations which can be applied to raw GOES/VISSR and other data collected at the CSU Earthstation and relayed in realtime to the PROFS Exploratory Development Facility.

5. ACKNOWLEDGEMENTS

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