# THE SATELLITE WEATHER INFORMATION SYSTEM (SWIS) PROGRAM

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***ABSTRACT***

*To use satellite imagery to its fullest potential, the NWS has developed the Satellite Weather Information System (SWIS), which will provide sophisticated capabilities for display and animation of GOES imagery at all Weather Service Forecast Offices (WSFO) and National Centers. The SWIS device will be integrated with the Automation of Field Operations and Services (AFOS) system at field sites and will allow simultaneous display of GOES imagery and numerical guidance products generated at the National Meteorological Center (NMC).*

*SWIS units will be installed in NWS offices beginning in early 1987. All units will be in place by the end of calendar year 1987. The deployment of SWIS should be accompanied by the delivery of a comprehensive users manual and supporting hardware and software documentation.*

*Training in animated imagery interpretation has been developed jointly by the National Weather Service (NWS) and the National Environmental Satellite Data and Information Service (NESDIS) and is being offered through a series of videotapes and a new Weather Service Forecasters Handbook.*

## 1. INTRODUCTION

Satellite imagery data have been a major element in the National Weather Service (NWS) warning and forecast program since the launch of the first Geostationary Operational Environmental Satellite (GOES)* in 1974. GOES Satellite pictures available every 15 to 30 minutes provide excellent temporal coverage of meteorological events, and the view from geostationary orbit provides extended spatial coverage over data-sparse oceanic areas adjacent to North America.

To use satellite imagery to its fullest potential, the NWS has developed the Satellite Weather Information System (SWIS), which will provide sophisticated capabilities for display and animation of GOES imagery at all Weather Service Forecast Offices (WSFO) and National Centers. The SWIS device will be integrated with the Automation of Field Operations and Services (AFOS) system at field sites and will allow simultaneous display of GOES imagery and numerical guidance products generated at the National Meteorological Center (NMC).

This paper describes both the NWS program to acquire and implement the SWIS system at all WSFO's, and plans for its operation and integration with the site AFOS systems at AFOS-equipped Forecast Offices. SWIS will also be deployed at all NWS WSFO's, including the WSFO's in Alaska, Hawaii, and Puerto Rico, that are not part of the AFOS system.

SWIS units will provide the capability to receive, selectively store, display, and animate GOES satellite imagery as well as the capability to transform and overlay AFOS graphics onto the satellite imagery. Integrated AFOS/SWIS units are planned for installation during calendar year 1987. The SWIS system will replace the currently used "GOES FAX" units which produce photographic hard copy of the GOES satellite images transmitted to the WSFO's over dedicated circuits (GOES-TAP) from the Satellite Field Service Stations (SFSS) operated by the NWS.

The SWIS system is designed for unattended operation (24 hours a day, year-round) and can function both as a stand-alone system and as an externally controlled system interfaced to the local site AFOS system. To support the stand-alone (local control) mode of operation, SWIS contains its own display monitor and Local Control Unit (LCU). The LCU functions as a command entry keyboard. Sophisticated display and animation capabilities will enable NWS forecasters to manipulate GOES imagery under locally selected color enhancements, at variable animation rates, and for variable lengths of animation sequences. The integration of SWIS and AFOS will allow the simultaneous comparison of animated satellite imagery with guidance material received from the National Meteorological Center (NMC). The superposition of NMC graphics and extended sequences of satellite images will enable forecasters to track NMC guidance relative to synoptic-scale motions in the atmosphere and to adjust forecasts accordingly. Most importantly, SWIS will help forecasters to identify developments and relationships that are precursors to rapidly developing subsynoptic scale events (e.g., severe thunderstorms).

## 2. HISTORICAL DEVELOPMENT

The use of animation of satellite pictures began in the late 1960's with the advent of NASA's geostationary Applications Technology Satellites (ATS). During that period, distribution of the data was limited to researchers and a small contingent of operational meteorologists at the National Environmental Satellite Center in Suitland, Maryland. In 1974, geostationary satellites of the GOES series were launched, and the distribution of

* See Appendix for definition of acronyms.

both visible and infra-red imagery began with the commissioning of the GOES-TAP system. However, animation of GOES imagery was available only at NESDIS and selected NWS offices where Satellite Field Service Stations (SFSS) were located. These sites included major forecast offices (one in each NWS region) and NWS National Centers.

Since the mid-1960's meteorologists connected with the satellite prograam at NESDIS, the SFSS's and other NOAA facilities have developed the interpretive skills required to relate animated satellite imagery to weather analyses and forecasting. Many wrote articles which documented and explained the correct interpretation of satellite data (3). Many of these articles concentrated on the use of animation to define and quantify specific meteorological features (4) (5). Numerous field seminars and videotapes were offered to train operational meteorologists in the use of animated imagery. These efforts formed the meteorological foundation for the increased use of GOES data in the NWS's weather warning and forecast process. During the coming year, the NWS will implement SWIS and therefore expand the use of animated satellite imagery as a valued forecast tool.

The SWIS Program Development Plan (6) was initiated in 1981 and, in 1982, formal program funding was approved. Development of the SWIS system had already begun in 1980 with the procurement and installation of two prototypes of the Satellite Image Display System (SIDS), which were installed at the SFSS in San Francisco and at National Weather Service Headquarters (NWSH) in Silver Spring, Maryland. By 1983, the NWS and NESDIS staffs at San Francisco, NWSH and the Washington Forecast Office completed their evaluation of the stand-alone SIDS system. Based on the field evaluation, the NWS Office of Meteorology developed functional requirements and the Office of Systems Development prepared system specifications and a formal Request for Proposals (RFP) for the development and production of the SWIS system. During the period 1983-1984, the Office of Systems Development defined and directed the development of user-interface software to support the future integration of the SWIS device with AFOS. This user-interface software was developed by the OAO Corporation of Beltsville, MD under contract to the NWS. The SWIS development/production contract was formally awarded to Alden Electronics, Inc., of Westborough, MA in September 1984. Alden Electronics subcontracted with Environmental Research and Technology, Inc. of Concord, MA for development of all software for the SWIS system, including its interface with AFOS.

In November 1985, environmental testing of the first SWIS unit was completed; in March 1986, functional testing using a simulated AFOS system was successfully completed at Alden's development facility in Massachusetts. The following month, the system was brought to NWS Headquarters and successfully passed formal functional acceptance testing while integrated with an actual WSFO AFOS system. In May, SWIS was moved to the AFOS Integrated Test Bed Facility for extended reliability testing.

It is intended that SWIS be supported by an operational AFOS software release when it is deployed. A contract award for production models was made in August 1986; it provides for delivery of the first twelve systems beginning in early 1987. The field reliability of these first twelve systems will be evaluated prior to full-scale deployment of SWIS. Further production and implementation at a rate of six per month will resume in the Spring of 1987, and full deployment should be completed by the end of 1987.

## 3. FUNCTIONAL ELEMENTS

All SWIS components, except the SWIS-AFOS Interface Hardware (SAIH) Chassis, are housed in the single-rack SWIS console, which is equipped with a workshelf for the LCU and optional graphics tablet. Fig. 1 shows the following SWIS components: Video Distribution Amplifier, Facsimile Input Processor, Color Monitor, Color Control Unit, Local Control Unit, Disc Drive Chassis, and the System Chassis. The SAIH Chassis is housed in an AFOS Communications/Computer Module (CCM) rack.

The SWIS will consist of the following functional elements:

(1) A system controller that interfaces with the GOES-TAP data source and collocated AFOS computer system, and which controls the overall operations of all other functional elements of the SWIS.

(2) A local control unit that provides operator selection of system storage and display operations.

(3) An image storage unit that provides long-term storage of satellite images.

(4) A display subsystem that provides operator viewing of satellite images and overlaid weather contours.

(5) A device that allows automatic scheduling/selection of the available GOES image transmission.

(6) An optional manual graphics input device.

A functional block diagram of the SWIS is shown in Fig. 2. Those elements shown in dashed lines are not part of the SWIS, but the interfaces and connections to them which are shown in solid lines are part of the SWIS and shall be furnished with the sytem. The layout of the LCU used to control SWIS while operating in the local control mode is shown in Fig. 3.

## 4. MAJOR SYSTEM CAPABILITIES

The SWIS system provides NWS forecasters with the ability to:

(1) Automatically Receive, Process, and Store GOES Satellite Imagery.

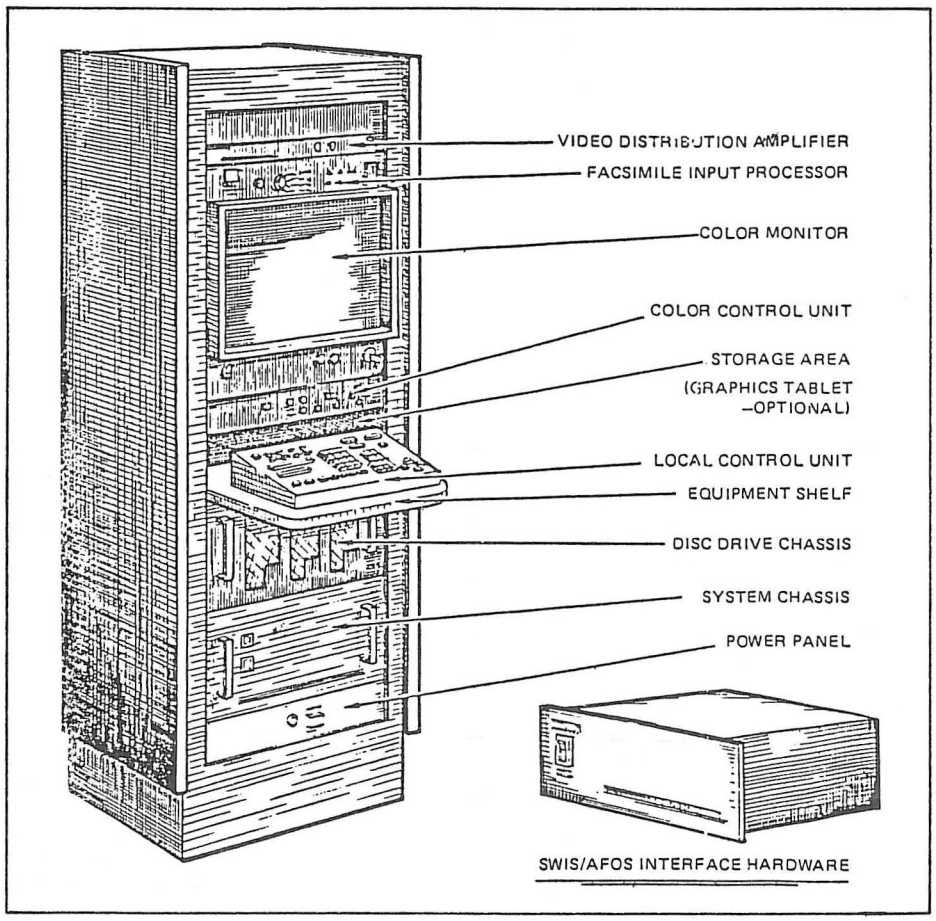


Fig. 1. Diagram of SWIS system depicting the major functional components of a field-deployed unit.

The SWIS system accommodates the automatic processing of images received via GOES-tap lines and their storage in appropriate data-base files. Within each file (defined by a GOES image sector), all images are stored sequentially as they are received. Each image received is stored at a reduced resolution for the full-sector area. This is necessary because the large volume of data inherent in the full-resolution satellite image exceeds the resolution of standard display monitors. As each sector image is acquired and stored, a full-resolution subsector image is automatically generated and stored within SWIS. The subsector image covers a user-defined geographic area approximately one-ninth the size of the full-sector image. SWIS allows the user to define up to six separate full sector files. Each of these user defined sector files has an associated subsector file. Any received image which does not correspond to a pre-determined sector file will be automatically stored in a "floater" file. A total of 400 images may be stored at any time in the sector, subsector, and floater files. The maximum size of any file is 150 images. Each sector, subsector, and floater file image is stored with the appropriate visual header attached so that the header is displayed along with the corresponding images.

Text messages (administrative messages) sent over GOES-TAP are also automatically recognized upon receipt, processed, and stored in a separate message file. Up to three text messages can be stored. A file for storage of up to 20 AFOS graphic products is also provided. For all files, new product inputs will replace the oldest products currently in the file when the file capacity is reached.

(2) Request Specific Images From the SFSS.

Satellite images for display on the SWIS system come from the GOES-TAP distribution system. This system has an existing set of procedures for transmitting facsimile format images and receiving request messages from users over four-wire leased telephone lines. A user-programmed scheduler for automatically requesting images from the GOES-TAP is included with each SWIS unit and is an integral part of the LCU. The SWIS user may select from a menu of images currently available from each Satellite Field Service Station (SFSS) at 30-minute intervals throughout the day. The SWIS scheduler contains 96 time slots which will accommodate the eventual upgrade of SFSS image transmissions to 15-minute intervals.

(3) Automatically Sort and File GOES Sectors by Sector ID, Image Type (Visible/Infrared), and Enhancement Curve

GOES image sectors are transmitted in alternating visible and infra-red format by day and

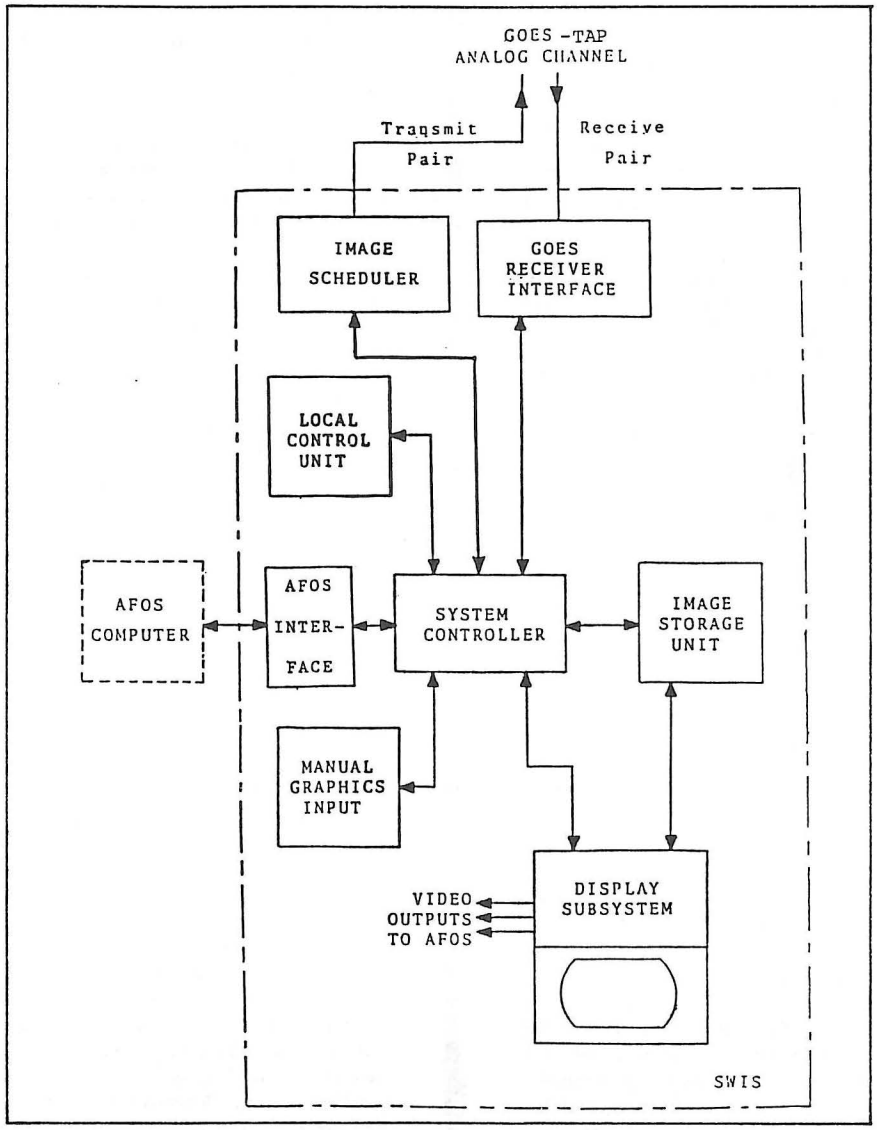


Fig. 2. Block Diagram showing the interfaces between the functional elements of SWIS.

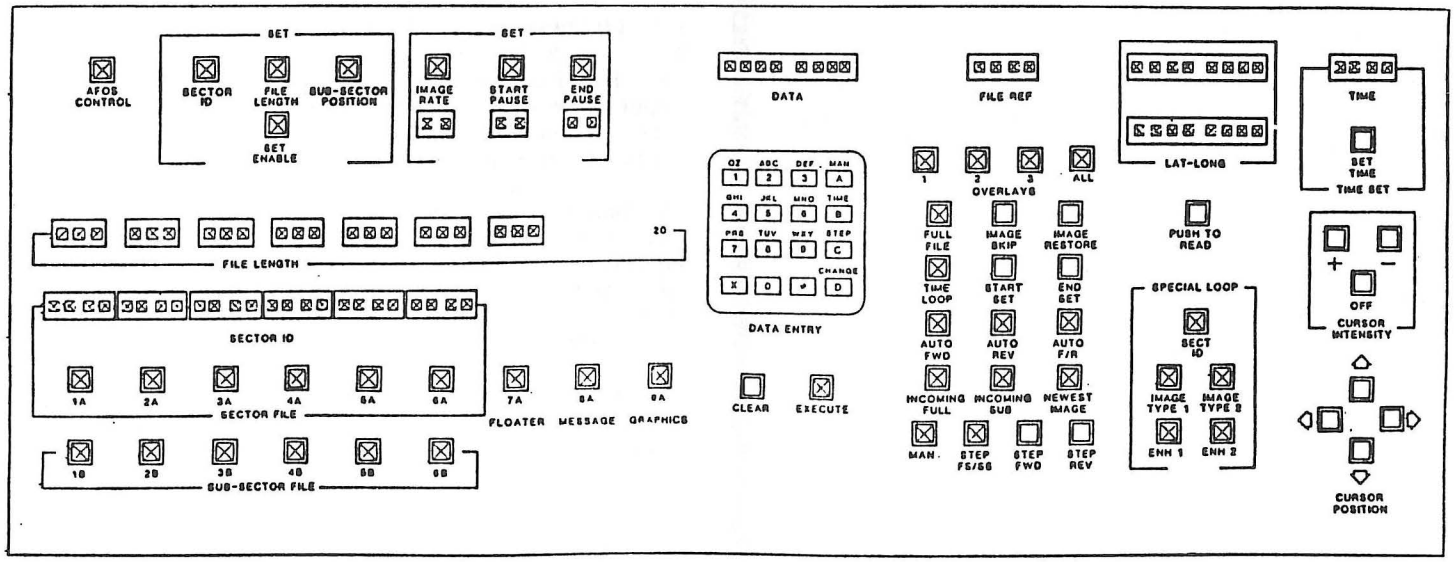


Fig. 3. Local Control Unit depicting push-button keys used to operate the SWIS system.

only in infra-red by night. Often several enhancement curves are used at night. SWIS will automatically sort and file incoming images by sector ID, image type, and enhancement curve. These unique or "Special" image files are then available for animation as "Special" image sequences.

(4) Display Stored GOES Images Singly or as Operator Selectable Loops

The SWIS is capable of displaying animated (time lapsed) sequences of imagery. The SWIS supports both the operator-specified sequencing in a manual mode or in an automatic mode at selectable, incremental, frame rates of 1-6 frames per second. The operator can also view the incoming image as it "builds" on the display, either in the full-resolution subsector or lower resolution full-sector modes. The length of image sequences is variable and can range from as few as two to as many as 150 images. Animation can be run in the forward, reverse, or alternating forward-reverse directions.

(5) Display GOES Images in Operator-Selectable Color

SWIS has the capability of mapping the incoming data containing 256 gray levels to as many as 192 levels of color (6 primary colors of 32 shades each) and 64 gray-tone values ranging from full black to full white. The operator can selectively define these colors to any of the 256 gray scale values or any range of values. In short, instead of being limited to a particular enhancement curve, forecasters can create as many as 16 of these user-defined color enhanced "curves" that can be recorded and stored within the SWIS unit. The operator can view any sequnce of images with any of the stored enhancement curves applied. In addition to the use of color for the display of the imagery, the operator is able to select any of the colors for each of the three graphic overlay planes. (See section 4.7 which follows, for more detail on the overlay capability). Also, the operator can erase all color and display the original gray-scale image.

(6) Interface With the AFOS System

The SWIS system has an interface to a Direct Memory Access (DMA) channel of the collocated AFOS Data General Eclipse S230 computer system to accommodate all communications and data transfers between AFOS and the SWIS device. This DMA interface is used for communicating control commands to SWIS when the AFOS keyboard has control and for transferring graphic products between the SWIS device and AFOS.

There are three elements of the interface:

- o SWIS-to-AFOS Interface Hardware (SAIH) Chassis
- o SWIS/AFOS User Interface Software
- o SWIS Device Driver Software

The SAIH is capable of transmitting data in either direction between the SWIS device and the AFOS Eclipse in blocks of up to 512 bytes, at data rates in excess of 1 Mbyte/second. Housed in an AFOS rack, the SAIH is connected to the SWIS unit by cables up to 50 feet in length.

The SWIS/AFOS User Interface Software controls the SWIS display and animation functions via AFOS commands entered by the user at an AFOS console. This capability supports the display of satellite imagery on any of the AFOS Graphics Display Modules (GDM). To provide this capability, new AFOS commands have been incorporated into the latest field software.

The SWIS Device Driver Software supports the exchange of commands and information between the two systems through the DMA channel. Device driver software resides in both the AFOS Eclipse and one of the three SWIS microprocessors (Motorola 68000).

(7) Receive, Transform, and Overlay AFOS Graphics

The SWIS device can receive AFOS graphics and transform them from their polar stereographic coordinate system into the GOES coordinate system, store them in a graphics file in the SWIS data base, and send the transformed graphics back over the interface to AFOS for storage. The graphics stored in the SWIS may be overlaid simultaneously on the SWIS satellite image display.

(8) Display the True Earth Coordinates of Selected Image Points

The SWIS device includes a moveable cursor that can be positioned by the operater anywhere on the displayed image. This allows for the exact position determination of features of interest. The cursor coordinates are converted by the SWIS device, upon user command, to Earth coordinates (latitude and longitude) and are displayed to the operator. These coordinates can be used as input data (on a separate computer) to calculate motion vectors.

(9) Provide for Entry of Manual Graphics

This function requires an add-on manual graphics input tablet that may be added to any SWIS unit. The graphics tablet will be provided on all SWIS units at collocated WSFO/SFSS sites for creation of derived graphic products. These manually generated graphics may be stored in the SWIS graphics file and transferred for storage to the connected AFOS system if so desired. Before being sent to AFOS, the manually entered graphics are automatically converted by the SWIS processor to polar-stereographic coordinates and AFOS projections.

Manual graphics capability allows the SWIS manually produced graphics (depicting meteorological features evident in the satellite imagery) to be displayed on AFOS in polar-stereographic projection. These derived products may be transmitted to other sites on the AFOS network if desired. Conversion to polar-stereographic coordinates accommodates comparison of the satellite "image" with NMC analyses and guidance material at

an AFOS console. Thus, manually generated graphics can be transmitted to WSO sites which have no other access to satellite imagery.

The layout of the graphics tablet is shown in Fig. 4. The tablet provides for the entry of lines, contours, text strings, and special weather symbols.

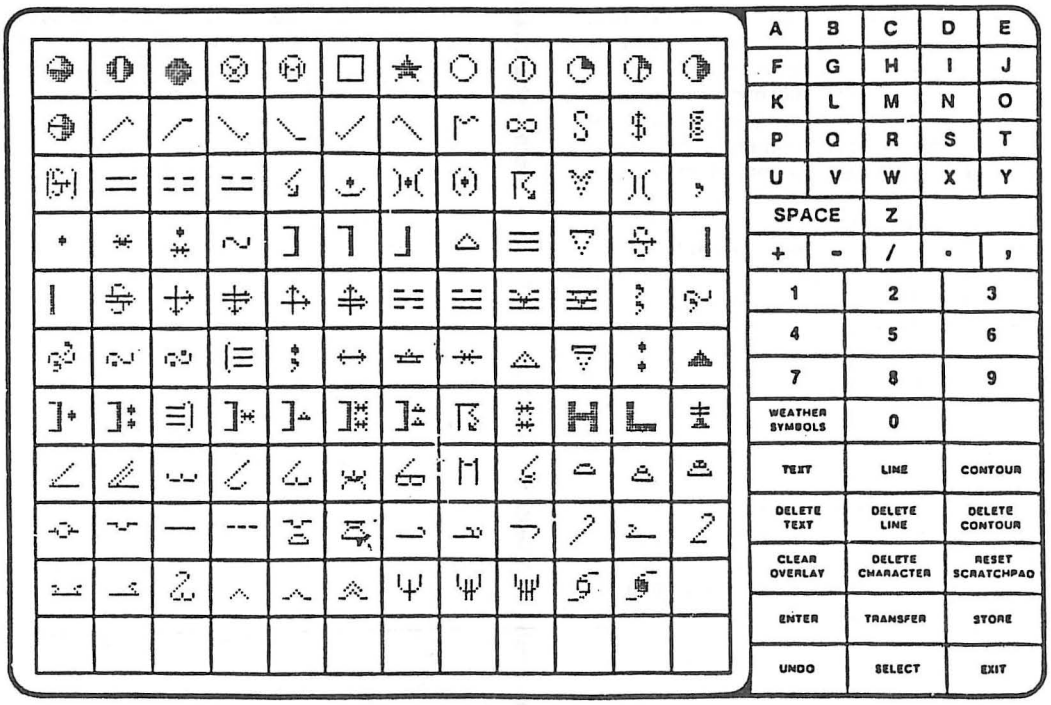


Fig. 4. GRAPHICS ENTRY TABLET depicting functional capabilities (lower right) and all alpha-numeric and special weather symbols available for character entry.

## 5. METEOROLOGICAL TRAINING

As with all new systems, field personnel must be trained not only in system operations but also in techniques for properly interpreting this new data source. Imagery animation and graphics overlay capabilities will present forecasters with a powerful new tool for monitoring the development and motion of convection and other local phenomena such as fog and wind shear lines. The NWS is placing increasing emphasis on severe-weather warning functions. Mesoscale weather events e.g., severe thunderstorms, tornadoes, and local fog, are among the major causes of loss of life and property from weather-related accidents.

The NWS and NESDIS have jointly developed a training program on satellite imagery interpretation with emphasis on imagery animation. The program has two components: a handbook on imagery interpretation and a collection of videotapes depicting various aspects of imagery analysis. The handbook entitled NWS Forecasting Handbook #6, "Satellite Imagery Interpretation for Forecasters" is a collection of 56 papers divided into eight chapters. Each chapter covers a unique meteorological phenomenon (e.g., basic interpretation, synoptic-scale analysis, convection, and fog and stratus). Most of the individual papers have appeared in publications such as the AMS Bulletin, AMS Conference Preprints, or the NWA Digest and have been carefully and critically reviewed for operational relevancy by members of the NWS and NESDIS satellite community before inclusion in the handbook. Copies of the handbook have been distributed to all WSFO's and National Centers in the NWS, and to numerous Air Force and Navy Weather/Oceanographic Units. The handbook is available to the general public through the NWA's Monograph 2-86.

The second component of the training program is a collection of 20-30-minute NESDIS-developed videotapes; four tapes, distributed in the summer of 1986, address basic cloud identification, tropical upper-air vortex motion, fog and stratus identification, and absolute/relative cloud motions. The tapes supplement two others which depict the initiation of convection and thunderstorm outflow boundaries from the satellite perspective. Other tapes covering synoptic and mesoscale frontal analysis and other topics will be developed and distributed in 1987 and later years.

During 1987, the NWS will develop a correspondence course based on both the handbook and videotapes. A series of lessons each reviewing a specific chapter and/or videotape will be developed and distributed to NWS forecasters. As with other NWS courses, e.g., pilot weather briefing, hydrological services, radar, etc., formal recognition for course completion will be offered.

## 6. SUMMARY/CONCLUSION

The SWIS/AFOS System will give the operational meteorologist the capability to combine satellite imagery with NMC guidance data and effectively apply that combination to NWS warning and forecast programs. By incorporating imagery animation, graphic overlays, and flexible enhancement features, the forecaster can view and analyze the broad synoptic patterns as well as the mesoscale events. These capabilities will improve the decision-making process. Effective continuing training of each forecaster is essential to the realization of this goal.

The SWIS system is designed for field use and represents a careful balance between flexibility and ease of operation. Long-term operation is assured by acquisition of extensive documentation material including hardware maintenance manuals, extensive software documentation, and operations manuals which will support field operations into the AWIPS-90 era.

## ACKNOWLEDGMENT

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## *NOTES AND REFERENCES*

*1. Michael T. Sikorski has held a variety of technical development and engineering management positions since joining the National Weather Service (NWS) in 1972. During the period April 1981 - July 1986, he was the SWIS development project manager within the Office of Systems Development and was responsible for the definition, development, and acquisition of the SWIS system. He is currently the Chief of the Communications Division of the NWS. Prior to joining the NWS, he held systems engineering positions with Westinghouse Electric Corporation, Vitro Laboratories, Computer Sciences Corp., and the Department of the Navy. He holds BSEE and MSEE degrees from Drexel University And the University of Pittsburgh, respectively.*

*2. Michael T. Young held meteorological intern positions in Chicago, Honolulu and Washington. He served as a forecaster with the U.S. Army's Meteorological Support Activity, Ft. Huachuca, Arizona, and managed the cloud motion winds program at NESDIS from 1974 to 1980. He developed the functional requirements for SWIS and is responsible for related training in imagery interpretation. He is a former AFOS instructor and is currently the Satellite Program Leader in the National Weather Service. He holds a B.S. in meteorology from Penn State.*

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## APPENDIX

AFOS - Automation of Field Operations and Services

AMS - American Meteorological Society

ATS - Applications Technology Sattelite

CCM - Communications/Computer Module (AFOS)

DMA - Direct Memory Access

GDM - Graphics Display Module (AFOS)

GOES - Geostationary Operational Environmental Satellite

GOES-TAP- Distribution of GOES Imagery via Telephone Line

LCU - Local Control Unit

NESDIS - National Environmental Satellite, Data, and Information Service

NMC - National Meteorological Center

NWA - National Weather Association

NWS - National Weather Service

SAIH - SWIS to AFOS Interface Hardware

SFSS - Satellite Field Services Stations

SIDS - Satellite Image Display System

SWIS - Satellite Weather Information System

WSFO - Weather Service Forecast Office