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APPENDIX 4

A SATELLITE FROST FORECASTING SYSTEM FOR FLORIDA

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A SATELLITE FROST FORECASTING SYSTEM FOR FLORIDA

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INTRODUCTION

The first of two minicomputers that are the main components of the Satellite Frost Forecast System (SFFS) was delivered in July of 1977 (Bartholic, 1977). SFFS has evolved appreciably since then (Woods, 1977; Sutherland and Bartholic, 1977; Bartholic and Sutherland, 1978; Woods, 1979; Sutherland, et al., 1979; Martsolf, 1979, 1980a,b,c,d; Gaby, 1980; Sutherland, 1980; Barnett, et al., 1980). A geostationary operational environmental satellite (GOES) system provides the satellite data [SMS-2 (synchronous meteorological satellite) a prototype for the GOES became the operational `east bird´ at 75 W in April of 1980; Schnapf, 1980]. This past frost season, 80-81, marked the fourth winter in the development of SFFS. The freeze of January 12-14, 1981, was documented by the system and increasing interest in potential of such systems (Brandli, 1981). Two major changes took place during these four years of development. One is that the satellite data is now acquired digitally (from NOAA/NWS in Suitland, MD; see fig. 1), rather than by redigitizing the GOES-Tap transmissions. Secondly, the data acquisition has been automated, i.e. the computers are programmed to operate the system with little, if any, operator intervention.

THE CURRENT SYSTEM

1. Computers

Figure 1 describes SFFS in block diagram as it was operated during the 1980-81 frost season. The system is operated by one of two minicomputers which acquires the data necessary to form the SFFS products automatically. A NASA-owned computer located at the NOAA/NWS Weather Forecast Office (WFO) at Ruskin, Florida, served as the main computer

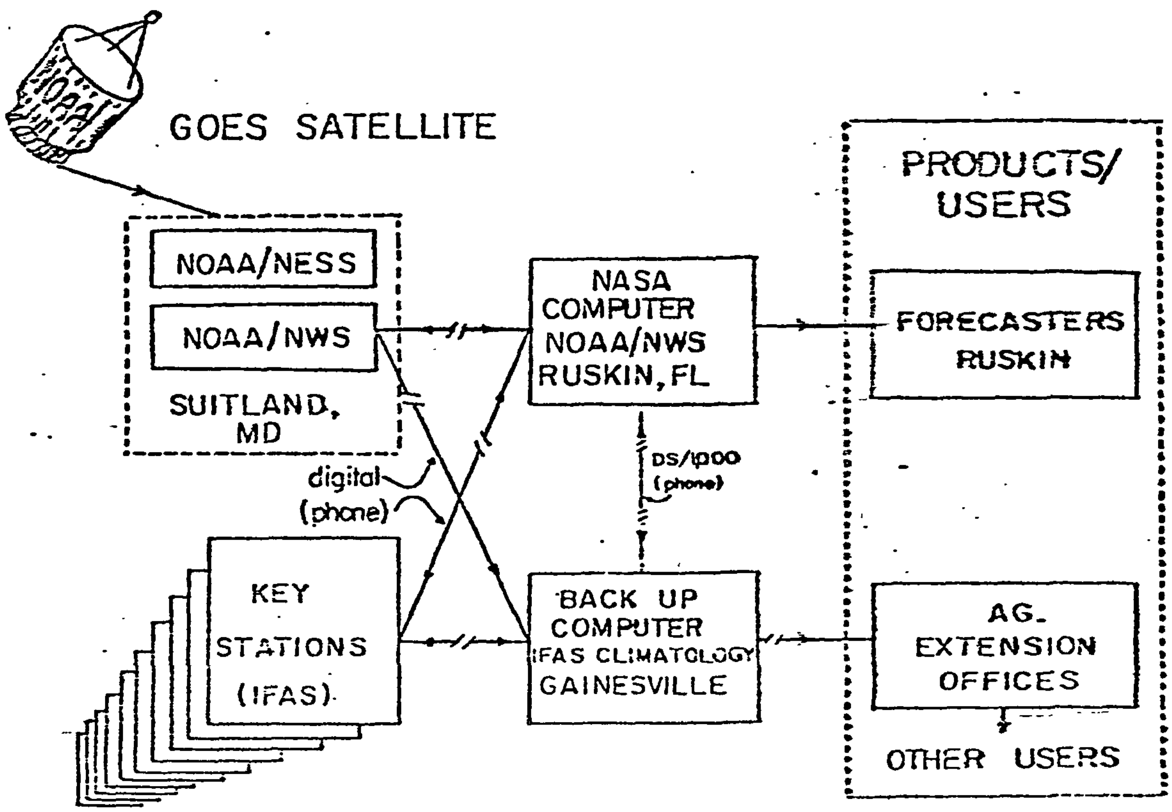

Fig. 1. Block diagram of SFFS indicating satellite digital data acquisition by phone link with NOAA/NWS-NESS in Suitland and links with 10 automated weather stations in Florida, the two computers linked by DS/1000 (a distributed system) that automate the acquisitions and process the data into products for forecasters at Ruskin, FL and for other users through Agriculture Extension offices.

with a similar machine located in the Climatology Laboratory of the Fruit Crops Department, IFAS, University of Florida, Gainesville, Florida, serving as a back-up machine.

The minicomputers are Hewlett-Packards (HP Series 1000) having RTE-IVB operating systems, and connected as a distributed system (DS/1000). The Ruskin machine is a model 2112 with 192 Kbytes of memory and accessing a 15 Mbyte disc (HP Mdl. 7905). The Gainesville machine is a model 2113 with 256 Kbytes of memory and accessing 2 each 5 Mbyte discs (HP mdl. 7900) with a third to be added in the near future. Both systems are controlled through CRT terminals (HP 2645A's) and store data on magnetic tape (800 BPI, HP Mdl 7970B). The major products are displayed on 15 inch Conrac Red-Green-Blue (RGB) Monitors, i.e. color TV displays. Automated use of telephone connections, both 300 and 1200 Baud is accomplished through a Vadic multiple chassis housing both auto-dialers and modems (Mdls 801, 305, 3415).

2. Satellite Data Link

Initially, GOESTAP analog data arriving at Ruskin WFO via Miami was redigitized to provide the satellite data input to SFFS, but planning to obtain the digital data was in progress during the first year of development (Bartholic, 1977).

During the third frost season, the development of a special driver made computer-to-computer communication between the SFFS HP's and NOAA/NWS's IBM's possible. SFFS auto dials a Vadic 3467 modem at NOAA/NWS (supplied by SFFS at first but now by NWS) in Suitland. Upon connection the SFFS computer interrogates a particular storage queue assigned by Mr. Arthur Bedient, Chief, Automation Div., NOAA/NWS. Previous to this step an NWS batch-mode program must have interrogated a large disc file (4 ea Mbyte discs) known as the VISSR Data Base (VDB; VISSR = Visible Infrared Spin-Scan Radiometer) via an IBM 360/195 (NOAA uses 2 with a third as a back-up) to select the Florida sector from the entire hemisphere of infrared data and pass it into SFFS's queue. The VDB must contain the particular VISSR data for the hour in question for the NWS program to be successful.

The VDB is filled by a batch-mode program on the IBM 360 that passes the satellite data from 22 Mbyte staging disks located in Wing 1 of FOB-4 near the 7-m dish antennae. Collecting the stretched VISSR data by antenna and processing it into the VDB are operations under NOAA/NESS jurisdiction (Waters and Green, 1979). Building the output

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queues for clients such as SFFS, i.e. the Florida Sector, is a responsibility of NOAA/NWS. During the 1980-81 frost season the staging disks sustained head crashes during a period when GTE was on strike and the VDB had to be filled by manually transferring 9-track 1600 BPI magnetic tapes from the VISSR Ingest Computers (GTE IS1000's) to transports serving the IBM 360's. Therefore, during the 80-81 frost season SFFS was successful in acquiring the sectorized satellite data in only 63% of its attempts. When the data were acquired, it was often 4 to 6 hours delayed during the early evening when the system is dependent on timely data to make convincing forecasts. Since the staging disks have been repaired and the data are transferred automatically (but by batch-processing) to the VDB, the reliability of map presence has not greatly increased nor has the delay decreased. Consequently, direct access to the satellite has been investigated. Sufficient insight was developed to suggest that the reception of the stretched VISSR data by large numbers of users was the dissemination method envisioned by the satellite's designers. Progress toward the procurement of an antenna system will be reported under a later section.

3. Automated Weather Stations

Initially these ground stations were manned by volunteers (in most cases). There were a dozen key stations selected to represent peninsular Florida in locations in which volunteers could be obtained to read and report the sensings. At the beginning of the third frost season 10 remaining stations were automated by the addition of microprocessors manufactured by Darcom.

The microprocessor controlled data acquisition systems that automate the key stations are Darcom model D303's. They are capable of interrogating up to 8 analog channels and totalizing on 2 additional six-digit electronic counters. These pulse counters can be remotely set to average the inputs over 7.5, 15, 30, or 60 minute intervals. They can be programmed to reveal the total as well as the rate over the selected time interval. These units were designed for, and have been extensively used by, gas line companies to monitor flow through pipelines by telephone. They have a built-in modem that for its cost handles the telephone communications very well. The Darcom Remote Terminal Units (RTU), as they are termed, are used at the key stations to accumulate counts from light chopper anemometers, and to scan 6 levels of thermistor sensed temperatures, a net pyrradiometer, and a reference voltage (see fig. 2).

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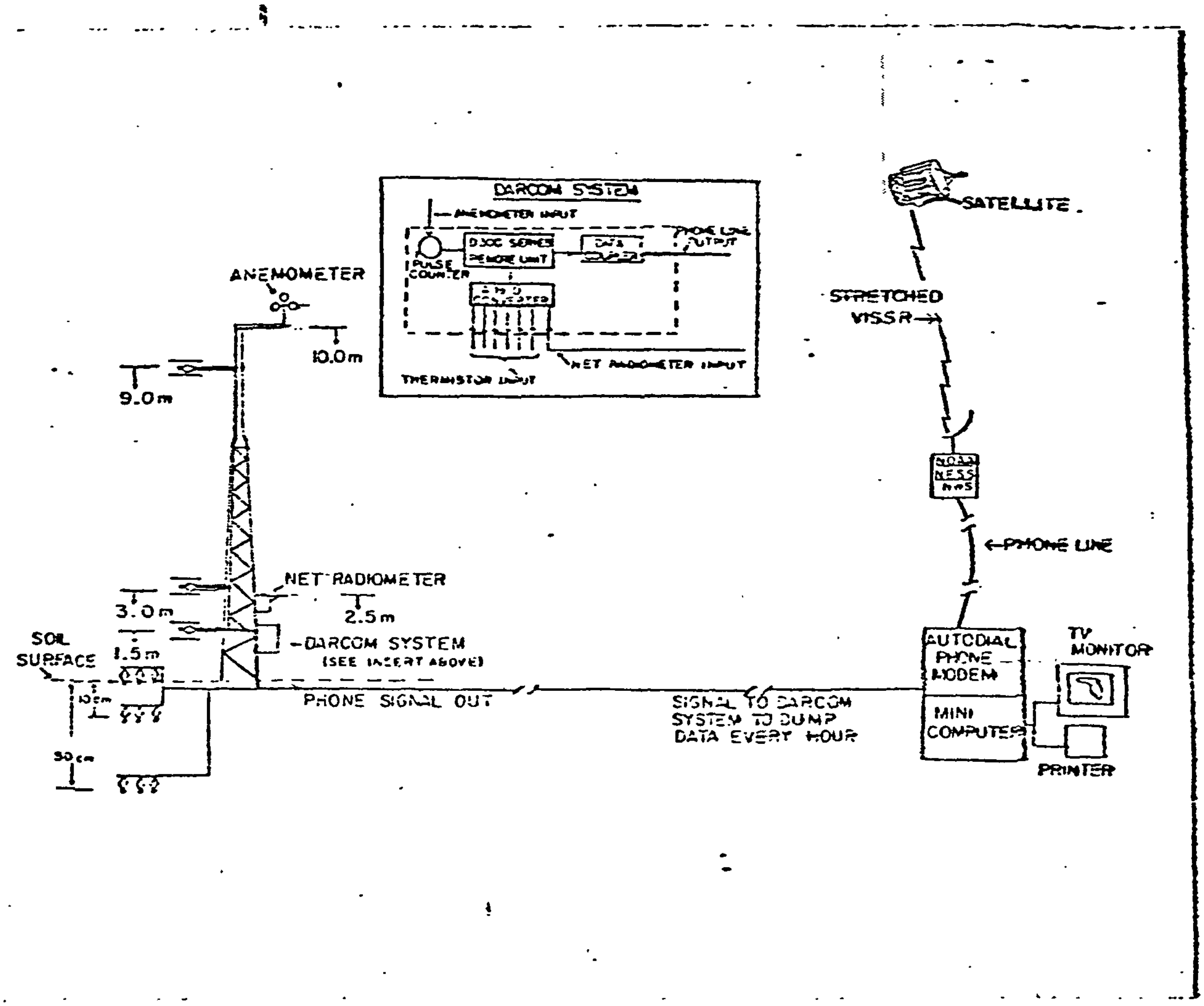

Fig. 2. Diagram of SFFS showing data acquisition links and featuring details of automated link with 10 surface weather stations scattered over peninsular Florida.

Table 1. List of key stations serving SFFS indicating their location and affiliation.

No.	Station	Location	Affiliation
1	Tallahassee	Airport	NWS
2	Jacksonville	Airport	NWS
3	Gainesville	Horticultural Unit 5 miles NW of Gainesville	IFAS/Fruit Crops
4	Tavares	Agr. Extension Center Rural, SW of Tavares	IFAS/Extension
5	Ruskin	Site of	NWS
6	Arcadia	Radio Station	Private
7	West Palm Beach	Airport	NWS
8	Belleglade	Branch Experiment Station	IFAS/AEC
9	Immokalee	Branch Experiment Station	IFAS/AEC
10	Homestead	Branch Experiment Station	IFAS/AEC

During a frost night they are scanned once per hour by one of the SFFS HP's by a fairly elaborate software package that checks to see if the station has been successfully interrogated. If not the computers tries to call the key station several additional times (a variable set by the operator) and then if unsuccessful, uses a substitution table or prearranged calculation to substitute information, while leaving a message for the operation that such a substitution has been necessary. This past frost season the key station data was acquired on 95% of the tries with most of the failures caused by chance phone line routing that resulted in very noisy lines. Regular voice grade lines are employed for these interrogations.

Seven phone companies are involved in providing the service. While these companies are required by law to provide similar service from place to place, experience with troubleshooting problems has revealed a variety of attitudes and policies regarding such service. For example, a problem developed when the Ruskin system began to interrogate the key stations (the Gainesville system had handled them during the development stage). Apparently, problems with crank calls in the Tampa Bay area had caused the phone company to hold lines open when one party hung up while the other held long enough for a trace. The procedure treated our Darcoms as a crank caller and prevented the system from completing additional calls until the rather long timeout occurred. A software change in our procedure corrected the problem relatively easily after it was isolated. But tracing problems through phone companies can not only be time consuming but quite frustrating.

Figure 2 diagrams the instrumentation on the key stations, the microprocessor controlled data acquisition system automating the station and the acquisition links that the SFFS uses to acquire the ground weather data and the satellite data used to construct the output products.

Initially, the key stations used thermocouples (copper-constantan for temperature measurement) but when they were automated in 1979, a switch to locally available thermistors (Atkins Technical, Gainesville, FL; Type 3) was made. To reduce cost, the bare thermistor beads were purchased and encased in epoxy. In 1980 the procedure was modified to increase the time constant of the sensor and its spatial integrating character by potting it in a 3.2 in length, 1/4 in diameter copper tube. The air temperature probes (3 each at 1.5m, 3.0m and 9.0m) are shielded by circular painted plywood shields (5in. dia., 1/4 in. thick) on both top and bottom. The sensor and the shields are horizontal with about 1.2 inch clearance between the shields where the natural airflow aspirates the copper-clad thermistor sensor. The same sensor configuration is used for 3 ea soil temperature measurements (surface, 10cm and 50cm in depth) except that three sensors are connected in series and enclosed in a 10 inch long copper tube to provide better spatial integration. The location of these thermistor sensors is indicated in Figure 2 but the indication of a bead thermocouple junction is an unfortunate carryover in the diagram from the first two years of SFFS operation when the manually operated key stations utilized thermocouples. Please recall that these stations are designed to operate at night only. Their purpose is more to demonstrate the procedure than to be accepted as a solution to an automated weather station for multiple uses.

The anemometer at each key station is 10 meters high. It is a Gill 3-cup light-chopper anemometer (Model 12202D, R. M. Young) which has been modified to avoid spurious counts from light scattered around the shutter and to effect a more reliable interface with the Darcom counting circuitry. Major changes involve the substitution of a GE silicon/Darlington Photo detector (Type L- 14-F1) and a IR Emitter (Type LED-55B). Currently the averaging period for the wind data is one hour but the Darcom has options for shorter periods. A shorter period is likely to be utilized in the future.

The measurement of net radiation at the key stations remains a troublesome problem. Early in the development of the key stations, shielded net pyrradiometers (Swissteco's) were used at 4 of the key stations. Covers (removable shields) were used to protect the polyethylene domes during non-frost periods but the need to manually remove and replace these was inconsistent with the automated concept. Properly maintained, the Swissteco's are excellent instruments but without such maintenance their outputs are less convincing. This past season an attempt was made to substitute ventilated net pyrradiometers that were on hand but in need of refurbishment. Delays and errors in the refurbishment process by the current vendor of the Gier-Dunkle type ventilated net radiometer precluded their use during the frost season. Tests with the delayed instruments have resulted in their return to the factory. If the ventilated net radiometers fail to provide sufficiently reliable sensings of the net radiant loss from the surface, there are several contingency plans under consideration. Several involve the development of a simple sensor that will in effect detect the presence of clouds or very moist atmospheric conditions. Others involve the use of the infrared satellite data.

4. System Products

The primary product of SFFS are a series of color-coded maps, often termed thermal maps, displayed on the Conrac color monitors located in Gainesville (the development system) and in Ruskin (the operational system). These products fall into two categories: observed maps and predicted maps. A scheduling program provides the operator with an opportunity to exercise options by modifying instructions when initiating SFFS operation. Once started (scheduled) SFFS operates on previous instructions, unless there are changes. Normally, one observed map and three predicted maps are displayed as the generating programs complete their construction during each hour of the system's operation. The scheduling program looks in an answer file for its instructions concerning the options. For example, the rather broad range of temperatures from 13 F to 50 F is often chosen for the initial thermal map display to assure complete coverage of the data. The operator then has the opportunity to request the system to refine the temperature resolution of the display by requesting a narrower temperature range.

In addition to flexibility in the temperature range per color, the operator has options in the type of presentation, e.g. split screen permitting comparison of two thermal maps side by side, or the enlargement of a particular portion of the screen (see figures 3 and 4). With a little practice the user can slice the temperature range into appropriate increments that reveal isotherms of temperatures near critical values in the forecast or for plant damage.

The big freeze of January 13-14, 1981, revealed that secondary products from the system were also in demand. Figure 5 is a copy of the printout of the so-called "symbols map." A translation table has been added that permits the

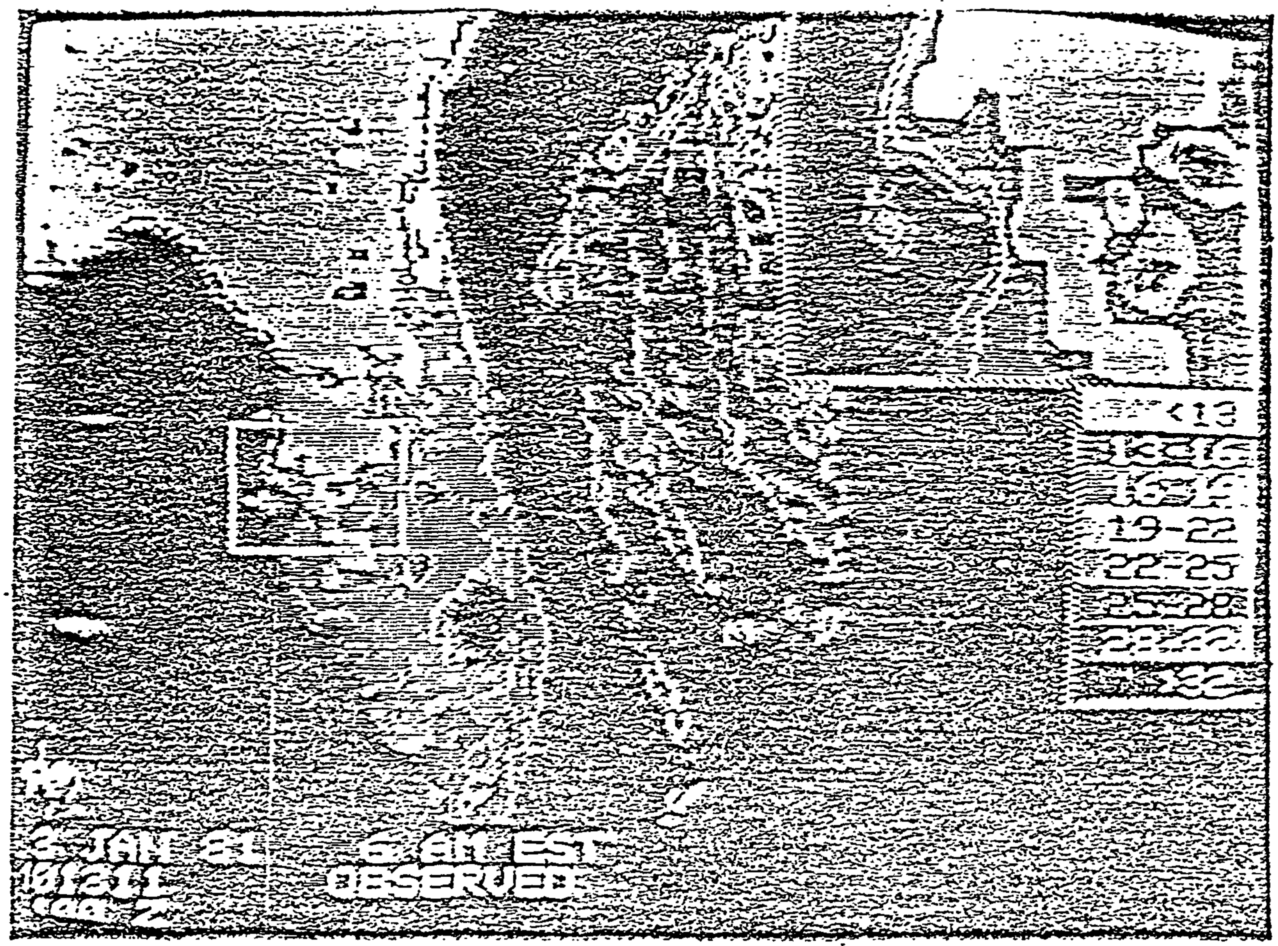

Fig. 3. Black-and-white print of the color-coded thermal map that is the primary product of SFFS. This view demonstrates the enlargement capability available to the operator through which he is able to control both the size of the box (multiplication factor) and its location on the peninsula.

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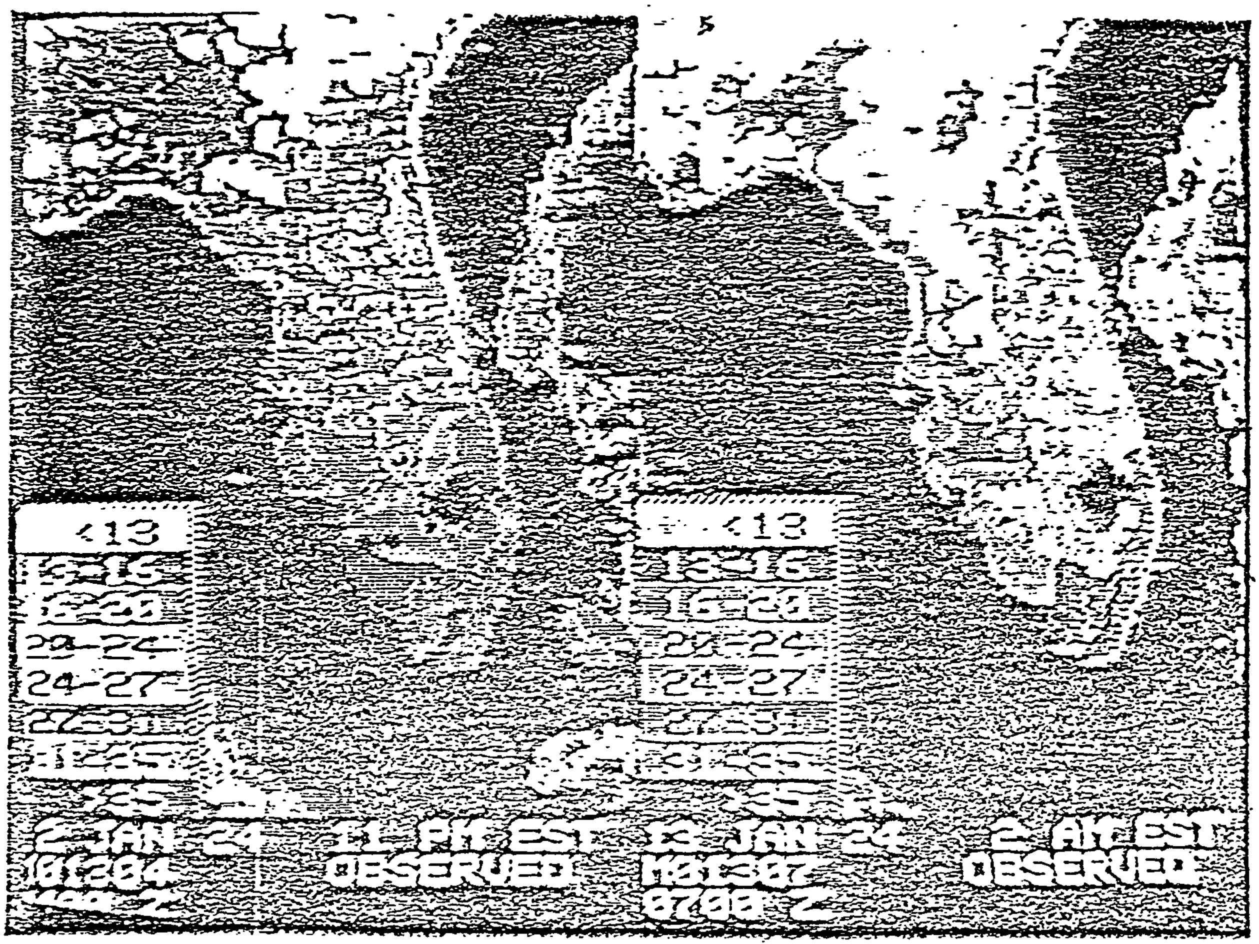

Fig. 4. Black-and-white representation of the color SFFS product demonstrating the split screen option. The operator may bring up for comparison any previously archived map for a side-by-side view of the thermal pattern similarity.

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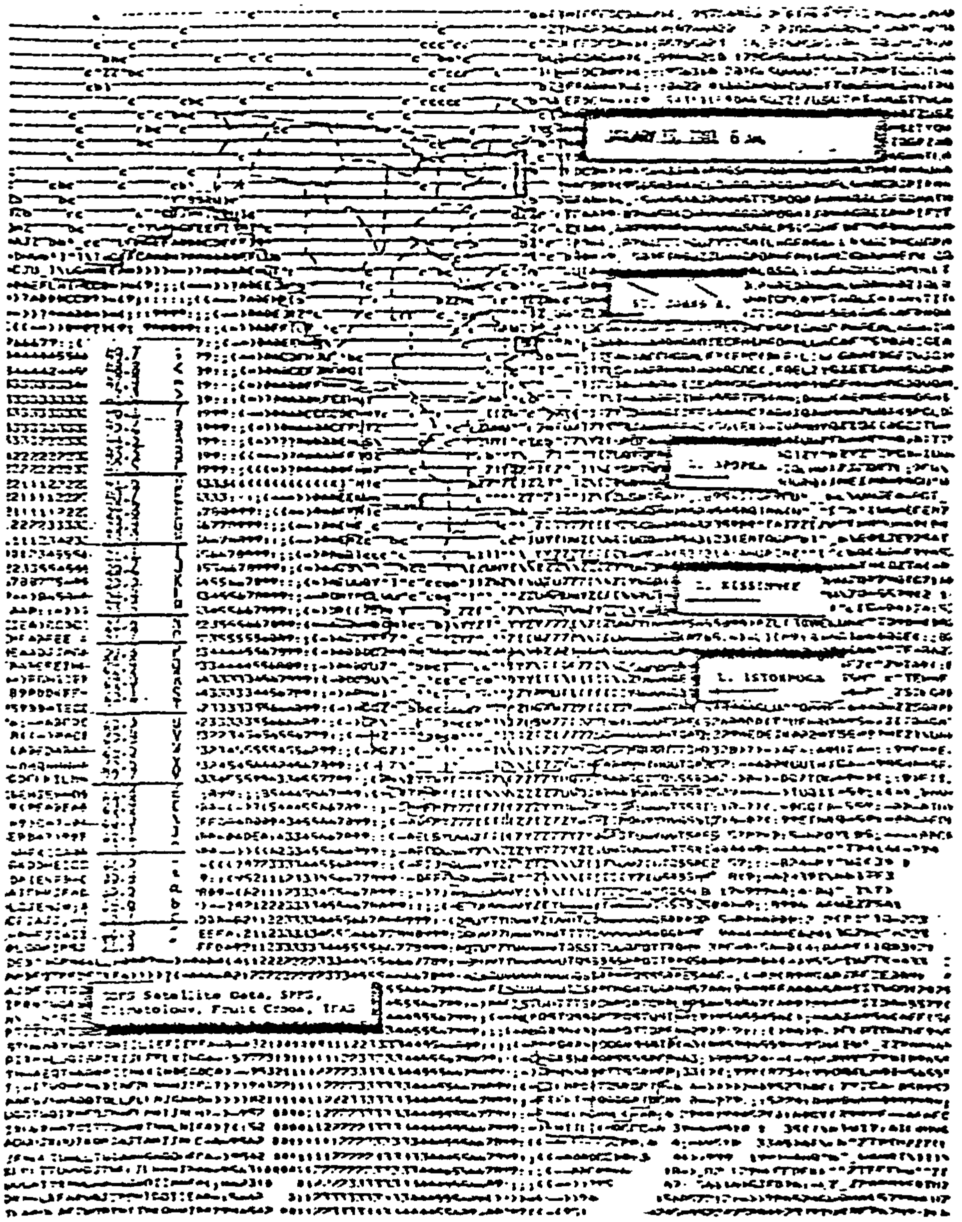

Fig. 5. A reduction (size) of the symbols map; a product of SFFS that become popular just after the big freeze (see date/time on map). The translation table on left margin permits the user to determine the temperature of any 5 km. by 5 km. pixel of interest. Users found this product much easier to archive than the color product viewed on a TV screen. Such maps were communicated from APPLE II to APPLE II for display in color.

Table 2. Printout of SFFS key station data for 1.5m air temperature for the indicated dates.

JAN. 12-13, 1981
1.5m air temperature (rounded to nearest degree F)

	18	19	20	21	22	23	00	01	02	03	04	05	06	07
Tallahassee	28	26	24	18	14	13	16	14	11	10	10	8	7	7
Jacksonville	27	24	17	20	18	13	16	15	13	9	13	13	11	11
Gainesville	30	26	20	19	18	16	14	14	13	12	11	10	10	9
Tavares	37	35	32	23	23	27	18	28	17	22	21	14	15	18
Ruskin	38	36	36	34	32	30	28	27	26	24	22	21	21	20
Arcadia	33	30	28	27	22	19	18	18	16	18	16	18	17	17
West Palm Beach	42	41	38	36	35	34	34	34	33	32	31	30	30	30
Belle Glade	40	39	37	37	36	36	35	35	35	34	34	33	33	32
Immokalee	36	35	32	36	31	29	27	23	22	22	22	20	20	20
Homestead	40	38	39	38	36	35	33	31	31	31	29	29	29	29

JAN. 13-14, 1981
1.5m air temperature (rounded to nearest degree F)

	18	19	20	21	22	23	00	01	02	03	04	05	06	07
Tallahassee	44	45	34	22	27	25	22	23	23	28	32	34	37	32
Jacksonville	39	30	30	34	19	31	30	29	29	29	29	28	27	28
Gainesville	38	35	33	28	22	20	20	20	20	20	20	20	21	27
Tavares	34	33	37	34	31	25	22	24	19	20	21	22	22	23
Ruskin	39	35	34	31	30	29	27	27	27	26	27	27	28	19
Arcadia	39	41	37	29	28	27	22	22	21	20	19	18	19	20
West Palm Beach	47	47	46	44	43	41	41	39	38	40	40	37	37	37
Belle Glade	41	38	38	36	35	32	33	33	33	33	31	30	30	31
Immokalee	42	37	34	31	28	27	31	30	27	26	28	28	30	30
Homestead	44	39	41	42	41	41	40	40	40	38	39	36	39	40

SFFS Key Station Codes:

TLH - Tallahassee
JAX - Jacksonville
GNV - Gainesville
TAV - Tavares
TBW - Ruskin

ARC - Arcadia
PBI - West Palm Beach
BLG - Belle Glade
IMK - Immokalee
HST - Homestead

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user to translate the symbols in a particular area into temperatures. The map can be easily reproduced in quantity and many of these have been used by decision makers in the areas of crop transportation, processing, futures, etc. A detail that becomes apparent in viewing this map is that differentiation of temperatures ceases below 12.8 F. This is an arbitrary limitation that results from the necessity of assigning a symbol set to temperature values in order to easily move them through the NOAA/NWS program and into the SFFS queue in Suitland. The raw data covers a much broader temperature range, i.e. -110 C to 568 C. covered by 256 counts.

Another secondary product of the system that was found quite useful after a damaging freeze was the printout of the 1.5m temperatures from the key stations. These data are available faster than those from minimum-temperature thermograph networks. The product is easily reproduced and inexpensively duplicated for mass dissemination (see Table 2).

5. Models Construct Predictions

Two models operate in series to produce the predicted products. The first, known as P-model, is an energy budget model requiring as inputs data from the key stations and estimated or observed dew points from the SFFS operator. The P-model has been published (Sutherland, 1980) and discussed in the literature (Shaw, 1981; Sutherland, 1981). Only a brief summary is made here.

The "P" in P-model stands for predictive as well as physical. The model outputs 1.5m air-temperature forecasts for the remainder of the night, i.e. up to 7AM the following morning. These forecasts are printed out in tabular form along with the previously observed 1.5m air temperatures at the key station for the operators to view at the system printer. The forecasters use these as part of the input information they have available to make their frost warnings for various areas of the state.

Currently the P-model requires 3 consecutive hours of key station to produce forecasts for subsequent hours. So the forecasts begin 3 hours after the system begins operation, often at 9PM EST. Each hour the system upgrades the forecasts for the remainder of the night using the most recent 3-hour sequence of input data.

The second model, called the S-model, requires the output of the P-model and the satellite data to produce

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forecasted satellite maps. The "S" stands for space, statistical and satellite. It must build a precited satellite view, a thermal map, from the predicted temperature at 10 locations into temperatures for each of the 8 km by 8 km pixels within the borders of the peninsula. A matrix of coefficients relates the predicted key station temperatures to pixels surrounding the key station. These coefficients have been developed from previous freezes. The operator has as an option the set of coefficients that he or she wishes to employ.

THE FUTURE SYSTEM

1. Direct Down-link Antenna System

Experience with SFFS over its 4 years of development has provided users and potential users of the system products numerous opportunities to voice their concern for both the speed and the reliability of the delivery of the products. If the system products are to influence decisions concerning the commitment of energy to heating, wind machines, irrigation pumps and combinations of these, the information must be available to the decision maker as early as possible.

The NOAA/NESS-NWS communication route in Suitland through which the system has received its satellite data during the 79-80 and 80-81 frost season does not rapidly communicate the satellite data. At least two batch operations in the computer-controlled data transmission are involved. The channel has been classed as a special project rather than an operational effort. During the 80-81 frost season SFFS received approximately 63% of the satellite data that it attempted to acquire. When the staging disks were brought back on line in March at NOAA/NESS in Suitland, the reliability of map acquisition failed to increase. IFAS/UF had little choice but to attempt to directly link to the satellite by antenna (fig. 6). At the time of this report all the components indicated in Figure 6 are available or on order except for the demodulator and the bit stream synchronizer. If arrangements can be made for these two components and all the components are functional when delivered, the antenna should be feeding satellite data to SFFS by December 1, 1981.

2. Communication of SFFS Products to Additional Users

The primary user of SFFS output is the forecaster. The NOAA/NWS forecaster is expected to incorporate SFFS information into his frost warnings and communicate these to

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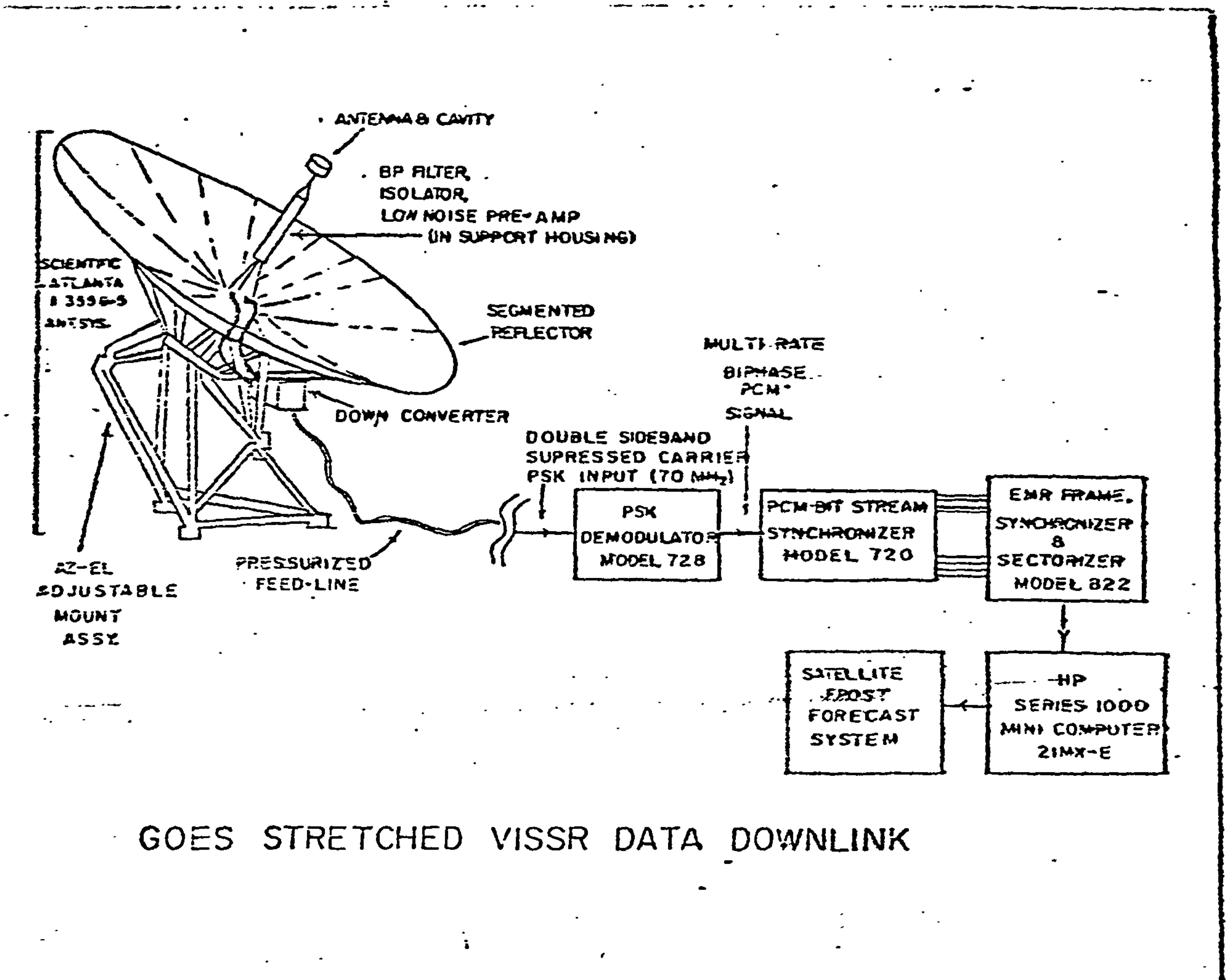

Fig. 6. Proposed antenna system for SFFS permitting direct access to digital data. Portions of this system are on order at the time of this report.

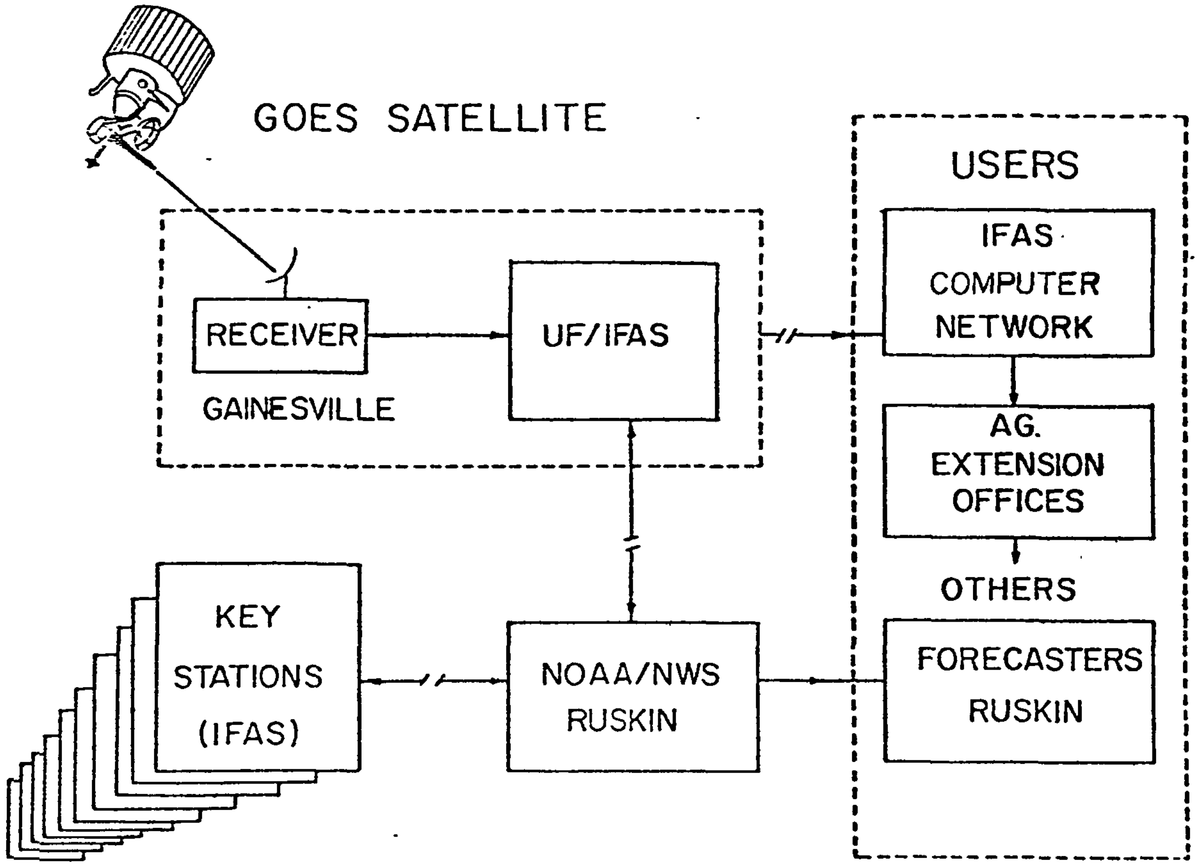

Fig. 7. Block diagram of SFFS when the antenna at UF/Gainesville (Fig. 7) becomes operational. Dissemination of SFFS products is expected to rely heavily on the IFAS computer network that is expected to link the county extension offices with the main campus of UF. Compare with Figure 1.

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users through the normal communication channels that NOAA/NWS has developed over years of service to its clientel. This has occurred during the developmental period, and is expected to continue independently of the presence of the antenna (fig. 7).

Additional users of SFFS information include all other consumers showing interest in receiving the information. During the 80-81 frost season, two county extension offices (one in Polk County and the other in Lake County) received the thermal maps by an APPLE II computer link with the Gainesville minicomputer. This was an experimental link in anticipation of the communication link that is expected to occur via the new IFAS Computer System in coming years. Growers, media, processors, etc. are expected to arrange to connect with the county computers or terminals to view thermal maps, as well as to obtain other system products through the cooperative extension service. This plan does not preclude dissemination of SFFS products from the Ruskin portion of the system as well.

SUMMARY

During 4 years of development, the Satellite Frost Forecast System has undergone significant change. From a system that initially depended upn the redigitizing of the analog GOESTAP data, it has retooled to operate with direct digital data from Suitland, MD, and is in the process of incorporating a direct link with the stretched VISSR data from the GOES satellite by antenna. The system began with manual (verbal) communications of ground truth (surface weather observations) and graduated to automated interrogation of ten key stations. Data from these two data bases (IR from GOES and air and soil temperature, wind and net radiation from key stations) are used to produce both observed and predicted satellite views of the temperature patterns over peninsular Florida. These color products, as well as some black-and-white documentation of the data acquired, are communicated not only to NWS forecasters but are expected to go to additional users through computerized communication channels developing in the Florida Cooperative Extension Service.

ACKNOWLEDGEMENTS

Both IFAS/UF and NASA (Contracts NAS10-9168 and NAS10-9892) have funded SFFS development with NOAA/NWS cooperating. Dr. Jon F. Bartholic served as the principal investigator (PI) during the first 1.5 years before becoming an Assistant Director at Michigan State University, Agricultural Experiment Station. Dr. John F. Gerber served as interim PI for a period of approximately one year and continues to support the work from his position as IFAS Grants Office Director. Dr. Michael J. Burke, Department Chairman, Dr. Ellen Chen, Post Doctorate Fellow, and Mr. James G. George, Consultant Meteorologist have provided leadership as well. Dr. James M. Dodge, NASA/HQ, Mr. U. Reed Barnett, Jr., and Mr. Frank W. Horn, Jr., both of NASA/KSC have coordinated NASA's support to the development. Mr. Frederick C. Crosby of NOAA/NWS has coordinated NOAA's cooperation and provided operational testing of SFFS at the Ruskin WFO. Mr. Ferris G. Johnson, Jr. has coordinated the software development with recent programming support from Mr. Fred D. Stephens, Mr. Steven E. Lasley, Mr. Robert A. Dillon and Mr. Bogdan Pelszynski. Mr. Eugene H. Hannah and Mr. Michael P. Baker have developed the key station instrumentation and the latter has responsibility for the antenna system. Mrs. Alice E. Grimes has coordinated secretarial and bookkeeping activities with aid from Miss Cindy M. Weygant and Miss Nancy S. Guzman. Of the many who have contributed to SFFS development only those who constitute the very recent team effort have been named.

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