VAS Processing System Requirements

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VAS Processing System Requirements

Contents

1.0 Introduction

1.1 Purpose of This Document

The primary purpose of this document is the communication of requirements and constraints which must be met by the VAS processing system to those who are developing the software and hardware subsystems that comprise it. It also will serve as a common reference point for all involved in the UW VAS program. Any changes or refinements in system requirements will be communicated by appropriate dated modifications of this document.

It is expected that evolution of the system design will be accompanied by evolution of this requirements document both as a result of new scientific information and as a result of conflicts between requirements and the practical realities of technological and budgetary limitations.

1.2 Document Control

All VAS personnel will be provided with a numbered looseleaf copy of the requirements document. Each copy will be updated by the VAS program secretary to maintain continuous agreement with the master copy retained by the VAS program manager. All revisions will be dated and substituted for previous versions on a section by section basis. In many cases it is expected that revisions will be additions rather than substitutions.

1.3 Organization of the Requirements

The organization of this document is based on the system functional breakdown described in the VAS System Definition Review presented to NASA on 9 November 1976. A summary of this review can be found in Appendix A. The elements of the system functions within which the requirements are grouped can be summarized as follows:

(1) Collection - reception of raw data (e.g. stretched VISSR modulated RF), decoding and preprocessing to obtain physical observables (e.g. I.R. radiances), and reformatting and archiving to provide convenient access to other system functions;

(2) Analysis - the processing of observables (e.g. I.R. radiances) to derive metoerological parameters (e.g. temperatures, winds, etc.); and

(3) Synthesis - the production of complete and consistent 4-dimensional data sets of atmospheric state parameters using all available information.

1.4 Basis for the Requirements

The basis for the requirements is the set of research and operational objectives delineated in the following set of documents:

(1) UW VAS Contract

(2) OSIP Plan

(3) UW/NESS Memorandum of Understanding

(4) VAS System Definition Review

(5) GOES Specification for GOES D, E, and F

1.5 Related Documentation

In some instances system requirements will require more detail for proper interpretation than is practical to include in this document. Additional information can be obtained from the following documents available in the VAS program library:

(1) Guide for Designing RF Ground Receiving Stations for TIROS-N. (NOAA Tec. Rep. NESS 75).

(2) VAS Phase II Design Review (Santa Barbara Research Center November 1974).

(3) VAS System Description (Santa Barbara Research Center June 1976).

(4) VAS Working Group Meeting Minutes.

2.0 Collection

As discussed in the System Definition review, all available data relevant to mesoscale weather phenomena will be incorporated into the VAS system data sets. Data of the following types will be collected:

(1) VAS
(2) Polar orbiting satellite (including TIROS-N and DMSP)
(3) Conventional weather
(4) Digital radar
(5) VISSR

The characteristics of each of these data types and the processing required to obtain physical observables in a convenient format are described in this section.

2.1 VAS Collection

Specification of the VAS collection function has been divided into the following categories:

(1) The VAS/GOES System - VAS instrument and system communications

(2) VAS Data Format

(3) Preliminary VAS Data Selection

(4) VAS Data Averaging - averaging data collected from multiple samples of the same earth location

(5) VAS Data Calibration

(6) VAS Data Reformatting - logical organization of the data to promote access

(7) VAS Data Archiving

(8) Navigation

2.1.1 The VAS/GOES System

2.1.1.1 The VAS Instrument

The Visible Infrared Spin-Scan Radiometer Atmospheric Sounder (VAS) will operate as an integral part of the Geostationary Operational Environmental Satellite (GOES) system. The GOES will be placed in an orbit at synchronous altitude (35.8×10^3 km) in a plane orthogonal with the earth's spin axis. The VAS will provide both day and night two-dimensional cloud mapping capability with a maximum satellite subpoint resolution of approximately 900 meters (0.5 nmi) in daylight and approximately 6.9 km (3.7 nmi) at night. Additionally, the VAS will obtain radiometric data in the earth's atmosphere water vapor and CO_2 absorption band providing the capability to determine the three-dimensional structure of the atmospheric temperature and humidity. The VAS is an advanced version of the Visible Infrared Spin-Scan Radiometer (VISSR) developed for world-wide geostationary meteorological satellite systems. A detailed description of the VAS instrument and its operating modes is given in Appendix B.

2.1.1.2 VAS Communications

2.1.1.2.1 Spacecraft Subsystem

The VAS instrument provides data to, and is controlled by, the remainder of the VAS system. The interface to the VAS instrument is provided by the GOES-D (E or F) spacecraft subsystem as shown in Figure 2.1. As described in Appendix B, the VAS may be commanded into any one of its operating modes - VISSR, Multispectral Imaging, or Dwell Sounding. Independently, the digital multiplexer may be commanded into its normal wideband mode (28 Mbps) or its backup wideband mode (14 Mbps). High resolution visible data and data from two thermal channels are simultaneously transmitted to the ground.

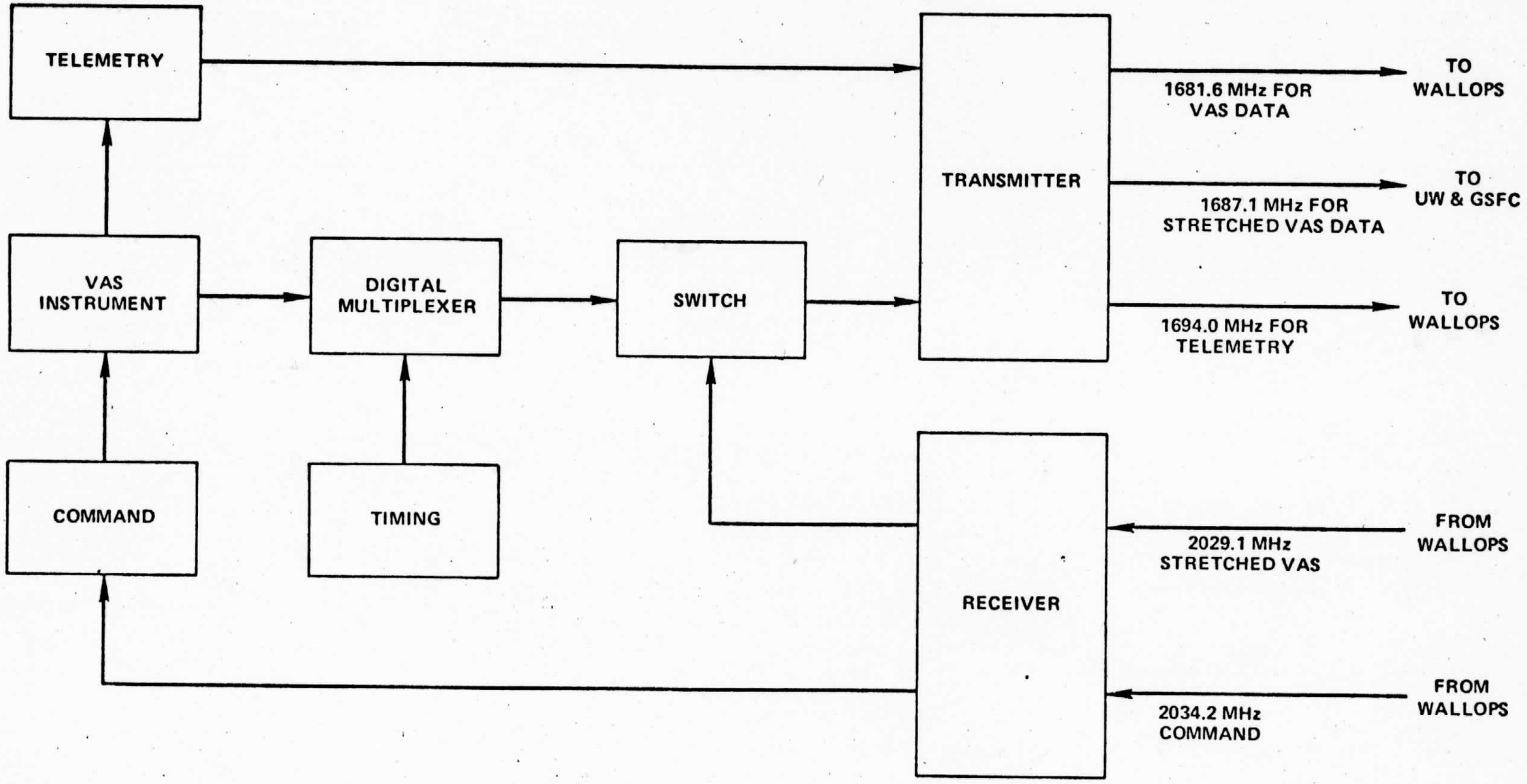


Figure 2.1 VAS Spacecraft Subsystem

At the present time, the only facility capable of receiving the wideband mode data exists at the NOAA station at Wallops Island, Virginia. However, this facility is fully utilized in gathering VISSR data from the operational SMS/GOES satellites and cannot be employed, even on a time-shared basis, to support the VAS Demonstration. However, this facility is being augmented to provide backup support for the two satellite operations. This backup includes a 13.0 meter dish and associated receive and transmit equipment. The decision has been made to utilize this equipment in support of the VAS Demonstration.

The digital multiplexer, under control of the timing subsystem, will provide an input to the spacecraft transmitter (Figure 2.1) during approximately 25 degrees of satellite rotation. During the remainder of each spin, the stretched VAS (SVAS) transmission from the ground station is routed through the switch from the spacecraft receiver to the transmitter. The SVAS data are at a rate of 1.75 Mbps and contain the full-resolution data for all VAS channels. The digital multiplexer can be commanded to convert the analog thermal channel data to either 8 or 10 bit digital samples. During the VAS Demonstration only 10 bit thermal data will be employed. A summary of the VAS operating modes is shown in Table 2.1.

The other two spacecraft units closely related to the VAS instrument are the command and telemetry subsystems. In addition to normal commanding, the command subsystem also provides means of loading 184 bits of control data to the VAS processor. The telemetry subsystem is used both for verification of all commands and for transmission of VAS temperatures and related parameters needed for proper use of the instrument data.

2.1.1.2.2 Data Flow

The VAS Demonstration data flow concept is similar to the NOAA VISSR data operational system. Payload data at 28/14 Mbps will be received at the NOAA

Table 2.1
VAS Operating Modes

Instrument Mode	Function	Spins Per Step	Visible Res. (km)	Infrared		Data			Coverage Rate km/min	Time (min)	
				Res. (km)	# Bands	Rate Mb/sec	# Bits VIS	# Bits IR		5° Lat	Full Disk
VISSR	NOAA Operational	1	.9	6.9	1	28*	6	8	691.2	.81	18
MSI	Imaging	1	.9	13.8	4	28*	6	10	691.2	.81	18
Dwell	Imaging	>1	.9	6.9	7	28*	6	10	153.3	3.7	81
Sounding	Sounding	>1	.9	13.8	12	28*	6	10	17.0	33	732 (12 hrs)

*Backup wideband mode of 14 Mb/sec may be selected. This provides reduced visible resolutions.

Wallops Island Command and Data Acquisition (CDA) station. A Stretched VAS (SVAS) output containing the VAS and other information of value (e.g., predicted orbit and attitude, time of day, and PCM telemetry) is retransmitted to the spacecraft at 1.75 Mbps. These data are made available to both users via the spacecraft transponder as shown in Figure 2.2. The SVAS data are received and retransmitted by the satellite directly to the GSFC and UW. This approach has therefore avoided the need for relatively large antennas, low-noise receivers, and complex preprocessing equipment at both user sites.

All spacecraft commanding will be done from Wallops Island under control of the Satellite Operations Control Center (SOCC), which will control the transmission of all commands and will receive and evaluate all telemetry data. During the VAS demonstration period, requests for specific VAS instrument and spacecraft configurations will be generated by the GSFC and University of Wisconsin. The VAS Working Group will be responsible for requesting satellite time for the experiments, and SOCC will schedule the experimenters' requests. These requests will be provided to SOCC by dial-up voice telephone. Table 2.2 summarizes the VAS demonstration interfaces. During the VAS demonstration data acquisition periods, the VAS Demonstration Manager will resolve any scientific conflicts (e.g., which storm to observe, etc.).

In addition to such command and telemetry data, communication of the VAS payload data is provided. The VAS data at 28/14 Mbps will be received at Wallops where it will undergo initial processing. VAS functions performed at Wallops involve only those required by both experimenters. These include line-start timing of the data, data interpolation and resampling, calibration, formatting the data and merging time, PCM telemetry, and predicted orbit and attitude data. After this initial processing, the data are transmitted from Wallops back to the satellite as SVAS data. The uplink data rate at 1.75 Mbps

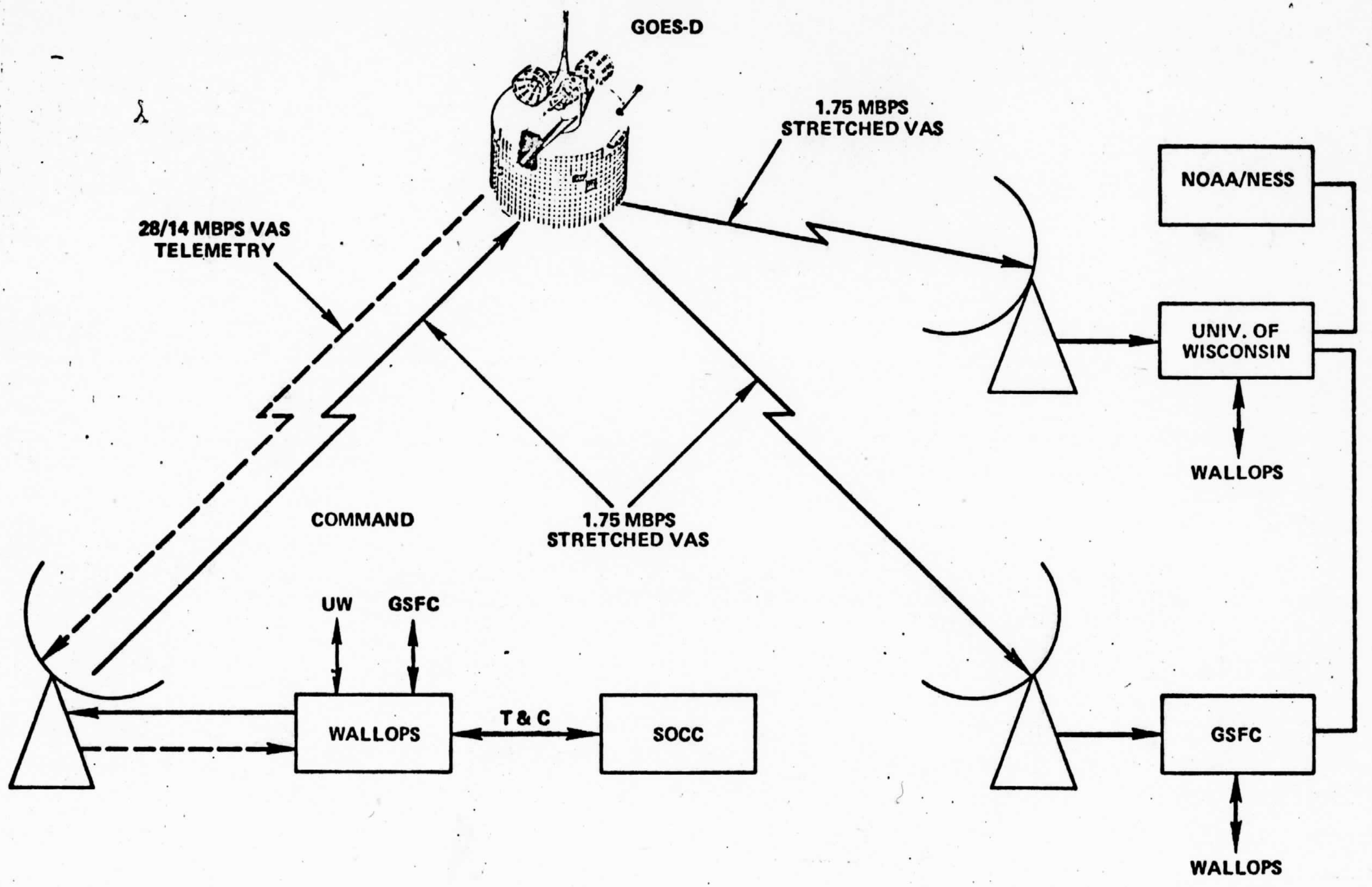


Figure 2.2 VAS Data Flow

represents at a reduction of 16 times that of the original downlink rate of 28 Mbps.

2.1.1.3 Ground Systems Communications

There are two separate ground communication networks required for the VAS Demonstration. They are described in the following two sections.

2.1.1.3.1 Wallops Communications Network. Coordination of the VAS Demonstration requires an on-line capability for sending various types of voice, analog, and low-rate digital data between the four key locations involved. These digital data include VAS programmer commands and orbit and attitude parameters required by Vallops and provided by the other stations. General data of these and other types, such as schedules, will have to be transferred to all sites.

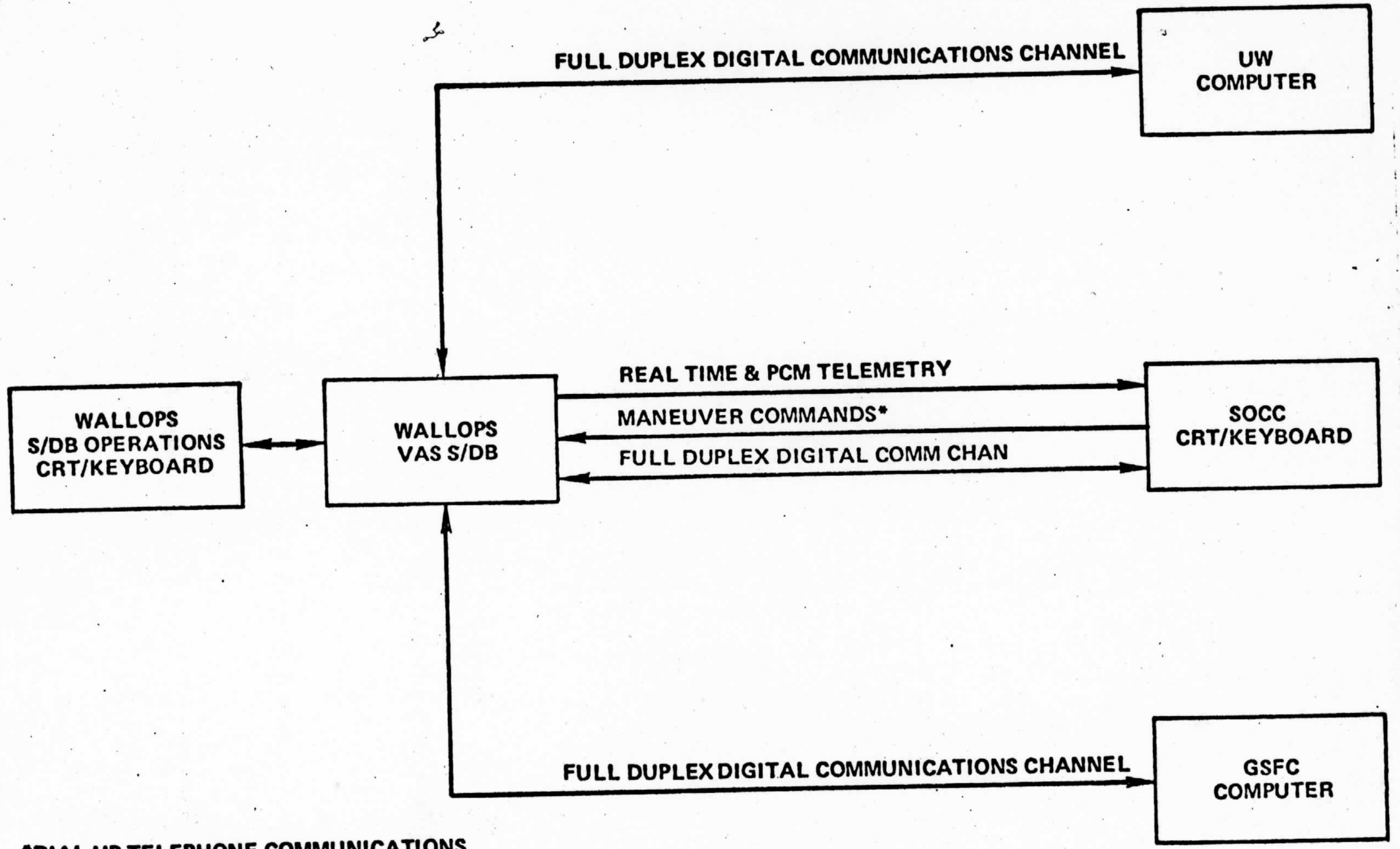
The planned network for exchange of these data is shown in Figure 2.3. The digital communications channels will permit GSFC, SOCC, and UW to independently pass data to, and receive data from, Wallops. The type of data transferred is shown in Table 2.2. Specific data will include VAS programmer command and telemetry, S/DB status, and orbit and attitude data. Dedicated and dial-up telephone lines are also shown in Figure 2.3.

The three full duplex digital communications lines are to be 4800 and 9600 Band, NASCOM compatible. The S/DB computer will also interpret the received VAS instrument commands, reformat them and, when placed in control by Wallops, transmit the data to the spacecraft. The received command verification will then be transmitted to SOCC for review. Commands related to the health and safety of the spacecraft will only be sent from Wallops.

2.1.1.3.2 UW Remote Terminal Network. This network connects UW with GSFC and NOAA/NESS as indicated in Table 2.2. The network supports the interchange of scientific data. It requires two full duplex digital 9600 Baud communications lines.

Table 2.2
VAS Demonstration Interfaces

GOES-D to Wallops ● VAS data at 2 8/14 Mbps ● PCM & Real Time Telemetry	Wallops to GOES-D ● Commands ● Stretched VAS data at 1.75 Mbps
SOCC to Wallops ● Voice command instructions for maneuvers ● Keyboard command entries and messages for Wallops, GSFC & UW	Wallops to SOCC ● CRT display of VAS command status and messages from Wallops, GSFC & UW ● PCM & Real Time Telemetry
GOES-D to GSFC and UW ● Stretched VAS data at 1.75 Mbps	GSFC and UW to GOES-D ● No signals
Wallops to GSFC and UW ● S/DB to computer transfer of VAS command status and messages	GSFC and UW to Wallops ● Computer to S/DB transfer of command instructions, O & A data, messages
SOCC to GSFC ● Estimated maneuver time and post maneuver state via TWX	GSFC to SOCC ● O & A data via TWX for maneuver computations
GSFC to UW ● Inter-computer communications	UW to GSFC ● Inter-computer communications
NOAA/NESS to UW ● UW remote terminal data requests	UW to NOAA/NESS ● UW remote terminal data



*DIAL-UP TELEPHONE COMMUNICATIONS

Figure 2.3 Wallops Communications Network

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : VAS Working Group/Distribution DATE: August 2, 1977

FROM : Applications Directorate
Earth Observation Systems Division

SUBJECT: Mode AA Format Definition

In response to Action Item 1 in the minutes of the VAS Working Group meeting held on July 14, 1977, Harold Ausfresser, in collaboration with Dave Small, has submitted the attached proposal.

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VAS Demonstration Manager

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Mode AA Format Definition

July 28, 1977

This note presents the characteristics of a synchronizer/data buffer (S/DB) format (Mode AA) to distribute the one-half mile visible data and the two channels of 10 bit thermal data. It is based upon the current mode A format now operationally employed by NOAA.

The mode A format, Figure 1, is divided into ten sectors. Note that there are eight sectors of visible data each occupying 36° and one IR sector of 45° (containing either IR1 or IR2 data) and an earth view (EV) sector.

During the transmission of the direct data from the spacecraft (28/14 MBPS), retransmitted SVAS data from the S/DB is ignored by the spacecraft. Therefore, the output format must have a portion where no useful data is being conveyed. This portion, called pre-IR or earth view, must be at least as large as the duration of the direct transmission. For the current operational system, the 28/14 MBPS direct transmissions can occur from -11.9° to +10.4° of spacecraft rotation or 22.3° total. The earth view portion is 27° which is certainly sufficient. The IR video is output as nine bit words at 524160 bps at 100 RPM. The MSB of each word is used for grid information and is output first. The visible video is output as six bit words at 1747200 bps at 100 RPM. Each video sector occupies one tenth of a spacecraft rotation and contains 15288 video samples.

The proposed format is designated mode AA and, for the visible data, is identical in all respects to the mode A format. Thus, there is 72° of spacecraft rotation for the EV and IR sectors. The EV sector would be increased to 28.6° thus decreasing the IR sector to 43.4°.

Wideband Transmission at 28 MBPS

Degrees	27	45	36	36	36	36	36	36	36	36
	EV	IR	V5	V6	V7	V8	V1	V2	V3	V4

IR	IR	VISIBLE
Resolution (Miles)	4x2	1/2x1/2
Time Interval/@ 100 RPM	75 msec	60 msec
Bits/Sample	9	6
Bit Rate @ 100 RPM	524,160 bps	1,747,200 bps
Initial Sync (Words)	418	1672
Documentation (Words)	128	512
Video (Words)	3822	15,288
Total Words	4368	17,472

Wideband Transmission at 14 Mbps

EV	IR	A3	A3	A4	A4	A1	A1	A2	A2

Note: $A1=\frac{V1+V2}{2}$, etc.

Visible resolution is 1x1 and all other parameters are the same.

Figure 1. Mode A Format

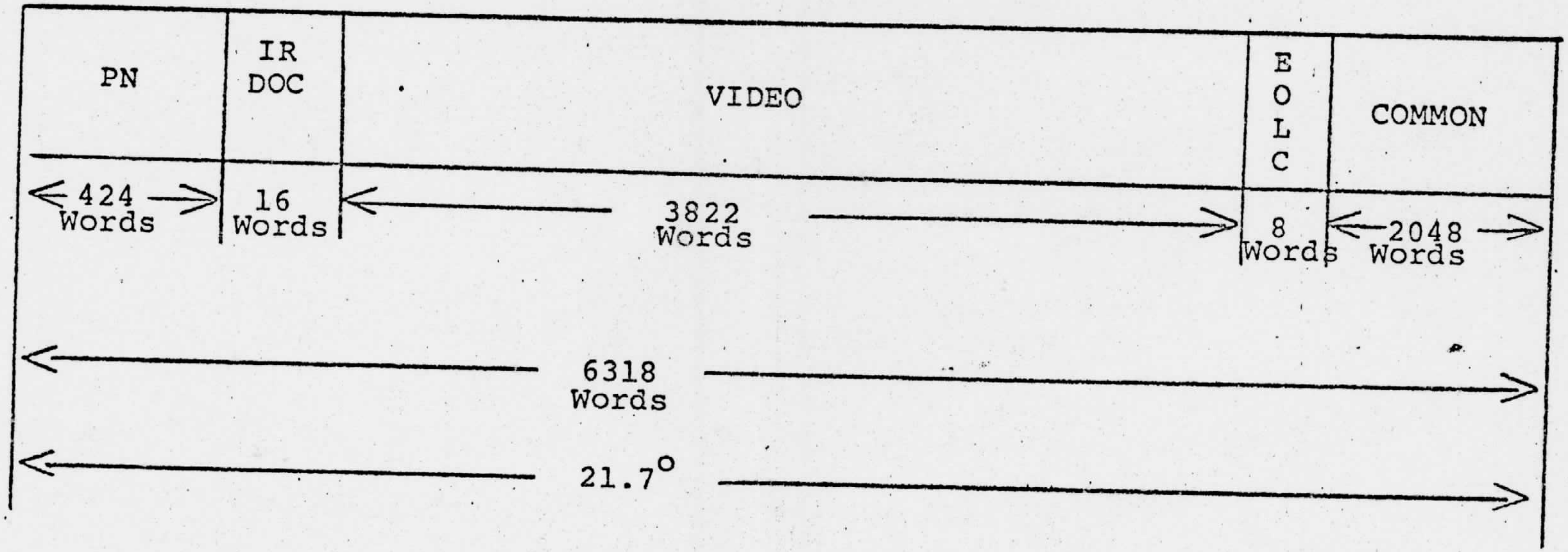
For GOES-D the direct transmission for 28/14 MBPS can occur from -12.6° to +10.6° for a total angle of 23.2°; this is an increase of 0.9° relative to the current spacecraft. Thus the 1.6° increase in the EV sector would compensate for the increased transmission angle and provide additional margin.

The IR video would be output as ten bit words during a spacecraft rotation angle of 43.4°. It would be divided into two parts each of 21.7° duration. The format of the two parts would be identical; however, the information content would be different. The format for one part is shown in Figure 2; it is divided into five sections:

(a) PN sequence for synchronization
(b) Documentation to define the IR1 and IR2 parts
(c) IR1 or IR2 video
(d) End of line code
(e) Common (part 1 of 2)

The 2048 words of common documentation in each part will be divided into eight sections of 256 words each. Only the eight least significant bits of each word will be employed for data. All of the presently planned documentation data for VAS will fit within one 256 word section. The remaining 15 sections (considering parts 1 and 2) may be employed to repeat the data in the first section or for other documentation such as gridding data.

The current operational S/DB's are capable of placing up to 507 grid points on each scan of data with a resolution of 4 x 2 miles. If it were desired to place up to 507 grid points using the mode AA format it could be done with a resolution of ½ x ½ mile using four 256 word sections of documentation. This would require only 25% of the total documentation. The technique would be to use a 16 bit number (8 LBS's of each of two words) per grid point. The three LSB's of each number would represent the visible channel (V1-V8) and the 13 MSB's would represent the sample number of the left half (1-7644) or right half (7645-15288)



Bits/word	10
Bit rate @ 100 RPM	1747200 bps
Time interval @ 100 RPM	36.2 msec

Figure 2. Mode AA Format for IR1 or IR2 Part

of the image. A code word (all 16 bits equal to one) would separate the left and right half numbers.

Of course, other gridding techniques may be employed; in any event no grid data will be inserted by the S/DB for the VAS demonstration.

2.1.2 VAS Data Format

2.1.2.1 General

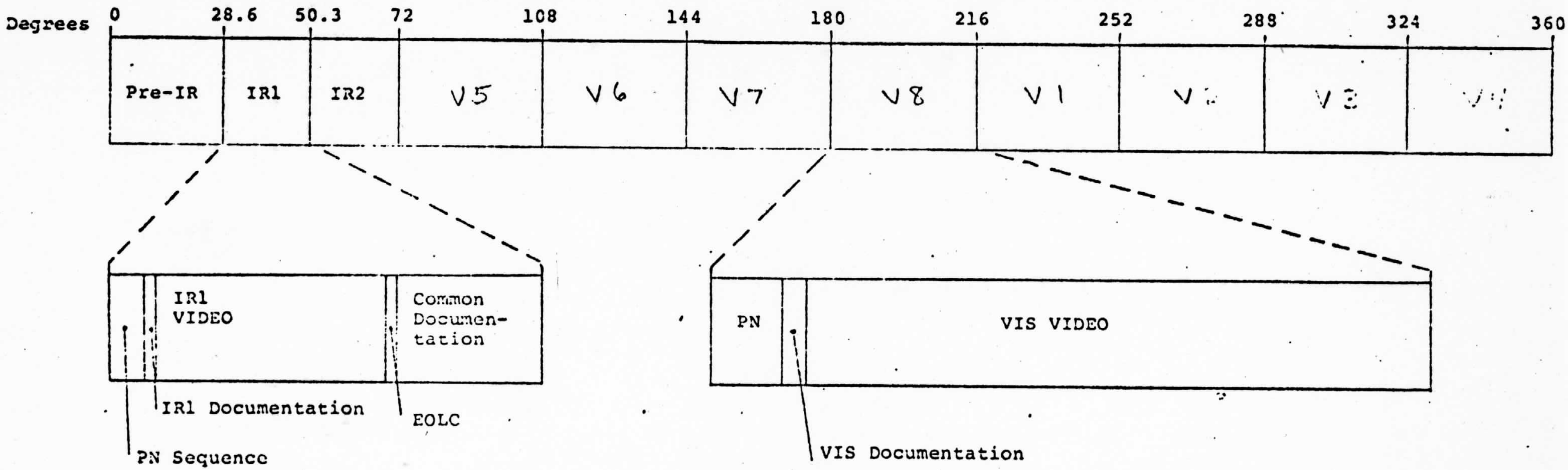
The S/DB provides processed data outputs at low rates for retransmission to the spacecraft and tape recording. This data will be provided in a fixed format independent of spin rate to facilitate both data processing and photographic image generation.

The Mode AA format is used by the S/DB to distribute the 8 channels of one-half mile visible data and the 2 channels of 10 bit IR data. If only 8 bits of IR data are available, they will occupy the 8 MSB's of the 10 bit word. The AA format is a derivative of the Mode A format now operationally employed by NOAA.

2.1.2.2 Mode AA Format

The Mode AA format, shown in Figure 2.4 is divided into 11 sectors: 8 visible sectors of 36 degree each, 2 IR sectors of 21.7 degree each, and one Pre-IR sector of 28.6 degree. During the transmission of the direct data from the spacecraft (28/14 MBS), retransmitted SVAS data from the S/DB is ignored by the spacecraft. Therefore, the output format must have a portion where no useful data is being conveyed. This portion, called Pre-IR or Earth View, must be at least as large as the duration of the direct transmission. For GOES-D the direct transmission for 28/14 MBS can occur from -12.6 degree to +10.6 degree for a total angle of 23.6 degree well within the 28.6 degree allocated for Pre-IR in the AA format.

The two IR channels will be output as 10 bit words during a spacecraft rotation angle of 43.4 degree. It is divided into two parts, Channel 1 and Channel 2, of 21.7 degree each. The formats for each channel are identical; however, the information content is different. Each channel consists of:



	IR1 and IR2	VISIBLE (Per Sector)
Time Interval @ 100 RPM	36.2 ms	60
Bits/Sample	10	6
Bit Rate @ 100 RPM	1747200	1747200
Initial Sync (Words)	424	1672
IR Doc	16	--
IR Common Doc	2048	--
VIS Doc	--	512
Video (Words)	3822	15288
EOLC (Words)	8	--
Total (Words)	6318	17472

Figure 2.4 Mode AA Format

a) PN Sequence for Synchronization

b) Documentation to Define the IR1 and IR2 parts

c) IR1 or IR2 video

d) End-of-Line-Code (EOLC)

e) Common Documentation

The 2,048 words of common documentation in each channel will be identical and will consist of eight groups of 256 words each. The data content of each group will also be identical. Only the 8 LSB's of the 10 bit documentation word will be used for data.

The visible portion of the AA format, consisting of 8 sectors, is identical to the visible portion of the Mode A format currently in use. Each 36 degree sector consists of a PN Sequence for synchronization, a visible documentation portion, and 15,288 six-bit visible video words.

The synchronization code for each sector is a pseudo-random noise (PN) sequence generated by a shift register whose input is the output of an exclusive-OR gate as shown in Figure 2.5. Bits eight and fifteen (MSB) of the shift register are the inputs to this gate. The output of this gate is combined with a data line using a second exclusive-OR gate in the controller combiner. The data line is at logic zero during the entire initial sync period. The shift register is preset so that its contents (15 bits) are at logic one during the final bit period of the initial sync. If this final bit period is given number zero and preceding bits are given negative numbers, etc., the best sequence out of the first exclusive-OR gate (and hence into the LSB of the shift register) is:

Bit Number	-5					0										10
Logic Level	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1

In Mode AA there are 424 words (10 bits each) of IR initial sync and 1672 words (6 bits each) of initial sync for each visible interval.

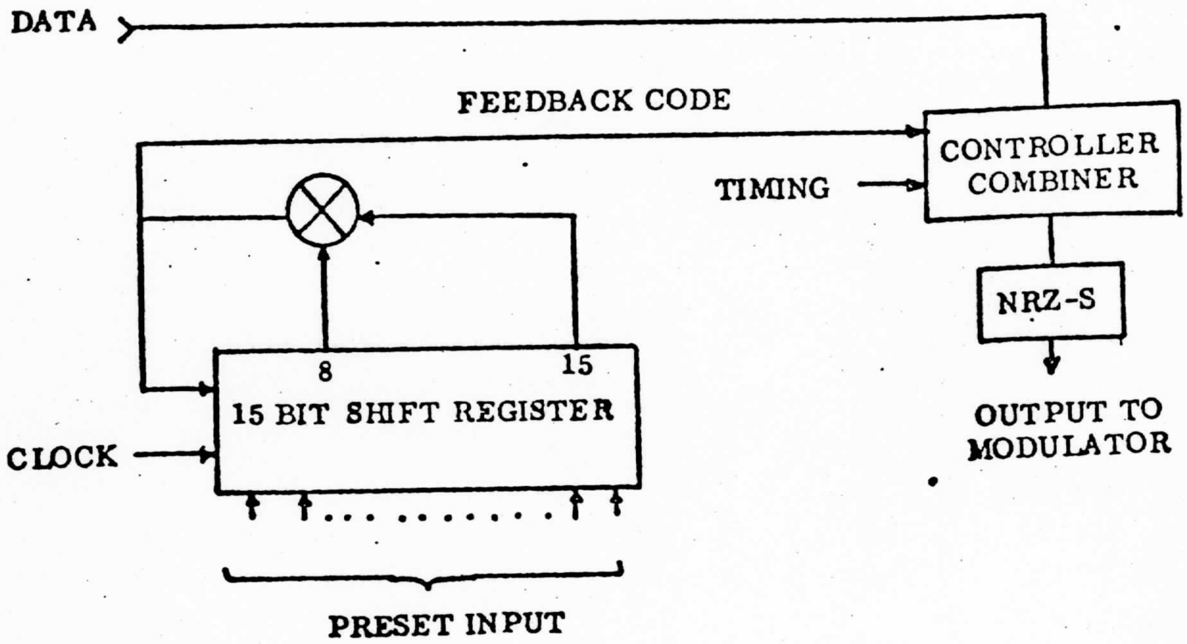


Figure 2.5 Synchronization Encoding

For documentation and video, even-numbered words are complemented; the number of the first word following initial sync is one. The documentation and video is provided to the data line input of the second exclusive-OR gate.

The output bit stream, as defined above, is passed through a NRZ-S differential encoding process. This process produces a transition for each logic zero input and none otherwise.

Mode AA Common documentation words are discussed in Section 2.1.2.3. Table 2.3 shows the visible documentation words.

Table 2.3. Mode AA Visible Documentation

Words 1, 2, 3	.	Sector code**	-	1-8 uses three words; each word represents a 0 or 1 state. (Example: Sector 5 is identified as 111110000001111110.) The most significant word is first. The sectors (following IR) have numbers 000, 001 ..., 111.
Word 4	.	Frame code**	-	ONE indicates picture transmission.
Word 5	.	Change code**	-	ONE indicates start of picture if frame code is ONE or end of picture if frame code is ZERO.
Word 6	.	Step code**	-	ONE indicates normal line transmission; ZERO indicates that this is not to be used to expose film and facsimile recorder line is not to be incremented (stepped).
Word 7	.	Line Offset	-	This is a three bit word from the line offset logic inserted into the last three bit positions with O's inserted into the first three positions, i.e., (oooxxx).

**All but the last bit in each code word are identical, e.g., 000001 (ZERO) or 111110 (ONE).

The contents of the IR1 and IR2 documentations are shown in Table 2.4.

Table 2.4. Mode AA IR Documentation

Words 1, 2	Channel code	Identifies IR1 and IR2. Word 1 = Word 2 = $FE for IR1 and $01 for IR2.
Word 3	Frame code	$FE indicates picture transmission; $01 indicates out-of-frame.
Word 4	Step code	$FE indicates step; $01 indicates no-step.
Word 5	Predicted header	In VISSR mode, $80, otherwise: (MSB) Bits 8, 9, Detector Type 00 = Small Hg Cd Te 01 = Large Hg Cd Te 11 = In Sb Bit 10, Step Scan Flag 1 = Step Scan On Bit 11, Filter Wheel Accuracy 1 = Ø < 2.5 0 = Ø > 2.5 (LSB) Bit 12 - 15, Filter Wheel Position Same Coding as P2.
Word 7	MSI Code	$00 MSI Band A 01 MSI Band B 02 MSI Band C 03 MSI Band D 04 MSI Band E 05 MSI Band F 06 MSI Band G 07 MSI Band H 08 Dwell Sounding
Words 7 - 15	Spare	Contents $00.
Words 16	Parity	Odd parity - sum of bits in each column is odd for words 1 - 16.

2.1.2.3 IR Output Documentation Format

TBD

2.1.3 Preliminary VAS Data Selection

The option exists to either interactively or routinely reduce the data volume early in the collection phase. Since emphasis will be placed on data over the continental U.S., from 1/2 to 2/3 of the data (eastern and western extremes) could be rejected routinely. This reduction should not apply to the archived data, but rather to the data to be used in near real time. More severe rejection of data based on interaction with earlier VAS and ancillary data will probably also be desirable.

2.1.4 VAS Calibration

In general, two types of calibration of the VAS radiometer are required: electronic calibration where the deviation of the response from linearity in radiance is accounted for and radiometric calibration where the transformation from digital level to radiance is made assuming linearity. The 10 bit A/D for VAS will be sufficiently linear that only radiometric calibration is required on a routine basis. Electronics calibration will be used as a diagnostic tool and is not discussed further in this section.

2.1.4.1 Algorithm for Radiometric Calibration

$$R_\nu = B_\nu(T_E)\left(\frac{D_\nu - D_{SP}}{D_{BB} - D_{SP}}\right)$$

where

R_ν = sample radiance for νth channel

D_ν = sample digital level for νth channel

D_{SP} = digital level of space view from average of n samples (ν independent)*

D_{BB} = digital level of internal calibration black body (ν dependent) (words 10 and 11 of IR Documentation)

B_ν = Planck function

T_E = Temperature of black body exterior to VAS which would give the same response D_{BB} as the interior black body.

specifically

$$B_\nu(T_E) = B_\nu(T_S) + \sum_{i=1}^{8} C_i \; (B_\nu(T_i) - B_\nu(T_S))$$

where

C_i = 8 predetermined coefficients

T_S, T_i = 10 bit temperatures contained in the Common Documentation (2 measurements of T_S are made)

* Average of 16 space samples east of Earth and 16 samples west are contained in IR Documentation - Probably use band 8 value for all channels.

The operations which must be performed on each sample are one subtraction ($D_\nu - D_{SP}$) and one multiplication $((B_\nu(T_E)/(D_{BB} - D_{SP})) \times (D_\nu - D_{SP}))$. A new value of D_{BB} is obtained for each line of data so one subtraction and one division are required per line to calculate $B_\nu(T_E)/(D_{BB} - D_{SP})$. The required update rate for temperatures T_i and T_S which determine $B_\nu(T_E)$ has not been defined. The rate will vary with the time of year, the most severe requirements occurring during and near eclipse periods. In non-eclipse periods the rate will probably be once every few hours, while during eclipse, updates may be required several times per hour.

2.1.4.2 Application of Calibration Algorithm

It is possible to calibrate the data at different stages of the processing varying between the extremes of calibrating all of the data to calibrating only the data used quantitatively. Calibrating all of the data is attractive because of its simplicity and because hardware calibration may be possible. However, the volume of data requiring calibration is much less than all of the data, and the trade offs need consideration.

Sequence for calibrating all the data:

(1) Following 1st scan line -

  (a) $B(T_E)$ is calculated using temperatures from Common Documentation and coefficients C_i with line # dependence. (frequency needs study)

  (b) Low noise channel (band 8 large detector) space average is compared to D_{SP} averaged from previous frame as diagnostic. If difference is small, use D_{SP}.

(2) If D_{SP} difference not small, average space average from ___ lines to get D_{SP}.

(3) Apply algorithm to all video and determine D_{SP} for next frame.

2.1.5 VAS Data Averaging

Multiple samples of the same earth location for a given detector size, band number and frame number are to be averaged. At least 12 bits of the average should be retained. Two types of averaging must be performed:

(1) Multiple scans of the same satellite scan line with a given detector and band number -

> average of up to 255 sequential lines of IR1 and of IR2 video resulting in 1 line of data for IR1 and 1 for IR2 (the sequence of averaging required in a given frame is specified in the VAS processor program included in the Common Documentation in each line of data).

(2) Average of IR-1 video from one satellite scan line with IR-2 for the same detector type and filter from a different scan line - to be discussed as part of VAS Data Reformatting.

It is probably feasible to perform averaging before the data is calibrated if it would be advantageous.

The information for determining which lines to average for type 1 averaging is contained in the Common Documentation. Although the documentation occurs on each line, the scan program and instrument mode (MSI or DS) do not change during a frame. No type 1 averaging is required for the MSI mode.

For the DS mode, the number of lines requiring averaging will vary in a repeating sequence which will change when the instrument is reprogrammed. The DS mode has three submodes, 1, 2 and 3. They occur in the order 1, 2, 3, 2, ... Type 1 averaging is only required in submode 2 where from 2 to 255 lines require averaging in each of from 1 to 12 groups.

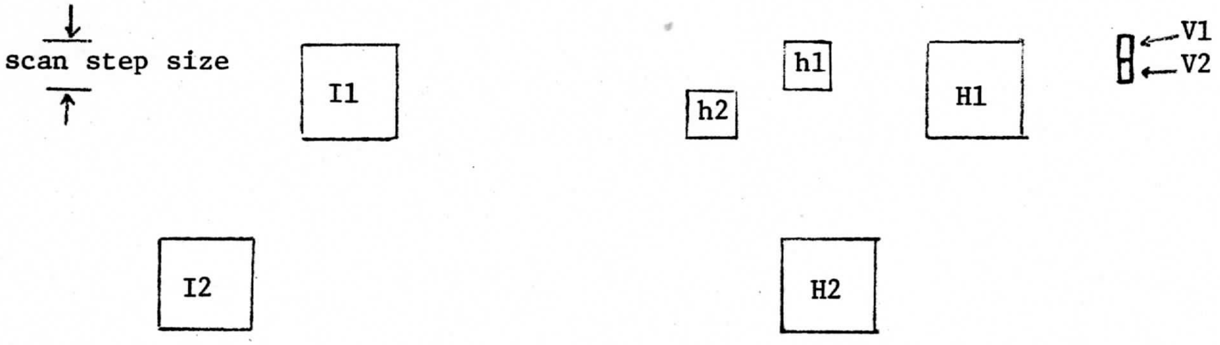
2.1.6 VAS Reformatting

The optimum format for VAS data will depend on the detailed scenario for its application and on hardware considerations. However, it can be assumed that the final format will be designed to facilitate access to:

(1) Images in each of the VAS spectral bands.

(2) Sample radiances from the same earth location in each spectral band.

In either case, it would be convenient to group data from the same Earth swath together and to order the groups to represent a north to south or south to north progression. This grouping does not occur naturally for VAS data because of the detector geometry shown below:



where

H = HgCdTe large detector
h = HgCdTe small detector
I = InSb detector
V = visible detector

Detectors 1 and 2 of the same type are sampled simultaneously and the samples make up the video IR1 and IR2 data.

One reasonable grouping would be to associate data from an earth swath of width equal to n large detector widths. A possible set of rules for such a grouping follow:

(1) Average IR1 and IR2 data lines (single Earth scans lines or averages of single Earth scan lines) taken from different satellite scan lines which sample the same Earth swath with the same detector type and band number.

	Earth Scan Lines Averaged	
Detector Type	IR1 Line	IR2 Line
H, I	n + 4	n
h	n + 1	n
V	none	

(2) Group a N-S or S-N sequence of data lines from the same detector type and spectral band. Defining such a group to be a record, each file containing all of the records from any earth swath has at most 14 records (1 visible, 1 h band 8, and 12 DS submode 2 h, H or I spectral bands). The actual number of records would vary with the VAS scan program.

The number of data lines/record varies with the detector size. Specifically

Detector Type	Number of Lines
H or I	n
h	2n
V	4n

(3) Sequence the records in each file in the following order:

(a) V record

(b) h records (with specified spectral band ordering - possible bands being 3-5, 7-10)

(c) H records (bands 1-5, 7-10 in specified order)

(d) I records (bands 6, 11, 12 in specified order)

(4) Order files in N-S or S-N sequence.

(5) Each data line should be preceded by documentation including the Mode E IR Documentation and Common Documentation and UW documentation specifying the averaging which has been performed etc.

2.1.7 VAS Data Archiving

All VAS data collected during the experiment should be archived in raw form (1.5×10^{11} bits/day for at least 79 days). Specific requirements for archiving the processing products have not been determined, but the data volume of products will be small compared to that for the raw data.

2.1.8 VAS Navigation

During the VAS Demonstration the Applications Directorate will operate the orbit/attitude determination program. Based upon approximately two visible images of 3.7 km resolution every other day and available USB ranging data, the orbit, attitude, and Earth-Sun beta-angle state will be determined and dynamically predicted as a function of time to about 1.0 pixel (3.7 km) rms accuracy. This orbit/attitude, Earth-Sun beta-angle state as a function of time will be sent to the Wallops CDA station to be merged as header data into the SVAS video data for GSFC and UW point transformation navigation; it will also be used by NOAA to generate orbit and attitude maneuvers which will be furnished to SOCC. It is estimated that 12 orbit/attitude maneuver computations will be required during the Phase A VAS Demonstration (1-year duration). SOCC will execute the commands to maintain the subsatellite point to within a ±1.0 degree latitude-longitude box and the spin axis to within a 0.15 degree half-angle cone about the normal to the orbit plane. The orbit/attitude software will be made available to UW for use in the UW processing system. The UW computing system will be capable of determining the orbit/attitude, Earth-Sun beta-angle state and transmitting it to GSFC and Wallops as a backup to the GSFC system.

In the following section we present more information concerning the Orbit, Attitude, and Navigation Requirements.

2.1.8.1 Orbit, Attitude and Navigation Requirements

The data provided in Table 2.5 is sufficient to meet all orbit, attitude and navigation requirements. The method of obtaining and distributing the data to the various users will be outlined below.

All the parameters listed in the Table with Data Note 1 are determined on the VAS Processor every other day and transmitted to Wallops. This data is determined from two visible images of 2 nmi. resolution every other day together with available ranging data. This data will then be transmitted to Wallops via a Keyboard/CRT colocated with the VAS Processor.

At Wallops this data is received and input into the SDB. All the parameters with Data Notes 3 and 4 are determined by the SDB and transmitted with Data Note 2 parameters, as part of the header in the stretched VAS (SVAS) data stream, through the spacecraft to the University of Wisconsin and GSFC.

SOCC receives the parameters listed with Data Note 5 from Wallops via a Keyboard/CRT (with hard copy capability) for determining maneuver requirements. After a maneuver has been performed, SOCC provides GSFC, through a Keyboard/CRT, the new predicted values for these parameters.

Table 2.5 Navigation Data

Item	Number of Parameters	Polynomials*		Data Notes**
		Coefficients per parameter	Total Number of coefficients	
Orbit Position	3	10***	30	1,2,5
Orbit Velocity at Epoch	3	Not Applicable (NA)	NA	1,2,5
Orbital Position and Velocity at 12 Hours	6	NA	NA	1,2
Spin axis attitude and rates	4	NA	NA	1,2,5
Navigation Biases	4	NA	NA	1,2
Beta Angle	1	9***	9	1
Beta Angle-Real Time	1	NA	NA	3
Spin Period	1	NA	NA	4,5
Greenwich Angle	1	2	2	1,2
Sun Declination	1	2	2	1,2
Sun Right Ascension	1	2	2	1,2
Epoch	5	NA	NA	1,2,5
Time Into Eclipse	4	NA	NA	1,2
Time Out of Eclipse	4	NA	NA	1,2
Retransmission Lag	1	4***	4	1
Retransmission Lag Real-Time	1	NA	NA	3

* The order and coefficient units of the polynomials will be defined following further analysis. Preliminary investigation indicates that the time unit for the polynomials will be msecs.

** The data can be broken up into 5 categories

1 - Input to SDB located at Wallops via the GSFC Keyboard CRT

2 - Note 1 data documented in SDB output

3 - Computed in real-time by SDB from Chebyshev coefficients and documented

4 - Measured in real-time and documented by SDB

5 - Data required by SOCC for spacecraft maneuvers

*** These items are fit using a Chebyshev polynomial characterization

Definition of Navigation Parameters

Orbit Parameters:

Position (X,Y,Z)	The coordinate location of the S/C in the true of date system
Velocity $(\dot{X},\dot{Y},\dot{Z})$	The velocity coordinates of the S/C in the true of date system

Attitude Parameters:

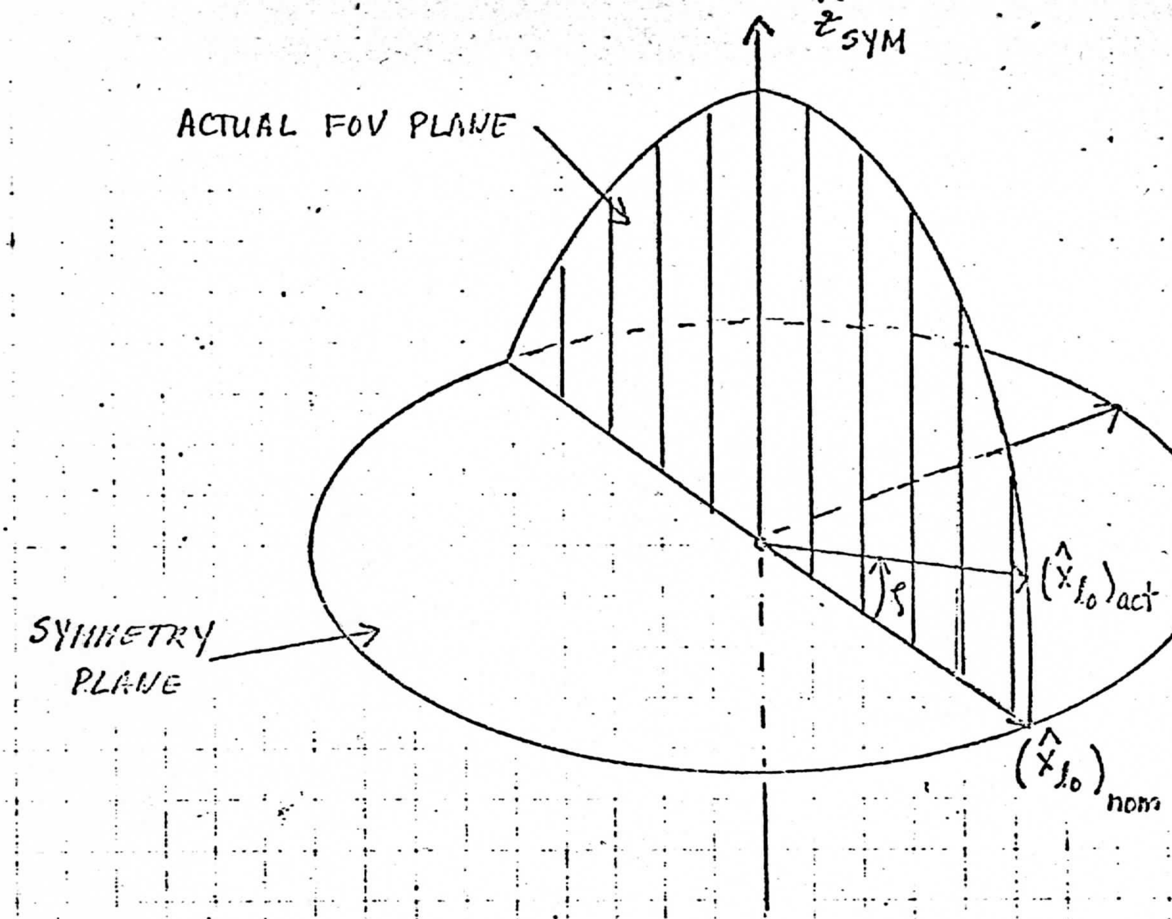
right ascension (α)	The angle measured counter-clockwise from the X-axis to the projection of Z_{spin} onto the X-Y plane. If $\hat{Z}_{spin}$ is aligned with the Z-axis, then $\alpha=0^{\circ}$.
right ascension rate ($\dot{\alpha}$)	The time rate of change of α.
declination (δ)	The angle between $\hat{Z}_{spin}$ and its projection onto the X-Y plane.
declination rate (δ)	The time rate of change of δ.

Navigation Bias and Associated Angle Parameters

Line bias (ζ)	The angle measured in the actual FOV plane between $(X_{1o})_{nom}$ and $(X_{1o})_{act}$. See figure 1.
Skew bias (η)	The angle between $\hat{Z}_{spin}$ and Z_{sym}. See Figure 2.
Element bias (ρ)	The angle measured in the spin plane between $(X_{1o})_{nom}$ and $(X_{int})_{act}$. See Figure 3.
Sun Sensor to VAS/VISSR angle(γ)	The angle measured in the spin plane between $(X_{1o})_{nom}$ and $\hat{X}_{sun}$. See Figure 4. Also the projection of $(Y_o + \Delta Y_o\ )$ onto the spin plane. See Figure 3.
Beta angle(β)	The angle measured in the spin plane between $(X_{1o})_{nom}$ and the satellite-earth vector when the sun sensor line-of-sight is aligned with the center of the sun minus 9.1875°.

Other Navigation Parameters

Spin period	The S/C spin period as determined by the SDB using successive sun sensor pulses.
Greenwich Hour Angle	The angle between the X axis and the Greenwich meridian (measured counter-clockwise)
Sun Declination	The angle measured positively north along an hour circle through the Sun from the celestial equator to the Sun
Sun Right Ascension	The angle measured positively eastward along the celestial equator from the X axis to the hour circle through the Sun
Epoch	The time at which the polynomial representations are initialized. Given as year, day into year, hours, minutes.
Time into Eclipse	The time (year, day in year, hours, minutes, seconds) at which the S/C enters the Earth's shadow which is assumed to be represented by a cylinder.
Time out of Eclipse	The time (as above) at which the S/C leaves the Earth's shadow.



$\hat{z}_{SYM}$
ACTUAL FOV PLANE
SYMMETRY PLANE
ρ
$(\hat{x}_{1,0})_{act}$
$(\hat{x}_{1,0})_{nom}$

Figure 2.6

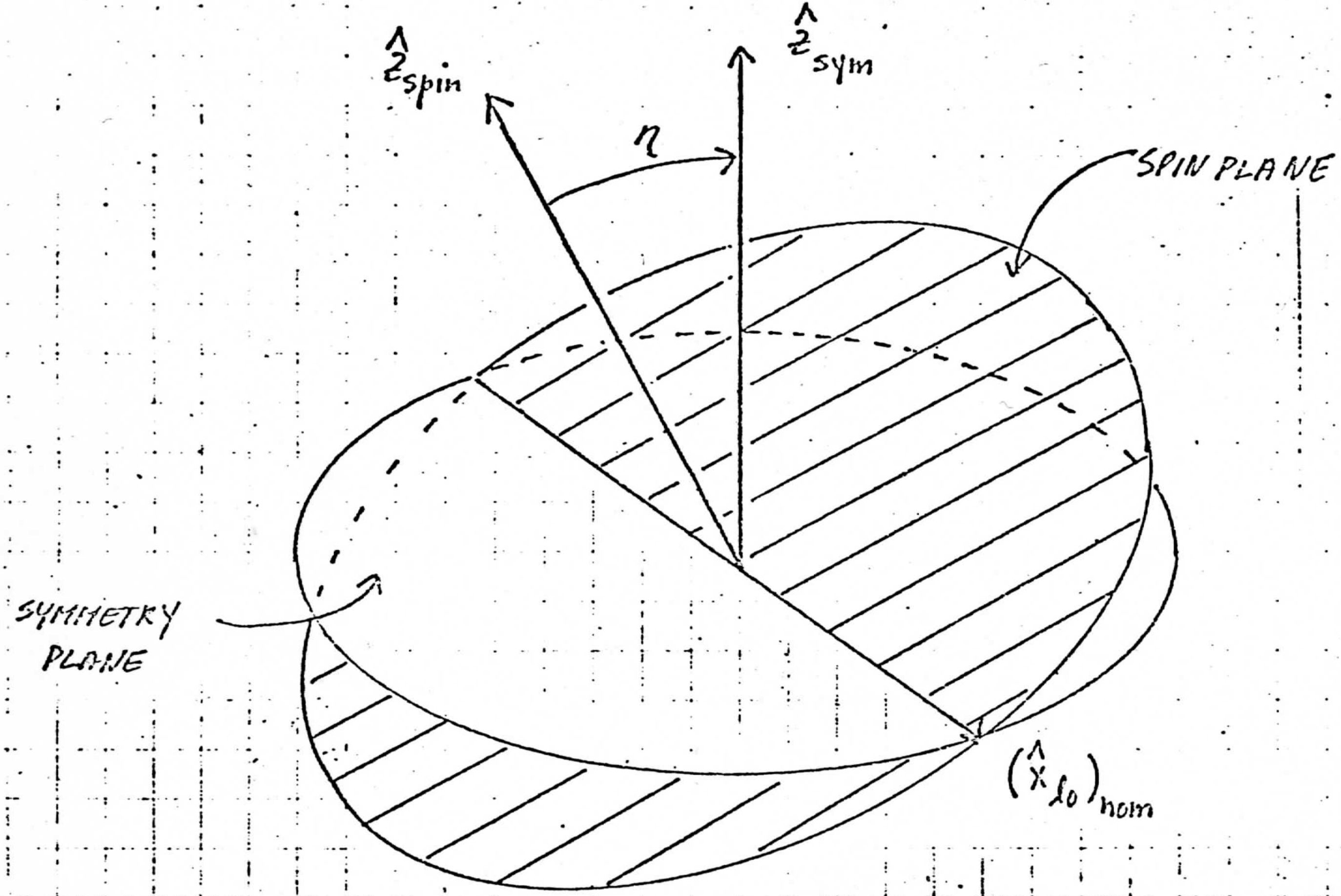


Figure 2.7

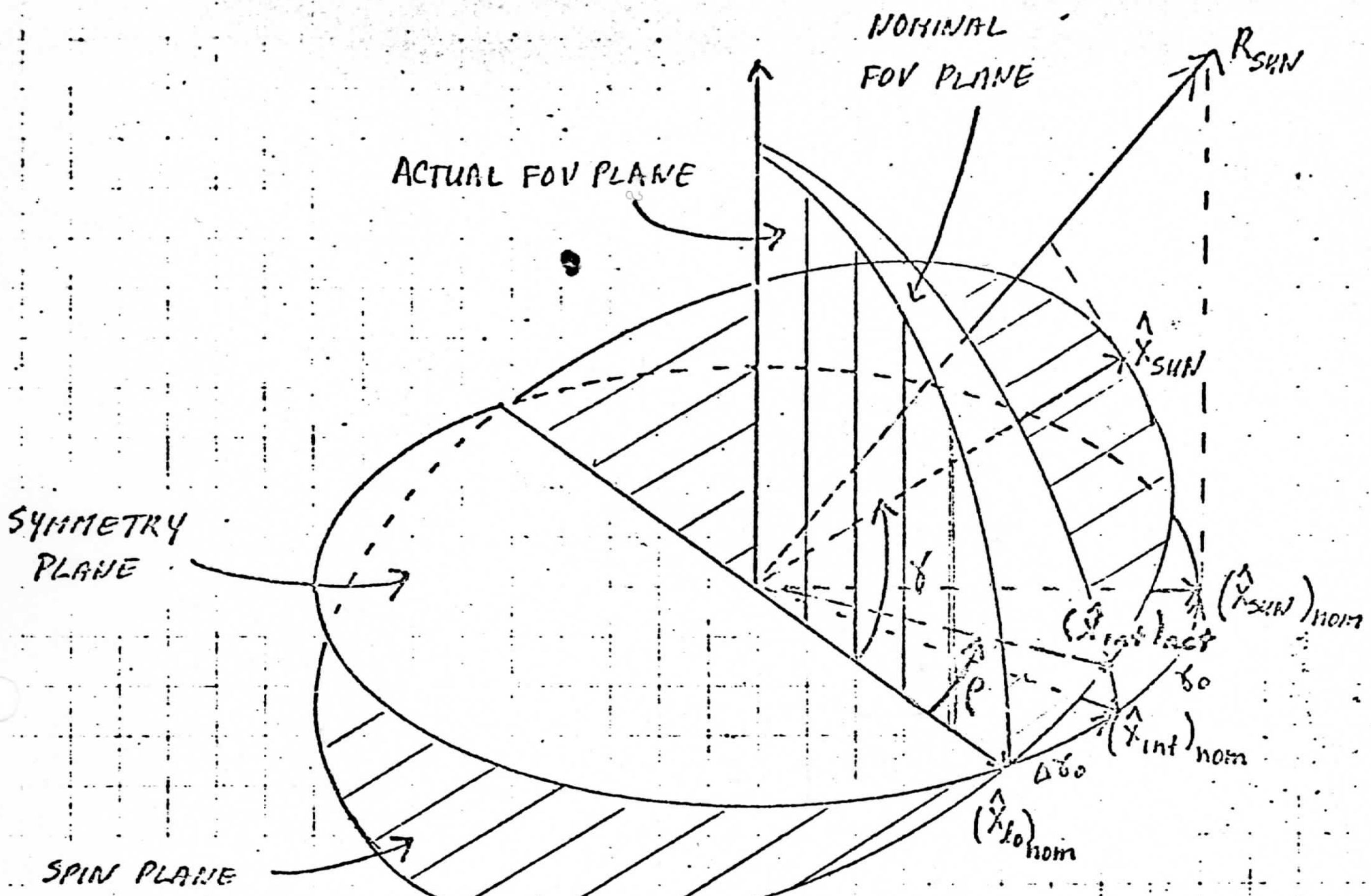
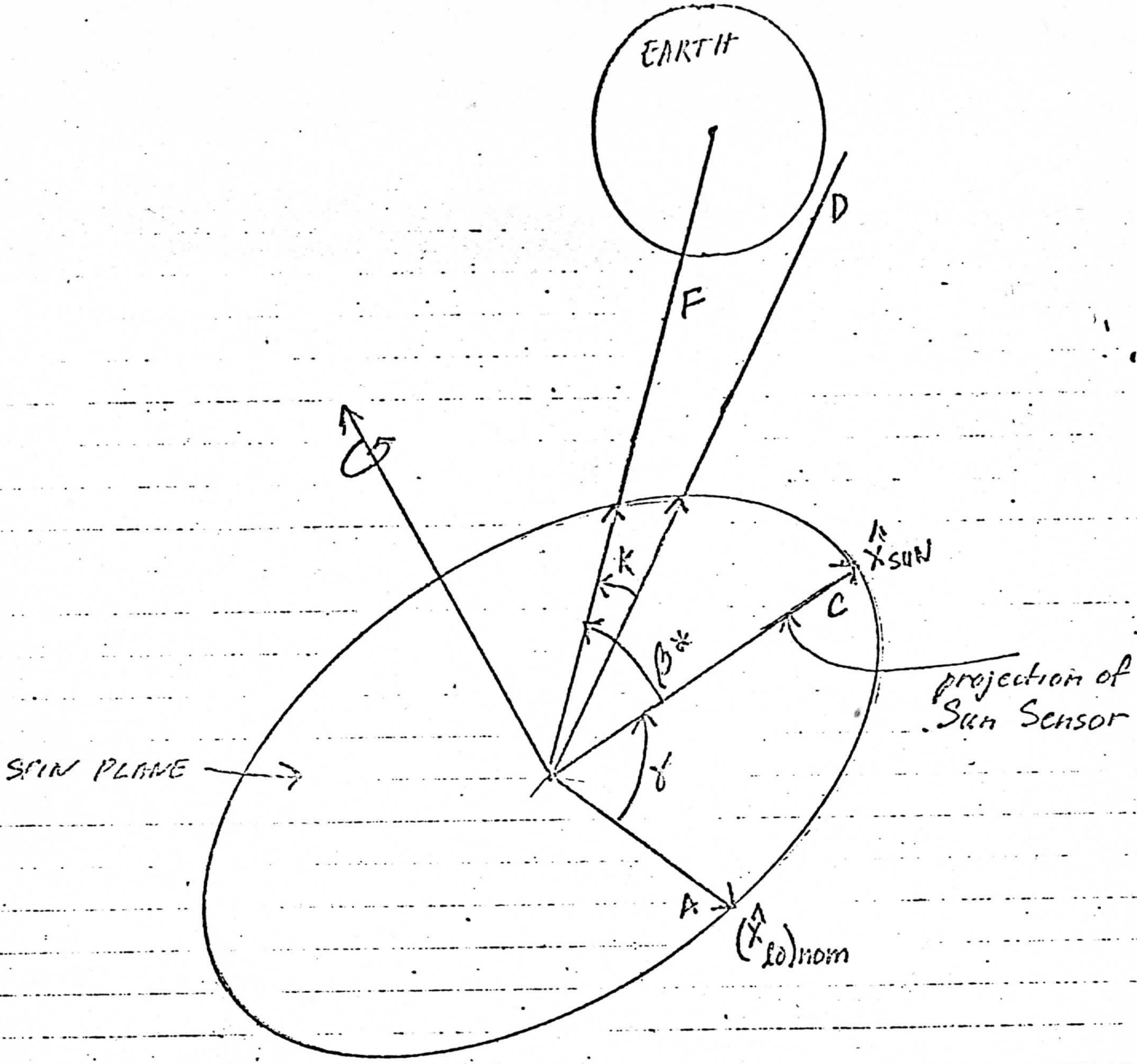

NOMINAL FOV PLANE
R_{SUN}
ACTUAL FOV PLANE
$\hat{X}_{SUN}$
SYMMETRY PLANE
γ
$(\hat{X}_{SUN})_{nom}$
$(\hat{X}_{int})_{act}$
γ_0
ρ
$(\hat{X}_{int})_{nom}$
$\Delta\gamma_0$
$(\hat{X}_{lo})_{nom}$
SPIN PLANE

Figure 2.8



$\beta = \angle AD = \beta^* - K + \gamma$

$\gamma = \angle AC$

$K = \angle DF$

$\beta^* = \angle CF$

Figure 2.9

2.2 Ancillary Data Collection

Specification of the Ancillary Data Collection has been started by including relevant portions of TIROS-N, DMSP, and Kansas City conventional weather documents. For TIROS-N information has been included from the NOAA Technical Report: Guide for Designing RF Ground Receiving Stations for TIROS-N. For DMSP pages from the Block 5-D Compendium have been included.

2.2.1 TIROS-N Collection

The TIROS Information Processor (TIP) formats data signals and status telemetry into one 8320 bps signal and distributes it. Inputs to TIP include:

(1) The TIROS Operational Vertical Sounder (TOVS) which consists of three separate and independent subsystems whose data may be combined for computation of atmospheric temperature profiles. They are (a) the Basic Sounding Unit (BSU), (b) the Stratospheric Sounding Unit (SSU), and (c) the Microwave Sounding Unit (MSU).

(2) The Space Environment Monitoring (SEM) data which measures the solar proton, alpha particle, and electron flux density, energy spectrum and the total particulate energy disposition at satellite altitude. The three components of this instrument are (a) the Total Energy Detector (TED), (b) the Medium Energy Proton and Electron Detector (MEPED), and (c) the High Energy Proton and Alpha Detector (HEPAD).

(3) The Data Collection and Platform Location System (DCPLS) which will provide for the receipt and storage of data (eg. temperature, pressure, altitude, etc.) from fixed and moving platforms for later transmission to the central processing facility, and for the location of the moving platforms. The platform location is for the purpose of determining the velocity of the fluid medium in which the platform is immersed (i.e. wind velocity in the case of balloons and ocean current at a depth of the drogue in the case of buoys).

(4) The housekeeping telemetry and on-board computer data.

These data are time division multiplexed into a format determined by a stored program within the TIP. The TIP output data stream will be directed to the VHF link for continuous real-time transmission.

The Basic Sounding Unit is a 14 channel instrument making measurements primarily in the infrared region of the spectrum. The instrument is designed to provide data that will permit calculation of 1) temperature profiles from the surface to 10 mb, 2) water vapor content at three levels in the atmosphere and 3) total ozone content. To accomplish this it employs 14 channels as indicated in Table 2 below.

Table 2.--BSU Spectral Channels

Central Wave No. (cm^{-1})	Half Power Bandwidth (cm^{-1})	Wavelength (μm)	NEΔN (mw/m^2-sr.cm^{-1})
2700	300	3.70	0.003
2350	50	4.26	0.03
1030	25	9.71	0.20
899	15	11.12	0.15
750	15	13.33	0.20
735	15	13.61	0.20
715	15	13.99	0.20
700	15	14.29	0.20
690	15	14.49	0.25
678	15	14.75	0.25
669	3.5	14.95	0.75
532	25	18.80	0.25
432	25	23.15	0.25
340	25	29.41	0.25

The Instantaneous Field of View (IFOV) of all detectors will be stepped together across the satellite track by use of a rotating mirror. This cross-track scan, combined with the satellite's motion in orbit, will provide coverage of a major fraction of the earth's surface. The essential parameters of the instrument are indicated in Table 3.

Table 3.--BSU Instrument Parameters

Parameter	Value
Calibration	Stable blackbody and space background
Cross-track scan	±49.5° (±1127 km)
Scan time	6.4 sec.
Number of steps	56
Step angle	1.8°
Step time	100 ms
Ground IFOV at nadir	21.8 km diameter
Ground IFOV at scan end	73.2 km cross-track by 37.3 km along-track
Distance between IFOV's	42 km along-track
Data rate	2.8 Kbs.

The Stratospheric Sounding Unit, to be provided by the United Kingdom, employs a selective absorption technique to make measurements in three channels. The spectral characteristics of each channel is determined by the pressure in a carbon dioxide gas cell in the optical path. The amount of carbon dioxide in the cells determines the height of the weighting function peaks in the atmosphere. SSU characteristics are shown in Tables 4 and 5 below.

Table 4.--SSU Channel Characteristics

Channel Number	Central Wave No. (cm^{-1})	Cell Pressure (mb)	Pressure of Weighting Function Peak (mb)
15	668	100	15
16	668	35	5
17	668	10	1.5

Table 5.--SSU Instrument Parameters

Parameter	Value
Calibration	Stable blackbody & space background
Cross-track scan	±40° (±737 km)
Scan time	32 sec.
Number of steps	8
Step angle	10°
Step time	4 sec.
Ground IFOV at nadir	147 km diameter
Ground IFOV at scan end	244 km cross-track by 186 km along-track
Distance between IFOV's	210 km along-track
Data rate	480 Bps.

The Microwave Sounding Unit is a four channel Dicke radiometer making passive measurements in the 5.5 mm oxygen band with characteristics as shown in Tables 6 and 7 below.

Table 6.--MSU Channel Characteristics

Parameter	Value
Channel frequencies	50.3, 53.74, 54.96, 57.95 GHz
Channel bandwidths	200 MHz
NEΔT	0.3°K

Table 7.--MSU Instrument Parameters

Parameter	Value
Calibration	Hot reference body and space background each scan cycle
Cross-track scan angle	±47.35°
Scan time	25.6 sec.
Number of steps	11
Step angle	9.47°
Step time	1.84 sec.
Angular resolution	7.5° (3 db)
Data rate	320 Bps.

Space Environment Monitor (SEM)

The Space Environment Monitor (SEM) data will also be included in HRPT and beacon transmission. This instrument, consisting of three separate and independent components, is being designed to measure solar proton, alpha particle, and electron flux density, energy spectrum and the total particulate energy disposition at satellite altitude.

The three components are:

1) Total Energy Detector (TED)
2) Medium Energy Proton and Electron Detector (MEPED)
3) High Energy Proton and Alpha Detector (HEPAD)

The SEM characteristics are shown in Table 8.

Table 8.--SEM Instrument Characteristics

Component	Detector	Measurement	
TED	Channeltron		0.3 Kev to 20 Kev in 11 bands
MEPED	Solid State	Telescope:	Protons 30 Kev to 2500 Kev 5 bands
		Telescope:	Electrons >30 Kev to >300 Kev 3 bands
		Telescope:	ions >6 Mev
		Omni :	Protons >10 Mev, >30 Mev, >60 Mev
HEPAD	Cerenkov Scintillator with photo multiplier		Protons 370 Mev to >850 Mev in 4 bands Alphas >640 Mev and >850 Mev

Data Collection and Platform Location System (DCPLS)

The Data Collection System (DCS) will introduce a new capability for polar orbiting operational satellites. These data will also be broadcast as a part of the HRPT and on the beacon. Characteristics of the instrument, which will be provided by France, are shown in Table 9.

Table 9.-- DCPLS Characteristics

Parameters (System)	Value
Data bit error rate	2×10^{-5}
Location accuracy	5-8 km rms
Wind speed accuracy	+3 mps
Visibility circle	5° elevation
No. of platforms in circle	200 max.*
Total platforms over globe	2000 max.
Parameters (Platform)	
Frequency	401.65 MHz
Emitted power	3W
Bit rate	400 Bps.
Message duration	420 ms.
Message repetition period	40-80 sec.

*Number of platforms requiring location, velocity determinations, and telemetering four sensor channels, visible in a 5° visibility circle. Actual number will depend on mix of platforms.

Instrument Scanning

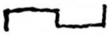
The three TOVS instruments will scan in a cross-track direction from left to right when viewing along the spacecraft velocity vector as shown in Figures 1, 2 and 3. The data from these and other low data rate instruments will be collected by the TIROS Information Processor (TIP) and combined (see Figure 4) with spacecraft telemetry for on-board storage and direct transmission to the ground in real time. Figure 4 also shows the routing of data from the instruments through the spacecraft processors to the transmitters. It should be noted that the TIP processed data are transmitted to the ground directly on the spacecraft VHF beacon link and are simultaneously combined with the AHVRR for transmission as a part of the HRPT service at S-Band.

2.2.1.1 Data Format and VHF Downlink Information

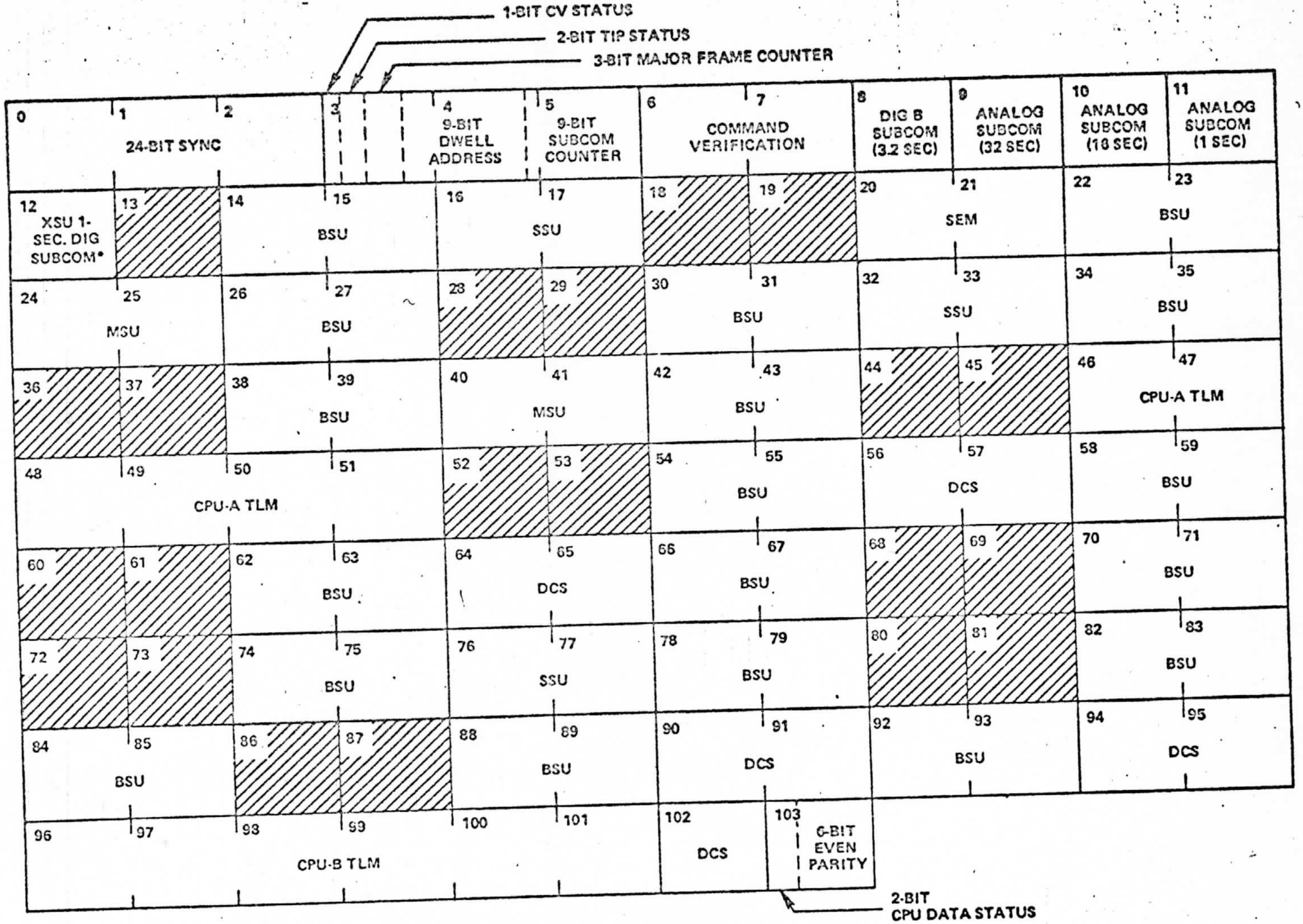
Beacon Data Transmission Characteristics

The TIP output on the beacon contains a multiplex of analog housekeeping data, digital housekeeping data and low rate instrument data. The format is based on a major frame (32 seconds - the time interval for one scan of the SSU and five scans of the BSU) containing 320 minor frames (0.1 second). The major frame permits adequate sampling of low rate analogue and digital housekeeping which is acquired in conjunction with the 550 words per second of instrument data. The key parameters of the data format* are contained in the following tables.

Table 16.--Real Time TIP Orbital Mode Parameters

Major Frame	
o Rate	1 frame every 32 seconds
o Number of minor frames	320 per major frame
Minor Frame	
o Rate	10 frames per second
o Number of words	104
o Format	See Table 17, Figure 6
Word	
o Rate	1040 words per second
o Number of bits	8
o Order	bit 1 = MSB bit 8 = LSB bit 1 transmitted first
Bit	
o Rate	8320 bits per second
o Format	split phase
o Data 1 definition	
o Data 0 definition	

*NOTE: With the addition of the fourth sounding instrument the format may change.



0	1	2	3	4	5	6	7	8	9	10	11
24-BIT SYNC			1-BIT CV STATUS 2-BIT TIP STATUS 3-BIT MAJOR FRAME COUNTER	9-BIT DWELL ADDRESS	9-BIT SUBCOM COUNTER	COMMAND VERIFICATION		DIG B SUBCOM (3.2 SEC)	ANALOG SUBCOM (32 SEC)	ANALOG SUBCOM (16 SEC)	ANALOG SUBCOM (1 SEC)
12 XSU 1-SEC. DIG SUBCOM*	13 ▨	14 BSU	15	16 SSU	17	18 ▨	19 ▨	20 SEM	21	22 BSU	23
24 MSU	25	26 BSU	27	28 ▨	29 ▨	30 BSU	31	32 SSU	33	34 BSU	35
36 ▨	37 ▨	38 BSU	39	40 MSU	41	42 BSU	43	44 ▨	45 ▨	46 CPU-A TLM	47
48 CPU-A TLM	49	50	51	52 ▨	53 ▨	54 BSU	55	56 DCS	57	58 BSU	59
60 ▨	61 ▨	62 BSU	63	64 DCS	65	66 BSU	67	68 ▨	69 ▨	70 BSU	71
72 ▨	73 ▨	74 BSU	75	76 SSU	77	78 BSU	79	80 ▨	81 ▨	82 BSU	83
84 BSU	85	86 ▨	87 ▨	88 BSU	89	90 DCS	91	92 BSU	93	94 DCS	95
96 CPU-B TLM	97	98	99	100	101	102 DCS	103 6-BIT EVEN PARITY 2-BIT CPU DATA STATUS				

NOTES: NUMBER IN UPPER LEFT HAND CORNER INDICATES MINOR FRAME WORD NUMBER.
TIME CODE DATA SHALL APPEAR DURING MINOR FRAME "0" WORD LOCATIONS 8 THROUGH 12.
////// WORD LOCATIONS ARE SPARE AND CONTAIN CODE 01010101.
- THE SUBCOMMUTATION FUNCTION IS ACCOMPLISHED IN THE CROSS STRIP UNIT (XSU).

Figure 6. TIP Minor Format

Table 17.--TIP Minor Frame Format

Function	Number of Words	Word Position	Bit Number 1 2 3 4 5 6 7 8	Plus Word Code and Meaning
Frame Sync & S/C[1] ID[2]	3	0 1 2	1 1 1 0 1 1 0 1 1 1 1 0 0 0 1 0 0 0 0 0 A A A A	The last 4 bits of word 2 are used for spacecraft ID
Status	1-	3	Bit 1:	Cmd[3] Verification Status; 1=CV[4] update word present in frame; 0=no CV update in frame.
			Bits 2&3 :	TIP status; 00=orbital mode, 10=CPU[5] memory Dump Mode, 01=Dwell Mode; 11 Boost Mode.
			Bits 4-6 :	Major Frame Count: 000=Major Frame 0 111=Major Frame 7; MSB first; Counter incremented every 320 minor frames.
Dwell Mode Address	1+	3 4	Bits 7&8 Bits 1-7 0 0 0 0 0 0 0 0 0 1 0 1 1 1 0 1 0 1	9 bit dwell mode address of analog channel that is being monitored continuously = Analog chan 0 MSB[6] is first = Analog chan 383
Minor Frame Counter	1+	4 5	Bit 8 Bits 1-8	0 0 0 0 0 0 0 0 0 = Minor Frame 0 1 0 0 1 1 1 1 1 1 = Minor Frame 319 MSB is first
Command Verification	2	6 7	Bits 9 through 24 of each received command word are placed in the 16 bit slots of telemetry words 6 and 7 on a one-for-one basis	

[1] S/C: Spacecraft

[2] ID : Identification

[3] Cmd: Command

[4] CV : Command Verification

[5] CPU: Central Processor Unit

[6] MSB: Most Significant Bit

Table 17.--TIP Minor Frame Format (Con't)

Function	Number of Words	Word Position	Bit Number 1 2 3 4 5 6 7 8 Plus Word Code and Meaning
Time Code	5	8, 9 9 9, 10,11,12	9 bits of Binary Day Count, MSB first bits 2-5: 0 1 0 1, Spare bits 27 bits of Binary millisec of Day Count, MSB first. Time code is inserted in word location 8-12 only in minor frame 0 of every major frame. The data inserted is referenced to the beginning of the first bit of the minor frame sync word of minor frame 0.
Digital B Subcom	1	8	A subcommutation of Discrete Inputs collected to form 8 bit words. 256 Discrete inputs (32 words) can be accommodated. It takes 32 minor frames to sample all inputs once (sampling rate = once per 3.2 sec). A major frame contains 10 complete Digital B subcommuted frames.
32 Sec Analog Subcom	1	9	A subcommutation of up to 192 analog points sampled once every 32 seconds plus 64 analog points sampled twice every 32 seconds (once every 16 seconds). Bit 1 of each word represents 2560 mv while Bit 8 represents 20 mv[1].
16 Sec Analog Subcom	1	10	These two subcoms are under PROM[2] control. A maximum of 128 analog points can be placed in the 169 slots; super commutation of some selected analog channels will be done in order to fill the 169 time slots. The 170th slot is filled with data from the analog point selected by command. The slot is word number zero of the one second subcom. The analog point may be any of the 384 analog points available. Bit 1 of each word represents 2560 mv while bit 8 represents 20 mv.
1 Sec Analog Subcom	1	11	

---

[1] mv: milli volts

[2] PROM: Programmed, Read Only Memory

Table 17.--TIP Minor Frame Format (Con't)

Function	Number of Words	Word Position	Bit Number 1 2 3 4 5 6 7 8 Plus Word Code and Meaning
XSU[1] Digital Subcom	1	12	The cross strap unit (XSU) generates an 8 word subcom which is read out at the rate of one word per minor frame. The XSU subcom is synchronized with its word 1 in minor frame 0, 8, 16....
Spares	21	13, 18, 19 28, 29, 36 37, 44, 45 52, 53, 60 61, 68, 69 72, 73, 80 81, 86, 87	0 1 0 1 0 1 0 1
BSU	36	14, 15, 22 23, 26, 27 30, 31, 34 35, 38, 39 42, 43, 54 55, 58, 59 62, 63, 66 67, 70, 71 74, 75, 78 79, 82, 83 84, 85, 88 89, 92, 93	8 bit words are formed by the BSU experiment and are read out by the telemetry system at an average rate of 360 words per second.
SSU	6	16, 17, 32 33, 76, 77	8 bit words are formed by the SSU experiment and read out by the telemetry system at an average rate of 60 words per second.

[1] XSU: Cross Strap Unit

Table 17.--TIP Minor Frame Format (Con't)

Function	Number of Words	Word Position	Bit Number 1 2 3 4 5 6 7 8 Plus Word Code and Meaning
SEM	2	20, 21	8 bit words are formed by the SEM sensor and read out by the telemetry system at an average rate of 20 words per second.
MSU	4	24,25,40, 41	8 bit words are formed by the MSU experiment and read out by the telemetry system at an average rate of 40 words per second.
DCS	9	56,57,64 65,90,91 94,95,102	8 bit words are formed by the DCS experiment and read out by the telemetry system at an average rate of 90 words per second
CPU A TLM[1]	6	46,47,48 49,50,51	A block of three 16 bit CPU words is read out by the telemetry system every minor frame.
CPU B TLM	6	96,97,98, 99,100,101	A second block of three 16 bit CPU words is read out by the telemetry system every minor frame.
CPU Data Status	1	103	Bits 1&2: 00 = All CPU data received 01 = All CPU-A data received; CPU-B incomplete 10 = All CPU-B data received; CPU-A incomplete 11 = Both CPU-A and CPU-B incomplete

[1] TLM: Telemetry

Table 17.--TIP Minor Frame Format (Con't)

Function	Number of Words	Word Position	Bit Number 1 2 3 4 5 6 7 8	Plus Word Code and Meaning
Parity	1-	103	Bit 3:	Even parity check on words 2 through 18
			Bit 4:	Even parity check on words 19 through 35
			Bit 5:	Even parity check on words 36 through 52
			Bit 6:	Even parity check on words 53 through 69
			Bit 7:	Even parity check on words 70 through 86
			Bit 8:	Even parity check on words 87 through bit 7 of word 103.

VHF Data Downlinks

The real-time TIP and APT data are simultaneously transmitted by both VHF downlinks. The VHF downlink characteristics are as follows:

1) Frequency
   - a) TIP: 136.77, 137.77 MHz
   - b) APT: 137.5, 137.62 MHz
2) Frequency stability $\pm 2 \times 10^{-5}$
3) Transmitter power
   - a) TIP: 1.0 watt
   - b) APT: 5.5 watts, beginning of life
     5.0 watts, end of life
4) Antenna gain,TIP
   - a) on axis, nadir +5.8 dBi
   - b) 5 degree elevation -6.0 dBi
   - c) Gain over 90% of sphere -14.0 dBi
5) Antenna gain, APT: see Figure 2-4
6) Polarization
   - a) TIP: linear
   - b) APT: right circular
7) Antenna type
   - a) TIP: dipole
   - b) APT: quadrifilar helix
8) Total antenna-transmitter loss
   - a) TIP: 3.5 dB
   - b) APT: 2.1 dB
9) Modulation
   - a) TIP: PCM/PSK
   - b) APT: Analog/FM

10) Modulation index

a) TIP: 67 ± 7.5 degrees, peak
b) APT: 17 ± 0.85 kHz, peak

11) Modulation rate on carrier

a) TIP: 8.32 kbps
b) APT: 2.4 kHz subcarrier

12) APT subcarrier modulation index: ≤92% AM

13) APT analog baseband: 1.6 kHz

14) TIP data code: split phase

15) Formats

a) TIP: see Figure 2-5
b) APT: see Figure 2-6 and 2-7

16) Transmitter operation: continuous

2.2.1.2 Data Rate, Schedule, and Data Volume

2a. TIP data rate is 8320 bps.

2b. TIROS-N will be launched into a near polar, sun synchronous orbit at nominal altitudes of 830 to 870 km. This orbit may have 0800 ± 2 hour LST descending node or 1600 ± 2 LST ascending node. Two TIROS-N satellites will orbit simultaneously, one with a morning descending node and the other with an afternoon ascending node.

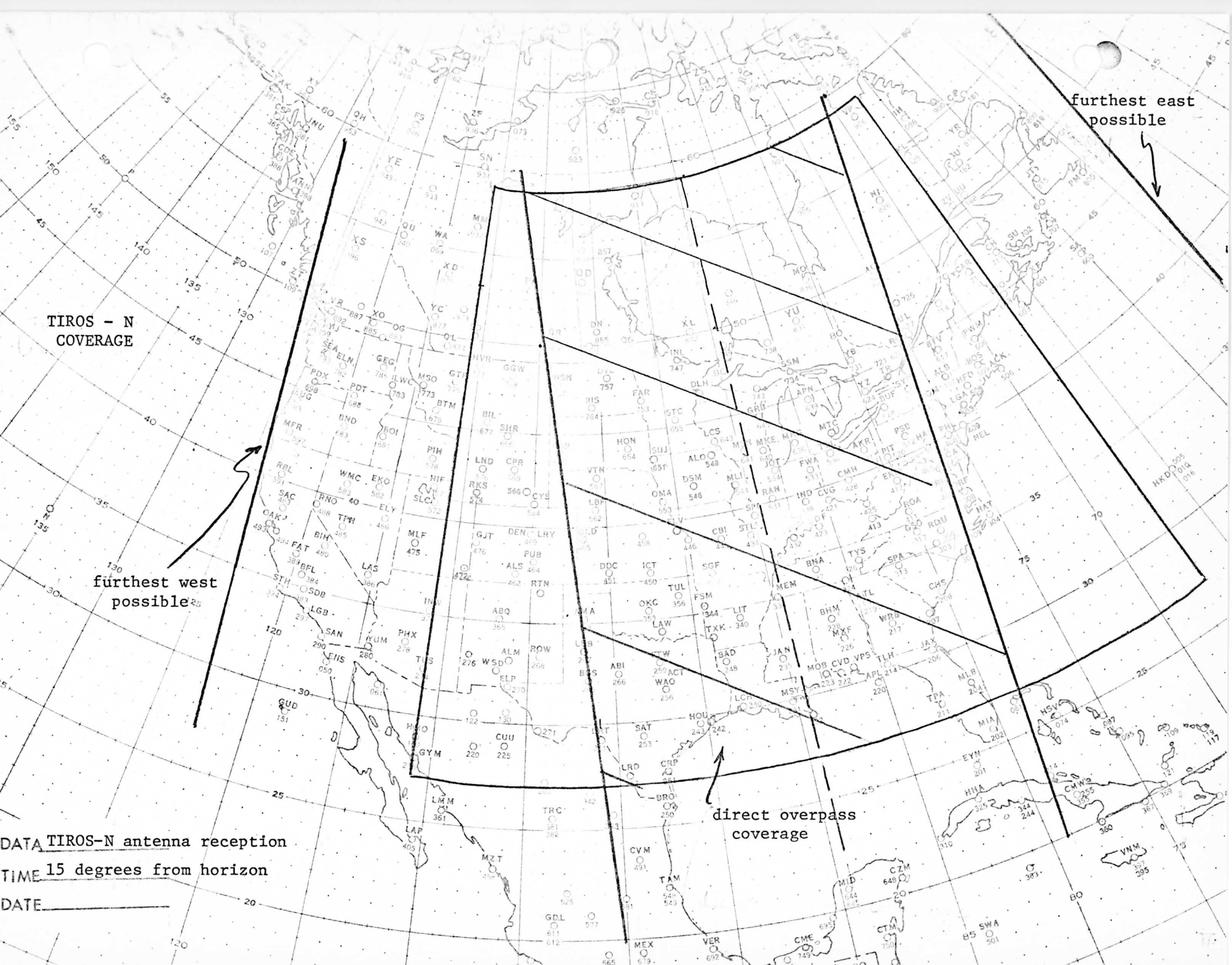
Elements of the mission orbit are

i	semi major axis	7211.54 km
ii	inclination	98.70 degrees
iii	anomalistic period	101.58 minutes
iv	height of perigee	833.3 km
v	height of apogee	833.4 km

With antenna reception 15° from the horizon the VHF antenna can receive the singal from the satellite from 1810 km away. The satellite sees ± 49.5° from the radial direction so the swath width is 2175 km. The coverage is indicated in the figure on the next page. Successive overpasses are separated by 25° longitude. Time for direct overpass is 9.1 minutes.

2c. Maximum # of overpasses from morning and evening TIROS-N satellites is 8. Therefore, if one overpass ingests 4.5 million bits, then for one day 36 million bits is an upper limit.

TIROS - N COVERAGE



DATA TIROS-N antenna reception

TIME 15 degrees from horizon

DATE__________

2.2.1.3 Data Calibration and Location

Calibration parameters will be acquired from NOAA with updates occurring every five to ten days for HIRS data. Earth location information will also come from NOAA with updates occurring daily. It will consist of ephemeris data and software needed to calculate locations.

2.2.2 Defense Meteorological Satellite Program

DMSP data cannot be usefully received by local antennae since the data are encrypted. Real time usefulness of DMSP data can only be achieved with a hookup to the computer (UNIVAC 1110) at Offutt Air Force Base. Efforts to investigate this are underway. Meanwhile mailed tape output from the Block 5-D satellites will be available with roughly a 2 day delay.

DEFENSE METEOROLOGICAL SATELLITE PROGRAM

The Defense Meteorological Satellite Program's Space Segment consists of two satellites in 450 nautical mile (nm) sun-synchronous polar orbits each carrying a payload of meteorological sensors. Primary cloud imaging sensors capable of globally viewing the earth in the visible (0.4 - 1.0 micrometers) and infrared (8 - 13 micrometers) spectrums are carried by every satellite. The ascending node of one satellite is in the early morning time period while the other is at mid-day. Each satellite collects data continuously scanning a crosstrack swath 1600 nm wide. The final data product is either in computer program format or film product directly usable for imagery analysis.

The satellites are commanded and controlled from sites located at Loring AFB, Maine (Site 2) and Fairchild AFB, Washington (Site 1) which also receive stored data read from tape recorders on board the spacecraft. This data is relayed to the Air Force Global Weather Central at Offutt AFB, Nebraska (Site 3) over a communication satellite link.

The data is also directly transmitted from the DMSP satellite to Air Force and Navy ground terminals and Navy carriers located throughout the world.

The Program has expanded to include sixteen Air Force and two Navy transportable data terminals. These terminals can be deployed to any point on the earth and made operational within 72 hours. Each is operated by a 2-man operator-maintenance crew. At the present time the U.S. Navy operates a data terminal on board the carrier USS Constellation, and will soon equip the carrier USS JF Kennedy for operation in the Atlantic. Plans also call for outfitting additional carriers with this capability. These stations employ a 2-antenna concept -- one on each side of the flight deck.

DMSP has a payload test facility at Vandenberg AFB, California (Site 4) for system checkout at launch and on-orbit analysis.

The program's Command and Control Center (CCC) is at Offutt AFB, Nebraska (Site 5). The 4000th Aerospace Application Group (SAC) is responsible for the on-orbit commanding through Sites 1 and 2 and the orbital telemetry analysis performed at the CCC.

DMSP KEY SYSTEM PARAMETERS

SATELLITE SYSTEMS	450 NM Sunsychronous Orbits
	One Satellite has Early Morning Ascending Node (0700-0800 Local)
	One Satellite has Noontime Ascending Node (1130-1230 Local)
	Visible and Infrared Imager
	Temperature Moisture Sounder
	Gamma Detector
	Electron Spectrometer
	Other Special Meteorological Sensors
GROUND SYSTEMS	Two Readout Stations For Command and Control
	Synchronous Communications Satellite Used as Link to AFGWC
	AFGWC is recipient of Digital Data for Processing
	Air Force and Navy Tactical Remote Terminals are recipients of Direct Data Read-outs over their areas
	Navy Shipboard Terminals Receive Direct Data Readouts Over Their Areas.
	Dedicated Facilities for Launch and Early Orbit Checkout of Satellites.

DMSP KEY SATELLITE CHARACTERISTICS

MISSION

Acquire meteorological data in visual and infrared spectra

- High-resolution (1.5nm x 1.5nm) global coverage
- Very-high-resolution (0.3nm x 0.3nm) coverage of selected areas
- Near constant resolution versus scan angle

Transmit acquired data to Control Readout Stations in continental U.S. and mobile ground stations and shipborne stations by command

ORBIT

Circular Sun-Synchronous

Altitude: 450 ± 9 nautical miles

Period: 101 minutes

Apogee-to Perigee: 17 nautical miles

Inclination: 98.7° ± 1.3°

Sun Angle: 0° to 95°

PAYLOAD

Meteorological sensors for tri-service users

- Primary sensor (OLS) and electronics (OLS/AVE)
- UP to Six Special meteorological sensors and electronics

Weight: 300 pounds

Power: 170 watts

WEIGHT

Integrated Satellite System

- On launch pad: 5850 pounds
- In orbit: 1032 pounds

DESIGN

Maintain precision co-alignment of payload sensors

Precision pointing of co-aligned spacecraft/payload sensors axis to local geodetic vertical.

DMSP KEY IN-ORBIT SATELLITE CHARACTERISTICS

Attitude Determination & Control	Zero Momentum; Three-axis Stablized; Earth Oriented
Primary System Accuracy	0.01°
Reference	Three orthogonal strap-down gyros plus one skewed as a back-up
	Solid State Optical Star Mapper
Back-up System Accuracy	0.1°
Reference	Solid State Static CO_2 Earth Horizon Sensor plus Sun Sensor
Control	Three orthogonal reaction wheels plus one skewed as a back-up
	Magnetic Momentum Unloading Coils
Power	Direct Energy Transfer System
Power Source	Sun Tracking Deployable Solar Array
Power Storage	Nickel-Cadmium Battery
Primary Bus	+28 Volts Regulated
Power Available	300 Watts Average
Command & Control	SGLS Compatible
	Controlled Command Access Period
	Stored & Real-Time Commands, Maintained by Redundant Ground Programmable CPU's
Central Processing Units	Stored Commands - 800
	2 Processor Memories - 16,000 Words Each
	High Accuracy Time Reference - Redundant Crystal Oscillator

DMSP KEY IN-ORBIT SATELLITE CHARACTERISTICS

Structure	Modular Construction
Precision Mounting Platform	Supports Payload Sensors & Attitude Determination Components
	Aluminum - Dip-Brazed Construction
	Co-Alignment of Sensors <10 arc-sec
Equipment Support Module	Supports Payload Electronics, Special Meteorological Sensors, Spacecraft Electronics
	Aluminum Frame and Lightweight Honeycomb Panels
Reaction-Control System Structure	Supports Reaction Control System & 3rd Stage Solid Motor
	Truss Supported Aluminum Monocoque construction
Thermal Control	Combination of Passive & Active Components
Sensor Control	Electrically Controlled Rectangular Louvers plus make-up Heaters
	± 1°C control
Spacecraft Systems	Electrically Controlled Pin-Wheel Louvers
	Make-up Heaters Thermal Finishes and Blankets
Communications	
S-Band Command, Data & Telemetry Links	
Up-Link	Redundant Receiver-Demodulator Unit
	1 KBPS Uplink Command Rate
Payload Data Links	Three Simultaneous S-Band Links
	1024 to 2670 KBPS Data Rate Each Link
Telemetry Down-Link	S-Band Redundant Transmitters
	2 KBPS or 10 KBPS Orbital Data Rate

DMSP KEY SENSOR CHARACTERISTICS

OLS-
OPERATIONAL
LINESCAN
SYSTEM

Meteorological Data Collected in Visible and Infrared Spectra

Visible Data Collected as 0.3nm x 0.3nm during day and 1.5nm x 1.5nm at night.

Infrared Data Collected as 0.3nm x 0.3nm at all times

Oscillating Scanner Collects Data in Both Directions Along 1600nm Swath.

Near Constant Resolution as a function of Scan Angle.

Three Digital Tape Recorders for Data Storage

Each Recorder can store 20 minutes of interleaved visual and infrared 0.3nm x 0.3nm of data.

Analog Filtering and Digital Averaging is used to smooth data to 1.5nm x 1.5nm for on board global storage.

Each recorder can store 400 minutes of interleaved visual and infrared 1.5nm x 1.5nm of data.

Telemetry and special meteorological sensor data are included within the primary smoothed data stream.

Real time encrypted transmission of 0.3nm and 1.5nm data.

THE OPERATIONAL LINESCAN SYSTEM (OLS)

The OLS is the primary imagery data acquisition system on the Block 5D spacecraft. This system gathers visual and infrared imagery data from earth scenes and provides such data, together with appropriate calibration, indexing, and other auxiliary signals, to the spacecraft for transmission to ground stations. The data is collected, stored and transmitted in fine (F data) or smoothed (S data) resolution. The OLS has a scanning optical telescope system driven in a sinusoidal motion by counter-reacting coiled springs and a pulsed motor. This motion moves the instantaneous field-of-view of the detectors across the satellite subtrack, with maximum scanning velocity at nadir and reversals at end of scan. Detector size is dynamically changed to reduce angular instantaneous field-of-view as it nears each end of scan, thereby maintaining an approximately constant footprint size on earth. The swath width is 1600 nm from a nominal altitude of 450 nm.

The optics consist of a cassegrain telescope, whose elements are common to both visual and infrared imagery, and a set of relay optics that separates the wavelengths and fields-of-view for the different detectors. On-board pre-processing of the data by the OLS provides for the various modes of data output. The OLS provides global coverage in both visual (L data) and thermal (T data) modes. Fine resolution data is collected continuously, day and night, by the infrared detector (TF data), and continuously during daytime only by a segmented, silicon diode detector (LF data). Fine resolution data has a nominal linear resolution of 0.3 nm. Tape recorder storage capacity and transmission constraints limit the quantity of fine resolution data (LF or TF) which can be downlinked from the stored data fine (SDF) mode to a total of 80 minutes of LF and TF data per ground station readout.

Data smoothing permits global coverage in both the infrared (TS) and visible (LS) spectrum to be stored on the tape recorders in the stored data smoothed (SDS) mode. Smoothing is accomplished by electrically reducing the sensor resolution to 1.5 nm in the along scan direction, then digitally averaging five such .3 x 1.5 nm samples in the along track direction. A nominal linear resolution of 1.5 nm results. 400 minutes of LS and TS data may be downlinked in a single ground station readout. An additional detector allows collection of visible data (LS) with a 1.5 nm nominal linear resolution under low light level conditions. In the fine mode visual (LF) channel, a 3-segment silicon diode detector is switched at ±400 nm from subtrack, using either of two segments from that point to end of scan. All three segments are used and summed together within 400 nm of nadir. Detector geometry and segment switching compensate for the optical rotation of the field-of-view, as a function of scan angle. A mirror in the telescope assembly is dynamically driven to accomplish image motion compensation by removing the satellite's along track motion of the instantaneous field-of-view to preserve scan line contiguity. The visual daytime response of the OLS is in the spectral range of 0.4 to 1.1 microns; chosen so as to provide maximum contrast between earth, sea and cloud elements of the image field. The visual fine mode is provided for day scenes only. The infrared detector, consisting of two segments, is switched at nadir to provide approximately constant ground footprint and image derotation. The detector is a tri-metal (HgCdTe) detector operating at approximately 105°K. The OLS infrared spectral response of 8 to 13 microns was chosen to optimize detection of both water and ice crystal clouds. The sensor output is normalized in terms of the equivalent blackbody temperature of the radiating object. A shaping network is employed to change the fourth-power-of-temperature response of the detector so that sensor output voltage is a linear function of scene temperature. This detector is passively cooled by a radiative cooler viewing free space. The tri-metal detector is accurate to within 1°K rms across the (equivalent blackbody) temperature range 210°K to 310°K. The noise equivalent temperature difference (NETD) of the infrared system is well within 1°K across this same range.

The OLS data processing subsystem performs command, control, data manipulation, storage, and management functions. Commands are received from the ground through the spacecraft command system, stored in the OLS and processed by the OLS according to time codes. The OLS executes commands, accomplishes the smoothing of fine resolution data, derives gain commands from orbital parameters for normalization of visual data and dynamic signal control, and outputs the data to the spacecraft communications system. All data is processed, stored and transmitted in digital format. The OLS also provides the data management functions to process, record and output data from up to six additional meteorological sensors.

A combination of either fine resolution data and the complementary smoothed resolution data (i.e., LF and TS or TF and LS) can be provided in the direct digital transmission mode. Either encrypted or clear direct data can be output simultaneously with two channels of stored data. The OLS system includes and controls three digital tape recorders, each with a storage capacity of 1.67×10^9 bits. Each recorder can record at any one of three data rates and play back at either of two data rates. These rates are:

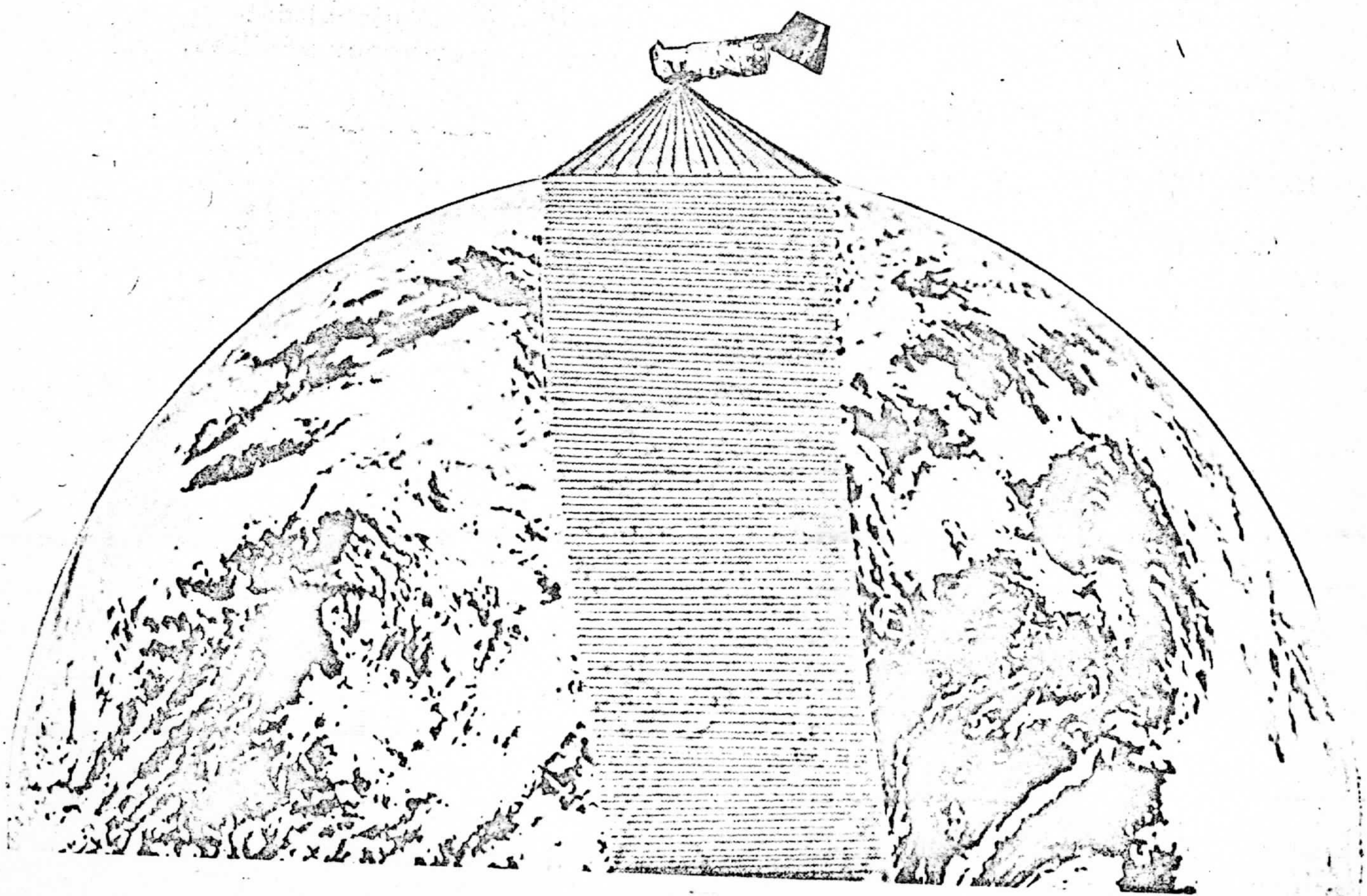
INPUT	STORAGE (Per Recorder)
66.56 Kbps (LS and TS interleaved bit by bit)	400 minutes
1.3312 Mbps (LF and TF interleaved bit by bit)	20 minutes
665.6 Kbps (LF or TF only)	40 minutes

OUTPUT	TIME/DATA
2.6624 Mbps	10 minutes/All LS and TS
2.6624 Mbps	10 minutes/All LF and TF
1.3312 Mbps	20 minutes/All LF or TF

All tape recorders are interchangeable in function, providing operational redundancy and enhanced system life expectancy.

OLS-SCANNING CONCEPT

- OSCILLATING SCANNER
- 0.3 NM × 1600 NM SWATH PER SCAN
- COLLECTS DATA IN BOTH SCAN DIRECTIONS
- 450 NM ORBIT
- INCLINATION 98.729°



SPECIAL SENSORS

(SSD) ATMOSPHERIC DENSITY SENSOR

The Atmospheric Density Sensor (SSD) will provide a measure of major atmospheric constituents (Nitrogen, Oxygen and Ozone) in the earth's thermosphere (100 to 250 Km in altitude) by making earth-limb observations of the ultraviolet radiation from this atmospheric region. The sensor will measure the radiation emitted in the ultraviolet spectral region from excitation of molecular nitrogen by impinging solar radiation. The intensity of the emitted radiation is proportional to the excitation rate and the number of molecules at any given altitude. Funneltrons and a photomultiplier tube will detect the radiation after it passes through a collimator which provides a $0.1 \times 4.0^{\circ}$ field-of-view. The SSD will be mechanically driven to scan vertically through the earth's limb in about 30 seconds. The instrument will provide approximately 50 sets of density profiles on the daylight portion of each orbit. The SSD is currently under development.

(SSJ) PRECIPITATING ELECTRON SPECTROMETER

A small, lightweight (3 lb) sensor, the SSJ counts ambient electrons with energies ranging from 60 eV to 20 KeV. Utilizing a time-sequenced variable electrostatic field to deflect the particles toward the channeltron detector, the sensor determines the number of electrons having energies within certain sub-ranges of the 60 eV to 20 KeV spectrum.

(SSH) TEMPERATURE/WATER VAPOR/OZONE RADIOMETER

The SSH, a scanning infrared radiometer, will provide global data which yields vertical temperature profiles, vertical water vapor profiles, and total ozone concentration.

(SSB) GAMMA DETECTOR

The SSB is a gamma radiation measurement sensor provided to DMSP by AFTAC.

— MICROWAVE TEMPERATURE SOUNDER

DESCRIPTION OF THE AIR FORCE INFRARED TEMPERATURE AND HUMIDITY SOUNDER (SSH)

J. Richard Yoder, Barnes Engineering Company

INTRODUCTION

The Defense Meteorological Satellite Program (DMSP) block 5D satellites will contain infrared multispectral sounders for humidity, temperature and ozone. For convenience these instruments are given the designation SSH which may be interpreted as the acronym for Satelliteborne Sounder, Humidity, to distinguish it from a previous series of instruments designed to sound primarily for temperature. The SSH gives soundings of temperature and of humidity and a single measurement of ozone for vertical and slant paths lying under and to the side of the subsatellite track.

The SSH makes a set of radiance measurements in narrow spectral channels lying in the spectroscopic absorption bands of carbon dioxide, water vapor, and ozone. These radiance measurements are mathematically inverted to yield vertical profiles of temperature and of water vapor and an indication of total ozone content.

The upwelling radiance in each spectral channel is a function of the (vertical) temperature profile, the (vertical) compositional profile and spectroscopic transmission functions. Several inversion techniques have been developed to yield either the temperature profile or the compositional profile if the other profile is known.

For temperature sounding, radiances are measured in channels lying in the wing of the $15 \mu m$ carbon dioxide absorption band. CO_2 is taken to have a constant mixing ratio or other assumed profile. Inversion then yields the temperature profile.

For humidity sounding, channels are selected to provide a range of absorption values in the rotational water vapor band. The temperature profile is available as described above; the inversion therefore yields the humidity profile.

The temperature profile is necessary as an input to obtain the humidity profile. The humidity profile can provide increased accuracy in the temperature profile determination by correcting for the water vapor absorption in the CO_2 band. It is advantageous that both CO_2 band and water vapor band radiances are measured by the same instrument and referred to the same radiance reference.

GENERAL DESCRIPTION

The SSH is a cross-track scanning, multi-channel filter radiometer.

CENTER μm	CENTER cm^{-1}	WIDTH cm^{-1}	SPECIES	ABSORPTION	NESN *
9.8	1022	12.5	O_3	---	.05
12.0	835	8	window	---	.11
13.4	747	10	CO_2	least	.12
13.8	725	10	CO_2		.11
14.1	708	10	CO_2		.11
14.4	695	10	CO_2		.10
14.8	676	10	CO_2		.09
15.0	668.5	3.5	CO_2	most	.30
18.7	535	16	H_2O	least	.15
24.5	408.5	12	H_2O		.14
22.7	441.5	18	H_2O		.09
23.9	420	20	H_2O		.12
26.7	374	12	H_2O		.18
25.2	397.5	10	H_2O		.16
28.2	355	15	H_2O		.25
28.3	353.5	11	H_2O	most	.33

* Noise Equivalent Spectral Radiance in ergs/sec-cm^2-str-cm^{-1}

TABLE 1, SSH SPECTRAL CHANNELS AND NOISE LEVELS

Cross-track scanning is accomplished in twenty-five 4° steps from -48° to +48° of nadir. The FOV dwells at each station for 1 second during which time the 16 spectral radiance measurements are accomplished. After each cross-track scan, the FOV is slewed to provide calibrating looks at space and at an internal reference blackbody source. The cross-track scan is repeated every 32 seconds.

The instantaneous FOV is circular (conical), 2.7° in diameter, subtending a 39.3KM spot at nadir. The along-track spacing is 208KM. The cross-track spacing is 58.4KM at nadir increasing to 136KM at the oblique maximum.

A 72mm dia Cassegrain objective collects radiance from a FOV pointed by a step-rotating diagonal scanning mirror. A rotating chopper interrupts incoming radiance, providing reference to a fixed constant internal radiance level. Near the focal plane of the Cassegrainian collector, two dichroic mirrors separate the incoming radiance into three separate paths. Two of these paths are conditioned by separate eight-sector filter wheels. One wheel provides the spectral channels for temperature sounding; the other, the channels for water vapor sounding. The third channel employs a fixed filter to make a single radiance measurement indicative of total ozone content. Each of the three optical paths is equipped with a cone-condensed pyroelectric infrared detector.

The band-defining filters are multilayer dielectric interference stacks on germanium or silicon substrates. Fractional bandwidths lie between 0.5% (668cm^{-1}) and 5% (420cm^{-1}).

The spectral width of a typical channel is 10cm^{-1}. Out-of-band radiance is potentially available throughout a width of several thousand cm^{-1}. Extraordinary care has been taken to accomplish effective spectral blocking. All refractive surfaces are incorporated into the blocking design. Intrinsic bulk absorption of optical materials is used where available. In all other blocking regions, at least two surfaces are treated with multilayer stacks to insure that transmission is held lower than 10^{-4}. Since measurement of such low transmissions is very difficult the design provides rejection on two separate surfaces, each of which can be conclusively measured. By this technique the total integrated out-of-band radiance is held to substantially less than 1% of the in-band radiance.

The signals from the three pyroelectric detectors are conditioned in separate analog channels and are then multiplexed into a single analog-to-digital converter. The signal train, indicative of the channel spectral radiances, is formatted and buffered in dual output registers available to externally-clocked interrogation.

The SSH optical unit is of irregular outline with maximum dimension 31.8 x 26.4 x 22.3cm. The electronics box 17.8 x 28 x 14cm can be mounted in a different spacecraft location. The SSH weighs 13.2Kg and consumes 8W of power.

In flight, calibration is refreshed every 32 seconds by exposing all sixteen radiometer channels to a cold source (space) and a warm source (internal blackbody).

PERFORMANCE

Typical noise levels of spectral radiance in SSH channels is given in Table 1. Spectral radiance accuracy is better than 0.5 erg/sec-cm^2-ster-cm^{-1} absolute and 0.2 erg/sec-cm^2-ster-cm^1 relative between channels.

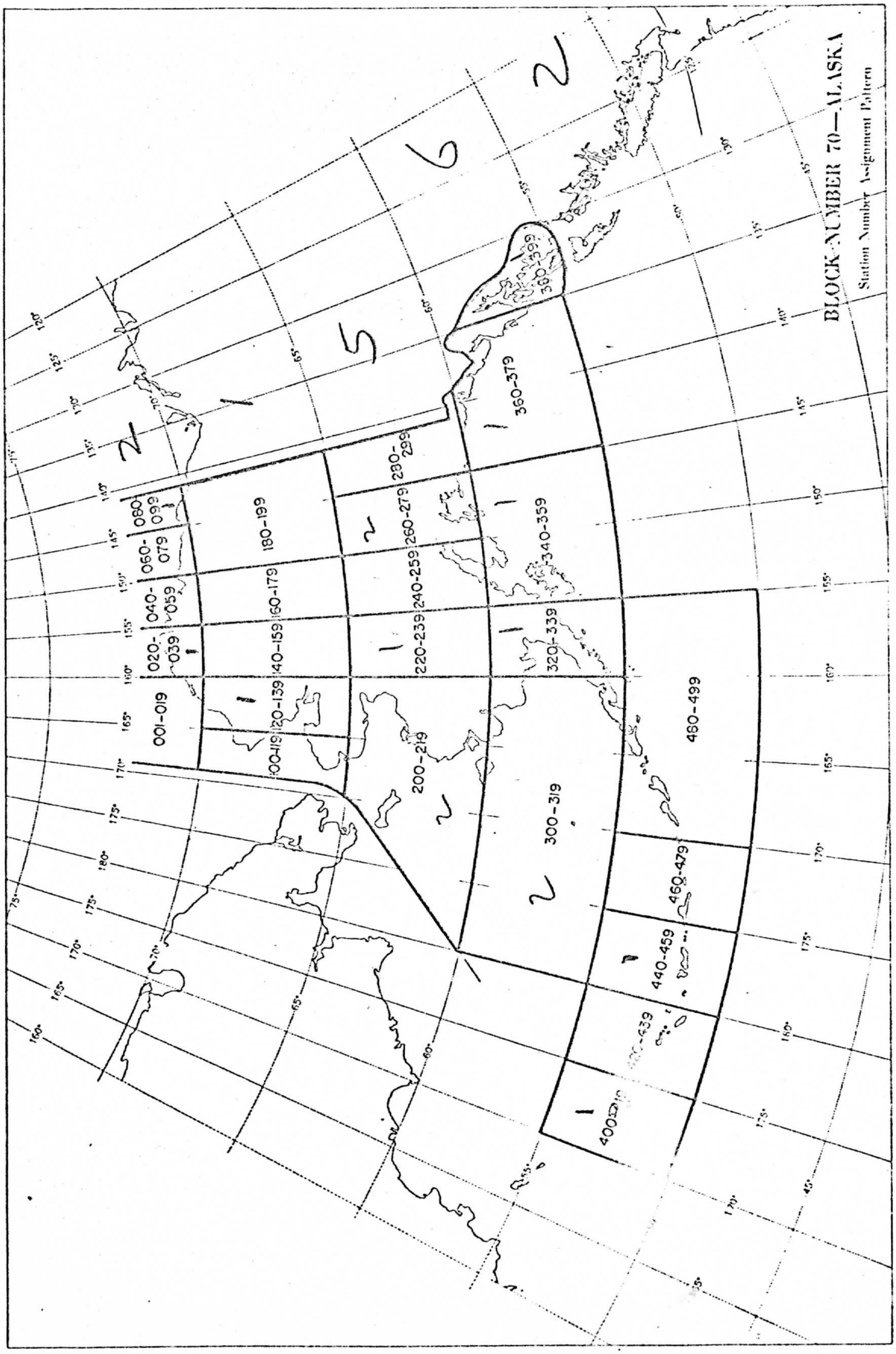
2.2.3 Conventional Weather Data Collection

The following pages indicate some of the information available from the Kansas City line. An important piece of information that the VAS ground processing system will require, that Kansas City does not offer, is the NMC prediction model output. Therefore it is expected that the VAS system will seek its conventional weather data from NMC. The system will also have the capability to incorporate special observations.

More information is coming in this area.

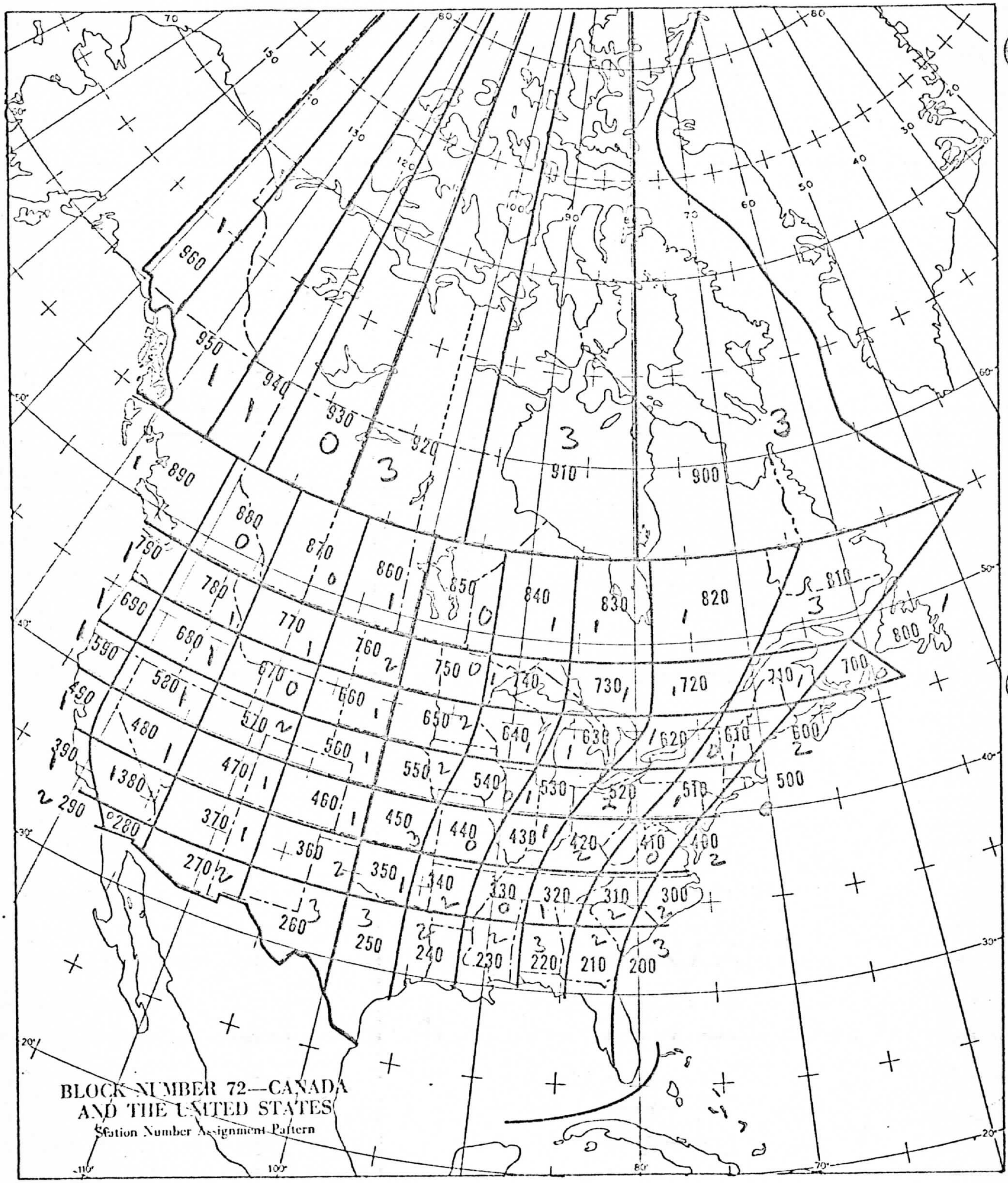
1 0 1 2 3 4 5 6 7 8 9

Regional Block Numbers

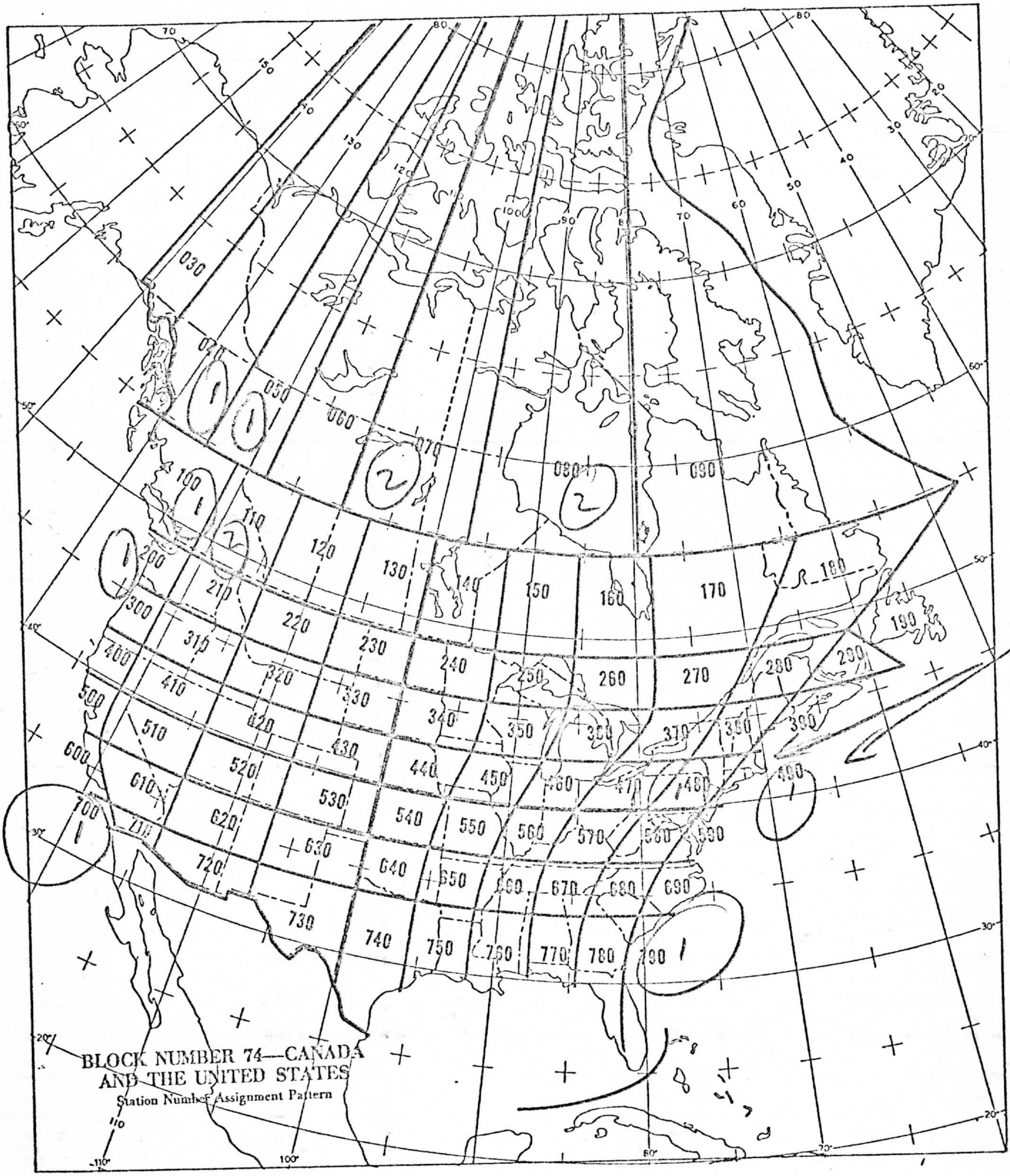


BLOCK NUMBER 70—ALASKA

Station Number Assignment Pattern

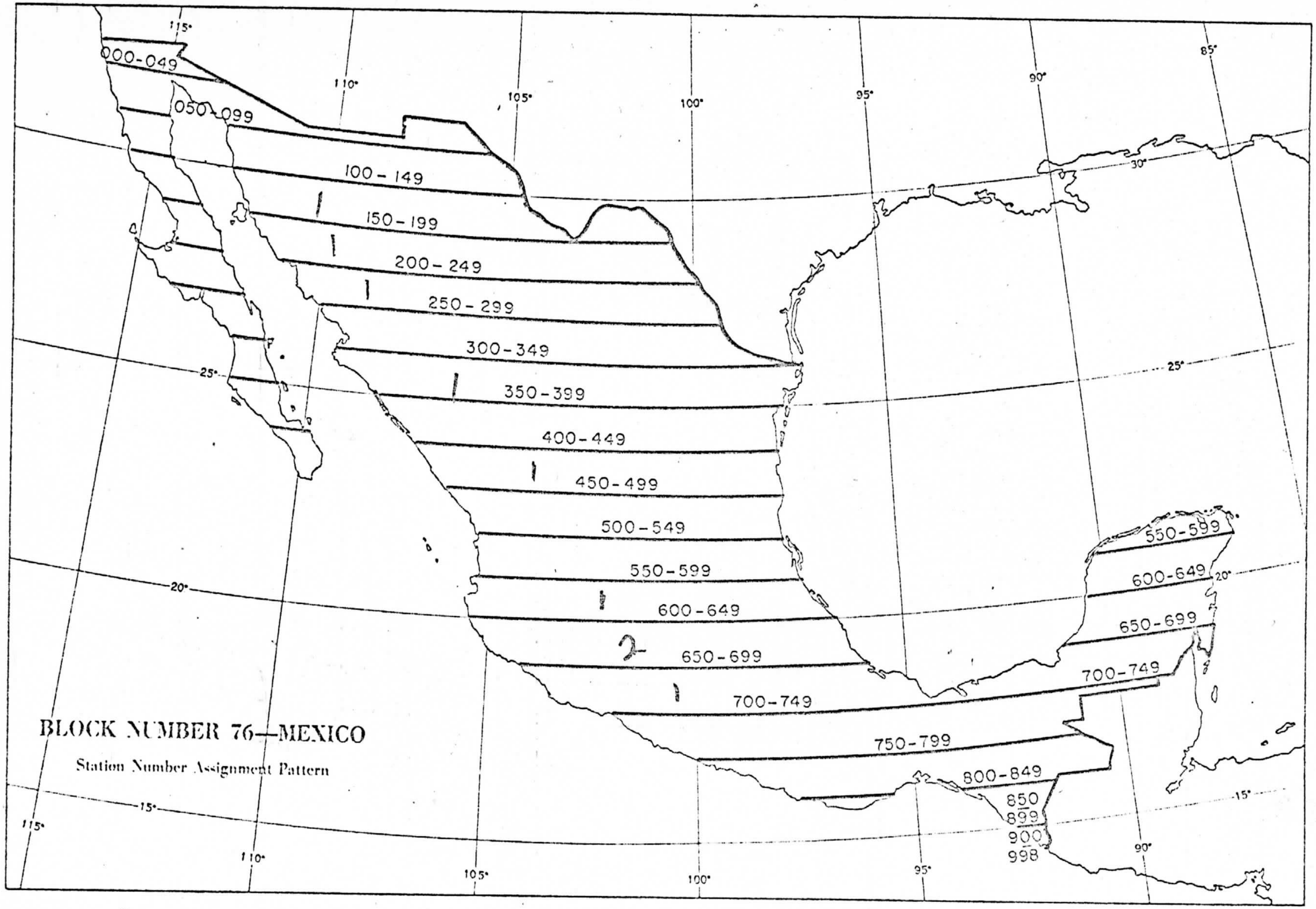


BLOCK NUMBER 72—CANADA AND THE UNITED STATES
Station Number Assignment Pattern



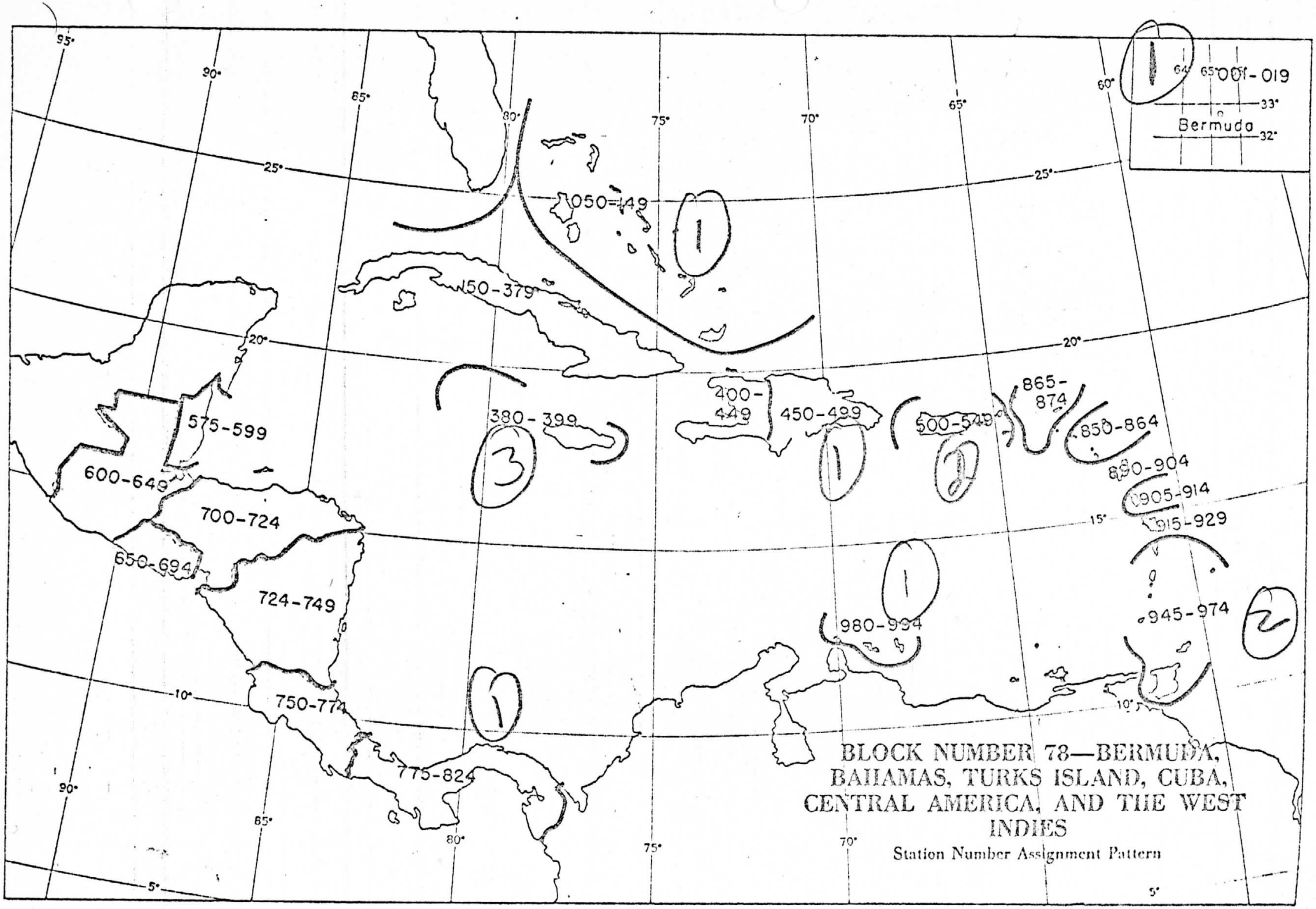
BLOCK NUMBER 74—CANADA AND THE UNITED STATES

Station Number Assignment Pattern



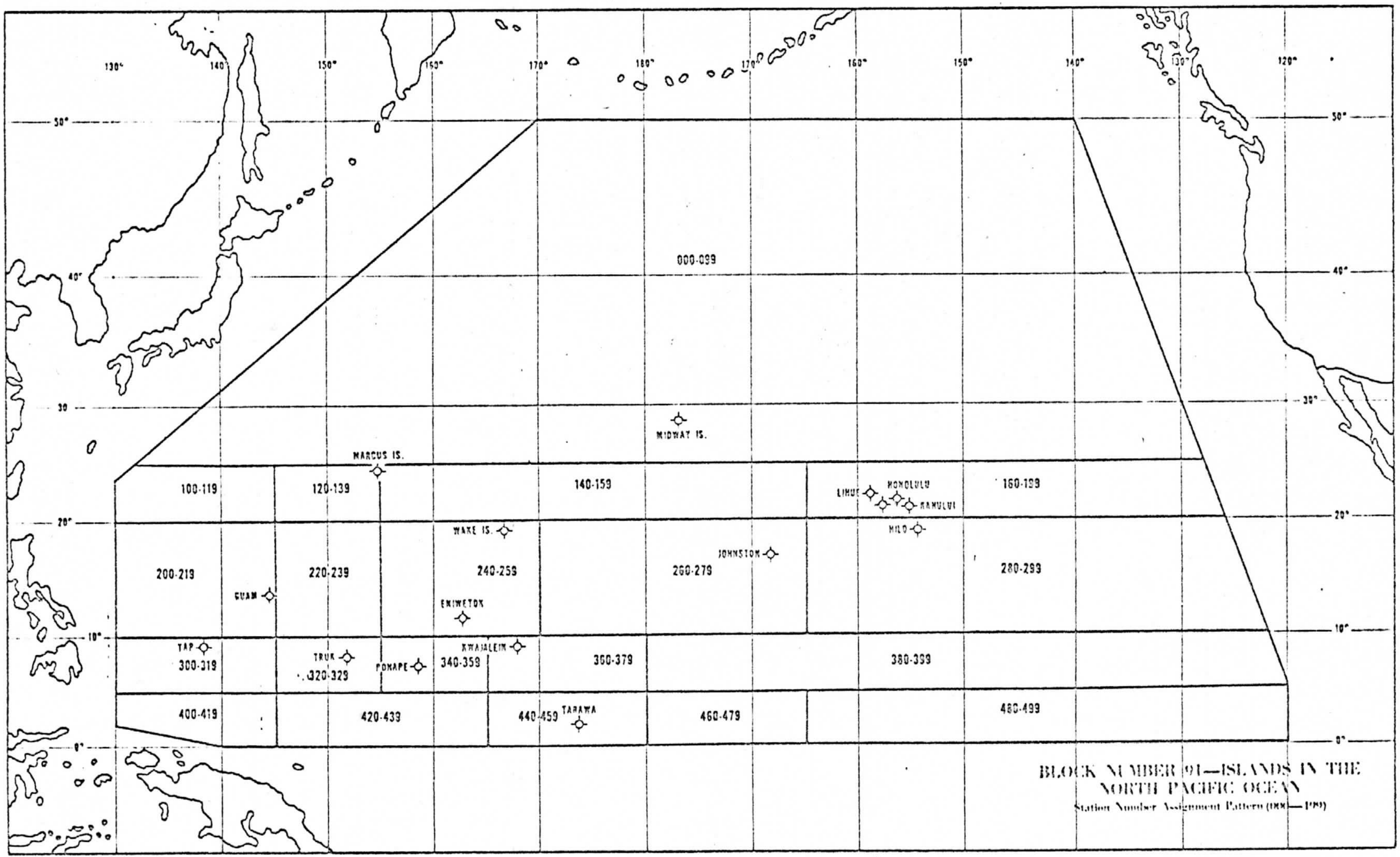
BLOCK NUMBER 76—MEXICO

Station Number Assignment Pattern



BLOCK NUMBER 78—BERMUDA, BAHAMAS, TURKS ISLAND, CUBA, CENTRAL AMERICA, AND THE WEST INDIES

Station Number Assignment Pattern



BLOCK NUMBER 91—ISLANDS IN THE NORTH PACIFIC OCEAN

Station Number Assignment Pattern (000—499)

Bulletin Description Symbol Code

SA - hourly surface observations

SW - hourly surface observations (minor stations)

NOSUM - airport information

FT - terminal forecast

FD1 - wind and temperature forecast (upper air)

FA/WS - forecast and extended outlook from forecast centers by state

WA - airmets (aviation advisory)

WW - weather warnings

SD - radar summary

UA - pilot reports (T, P)

NOUS1 - miscellaneous information

NFDC - notam (notice to air men)

AB - weather summaries

D

BULLETIN NUMBERS FOR
1200 BIT PER SECOND CIRCUIT
GD-90488-604
(WMSC IDENTIFICATION - CHANNEL 418)

NUMBER	start	finish	freq.			BULLETIN DESCRIPTION
✓00200	0004	0015	hrly			SA - New England States
00201						SA - Eastern States
00202						SA - Mid Atlantic States
00203						SA - Southeastern States
✓00204						SA - Great Lakes States
00205						SA - Ohio Valley States
00206						SA - Northern Plains States
00207						SA - Great Plains States
00208						SA - Gulf Coast States
00209						SA - Northern Rockies States
00210						SA - Southwestern States
00211						SA - Pacific Northwest States
00212						SA - Pacific States
✓00213						SA - Western Military Bases
00214						SA - Eastern Military Bases
00215						SA - Eastern Canada
00216						SA - Western Canada
✓00217						SA - Mexico and Caribbean
00218						SW - New England States
00219						SW - Eastern States
00220						SW - Mid-Atlantic States
00221						SW - Southeastern States
00222						SW - Great Lakes States
00223						SW - Ohio Valley States
00224						SW - Northern Plains States
00225						SW - Great Plains States
00226						SW - Gulf Coast States
00227						SW - Northern Rockies States
00228						SW - Southwestern States
00229						SW - Pacific Northwest States
00230						SW - Pacific States
00231						NOSUM - New England States
00232						NOSUM - Eastern States
00233						NOSUM - Mid-Atlantic States
00234						NOSUM - Southeastern States
✓00235						NOSUM - Great Lakes States
✓00236						NOSUM - Ohio Valley States
00237						NOSUM - Northern Plains States
00238						NOSUM - Great Plains States
00239						NOSUM - Gulf Coast States
00240						NOSUM - Northern Rockies States

	Start Time	Done Time	Freq.	Sector per	
00241					NOSUM - Southwestern States
00242					NOSUM - Pacific Northwest States
00243					NOSUM - Pacific States
00244					NOTAMS - Eastern Canada
00245					NOTAMS - Western Canada
✓00246	2140		6	5	FT - New England States
00247					FT - Eastern States
00248					FT - Mid-Atlantic States
00249					FT - Southeastern States
✓00250	1441		6	7	FT - Great Lakes States
✓00251					FT - Ohio Valley States
00252					FT - Northern Plains States
00253					FT - Great Plains States
00254					FT - Gulf Coast States
00255					FT - Northern Rockies States
✓00256	2119		6	1-4	FT - Southwestern States
00257					FT - Pacific Northwest States
00258					FT - Pacific States
00259					FT - Eastern Canada
✓00260	17		6	11	FT - Western Canada
✓00261	1746		6	12	FD1 - Western United States
00262					FD2 - Western United States
00263					FD3 - Western United States
✓00264					FD1 - Eastern United States
✓00265					FD2 - Eastern United States
✓00266					FD3 - Eastern United States
00267					FD1 - Western Canada
00268					FD2 - Western Canada
00269					FD3 - Western Canada
00270					FD1 - Eastern Canada
00271					FD2 - Eastern Canada
✓00272	6725		?	4	FD3 - Eastern Canada
✓00273					FA/WS - Great Lakes and East Coast States
✓00274					FA/WS - Central States
00275					FA/WS - Mountain States
00276					FA/WS - Pacific Coast States
✓00277	1715		6	6	FA - Mexico and Caribbean/So. America
✓00278					FA/WS - Eastern Canada
00279					FA/WS - Western Canada
✓00280	random			1	WA - Eastern United States
00281					WA - Western United States
✓00282	1632		6	6	WW - WH Weather Warning Hurrican Advisory
✓00283	0057		daily	6	SD - Eastern US and Canada
00284					SD - Western US and Canada

Start Time	Done Time	Freq	Sectors per	Need Blanks	
✓00285 random			1		UA - Eastern United States
00286					UA - Western United States
X 00287- random					NOUS1 - General Notices Service A
✓00288- 1414		?	1		NFDC - Carf and International NOTAMS
✓00289-random			6	✓	- Miscellaneous Meteorological Messages
✓00290-0020		Hrly	6		SA - Alaska
00291					SA - Hawaii
✓00292- 1701		6	4		FT - Alaska
00293					FT - Hawaii
✓00294-1740		6	10		FA - Alaska
00295					FD - Alaska
✓00296-0026		hrly	6		UA - Alaska and Hawaii
00297					FT - Mexico
✓00298-1855					FD - Pacific
00299					FD - Caribbean
✓00300-0215		Mixed			AB and AS - Weather Summaries
✓00301-0220					AB - Temperature and Precipitation Table
✓00302-					FE - Extended Forecasts
X 00303-					FM10 - Temperature Extreme Forecasts Eastern U.S.
X 00304—					FM10 - Temperature Extreme Forecasts Western U.S.
✓00305-1822		6	16		FO - Forecast Guidance, Precipitation, Humidity and Wind Forecasts
✓00306 - 1735		6	6		FP - Canadian Public Forecasts
00307		6hr			FP - Alaskan and Hawaiin State Forecast
✓00308-0420					FP1 - State Forecasts - Northern U.S.
00309					FP1 - State Forecasts - Southern U.S.
✓00310 0358		6hr	10		FP3 - Forecast Explanation
✓00311-2158					FP4 - Probability of Precipitation
✓00312-1724		hrly	10		FP5 - Zone Forecasts
X 00313-					FZ6 - Marine Forecasts
✓00314-1620		6	1		FS, FX, FU - Prognostic Map Analysis, Quantitative Precipitation Forecasts
✓00315- random			17		FW - Sports Forecasts
✓00316- random					Miscellaneous Service C Messages
00317					GENOTS - Service C
✓00318-			5		SI - Synoptic Surface Reports (Intermediate hours)
✓00319 -			12		SM - Synoptic Surface Report (Main Hours) Alaska and Northern Canada
✓00320 -					SM - Synoptic Surface Reports (Main Hours) Southern Canada

Start Time	Done Time	Freq	Sectors per		
✓ 00321 - 1713				SM	Synoptic Surface Reports (Main Hours) Northern U.S.
00322				SM	Synoptic Surface Reports (Main Hours) Southern U.S.
00323				SM	Synoptic Surface Reports (Main Hours) Atlantic, Caribbean
X 00324 -				SR	River Reports, etc.
✓ 00325				UC	RAWINS and PIBALS U.S.
✓ 00326 -			5	UG	PIBALS U.S.
00327				UJ1	RAOBS TO 100 MB Northern U.S.
✓ 00328 -				UJ1	RAOBS TO 100 MB Southern U.S. and Caribbean
✓ 00329 - 1652		12	46	UJ2	RAOBS above 100 MB U.S.
✓ 00330 -				UM	RAOBS Northern U.S. and Canada
✓ 00331 -				UM	RAOBS Southern U.S.
✓ 00332 - 1755		6	2	UN	Rocket Winds North and Central America
✓ 00333 -				UW/US	RAOBS Mandatory Levels - U.S.
✓ 00334 -				UX	RAOBS Selected Levels - North America
00335 -				WH	Hurricane Bulletins and Advisories - Atlantic, Caribbean and Pacific
00336 -				WW	Winter Storm Conditions U.S.
✓ 00337 -				FP	Eastern Caribbean 36 hour Area Forecasts
00338 -				FS	Surface Prognosis Atlantic/Europe
✓ 00400 -			32	FT	Civil U.S. in TAF code
00401				FT	Military U.S. in TAF code
00402				FT	Canada in TAF code
✓ 00403 0113				FT	Far East in TAF code
00404				FT	Caribbean/South America in TAF code
00405				FT	Southern Europe in TAF code
00406				FT	Northern Europe/Iceland in TAF code
✓ 00407 -			6	FU/FX	Upper Air Prognostic Charts and Miscellaneous Forecasts - No. Atlantic/Caribbean
✓ 00408 -			4	SD	Radar Reports - Pacific
X 00409 -				SI/SH	Intermediate Hour Synoptic - Pacific
✓ 00410 -			15	SI	Intermediate Hour Synoptic - Caribbean
✓ 00411 -			1	SI	Intermediate Hour Synoptic - Atlantic/Europe
✓ 00412 -			123	SM	Main Hour Synoptic - Pacific/Far East
✓ 00413 -			50	SM	Main Hour Synoptic - Europe
✓ 00414 -			54	SM	Main Hour Synoptic - Atlantic/Caribbean/South America
✓ 00415 -				SM	Main Hour Synoptic - Near East/Mid-East
✓ 00416 - random			4	SX	Miscellaneous Surface Data
✓ 00417 -				UC/UG/UH/UI	Pibal/Rawin Data - Pacific/Canada
✓ 00418 -			1	UC/UG/UI	Pibal/Rawin Data - Caribbean
X 00419 -				UG/UH/UI	Pibal Data - Atlantic/Europe/Africa
✓ 00420 -			9	UK	Radiosonde Data (Part B)

Start Time	Done Time	Freq	Sectors Per		
00421-			10	UL	Radiosonde Data (Part C)
00422-				UM	Radiosonde Data (Parts A and B) - Pacific
00423-			43	UM	Radiosonde Data (Parts A and B) - Atlantic/Europe/Africa
00424-				UP	Pibal Data (Part A)
00425-			8	UR	Reconnaissance Reports
00426-1150			10	US/UW	Radiosonde (Part A) and Rawin (Electronic) - Pacific
00427-				US/UW	Radiosonde (Part A) and Rawin (Electronic) - Atlantic/Europe
00428-				US/UW	Radiosonde (Part A) and Rawin (Electronic) - Caribbean
00429-				AU/UX	Miscellaneous Upper Air Data - other than North America
X 00430-				UF/UE	Temp Ships Part C and D
X 00431-					SVC C Genot
00432-					Global Satellite Prediction
433			5		

2.2.4 Digital Radar Collection

TBD

2.2.5 VISSR Collection

3.0 Analysis

The purpose of this section is to estimate the computational, display, and storage requirements for obtaining meteorological parameters from VAS, polar orbiting satellites and VISSR.

The strategy for the use of these three data sources is an important factor in making this estimate. It is assumed that the regions of interest range from the small synoptic or regional scale (~2500 km square coverage) down to the mesoscale (~250 km square coverage). In general, the polar satellites and VISSR will be used for regional scale coverage because of their lack of high time resolution. VAS will both augment this regional coverage and be the primary source of mesoscale coverage.

Regional scale soundings covering most of the U.S. will be provided by two TIROS and two DMSP satellites at roughly two to three hour intervals with a few voids. VAS will be used to fill the voids in regional scale coverage in areas surrounding potential mesoscale activity. However, the primary use of VAS soundings will be for more rapid coverage of smaller regions (1000-500 km square) where variations of water vapor distribution can be especially important.

For imaging coverage also the VAS will play two different roles. On the regional scale it will be used to augment VISSR coverage by providing winds from water vapor tracking and improved cloud height determinations. On smaller scales, in addition to winds the VAS will provide water vapor distributions and surface temperatures to augment those obtained from sounding.

The analysis required for VAS, polar satellites and VISSR are discussed separately in the subsections which follow.

3.1 VAS Analysis

The VAS analysis will be divided into two categories: sounding data analysis and imaging data analysis. The distinction between sounding and imaging data is indicated in the following table:

	Characteristics of observables
Sounding data	•Spectral radiances giving complete vertical coverage •Sampling sufficient to give 1 Wark accuracy after space and time averaging.
Imaging data	•Spectral radiances chosen for specific application (incomplete vertical coverage). •Sampling required varies with application.

The processing techniques for these two types of data differ considerably both with regard to the specific algorithms required and to the overall nature of the processing. Sounding data analysis requires a larger amount of numerical processing and image data analysis makes more use of interactive image processing. It is expected that the VAS will collect sounding data about 50% of the time and imaging data about 50%.

3.1.1 VAS Products

The basic VAS products are:

Imaging
(1) Water vapor fields
(2) Temperature fields
(3) Surface temperature

Sounding

(4) Cloud motion winds
(5) Water vapor motion winds
(6) Cloud heights
(7) Cloud types

Imaging

WATER VAPOR FIELDS
SURFACE TEMP

The primary products of sounding data will be items 1-3. Cloud heights and types can also be obtained for use with VISSR data.

The primary products of imaging data will be items 4-7. A secondary, but possibly important, use of imaging data will be to obtain water vapor fields and surface temperatures with higher time resolution than is obtainable from sounding.

3.1.2 VAS Sounding Data Analysis

The following topics will be discussed in this section:

(1) Instrument scan program for sounding

(2) Processing steps for sounding data analysis

(3) Computational requirements

(4) Interactive data selection and editing requirements

(5) Data storage requirements.

3.1.2.1 VAS Sounding Scan Program

The major options in selecting a sounding scan program are the following:

(1) Sound with all sounding bands or exclude 4μ sounding bands

(2) Spatial resolution for sounding - 13.8 or 6.9 km

(3) Number of multiple scans of each band required for noise reduction.

The option of whether to collect visible data is also available. However, the impact on scan time and processing is so small that it will be assumed that visible data will be acquired.

For the purpose of specifying the processing system requirements, the following 2 cases will be considered:

Case	Sounding Bands Used	Spatial Resolution	Spin Budget*
I	no 4μ	13.8 km	86
II	all	13.8 km	167

* standard spin budget to attain required noise reduction from 30 km square clear areas (150 km square for stratospheric band 1)

Case I places the most severe load on the processing system that is likely to occur because it has the smallest likely spin budget. For a given sounding spatial resolution, small detector data requires less rapid processing than large detector data (scanning is roughly 4 times slower and there are only twice as many averaged data samples).

Characteristics of Case I and II scan programs are given in Table 3.1.

Table 3.1 Characteristics of VAS Sounding Scan Programs

Characteristic	Case I	Case II
Sounding rate		
- km/hr at subsatellite point (v)	1765	948
- km/hr at 40° latitude (v')	2304	1237
- large detector earth swaths/hour ($\dot{\ell}$)	127.7	68.6
Number of sounding retrievals assuming 50% of a square area is sounded at a 40° latitude resolution of		
$((\dot{\ell}t\cancel{\cdot}3)(v't/50))$ 3x15 - 50 km	980 t^2(hr)	282 t^2(hrs)
6x30 - 100 km	245 t^2	70 t^2
Data volume for square 1 hour sounding area - 10 bit words	8.8 t^2M wds	4.7 t^2M wds
$((\frac{v't}{3.14})\ \dot{\ell}t(\text{spin budget} + 4.1 + 2.2))$		
Data volume after averaging - 16 bit words	1.5 t^2M wds	0.48 t^2M wds

3.1.2.2 VAS Sounding Data Processing Steps

The major steps for processing sounding data are:

(1) Interactive data selection

(2) Numerical processing

(3) Interactive product editing.

The first step is to select the data which is sufficiently cloud free to be processed. It is not clear at this time how much selection will be done interactively and how much will be done by objective processing. However, it is assumed that time sequence image data (visible, 6.7μ H_2O, and 11.2μ window) collected prior to the sounding data collection will be required.

The numerical processing required for sounding has been developed for use with polar satellites over the last decade. The functions which must be performed are:

(1) Clear column radiance retrieval

(2) Water vapor profile inversion

(3) Temperature profile inversion

(4) Surface temperature determination

(5) Cloud height determination.

The sequence in which these are performed is illustrated in Figure 3.1. The techniques available for performing these functions are summarized in Table 3.2.

The final step in sounding analysis is to edit the results of numerical processing. This editing is restricted to detecting non-physical spatial gradients in the derived parameters. Interactive editing will be performed using contoured vertical and horizontal cross sections of the derived parameters.

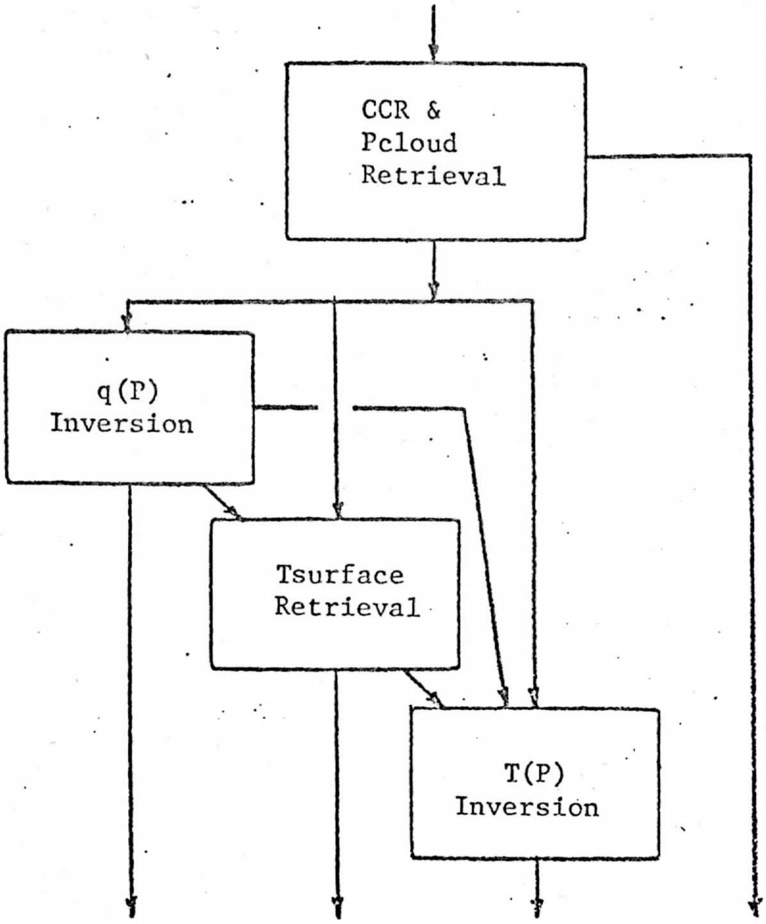


Figure 3.1 Numerical Processing Sequence for Sounding Analysis

Table 3.2 EXISTING TECHNIQUES FOR NUMERICAL SOUNDING ANALYSIS

OUTPUT	TECHNIQUE	DATA REQUIRED	STATUS
Clear Column Radiances (CCR)			
- Initial Classification of cloud coverage	man interactive - man distinguishes between clear, overcast, broken one cloud type & broken mixed cloud types	- time sequence visible & IR window channel radiances	- undeveloped: McIDAS experience shows feasibility
	objective techniques - use standard dev. of window radiances to distinguish broken clouds from clear or overcast conditions	- window channel radiances	- used for NIMBUS 5 processing (appropriate use of man and objective techniques will be evaluated on McIDAS)
	- compare 11.2 black body temperature with surface T estimate to detect overcast	- window channel radiances - surface temperature estimate	
- CCR for Clear or overcast areas	average radiances	- any channel	- may require undeveloped diffraction correction if if clouds nearby
- CCR for Broken cloud cover	histogram technique + non-statistical paired FOV technique	- window channel radiances - sounding channel radiances	- established technique, except that diffraction correction techniques need testing for VAS
	eigenvector paired FOV	- all VAS or TIROS-N channels - radiance eigenvectors from historical set of radiances	- developed by NESS for TIROS-N

Table 3.2 EXISTING TECHNIQUES FOR NUMERICAL SOUNDING ANALYSIS (continued)

OUTPUT	TECHNIQUE	DATA REQUIRED	STATUS
Temperature fields	eigenvector regression inversion	- All VAS or TIROS-N channels - Regression matrix from historical set of radiance and temperature profiles	developed by NESS for TIROS-N
Temperature time gradient fields	minimum information inversion	- VAS 12 channel sounding data at 2 times - Atmospheric transmission fns - Water vapor fields - Surface temperature - Surface pressure	established technique - has not been applied to time domain data
Water vapor mixing ratio fields	eigenvector regression inversion	- All VAS or TIROS-N channels - Regression matrix from historical set of radiance and mixing ratio profiles	developed by NESS for TIROS-N
Cloud heights and amounts	eigenvector technique	- All VAS or TIROS-N channels - Radiance eigenvectors from historical set of radiance profiles	- developed by NESS for TIROS-N
	dual channel techniques	- Colocated cloud sensitive channel radiances - Clear column radiances for these channels	- used for NIMBUS-5 processing

Table 3.2 EXISTING TECHNIQUES FOR NUMERICAL SOUNDING ANALYSIS (continued)

OUTPUT	TECHNIQUE	DATA REQUIRED	STATUS
Surface temperature over water	radiation transfer equation + spatial or temporal continuity	- IR window channel clear column radiances - atmospheric transmission fns. - temperature field estimates - water vapor field estimates	- well known technique - needs development for use over land
	dual window channel technique	- long and short wave window channel clear column radiances - surface temperature estimate - incident solar radiation	- used for NIMBUS-5 processing - potential problem caused by insufficient registration - needs development for use over land

An intermediate result, the clear column radiance field, also requires editing. Further editing using all of the available data for testing consistency will be performed as part of the synthesis function.

3.1.2.3 Computational Requirements for VAS Sounding Data Analysis

The VAS analysis techniques which place the largest demand on CPU time are clear column radiance retrieval using Smith's eigenvector technique and temperature inversion using the minimum information technique. Some timing test of the existing NOAA software for these techniques have been made, and other timing information has been scaled from these results using calculations of the number of arithmetic operations involved. The results are shown in Table 3.3. Minimum information inversion has been divided into two parts; the atmospheric transmission function calculation and the actual inversion of the radiation transfer equation. The expected CPU time requirements per VAS temperature retrieval are shown in Table 3.4 for various spatial resolutions. These times were calculated using the 360/195 CPU times from Table 3.3. The table shows that for high resolution sounding the time required for inversion dominates and that for lower resolutions the clear column radiance retrieval becomes dominant.

Now a comparison between the CPU times required for sounding and the data collection times can be made. Using the VAS scanning programs discussed in section 3.1.2.1 and the information from Table 3.4, the CPU times for one hour sounding were estimated and are shown in Table 3.5. The worst case shown, Case I sounding scan program with 50 km spatial resolution, shows that the VAS CPU must be at least as fast as the 360/195.

Table 3.3 CPU Demands for Sounding Analysis Routines - Timing Tests and Scaling Results

	# Arithmetic Operations			CPU Times (sec.)		
	×	+	÷	360/195	McIDAS	McIDAS** with floating pt. hw.
Clear Column Radiance Retrieval/100 FOV Pairs NOAA Nimbus[a] Routine	80×10^3	78×10^3	7.0×10^3	0.63 ††	34.0 †	0.85
Expected VAS[b] Routine	33×10^3	30×10^3	4	0.24 *	13.0 *	0.32 *
Atmospheric Transmission Function Calculation /profile (12 bands, 40 levels)	520×10^3 operations *			2 †††	106 *	2.7 *
RTE Inversion (12 bands, 40 levels)	4.4×10^3	4.2×10^3	78	0.033 *	1.79 *	0.045 *

* Scaled from other information in table (division weighted twice × or +).
** estimate = McIDAS time ÷ 40.
† 18 min. charged CPU time for 20 x 40 FOV (3176 FOV pairs) (10^4 disc accesses).
†† Same case as † required 20 sec. charged CPU time.
a 21 bands and 6 eigenvectors applied twice/FOV pair (once for 4μ bands + SCAMS and once for 15μ band + SCAMS).
b 12 bands (including 3 4μ bands) and 8 eigenvectors applied once/FOV pair assuming 2N* routine used.
††† Timing test for unoptimized program yielded 3 sec CPU for 16 bands.

Table 3.4 CPU Time* Estimate/VAS Temperature Profile Retrieval (times are in seconds)

operation \ resolution (40° lat.)	50 km	100 km	150 km	200 km
Clear Column** Radiance Ret.	.35	1.7	3.7	6.8
Minimum Information Inversion	2	2	2	2
Total	2.4	3.7	5.7	8.8

* 360/195 equivalent time

** the number of pairs assumed/profile were:

50 km	100 km	150 km	200 km
147	702	1528	2849

Table 3.5 CPU Time* Estimate/1 Hour Sounding Time

operation \ scan program/ resolution	Case I/ 50 km	Case I/ 100 km	Case II/ 50 km	Case II/ 100 km
Clear Column** Radiance Retrieval	11.4 min.	13.8 min.	3.2 min.	4.0 min.
Minimum Information Inversion	32.6 min.	8.2 min.	9.4 min.	2.3 min.
Total	44.0 min.	22.0 min.	12.6 min.	6.3 min.

* 360/195 equivalent time

** Assuming all available FOV used

3.1.2.4 Interactive Selection and Editing Requirements

Studies to determine these requirements using NIMBUS data are planned. The type of image data which is expected to be useful will be indicated here.

The qualitative judgments which a man might make in selecting sounding areas would probably be influenced by such factors as:

(1) cloud coverage

(2) water vapor coverage

(3) cloud type

(4) relative cloud motions.

To present this information, time sequences of images acquired before sounding is begun can be used. Three image sequences of the following are suggested:

(1) visible (3.45 km)

(2) 11.2μ window (6.9 km)

(3) 6.7μ H_2O (13.8 km)

To cover the largest area which can be sounded in one hour (using Case I scan program), the visible image would contain about 500 by 700 lines and elements. The 11.2μ and 6.7μ images would be 250 x 700 and 125 x 700 respectively. Cursor controlled selection of areas to sound or not to sound would be made from these image sequences.

Interactive editing of the sounding results will probably use contour maps overlaid on visible or 11.2μ window band images. Examples are contour maps of:

(1) surface temperature

(2) 500 mb temperature

(3) low level water vapor

(4) clear column radiances for a lower tropospheric band.

The maximum number of soundings to be contoured for each map is about 1000 for 1 hour of sounding.

3.1.2.5 VAS Sounding Data Storage Requirements

3.1.3 VAS Imaging Data Analysis

The following topics will be discussed in this section:

(1) Instrument scan program for imaging

(2) Processing steps for imaging data analysis

(3) Display requirements

(4) Computational requirements

(5) Storage requirements

3.1.3.1 VAS Imaging Scan Program

The number of options for acquiring imaging data with VAS is very large. To simplify this discussion, a small number of likely scan programs will be specified and assumed to be representative.

There are two instrument modes, multispectral imaging (MSI) and dwell sounding (DS), which can be used to collect imaging data. The MSI mode allows only one scan per step of the scan mirror and does not provide visible data when the instrument is used in its low data rate mode (as it will be during the Experiment). Therefore, this mode will probably see little use during the experiment, however, since MSI imaging places the largest demand on the processing system, one scan program selected uses the MSI instrument mode.

The four scan programs selected as representative are shown in Table 3.6. Case I is the MSI mode program and would allow cloud and water vapor tracking, and surface temperature determinations (most reliably at night over water). Cases II and III are designed to be used together as the main cloud and water vapor tracking programs. Rapid imaging for wind speed determination would be accomplished using Case II; Case III includes imaging in three bands for cloud height determination. Finally, the Case IV program would provide surface temperature determinations and also water vapor profiles by utilizing clear column radiances obtained from sounding data.

The characteristics of each of these scan programs are shown in Table 3.7. This information was used to estimate typical characteristics of one hour of VAS imaging as shown in Table 3.8. It was assumed that water vapor distributions and surface temperatures would be determined once during the hour and that two sets of image sequences (time intervals of 2-4 min.) would be collected for wind determinations. Case III imaging would be used once with each image sequence to provide cloud height information.

Table 3.6 Representative VAS Imaging Scan Programs

Case	Band Centers (μ)	Spatial Resolution (km)	Spins/ line	Major utility
WORST CASE I	11.2	6.9	1	cloud tracking, surface T
	6.7	13.8	1	H_2O vapor tracking
(MSI Mode)	4.0	13.8	1	surface T, low cloud tracking
II	visible	3.45	1	cloud tracking
	11.2	6.9	2	cloud tracking
(DS Mode)	6.7	13.8	1	H_2O vapor tracking
III	visible	3.45	1	cloud tracking
	11.2	6.9	2	cloud tracking
(DS Mode)	6.7	13.8	3	H_2O vapor tracking
	11.2	13.8	1	cloud height determination
	14.0	13.8	7	cloud height determination
	13.3	13.8	7	cloud height determination
IV	visible	3.45	1	solar correction to 4μ
	11.2	6.9	2	
(DS Mode)	6.7	13.8	3	H_2O vapor profiles
	7.25	13.8	16	H_2O vapor profiles
	12.66	13.8	7	H_2O vapor profiles
	11.2	13.8	1	surface temperature
	4.0	13.8	4	surface temperature

Table 3.7 Characteristics of VAS Imaging Scan Programs

Characteristic	Case I	Case II	Case III	Case IV
Time/1500 km N-S swath (centered at 40° lat)	1.7 min	3.7 min	10.8 min	16.2 min
Data volume for 1500 x 2500 km area (10 bit words)	265 K wds	597 K wds	1.72 M wds	2.59 M wds
Data volume after averaging (16 bit words) (1500 x 2500 km)	265 K wds	464 K wds	662 K wds	731 K wds
Data volume/hour after averaging	9.35 M wds	7.44 M wds	3.68 M wds	2.71 M wds
Number of images/hour*	~106	~48	~36	~28

* image sizes are:

FOV resolution	lines x elements
3.45 km (visible)	332 x 796
6.9 km	166 x 796
13.8 km	83 x 796

Table 3.8 Estimated Typical Characteristics of 1 Hour VAS Imaging Covering 1500 x 2500 km.

Scan Program	Number of Frames	Time (min)	Data Volume After Averaging	Number of Frames
Case I	4	6.8	1.1 M wds	12
Case II	4	15.0	1.9 M wds	12
Case III	2	21.6	1.3 M wds	12
Case IV	1	16.2	0.7 M wds	7
Total		59.6	5.0 M wds	43

3.1.3.2 Processing Steps for VAS Imaging Data Analysis

The processing steps for imaging data analysis will be divided into two groups; those steps required for obtaining winds and those required to derive other imaging data products.

The basic approach for obtaining winds will be the McIDAS approach. Wind tracers will be selected from time sequence images (visible, 11.2μ window or 6.7μ H_2O). Automatic tracking and speed computations will be performed, and objective cloud height determinations will be made. Cloud height determinations will use measurements in two lower tropospheric 15μ CO_2 bands and the 11.2μ window band along with clear column radiances for these bands obtained while sounding. The existing algorithm for cloud height determination requires minimal computation.

The other important products of imaging data are surface temperatures and water vapor profiles. Although, the techniques required for these applications need further development, the major processing effort will most likely be clear column radiance retrieval. The steps required are similar to those for sounding data analysis. They are:

(1) Interactive Data Selection

(2) Numerical Processing

(3) Interactive Product Editing.

The numerical processing will determine clear column radiances for the imaging channels and will utilize the clear column radiances from previous sounding data analysis to complete the required data set for water vapor inversions.

3.1.3.3 Display Requirements for VAS Imaging Data

These display requirements are based on the combination of VAS scan programs characterized in Table 3.8. The requirements are meant to be typical and the variance from this estimate may be large.

For wind determinations, two sets of up to five image time sequences require display per hour. Each set contains image sequences in three different spectral bands. In addition to wind determination, these sequences will be used for interactive data selection as part of clear column radiance retrieval from both sounding and imaging data.

Editing the surface temperatures and water vapor distributions obtained from imaging data will require the same interactive tools as suggested for sounding product editing. These are contours maps of the following results overlaid on visible, IR window or water vapor images of Case IV data:

(1) Surface Temperature

(2) Low Level Water Vapor

(3) Clear Column Radiances for the 11.2μ Window Band

(4) Clear Column Radiances for one Water Vapor Channel

3.1.3.4 Computational Requirements for VAS Imaging Data

3.1.3.5 Storage Requirements for VAS Imaging Data

3.2 Ancillary Data Analysis

In addition to VAS it is expected that TIROS-N, DMSP and VISSR data will require analysis on the VAS processing system. A ground rule for the processing of this ancillary data is that it should not substantially increase the required capabilities of the processing system. It will be shown in this section that significant analysis of ancillary data can be performed within this constraint.

3.2.1 TIROS-N Analysis

The major products which are desired from TIROS-N are temperature fields, water vapor fields and surface temperatures. The techniques available for obtaining these products are the same as those described in section 3.1.2 for VAS. The computational requirements for TIROS-N data have been estimated using the timing information from Table 3.4 of that section and are shown in Table 3.9. Two estimates are given for each assumed resolution. Both estimates assume that all of the data collected is processed, and that 50% of the area is soundable. The first, which assumes that minimum information inversion is used for all of the soundings, is a worst case estimate. The second, which assumes that only 10% of the soundings use minimum information inversion, is typical of NOAA NIMBUS data processing.

The display requirements for TIROS processing will be minimal.

Table 3.9 CPU Time* Estimate/TIROS Overpass

Resolution	90 km	180 km
number of possible soundings/overpass	1000	250
average number of FOV pairs/sounding	20	80
time for clear column radiance retrieval/ overpass	1.1 min	1.1 min
time for minimum information inversion (50% of area clear enough to sound)	16.6 min	4.1 min
time for statistical inversion	negligible	
total time using minimum information inversion	18 min	5 min
total time using minimum information inversion 10% and statistical inversion 90%	3 min	2 min

* 360/195 equivalent time

3.2.2 DMSP Analysis

The requirements for DMSP analysis are expected to be similar to those for TIROS-N. No specific information is available at this time.

3.2.3 VISSR Analysis

1/10/79

Grid pt interpolation   Tom Whittaker

Gandeen   opt interp w nor wts
(2→3 times longer than Barnes)

✓ Barnes   an desm , stable, cheaper

4 parameters
7 time periods
20 press levels
21x37 grid → 2° lat lon
115 stations / time period

mem req 42K
total CPU time 54 min of CPU } 1110

1 time period ~ 8 min

21K in core for raob data
(save disc accesses)

core vs. CPU vs disc accesses trade offs

4.0 Synthesis

4.1 Basic Objects and Functions of Synthesis

The basic object of what we have termed "Synthesis" is the production of 4-dimensional data sets which describe atmospheric conditions in a restricted space-time region as completely as possible, taking proper account of all available information from both conventional and satellite sources. These data sets are actually a time series of three dimensional data sets each of which consists of an array of numerical parameter values for each grid point in a specified three dimensional volume. These data sets will be used to study the small synoptic scale and mesoscale atmospheric processes and serve as a data base for development and testing of predictive models on these scales.

The required characteristics of the output of the synthesis process (the data sets) are quite different from the characteristics of the input data (the direct and derived meteorological parameters originating from the measuring systems). While each of the data inputs has a different spatial coverage, spatial sampling, spatial resolution, as well as a different error characteristic and measurement time, and while there are redundancies and incompatibilities among different data sources, the synthesized data sets must be uniform. They must provide contemporaneous data at each time step in the series as well as complete spatial coverage and fixed spatial resolution and sampling; and the data at each grid point must be unique and compatible. These requirements are severe and very difficult to satisfy.

At this point in time we do not know how to meet the synthesis requirements even in general, let alone in specific detail. Many years of research will be needed to even approach a viable solution to this problem. In spite of the present uncertainties in this area, it is necessary to make some estimates of processing procedures and requirements so that the necessary research, or at least part of it, can be undertaken with the aid of the VAS processing system. These estimates which are described in the following sections are based on possible approaches rather than definite ones.

4.2 Synthesis Products

Three distinct synthesized data sets have been identified:

(1) Small Synoptic Scale Data Set;

(2) Modelling Mesoscale Data Set; and

(3) Monitoring Mesoscale Data Set.

These are distinguished by space-time coverage and resolution as indicated in Table 4.1. The primary parameters indicated are definitely required and form the standard parameter set for present models. These are temperature T(P), humidity Q(P), eastward wind speed U(P), and northward wind speed V(P), as a function of pressure P. Secondary parameters are either boundary conditions or assumed to be determinable from primary parameters thus serving as reference data for comparing against model output and as a constraint to impose on primary parameters to make them more representative of the true atmospheric state. These parameters (secondary) also provide in many cases more direct descriptions of current meteorological activity.

The Small Synoptic Scale (SS) Data Set is configured to work with a modified Limited Fine Mesh Model (LFM) with twice the horizontal resolution of the operational LFM. The M1 set is postulated for use with initial mesoscale models which might become available in several years. The Monitoring Mesoscale (M2) Set is essentially a data base for research on the most rapid mesoscale processes that we can observe with the available data sources. In this set completeness will be very difficult to achieve because of the short time intervals involved.

Table 4.1 Summary of Synthesis Products

	Small Synoptic Scale (SS)	Modelling Mesoscale (M1)	Monitoring Mesoscale (M2)
Primary Parameters	(-------------------- T(P), Q(P), U(P), V(P) ---------------------------)		
Secondary Parameters	liq. H_2O, vertical motion, cloud characteristics, precipitation, ground cover, sea state, etc.		
Pressure Levels	6	12	12
Horizontal* Grid Spacing	90km	50km - 30km	30km - 1km
Time Spacing	3 hr	2 hr	30 min - 10 min
Horizontal Coverage	4500km x 4500km	2000km x 2000km	1200km x 1200km
Temporal Coverage/Set	3 days	1 day	6 hours
No. of 3-D Grid Points	2500 x 6 = 15,000	1600 x 12 = 19,200**	1600 x 12 = 19,200***
No. of 4-D Grid Points	15,000 x 24 = 360,000	19,200 x 12 = 230,400	19,200 x 12 = 230,400****
No. of Parameters Per Grid Point	4 primary + TBD secondary		

* approximate values are indicated; spacing varies with horizontal grid format (probably rectangular grid on polar stereographic map or a lat-lon grid).

** assumes a grid spacing of 50km.

*** assumes a grid spacing of 30km.

**** assumes a time spacing of 30 min.

4.3 Processing Steps in Data Set Synthesis

Given a requirement for 3-Dimensional data sets at times t_0, t_1, ... t_N the processing steps to be performed are as follows

(1) prepare initial 3-D data set $[D(t_0)]$ based on observations and predictions available at t_0

(2) predict 3-D data set at t_i $[D^*(t_i)]$ from 3-D data set at t_{i-1} $[D(t_{i-1})]$

(3) collect observations made between t_{i-1} and t_i

(4) modify predicted 3-D data set at t_i $[D^*(t_i)]$ to reflect new information collected between t_{i-1} and t_i forming a revised data set at t_i $[D(t_i)]$

(5) if $i < N$ increment i by 1 and repeat steps (2) through (4).

The sequence of steps listed above are also represented in Figure 4.1. The two primary processes in this sequence are the prediction process and the data modification process. Since it often will be the case that new information collected between t_{i-1} and t_i will be much less than that required to fill in the data grid, it is necessary to use predicted information in place of measurements which are not available. Incompleteness of new information may arise from incomplete spatial coverage (i.e. hourly surface observations do not describe vertical structure), or from incomplete parameter sampling (i.e. VISSR derived winds do not provide temperature or humidity information). In general, the predictions and measurements must both be included, but weighted to reflect their probable error contributions.

The data modification process includes interpolation, diagnostic analysis, and quality control processes. The way these processes are linked together

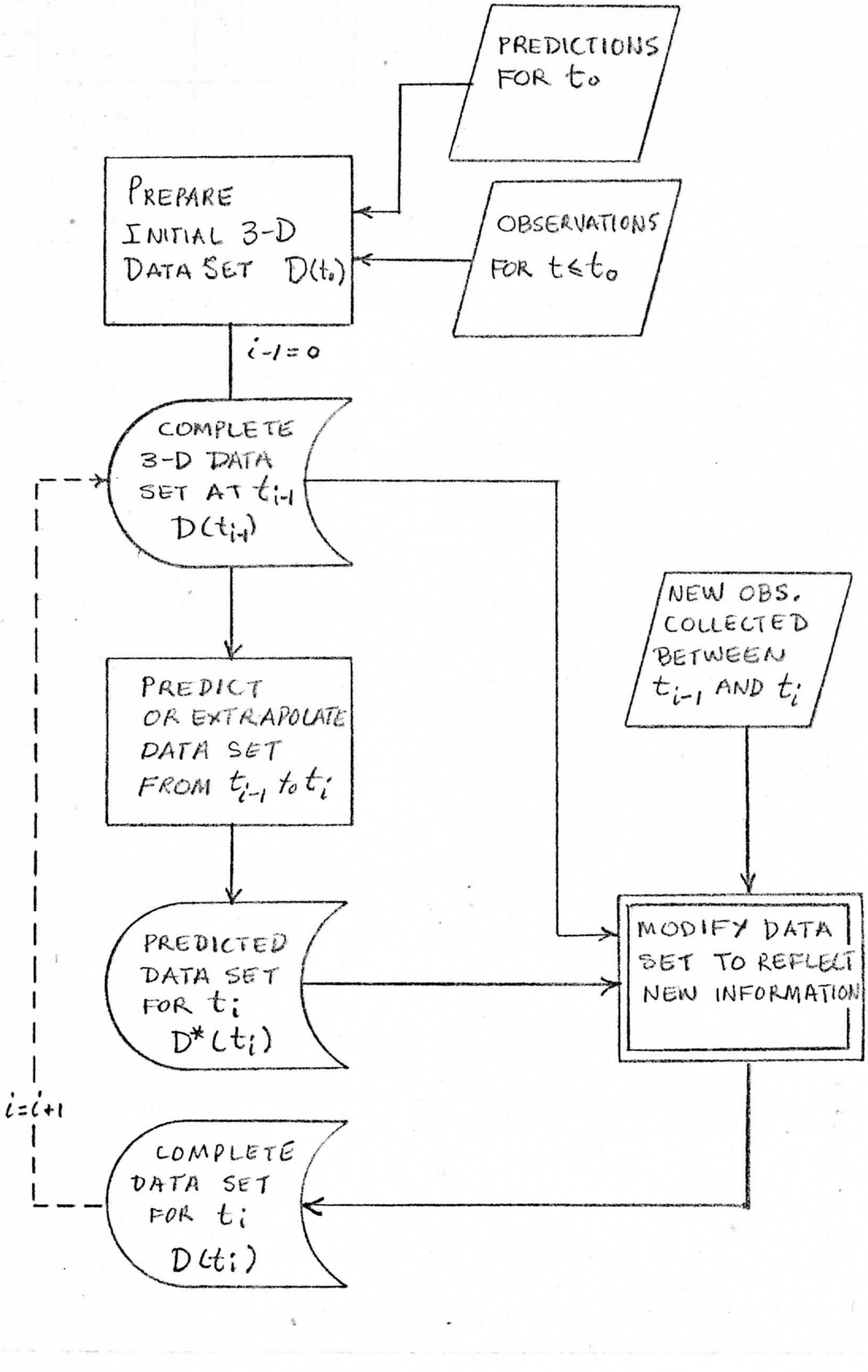


Figure 4.1 Synthesis of a 4-D data set by preparing an updated time sequence of 3-D data sets for times t_0, t_1, t_2, ..., t_n.

is indicated in Figure 4.2. New data is added to the predicted data by a statistical interpolation technique called optimal interpolation. This technique, discussed in section 4.4.1, not only places non-uniformly spaced data on a fixed grid, but also weights the influence of new information according to statistical correlations in space, time, and between different parameters, as well as according to the noise characteristics of all the information sources.

From the interpolated primary data the diagnostic models estimate secondary parameters such as rainfall, vertical motion, and cloudiness, and calculates budgets of conserved quantities such as mass and moisture. The behavior of conserved quantities and the comparison between measured secondary parameters and those estimated by the diagnostic model are used to identify data problems. The pattern of inconsistency will be used to identify bad data points or faulty measurement sources. These are removed from the primary data set and the set is subsequently reinterpolated and evaluated in a feedback loop as indicated in the diagram. The feedback adjustment process is mainly man-interactive except for the diagnostic model which is described in section 4.4.2.

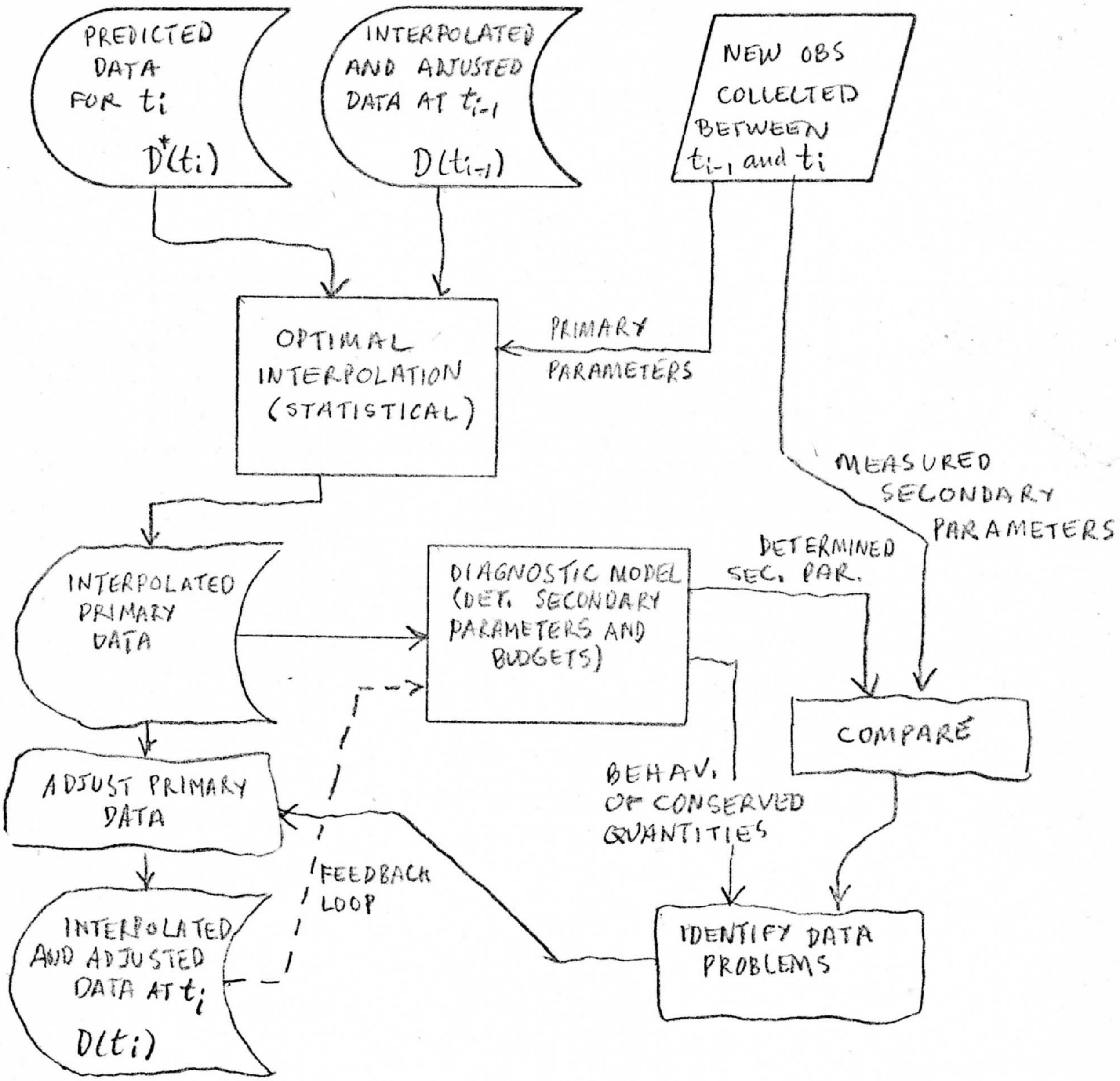


Figure 4.2 Interpolation and adjustment of 3-D data to reflect new information.

4.4 Mathematical Models Employed in Synthesis

In previous sections references have been made to mathematical models of how the atmosphere changes with time, how it changes over space, and how one set of atmospheric parameters are related to other sets. These can be summarized and functionally defined as follows

1. interpolation model: determines complete sets parameters on a uniform space-time grid from incomplete observation made on a non-uniform space-time grid;
2. diagnostic model: derives secondary parameters (e.g. rain areas) from primary parameters (e.g. T, Q, u, v); used to check consistency of derived and observed secondary parameters;
3. predictive model: predicts future values of primary parameters from initial conditions; and
4. extrapolation model: a subset of predictive models characterized by simplicity and useful accuracy only for short time intervals.

The specific models of each type listed above which are proposed for use in the synthesis process are described in detail in the following subsections.

4.4.1 Optimal Interpolation

The two main ideas embodied in the process of optimal interpolation are (1) the value of a parameter at a given space-time grid point is equal to the predicted value at that point corrected by a weighted linear combination of differences between measured and predicted parameters in the space-time vicinity of the given grid point and (2) the weights are determined by minimizing the mean square error of interpolation for a statistical ensemble. In order to express these ideas in a mathematical expression, the following definitions are required:

$\Psi_\ell(\vec{r}_i)$ = the true value of the ℓ^{th} primary parameter at the i^{th} grid point (at space-time location $\vec{r}_i$);

$\Psi^P_\ell(\vec{r}_i)$ = the predicted value of the ℓ^{th} primary parameter at location $\vec{r}_i$;

$\Psi^o_m(\vec{r}_k)$ = the observed value of the m_{th} parameter at location $\vec{r}_k$ (not a grid point); and

$\Psi^P_m(\vec{r}_k)$ = the predicted value of the m_{th} parameter at location $\vec{r}_k$.

In terms of these parameters, the optimally interpolated value of the ℓ^{th} parameter at $\vec{r}_i$ is given by

$$\Psi^I_\ell(\vec{r}_i) = \Psi^P_\ell(\vec{r}_i) + \sum_{k=1}^{N_o} \sum_{m=1}^{N_p} W_{\ell m}(\vec{r}_i,\vec{r}_k)[\Psi^o_m(\vec{r}_k) - \Psi^P_m(\vec{r}_k)]$$

in which equation N_o is the number of observations which can influence $\Psi^I(\vec{r}_i)$, N_p is the number of parameters which are measured at each observation point k, and $W_{\ell m}(\vec{r}_i,\vec{r}_k)$ is a statistical structure function describing the weight of a parameter m prediction error at $\vec{r}_k$ in correcting parameter ℓ at grid point $\vec{r}_i$. Normally, the structure function is restricted to depend only on the relative positions of the observation and the grid point $\{\vec{r}_i - \vec{r}_k\}$ or, assuming isotropy, only on the distance between them $\{|\vec{r}_i - \vec{r}_k|\}$. Derivation of structure functions for similar restrictions in generality can be found in 4-Dimensional Assimilation of Meteorological Observations, GARP Publication Series No. 15, and a paper by Lennart Bengtsson (Tellus XXIII, p. 328, 1971).

The number of observations which can influence a given parameter interpolation to a given grid point depends on the density of observations and the behavior of the structure functions. It is expected that beyond a certain distance from a grid point, which can be called the "radius of influence," the statistical weight of an observation is negligible, with the radius depending on the parameter interpolated and the parameter observed. All observations which have their circles of influence containing the grid point of interest are included in the interpolation process. This is illustrated for a two dimensional case in Figure 4.3. Although the behavior of the structure functions to be used in the small synoptic and mesoscale data sets described in section 4.1 is dependent on statistical information not now available, it is probable that circles of influence will often extend beyond several hundred kilometers, perhaps out to a few thousand kilometers. For the largest circles of influence and the smaller data grids this means that addition of information from a small localized region could require interpolation of all parameters at all points.

A rough order of magnitude estimate of computational requirements can be made with the help of a few simplifying assumptions. Consider the SS grid described in Table 4.1. In reference to this grid the following will be assumed:

(1) at each time in the sequence of 3-D grids 15,000 x 4 = 60,000 new parameters will be measured with a spatial distribution roughly uniform over the grid (this number is equal to that of the parameters to be interpolated);

(2) each parameter at each grid point is influenced by 4 (vertical) x 5 (horizontal) x 5 (horizontal) = 125 nearest neighbors;

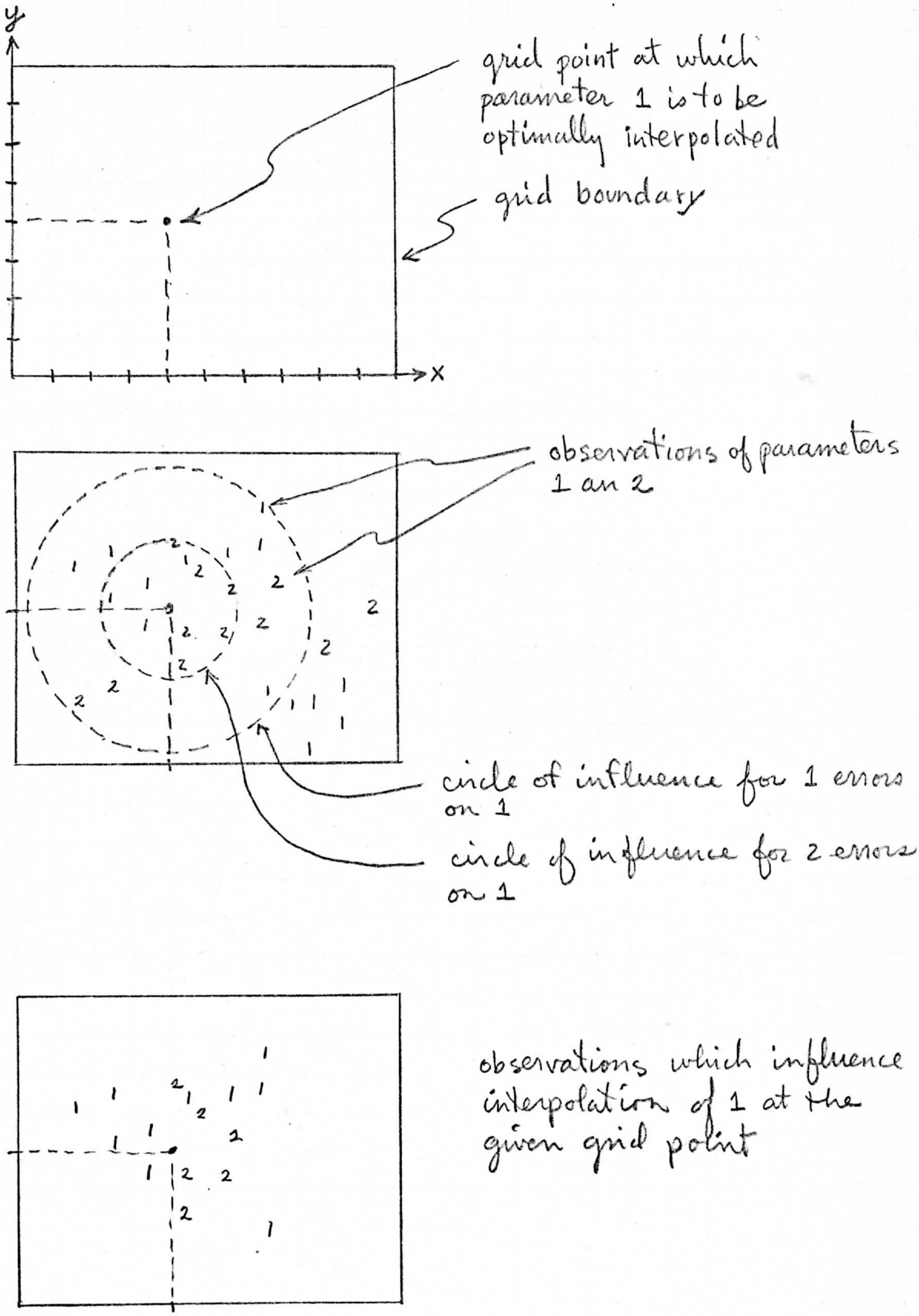


Figure 4.3 Illustration of which observations are included in the interpolation summation.

(3) each predicted value at each observation point is derived from a linear combination of predicted values at the corners of the grid box containing the observation point, with weights depending on the vector distances between the observation point and surrounding grid points; and

(4) the structure functions $W_{\ell m}(\vec{r}_i, \vec{r}_k)$ are spatially isotropic, depending only on the distance $|\vec{r}_i - \vec{r}_k|$.

With the above assumptions, the optimal interpolation of each SS 3-D grid requires evaluation of 60,000 equations ($\ell = 1,4$; $i = 1,15000$) of the form

$$\Psi_\ell^I(\vec{r}_i) = \Psi_\ell^P(\vec{r}_i) + \sum_{k=1}^{100} \sum_{m=1}^{4} W_{\ell m}(|\vec{r}_i - \vec{r}_k|)[\Psi_m^o(\vec{r}_k) - \Psi_m^P(\vec{r}_k)],$$

in which there are 401 terms of which 400 are products of $W_{\ell m}(|\vec{r}_i - \vec{r}_k|)$ and $[\Psi_m^o(\vec{r}_k) - \Psi_m^P(\vec{r}_k)]$. Excluding the evaluation of $W_{\ell m}$ and the parameter differences between observation and prediction, this yields a total of 24×10^6 products and 24×10^6 sums for each 3-D grid of the SS type. Since there are only 15,000 different observation points, there are only 15,000 different differences $\Psi_m^o - \Psi_m^P$. However, each of these requires evaluation of a sum

$$\sum_{g=1}^{4} f(|\vec{r}_k - \vec{r}_g|)\ \Psi^P(\vec{r}_g)$$

where $\vec{r}_g$, $g = 1, \ldots, 4$ are the grid points surrounding the observation point $\vec{r}_k$, and f is the weight function which depends on the squared distance $|\vec{r}_k - \vec{r}_g|^2$. In order to determine the distance it is necessary to take 3 differences (one for each component) and sum 3 products. Assuming a simple weight function of the form

$$f(d_g) = \frac{1/d_g^2}{\sum\limits_{g'=1}^{4} 1/d_{g'}^2}$$

each of the 15,000 differences requires (3 differences + 3 products + 2 sums) + (4 divisions + 3 sums) + 4 divisions + (4 products + 3 sums) for a total of 3 differences, 7 products, 8 divisions, and 8 sums. The structure functions $W_{\ell m}(\vec{r}_i - \vec{r}_k)$ require calculation of a total of 15,000 x 100 = 1.5 x 10^6 distances each requiring 3 differences and a sum of three products (ignoring the square root).

4.4.2 Diagnostic Models

Operation of diagnostic models can be divided into two steps: calculation of mathematical transforms of primary grid data to reveal characteristics not apparent in the original form of the data, and interpretation of the transformed data to predict values of secondary data (e.g. rainfall) and to determine physical reasonableness and consistency of the primary data.

In its simplest form the diagnostic routines must be capable of evaluating the following functions of primary data:

(1) potential temperature,
(2) equivalent potential temperature,
(3) mixing ratio, fcn of dewpoint and P
(4) divergence, of wind field
(5) vorticity, curl
(6) shear deformation,
(7) stretching deformation, } changes of wind fields
(8) temperature advection, T change due to winds
(9) temperature divergence $(\nabla \cdot (\vec{V}T))$,
(10) dew point divergence, related to outputs of severe weather

(11) mixing ratio divergence,

(12) potential temperature divergence,

(13) equivalent potential temperature divergence, and combines T and q

(14) pressure divergence.

These are all presently programmed on McIDAS for Service A processing (T. Whittaker should be consulted for documentation).

Additional functions which are particularly relevant to synoptic scale systems are derived from the geopotential tendency equation and the vertical motion or omega equation (Holton, An Introduction to Dynamic Meteorology, Chapter 7, Academic Press, 1972). These functions are

(15) differential vorticity advection,

(16) thickness advection,

(17) vorticity advection, and

(18) differentail thickness advection.

The mathematical form of these functions can be found in the previous reference (Holton, 1972). The specific computational algorithms remain to be derived.

Two integral functions are also required:

(19) net mass flow through a specified 3-D closed surface, and

(20) net moisture flow through a specified 3-D closed surface.

Computational algorithms for these functions have been developed for use on the UNIVAC 1110 (consult R. Peterson, Meteorology Department).

Specific formats for presentation of these functions, and the more sophisticated algorithms for interpretation remain to be specified or to be determined.

An example of one diagnostic process is roughly outlined in Figure 4.4. Vertical motion fields derived from primary data are compared with physical constraints and information from auxiliary (or secondary) data to isolate regions of inconsistent data.

4.4.3 Predictive Models

There are a number of predictive models which will be directly or indirectly involved in the VAS processing system. These can be summarized as follows:

(1) NMC Primitive Equation (PE) Model - used to predict northern hemisphere synoptic large scale weather and provide boundary conditions for the North America region;

(2) NMC Limited Fine Mesh (LFM) Model - has approximately 190km horizontal grid spacing, used for North American synoptic forecasts, covers a region 65 grid pts on a side;

(3) Increased Resolution Fine Mesh (IRFM) Model - a NOAA-NESS adaptation of the LFM to obtain a 100km grid spacing and containing improved parameterization physics and initialization [this will be developed during the course of the VAS system development and evaluation];

(4) Simplified Quasi-Geostrophic (SQG) Model - possible use for short time extrapolations of parameters on the sub-synoptic scale (100km); expected to be 1/4 to 1/2 the size of the LFM;

(5) Kinematic Model - used for very short term extrapolation of parameters based on fluid flow rather than underlying physical forces, exact form and role remains to be determined; and

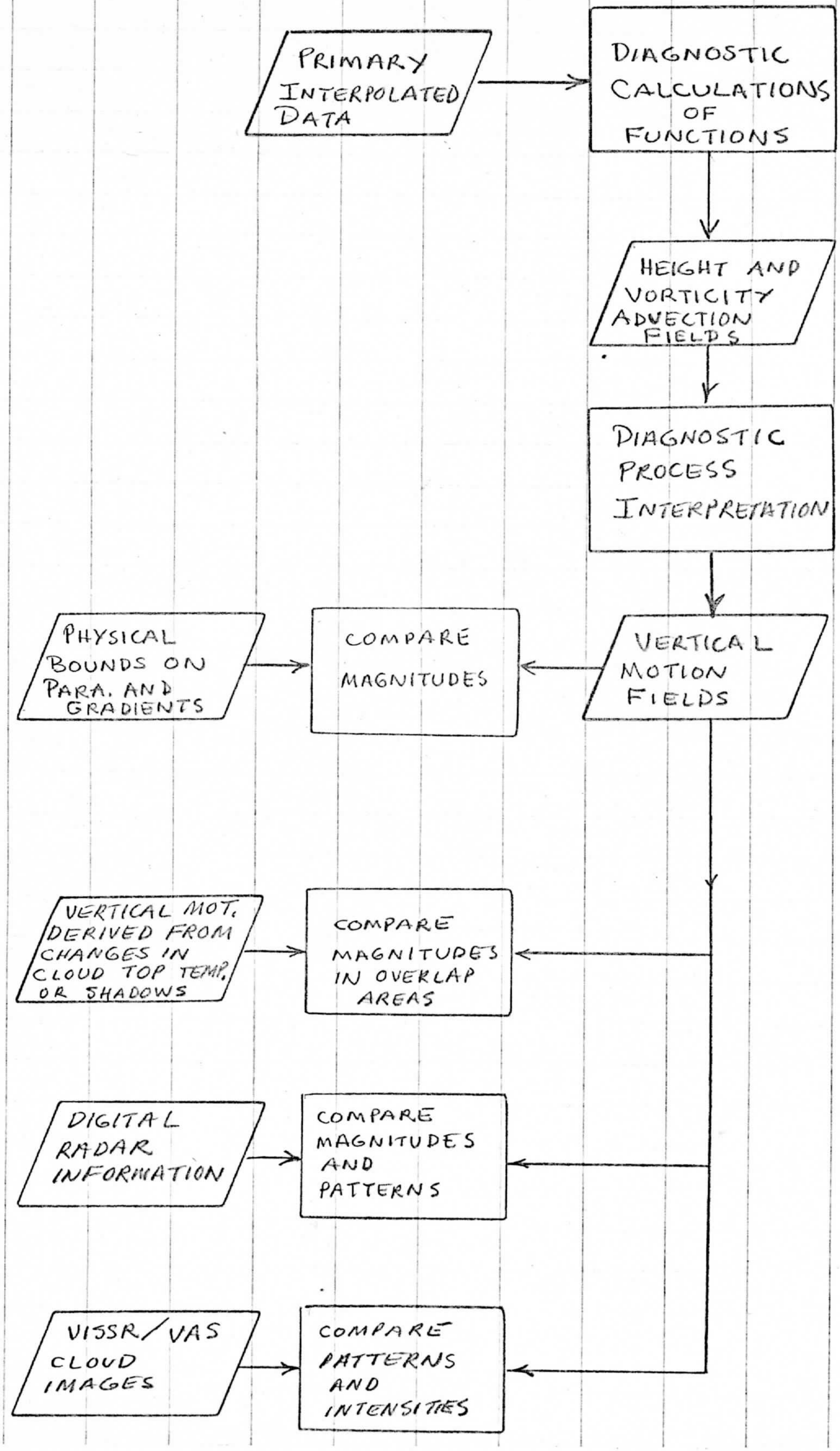


Figure 4.4 Example of Diagnostic Process for Data Evaluation using Vertical Motion Fields

(6) Mesoscale Model - characterized by fine grid spacing and inclusion of unbalanced motions; not expected to be part of the VAS processing system, but rather a user of the synthesized VAS data.

The output of the NMC PE and LFM models will be employed in the VAS processing system initially as the predicted data reference for the optimal interpolation process, and later, following the development of finer scale models, as boundary conditions for these models.

The Increased Resolution Fine Mesh Model will provide predicted reference data for optimal interpolation of the Small Synoptic Scale Grid. Initially this model will be run external to the VAS system on IBM 360's at NOAA, and when possible, and probably after considerable modification, within the VAS system. Our present knowledge of this model indicates the following computational characteristics (Kit Hayden, NOAA/NESS):

core requirements - 550,000 bytes (8 bit), probably 300K minimum;

and

run time - 10 minutes per 12 hour forecast (large machine environment).

Although the design of the VAS processing system should not be primarily constrained to run this model, the required capability should be kept in mind so that unnecessary constraints do not eliminate this possibility and especially so that the capability could be obtained by subsequent minor additions to the VAS processing hardware (e.g. memory expansion). It may be more convenient to use the SQQ Model in place of the IRFM Model on the VAS system as a result of its relatively small core requirements (100K bytes to 150K bytes).

4.5 Man Interactive Requirements

To insure useful human participation in the data synthesis process the following tools (or capabilities) are required:

(1) intensity and contour display of any data set primary parameter in either vertical or horizontal cross section in time sequence, selectable by the human operator, and presented within a few seconds of selection;

(2) presentation of above described horizontal cross sections in satellite coordinates (for any of the following satellites: VAS, VISSR, TIROS-N, DMSP) with timeliness comparable to that in (1);

(3) listing of any designated raw data sources in the region defined by the operator either by numerical coordinates or cursor overlay on the displayed information;

(4) presentation of overlays of synthesized data intensities and/or contours and satellite image data in time sequence;

(5) presentation of intensity and/or contour displays of diagnostic functions of primary parameters in vertical or horizontal cross section, in time sequence, and in the form of overlays on satellite data with coordinates adjusted to match the appropriate satellite.

5.0 Summary of Display Requirements

6.0 Summary of Computational Requirements

7.0 Summary of Archive and Storage Requirements

7.1 Archive Requirements

All the raw data collected and the data sets derived during the VAS Experiment period should be archived. This period will include at least 79 days of data. The required archive capability is determined almost completely by the volume of raw VISSR and VAS data. These volumes are:

VISSR (assuming that 1/4 of all VISSR data centered over the U.S. is archived)	3.8 x 10^{10} bits/day
VAS	1.5 x 10^{10} bits/day.

8.0 Data Distribution

8.1 Methods of Distribution

The data array products from the VAS ground processing system will be distributed to data users in _____ different ways. This section describes these different methods of distribution.

1. AFOS Output

There shall be one output port on the system which can deliver data in a AFOS compatible format. That is the system shall be capable of producing VAS derived AFOS compatible data products.

The AFOS output shall be able to operate continuously without significantly affecting the other data processing functions of the system.

2. NESS GOES Distribution Output

The system shall have one output line which delivers data in a format compatible with the existing NESS GOES Distribution System format. The system design shall be such that this capability can be easily expanded to _____ such output lines.

3. Electronic SFSS Format

There shall be one output line which produces data in a format compatible with the future electronic SFSS format. The system design shall be such that this capability can be easily expanded to _____ such output lines.

4. Remote Terminals

Two remote terminals shall be built. For a description of their capabilities see section 8.2. These terminals will be designed such that they receive their input data in the format identified above as Electronic SFSS format.

5. Computer Compatible Tape

A tape deck shall be included as part of the system. It shall deliver tapes of the output data arrays according to a standard computer format. The purpose of this tape is to deliver VAS data to modelers throughout the country for use on their computers.

6. NOAA Suitland Computer

A telephone interconnection between the VAS computer and the IBM 360/195 computers in Suitland shall be provided. The VAS system shall be capable of acting as a remote terminal to the NOAA computer for remote job entries, receive NMC data from the Suitland Computers and distribute VAS data to NMC for use on their LFM etc. models.

8.2 Remote Terminal Capabilities*

The remote display systems will provide the user with the following capabilities:

(1) Access to and display of preprocessed VAS data sets, ingested non-VAS data sets, and the outputs of the central processing operations.

(2) Interaction by means of a set of specific commands/routines in the derivation of products at the central processor.

(3) Small-scale operations on data sets that are in storage at the remote display system.

As shown in Figure 8.1, the remote display system consists of storage, a processor for small scale operations, and display devices such as a CRT and a printer.

8.2.1 Access to Centrally Stored Data Sets

A catalogue of all centrally stored data sets will be readily available at the remote display. Upon request from the remote display, the centrally stored data sets will be formatted and transmitted to the remote display storage area.

Depending on the particular type of data, the user will be able to select in the form of numerical fields:

(1) horizontal distributions of a parameter

(2) vertical distributions of a parameter

(3) time distributions of a parameter

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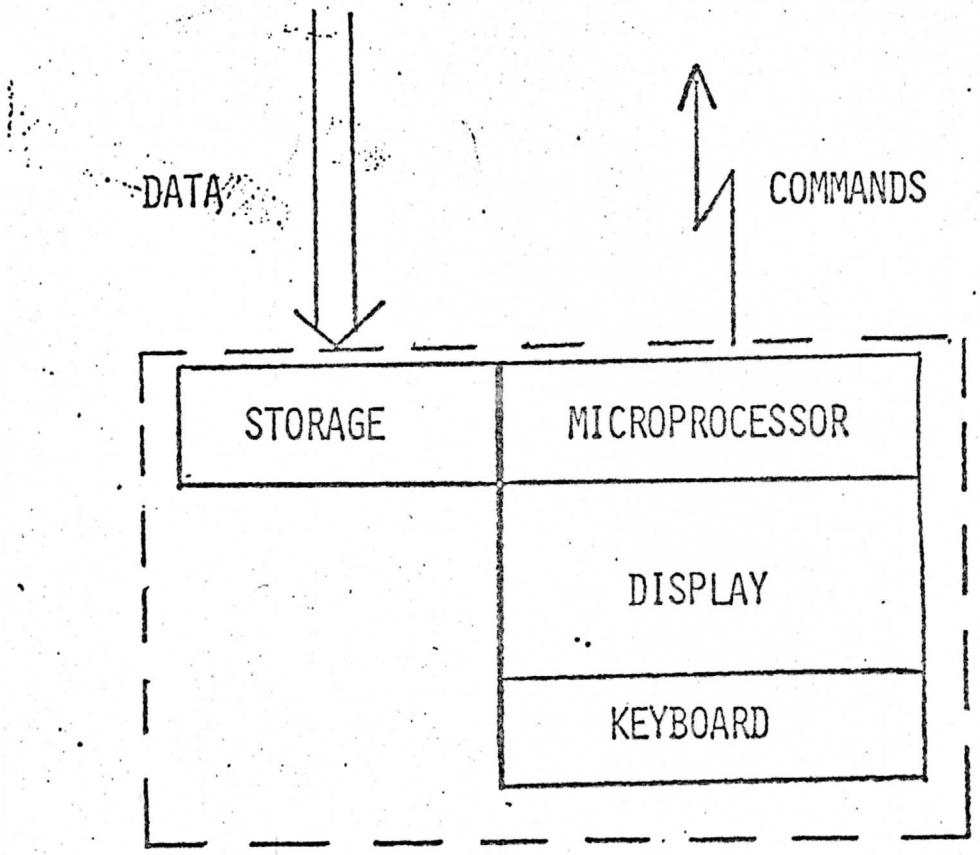
* This section was excised from a memo from Larry Hambrick, NOAA, entitled VAS Operational Data Processing System dated June 18, 1976.

Figure 8.1 REMOTE TERMINAL



The user would specify the parameter of interest, the data set of interest, contour and gridding operations, and accuracy (e.g., 4, 8, or 16 bit).

8.2.2 Interaction in the Processing of Data

The user of the remote display system can request that any of the central processing operations be performed on or within particular data sets and on edited versions of the data sets. The user would take advantage of human insight and ancillary data to edit data sets before operations are performed. The user would also be able to inject constraints or supplementary information into the algorithms.

For the interactive processing the following capabilities are needed at the remote display:

(1) Access to all centrally stored data sets

(2) Editing of data sets at the terminal

(3) Transmission to central storage of edited data sets and editing via the terminal on data sets at the central computer

(4) Specific commands and/or routines for injecting information into processing of each operation.

8.2.3 Small-Scale Operations at the Remote Display System

The user will be able to perform certain operations on data sets stored at the remote display system independently of the central computer. Just how much processing capability there should be at the remote terminal depends on details of the overall system design. As a minimal requirement, the user of the remote display will need to retrieve and display data sets in local storage. The capability for additional small-scale operations such as the following would be desirable:

(1) Selection of data from within a data set to form a new data set

(2) Grouping of data sets to form time sequences

(3) Simple arithmetic and logical operations for enhancements involving one or more data sets

(4) Color coding and gray scale schemes

(5) Graphics (e.g., line plots)

(6) Editing of data sets:

    (a) Deletions and changes, point by point or by area, in a displayed field

    (b) Extrapolations over a particular area in a field from adjacent points

APPENDIX A: Summary of VISSR Atmospheric Sounder System Definition Presentation

This paper is a summary of a presentation by the Space Science and Engineering Center, University of Wisconsin on 9 November 1976. The presentation discussed the concepts and objectives of the joint University of Wisconsin-NOAA-NASA program to conduct the demonstration phase of the VAS program.

The basic outline of this paper contains (a) an explanation of the meteorological utility of VAS; (b) an overview of the system elements and the role of man interactive feedback; (c) a brief discussion of data collection, (d) data analysis, and (e) data synthesis.

The goals of VAS sounding research as outlined in the OSIP (Operational Satellite Improvement Program) Plan for the VAS Demonstration are (1) to increase our understanding of short lived weather phenomena, and (2) to increase the ability to predict the behavior of short lived weather phenomena. Short lived weather (also referred to as mesoscale) phenomena include tropical storms, mid-latitude tornadoes and thunderstorms, frost and freeze, dust storms, fog, etc. To achieve the goals stated in the OSIP Plan, a detailed and consistent four dimensional description of the atmospheric state during mesoscale phenomena must be accumulated. Here four dimensional description implies a coordinated horizontal, vertical, and temporal description. Detailed and consistent indicates that there are no major data gaps at the scale of interest, and that the data are internally consistent (eg. rainfall areas should have clouds present).

The anticipated sources of meteorological observations include VAS, VISSR images from the SMS/GOES, polar orbiting satellite images and soundings from TIROS-N and the satellites of the DMSP (Defense Meteorological Satellite Program), conventional weather data, and digital radar information. If other sources of information prove valuable, we will try to incorporate them also. The data set should be as complete as possible to support the program research objectives.

Data must be gathered from a number of sources. In a 1971 SEOS feasibility study conducted at SSEC, requirements for information essential to mesoscale meteorological research were listed in order of importance. Table 1 shows them and indicates the respective sources of information.

The most important knowledge requirement is the boundary layer motion field. The boundary layer is considered to be the lower 10% of the atmosphere where the vertical viscous force is comparable in magnitude to the pressure gradient and Coriolis forces. The turbulent stresses of the boundary layer are both mechanical (such as friction) and thermal (such as solar heating) and are strongly dependent on topography, ground cover, and moisture content of the air. The evaporation of water is a major source of energy for baroclinic disturbances. From VAS we expect information on the low level moisture fields and conventional weather data should relate ground cover and winds. The wind magnitude and direction is a key indicator of developing activity because it shows where convergent and divergent regions are.

Vertical stability is an important parameter in mesoscale weather prediction. Relieving stresses caused by unstable layering in the vertical direction in the atmosphere implies large vertical motions and energy releases. Information on the time rate of change of the temperature and moisture fields in three dimensions are required to describe vertical instability. VAS and polar orbiting soundings and conventional weather radiosonde will provide this information.

Surface temperature will be derived from blackbody temperatures of window channel radiances on VAS, VISSR, and polar orbiters and from ground observations

KNOWLEDGE REQUIREMENTS (listed in order of importance)	SOURCE				
	VAS	Polar Orbiter	VISSR	Conventional Weather	Radar
1. Boundary Layer Motion Field	X			X	
2. Vertical Stability	X	X		X	
3. Surface Temperature	X	X	X	X	
4. Temperature Lapse Rate	X	X		X	
5. Regions of Strong Convective Activity	X		X	X	X
6. Middle and Upper Tropospheric Motion	X		X	X	
7. Pressure Field in Boundary Layer				X	
8. Moisture Field	X	X		X	
9. Convergence and Divergence	X		X	X	
10. Wind Shear and Jet Stream	X		X	X	

Table 1

at weather stations. Temperature lapse rates will come from soundings and radiosondes. Regions of strong convective activity will be found from time sequence imaging on VAS and VISSR, ground observations, and hydrometeor detection by radar. If convective activity is strong enough, it will be raining. And so on down the list. The pressure field in the boundary layer is available only from conventional weather data.

It should be noted that the knowledge requirements were ranked primarily for convective mesoscale phenomena. Priorities for non-convective phenomena such as fog or frost would be different. The table should be viewed with that in mind.

The table also fails to indicate what VAS offers that other sources do not. It seems to indicate that all knowledge requirements could be satisfied without VAS because it does not include consideration of space and time scales. Conventional weather observations are obtained on the synoptic scale from weather stations separated by 300-400 km. Polar orbiter satellites under-sample some areas, over-sample others and do so every 4 to 6 hours. These time and space scales are adequate to describe larger scale weather phenomena but they are inadequate to describe mesoscale phenomena. To see this more clearly consider Table 2. The space and time resolution of data required to describe active mesoscale conditions cannot be met by existing observing capabilities.

VAS will help to fill the observation time and space gaps. An adequate four dimensional data set will rely heavily on VAS to provide information where non-VAS coverage is missing or untimely.

Surface data from weather stations is updated every hour. The capability to incorporate special observations exists; i.e., if a front crosses over

Mesoscale Phenomena

Space and Time Resolution*

Atmospheric Condition	Resolution Desired	
	Space	Time
Stable	200-400 Km	1-2 Hr
Active	20-50 Km	1-2 Hr
Severe	20-50 Km	5-15 Min

* from 1971 SEOS feasibility study

Table 2

a weather station or severe weather occurs, more frequent reports are usually sent. However, these special reports fit poorly into automated data processing systems. Upper air data from radiosondes and aircraft are available every 12 hours. Between observations, upper air information is derived from the NMC model predictions. Departures from these predictions, evaluated assuming a balanced state of the atmosphere, may indicate areas of interest for further VAS and VISSR observations. Digital radar can be available nearly continuously. VISSR updates normally occur every 30 minutes. TIROS-N morning and evening satellites have overpasses at 4, 8, 16 and 20 hours LST. DMSP provides noon-midnight and dawn-dusk coverage. The maximum in severe weather activity usually occurs at 3 or 4 in the afternoon, when non-VAS observations are sparse. VAS is needed to fill both time and space scale gaps.

Table 3, also taken from the SEOS report, indicates the vertical location of the observable physical fields (mass, motion, thermal, moisture, hydrometeor,...) required to comprehend mesoscale weather phenomena. Most of the information requirements must be met by observations near the earth's surface. Conventional weather observations are needed to provide the majority of this information. Clearly VAS data by itself would be incomplete.

The ancillary data base will provide the foundation upon which VAS data will build. The data base will provide a description of the boundary layer, provide ground truth and reference data, and will provide microwave sounding information which allows soundings where there are clouds. The polar orbiting satellites will be equipped with microwave sounders, and the data they will produce should help greatly to fill in areas obscured by clouds.

Achieving the goal of understanding short lived weather phenomena requires atmospheric data with a spatial scale fine enough to resolve severe

Location of Mesoscale Knowledge Requirements

	Physical Field					
Location	Mass	Motion	Thermal	Moisture	Hydrometeor	Other
Earth Surface and Boundary Layer	X	XX	XX	X	X	XX
Middle Troposphere		XX	X	X		X
Upper Troposphere		X				
General Atmosphere						XX

Table 3

weather activity (several tens of kilometers) as well as observations frequent enough to determine rates of change in relevant atmospheric parameters (half hourly). We plan to provide these data with a system centered around soundings from geosynchronous platforms which incorporates ancillary data from the areas of interest.

Figure 1 indicates a general definition of the four system elements - collection, analysis, synthesis, and modelling. Collection involves receiving raw data, preprocessing it to obtain physical observables (eg. raw radiances from VAS, conventional weather ground temperature) and then filing those observables. Analysis includes processing the observables to derive meteorological parameters (such as temperature profiles, winds, ...). The Synthesis step produces a complete and consistent four dimensional data set of atmospheric state parameters. Under Modelling the system predicts the future state of the atmosphere and determines auxiliary descriptors (eg. rainfall areas).

The man interaction with the system will be through data selection, quality control, process modification, and overall system evaluation. The man will select from the incoming high data volume that information which will best describe the mesoscale weather of interest. Output of each system element will be compared against reference standards (eg. winds inferred from time sequence images of clouds can be compared to ground station observations). Subjective and objective processes will be tested against one another. Processes will be modified and the modified processes rated. Coordination of the system elements into an efficient processing system will require iterative evaluation. Figure 2 is a schematic diagram showing an example of feedback learning.

The following paragraphs describe more explicitly the first three system elements. Table 4 reviews the ancillary data collection. Surface data yields

GENERAL DEFINITION OF SYSTEM ELEMENTS.

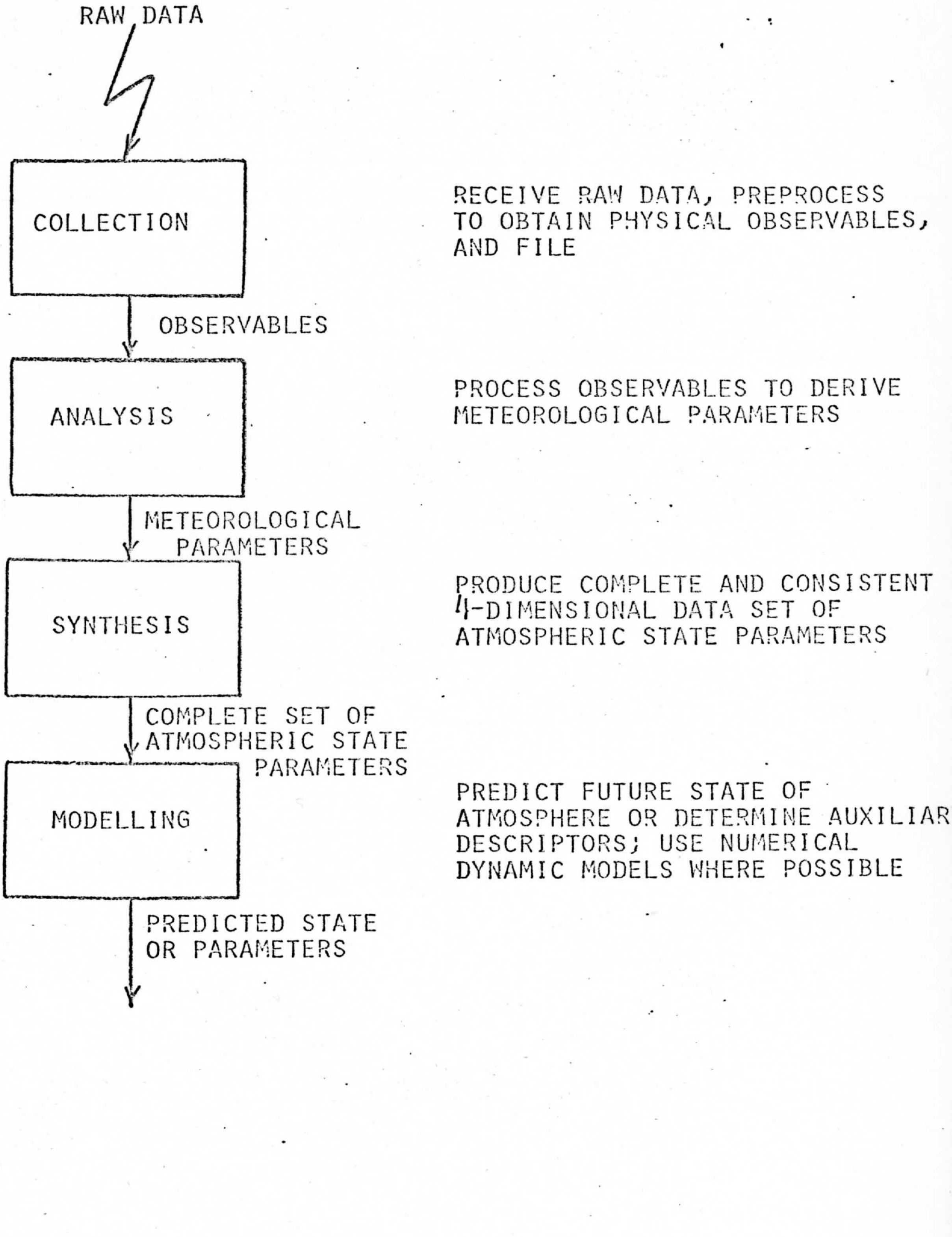
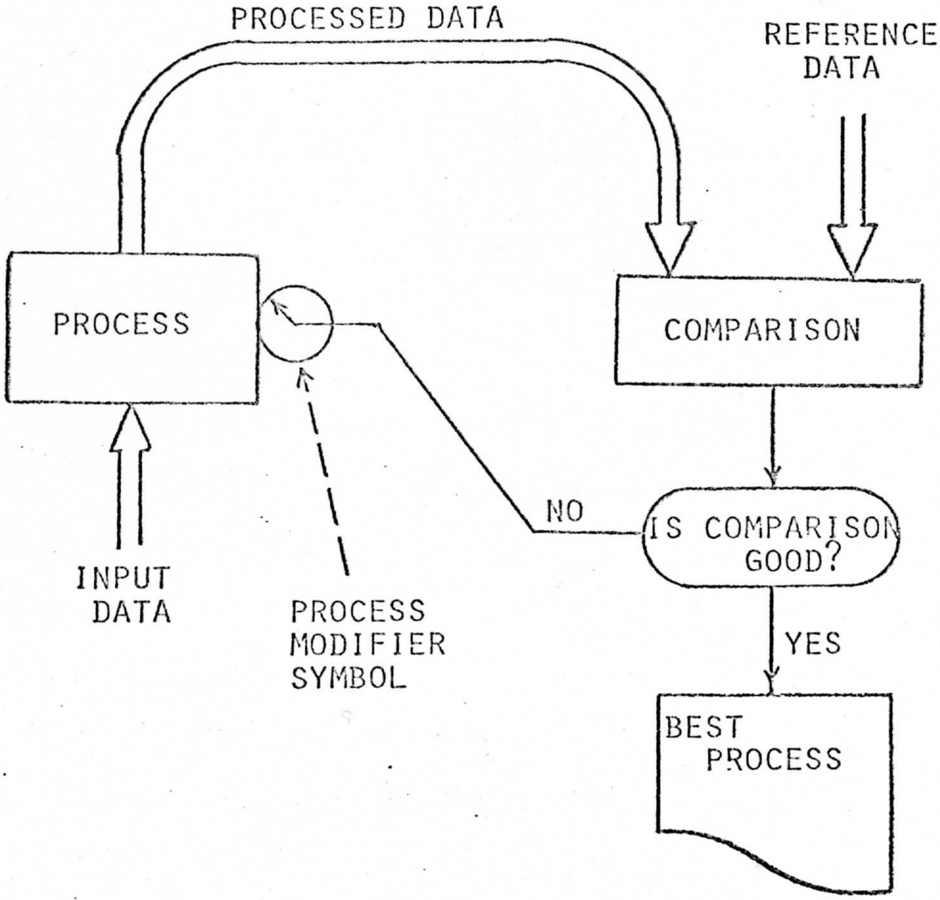


Figure 1

ROLE OF FEEDBACK

EXAMPLE OF FEEDBACK LEARNING:



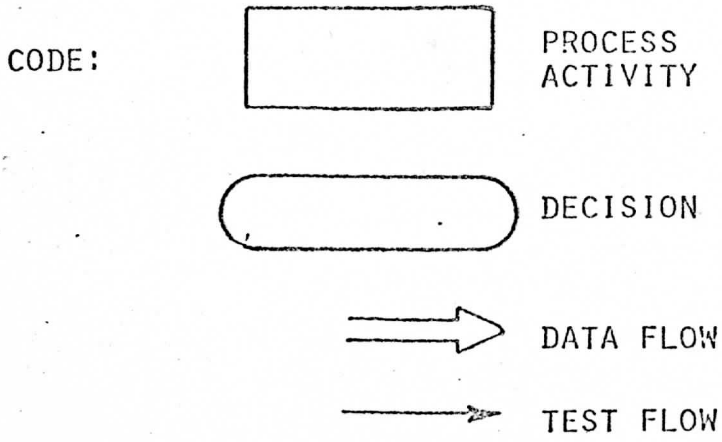


Figure 2

Ancillary Data Collection

SOURCE	DATA TYPE	REMARKS
Conventional Weather Data		
- surface	T_s, P_s, v_s, cloud hts. visibility	Description of Boundary Layer, Ground Truth Information Auxiliary Data for Clear Column Retrieval
- upper air	T(P, Q(P), v(P)	Vertical Resolution of Temperature and Humidity Fields
- radar	radar	Liquid Water Content
VISSR	high resolution visible images, IR window images	Description of Motion Fields, Cloud Types
Polar Orbiting Satellites		
- TIROS-N		
BSU	14 channel IR sounding	Intercomparison Soundings with VAS
SSU	3 channel IR sounding	Stratospheric Soundings
MSU	4 channel Microwave sounding	Soundings in Cloudy Regions
AVHRR	high res. visible images	Different Viewing Angle than VISSR helps with Cloud Height Determination
- DMSP	high res. visible images IR channel soundings Microwave soundings	More Complete Data Base, Better Cloud Height Determinations

Table 4

surface temperature, pressure, velocity, visibility, etc. Upper air yields profiles. Radar yields liquid water content. VISSR yields time sequence images allowing description of motion fields and identification of cloud types. Polar orbiters provide stratospheric soundings (the slowly varying stratosphere is adequately sampled by polar orbiters and helps pin down upper tropospheric determinations), soundings in cloudy regions (as mentioned before), and intercomparison soundings with VAS. In addition they also offer a different viewing angle than VISSR (or VAS) that may help with cloud height determinations. Observations from different sources may be combined to produce inferred data. For example, if a weather station observes ground temperature of 20°C and the VISSR window channel blackbody temperature of the same area reads a lower temperature, 10°C, then it can be inferred that the FOV is cloudy. This would be an example of auxiliary data for clear column retrieval.

Figure 3 indicates how VAS may be programmed in a typical day of severe storm observation. Early in the day the NMC prediction indicates 10 to 20 possible danger areas deserving attention. Often a strong correlation exists between morning conditions and afternoon severe weather. Coordinating the NMC prediction with the latest mesoscale analysis and synthesis and with early morning VAS and VISSR images, the man in the loop can direct the VAS to the areas of possible severe weather and program the instrument for sounding or imaging as appropriate. The new VAS data will be used to update the mesoscale analysis and to redirect the VAS operating mode and target. This concept for VAS operation illustrates the advantage offered by VAS to watch for storms and to follow them as they develop. It allows the operator to control the instrument so that VAS data contains information that cannot be gotten from other sources - the hard to get soundings around active weather and the gradients required to describe the mesoscale situation.

Concept for Selection of VAS Operating Mode

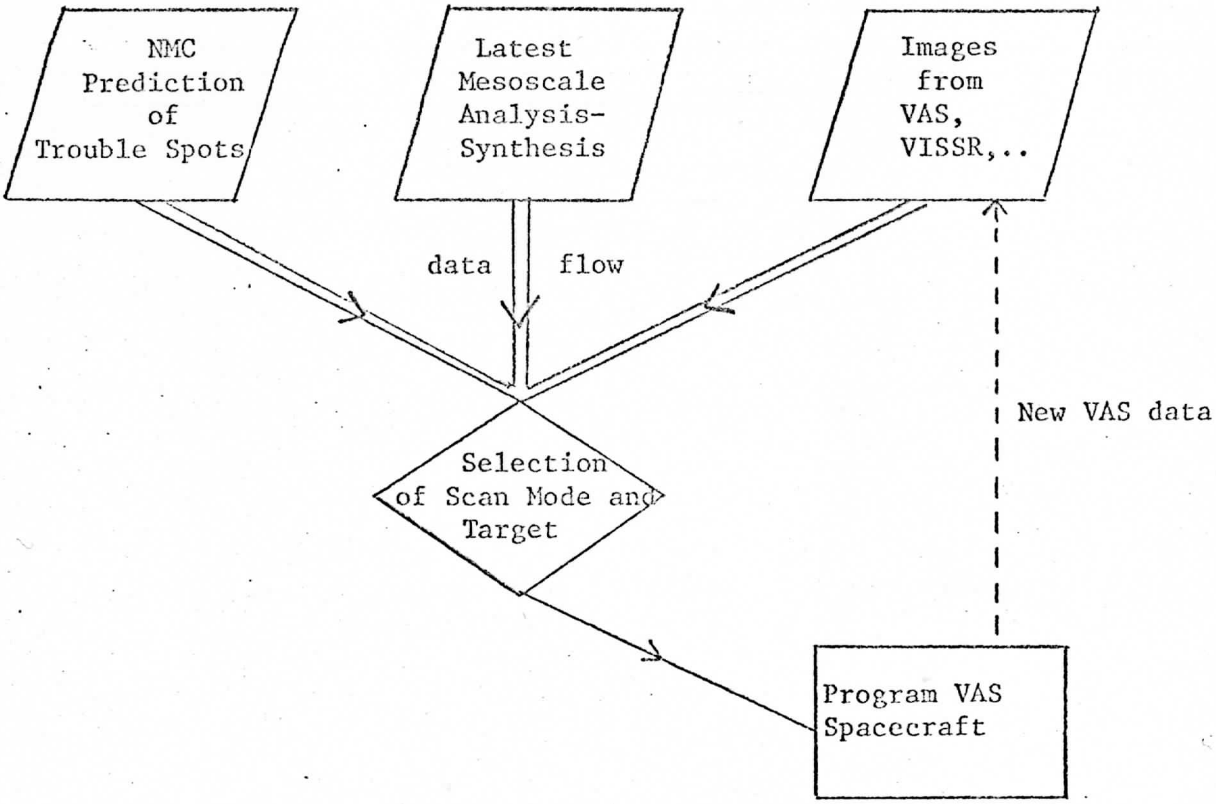


Figure 3

Analysis is that system element which converts observations into derived meteorological parameters. For the VAS there are two types of observables - sounding data and imaging data. The characteristics of the sounding data are twelve channel radiances that give complete vertical coverage to an accuracy of 1 Wark (.25 erg/etc for the 15μ window channel) after time and space smoothing. The imaging data emphasizes horizontal coverage leaving vertical coverage incomplete. Spectral radiances here are chosen for specific applications (eg. the 4μ window channel would be used to evaluate sea surface temperatures over broad areas) and the sampling accuracy required also varies with application.

The derived meteorological parameter outputs can be classified by clear and cloudy areas. From clear areas we will derive water vapor fields, winds from water vapor tracking (time sequence H_2O channel images), temperature fields, and surface temperatures (blackbody temperature determinations from window channel radiances). From the cloudy areas we will determine winds from cloud tracking, cloud heights, liquid water content, and cloud types.

Table 5 indicates an overview of the status of the techniques to be used to analyze the observables. For sounding analysis, existing polar orbiting sounder techniques need adaptation to account for characteristics of geosynchronous soundings and the interactive small machine environment. For imaging analysis, McIDAS techniques are directly applicable for retrieving cloud motion winds and polar orbiter techniques are applicable for determining cloud heights. Techniques for water vapor motion winds, surface temperature, cloud type, and perhaps other derived quantities await development.

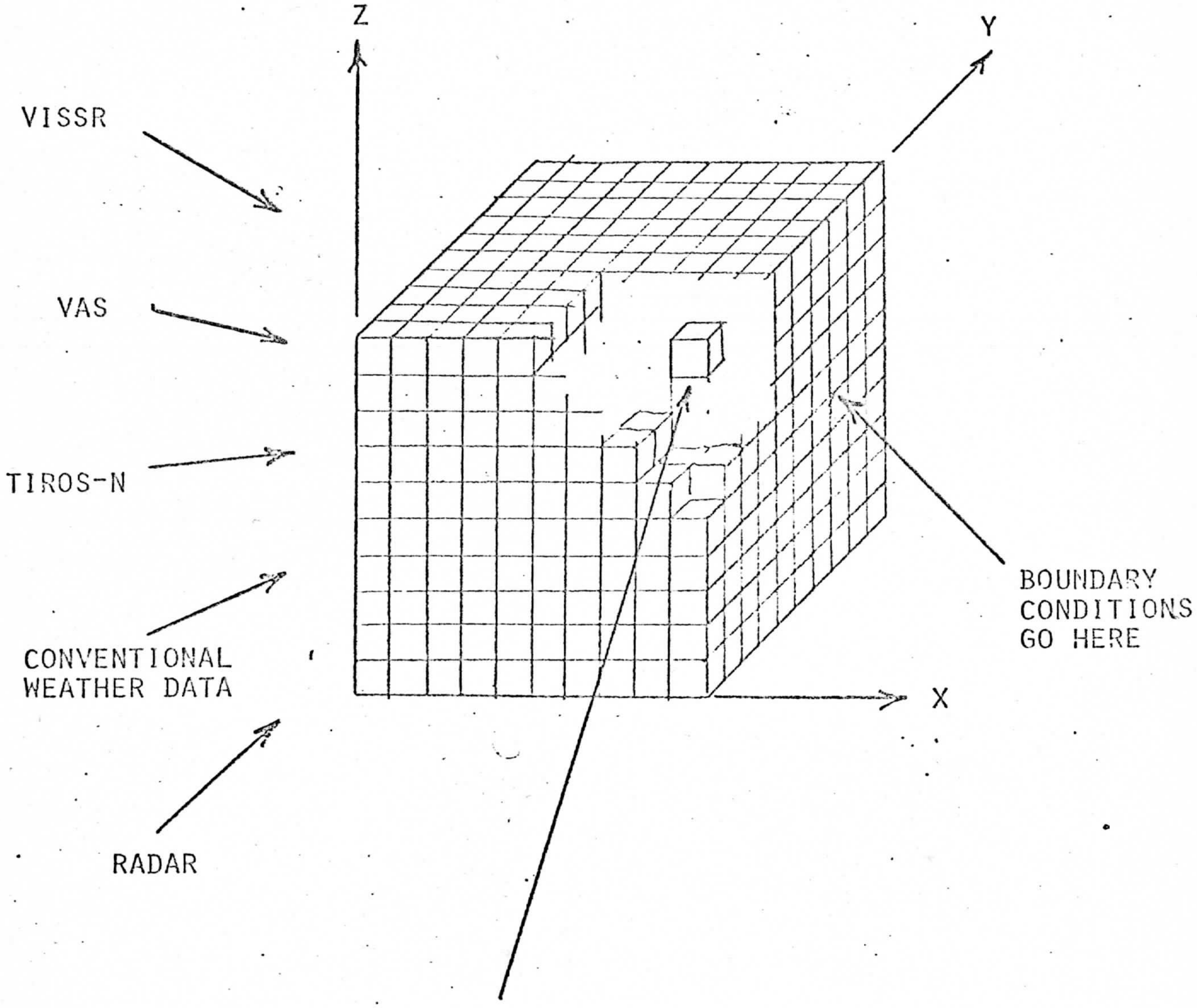
In the Synthesis step the system combines the derived meteorological parameters to produce the four dimensional data set. The basic objective of Synthesis is to create an adequate data set for a predictive model. Every

OVERVIEW OF TECHNIQUE STATUS

	Input Sources	Outputs	Status of Analysis Techniques
Sounding Analysis	Primary sources: VAS TIROS-N Auxilliary sources: Assimilated data Historical data VISSR images	q(P) T(P) Pcloud Tsurface	Existing polar orbiting sounder techniques need adaptation to interactive small machine environment.
Imaging Analysis	Primary sources: VAS VISSR Auxilliary sources: Assimilated data	- Cloud motion winds	- McIDAS techniques directly applicable
		- Pcloud	- Existing polar orbiter techniques applicable
		- Water vapor motion winds Liquid water content Tsurface Water vapor distribution Lower tropospheric temperature Cloud type	- Need development

Table 5

BASIC OBJECT OF SYNTHESIS



EVERY BOX IN THE MESOSCALE VOLUME IS FULL OF NUMBERS:

$(T, P, Q, \vec{V}, \text{liq. } H_2O, \ldots)$

Figure 4

box in the mesoscale volume should be full of numbers that describe the atmospheric state (T, P, Q, $\vec{V}$, liq H_2O, ..). Since the synoptic scale phenomena such as highs, lows, and fronts are often the driving forces behind mesoscale weather they must be incorporated into the data as boundary conditions. The model will be scaled temporally and spatially to be useful for short term forecasting and the required data set must be conditioned to mesh with these scales.

To assimilate the variously derived data into a consistent four dimensional depiction of the state of the atmosphere will require different synthesis functions. These functions must eliminate data gaps and discontinuities that would cause predictive models to blow up and put heavy clouds and thunderstorms in the middle of high pressure areas. Interpolation, correlation, smoothing, deconvolution, extrapolation, uniform weighting, and quality control are all methods that will be used to transform incomplete, uneven, and irregular spatial and temporal coverage into a uniform, complete, and consistent data set. See Figure 5.

Many of these synthesis functions will be incorporated in various models. An interpolation model will determine values on a uniform grid from measurements made on a nonuniform grid. A diagnostic model will derive secondary parameters (eg. rain areas) from primary parameters (eg. T, P, Q) to check consistency of derived and observed secondary parameters. An initialization model will prepare data for predictive models by filtering data to eliminate scales and processes inappropriate to the model. Predictive models will predict future values of primary parameters from initial conditions. An extrapolation model (eg. kinetic model), characterized by simplicity, will be useful for very short time period predictions.

DATA SET SYNTHESIS FUNCTIONS

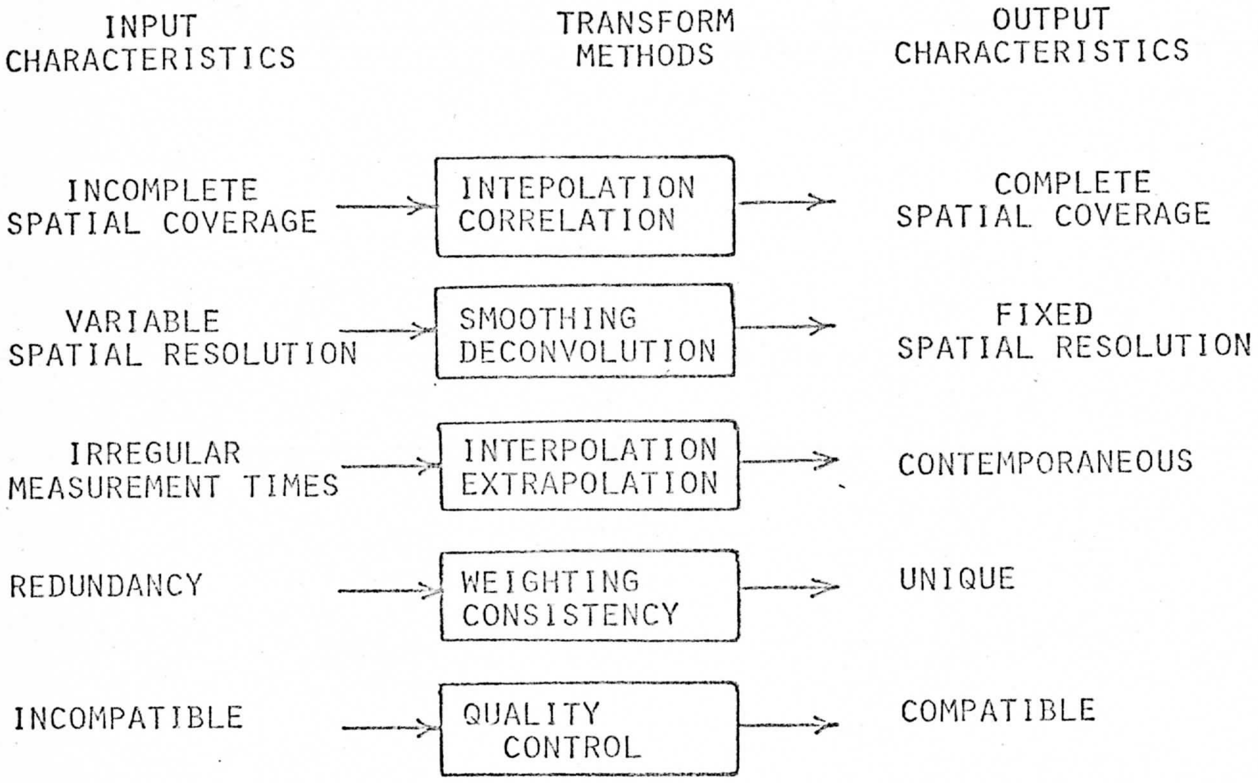


Figure 5

Once a proper and fully consistent description of the past and present states of the atmosphere is produced, then scientists from UW, NESS, GSFC, NWS, and other institutions will perform the modelling which extends the present into the future. This is the last system element. Its successful development will rely heavily upon the coordination of many people and resources in the meteorological community.

Such a complete system will accomplish the primary objective of the VAS mission - to better understand and improve prediction of mesoscale weather phenomena.

APPENDIX B. VAS Instrument Description*

The VISSR Atmospheric Sounder (VAS) is a modification of the Visible and Infrared Spin Scan Radiometer (VISSR) which has increased capabilities. In addition to providing both day and night cloud mapping capabilities, the VAS also will measure radiances in CO_2 and water vapor bands so that the vertical temperature and moisture profiles can be derived. By using multiple detectors and a filter wheel the VAS instrument can measure radiances in up to 12 infrared spectral bands. These are described in Table B.1.

The VAS arrangement as used in the spin-stabilized geostationary satellite is shown in Figure B.1. As indicated by this figure, the mapping raster is formed by the combination of the satellite spin motion (spin-scan) and the step action of the scanning optics. One raster line, corresponding to the earth's west-east (W-E) axis (longitude), is formed for each revolution of the spinning satellite, and the VAS scanner positions each successive line in the north-south (N-S) (latitude) direction. Each 0.192 milliradian (mr) N-S axis scan step corresponds to the total field of view (FOV) of the eight visible channel detectors. The 900-meter resolution in the visible spectrum (0.55 to 0.72 μm) is obtained by using a linear array of eight detectors aligned so that they sweep out the complete scan line path. The instantaneous geometric field of view (IGFOV) of each of the visible channels is 0.025 mr (W-E) × 0.021 mr (N-S), allowing 20% underlap between field stops for fabrication considerations. The reduced data rate mode of VAS, which will be used during the initial experiment, will not provide 900m resolution visible data. Instead the signals from the top four visible detectors and from the bottom four will

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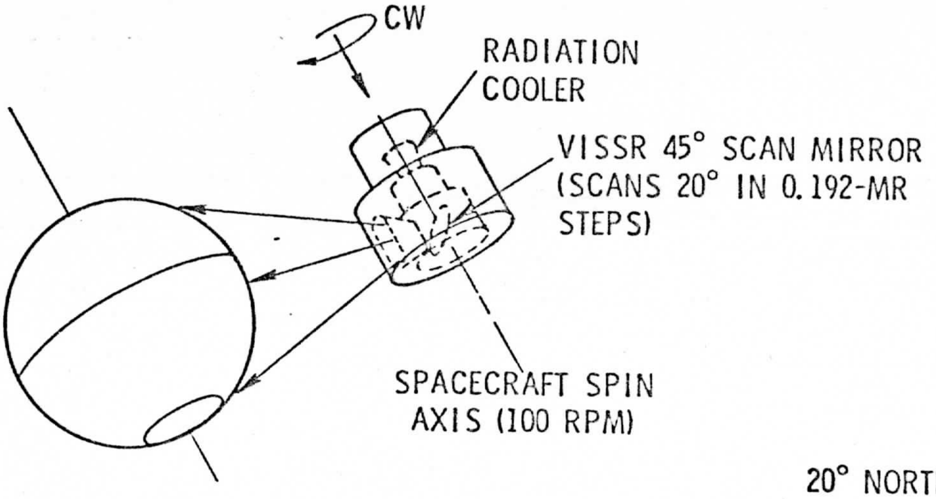
* For a complete description of the VAS instrument refer to Technical Specification Visible Infrared Spin-Scan Radiometer Atmospheric Sounder (SBRC number 15570, latest revision).

Table B.1

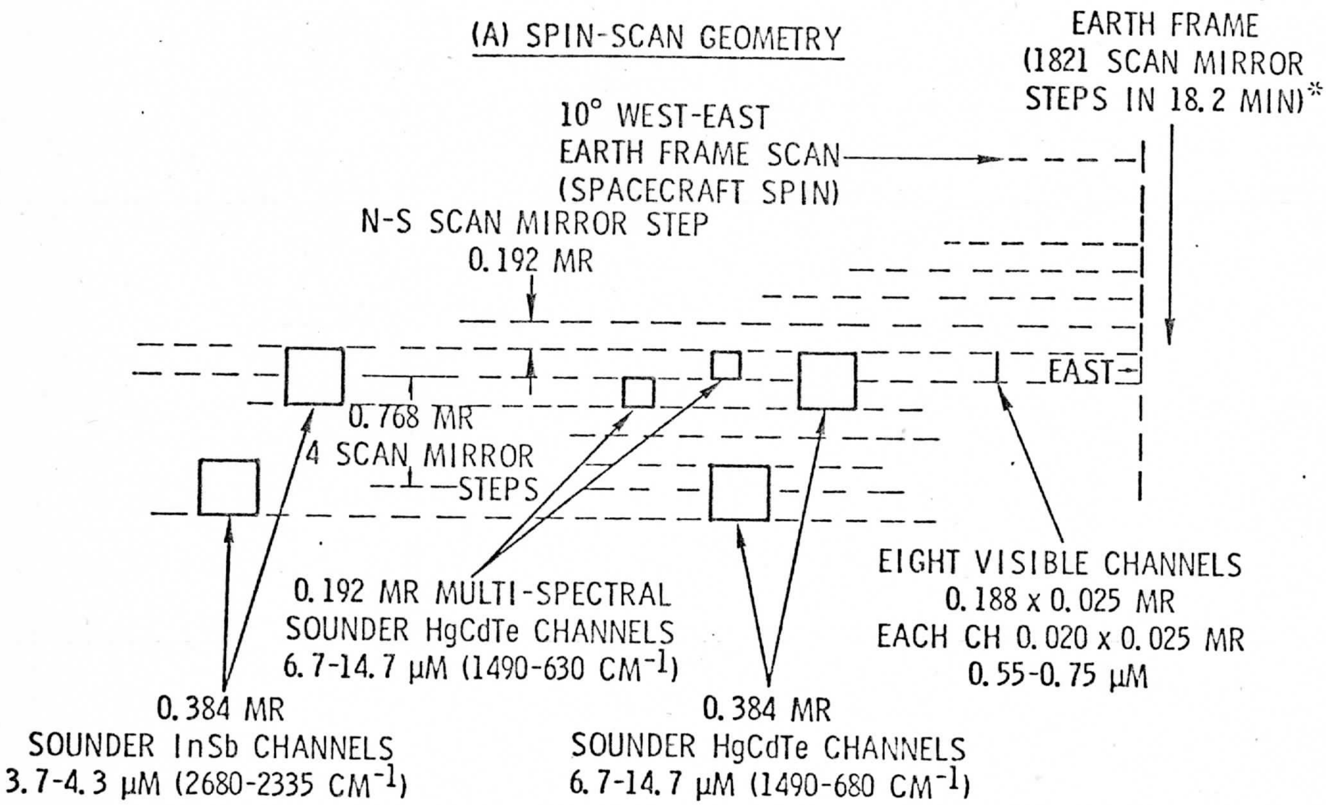
VAS Infrared Spectral Bands

SPECTRAL BAND	ATMOS. PRESS. (mb)	ν (cm^{-1})	λ (m)	$\Delta\nu$ (cm^{-1})	NOMINAL SPIN BUDGET* FOR 20°C SCANNER TEMPERATURE	REMARKS	
						BAND	DETECTOR TYPE
1	65	680	14.71	10	6	CO_2	HgCdTe
2	100	692	14.45	16	14	CO_2	
3	300	703	14.22	16	11	CO_2	
4	500	715	13.99	20	7	CO_2	
5	900	750	13.33	20	7	CO_2	
6	850	2210	4.52	20	35	CO_2	InSb
7	1000	790	12.66	20	7	H_2O	HgCdTe
8	SURFACE	895	11.17	140	1	WINDOW	
9	400	1380	7.25	40	16	H_2O	
10	300	1490	6.71	150	3	H_2O	
11	700	2250	4.44	40	46	CO_2	InSb
12	SURFACE	2535	3.94	140	4	WINDOW	

* Assumes 30 km square averaging area for bands 2-12 and 150 km square for band 1.



(A) SPIN-SCAN GEOMETRY



DETECTOR INSTANTANEOUS GEOMETRIC FIELD OF VIEW (IGFOV)

(B) PICTURE DATA FORMAT (NOT TO SCALE)

NOTE: ONE INFRARED DETECTOR PAIR USED DURING EACH SCAN LINE (PERMITS USE OF UNMODIFIED SPACECRAFT MULTIPLEXER)

*Normal VISSR and Multispectral Imaging Mode

Figure B.1 VAS/Spacecraft Spin-Scan Geometry and Picture Data Format Arrangement be averaged and each set will be sampled at the IR sampling period of 8 sec. The resulting visible resolution at the subsatellite point will be 3.45 km N-S and 3 km W-E. The earth is covered in the N-S direction with 1821 successive latitude steps until 20° coverage is obtained.

The VAS, as indicated in Figure B.1, has six infrared detectors. Two have a subpoint resolution of 6.9 km (IGFOV of 0.192 × 0.192 mr) used primarily for imaging and four have a resolution 13.8 km (IGFOV of 0.384 × 0.384 mr) and are used for sounding information. The two small infrared channel detectors are mercury-cadmium-telluride (HgCdTe) long-wavelength detectors. Two of the large infrared channel detectors are HgCdTe and the other two are indium antimonide (InSb).

Although there are six VAS infrared detectors, only two will be in use during any satellite spin period. Pairs of channels - the small HgCdTe channels, the large HgCdTe channels, or the InSb channels - will be automatically switched into the satellite video digital multiplexer by the VAS Processor depending on the selected mode of operation. In the manual mode (called the VISSR mode) the detector size and type are determined by the Filter Wheel position.

The three distinct operating modes which accomplish both the operational and research mission of VAS are summarized as follows:

(1) Normal VISSR Mode. In this mode of operation, the principal VAS power consuming subassemblies are switched off and the sensor operates as a normal cloud mapping VISSR. It is considered a fall-back mode of operation utilized at the satellite solar-cell end-of-life period when the added VAS power (10 watts) may limit operational lifetime. Both day and night cloud cover pictures will be possible. This mode will not be available during

the initial experiment when VAS will be operated with a reduced data rate. In the VISSR mode, only the 0.192 mr infrared detectors are used. The detector IGFOV in VAS is 6.9 km, however, rather than the original 9 km in VISSR. Although the IGFOV's of the VAS infrared imaging channels are smaller than those of the VISSR, the same minimum Noise Equivalent Delta Temperature (NEDT) requirement (1.2 K at 200 K scene temperature) is expected. The electronic calibrate staircase is replaced by a linear ramp in the VAS and the internal thermal calibration signal is available in each scan line throughout the frame in the thermal channels.

(2) Dwell Sounding Mode. This is the sounding mode for the VAS experiment. Up to 12 spectral filters in a filter wheel covering the range 680 cm^{-1} (14.7 μm) through 2680 cm^{-1} (3.7 μm) can be positioned into the optical train while the scanner is dwelling on a single N-S scan line. The filter wheel can be programmed so that each spectral band (filter) can dwell on a single scan line for from 0 to 255 spacecraft spins. Either the 6.9-km or 13.8-km resolution detectors can be selected for the eight filter positions operating in the spectral region 703 cm^{-1} (14.2 μm) through 1490 cm^{-1} (6.7 μm). For the remaining four spectral bands the 13.8-km resolution detectors are used. Selectable frame size, position and scan direction are also programmable via ground command.

In some of the spectral regions, multiple line data are required to enhance the signal to noise (S/N) ratio. Typically 167 satellite spins at the same N-S scan line position are required to obtain the desired sounding data. This number of spins per line should be adequate to obtain soundings having a 30 × 30 km resolution and require approximately 1.9 minutes on the average.

The parameters associated with the spectral filters, detector size, dwell spins and scan direction are selected and preset in the VAS electronic memory. Programming is accomplished using a dedicated command line where a bit stream of 184 bits sets the processor memory to the desired program. The bit stream is transmitted via a redundant satellite command line and requires approximately 11 seconds for loading.

(3) Multi Spectral Imaging (MSI) Mode. This is the most rapid imaging mode for the VAS experiment, however, no visible imaging will be possible when VAS is operated in its full data rate mode. This mode can provide normal VISSR imaging plus data in any two selected spectral bands having a spatial resolution of 13.8 km. This mode of operation takes advantage of the small HgCdTe detector offset in the N-S plane. Using the data from these detectors simultaneously produces a complete infrared map when they are operated every other scan line. This allows using the larger detectors during half of the imaging/scanning sequence period to obtain additional spectral information. Unlimited N-S frame size and position selection, within the maximum N-S FOV scan direction, can be selected. Parameters are programmed via ground commands as in the dwell sounding mode.

Table B.2 summarizes the instrument modes of operation and functions to be utilized in the time frame of the VAS demonstration.

Table B.2

VAS Operating Modes

INSTRUMENT MODE	FUNCTION	SPINS PER STEP	VISIBLE RES. (KM)	INFRARED		DATA			COVERAGE RATE KM/MIN	TIME (MIN)	
				RES. (KM)	# BANDS	RATE Mb/sec	# BITS			5° LAT	FULL DISK
							VIS	IR			
VISSR[a]	NOAA OPERATIONAL	1	.9	6.9	1	28	6	8	691.2	.81	18
MSI[b]	IMAGING	1	N/A	13.8	4	2.5	N/A	10	691.2	.81	18
DWELL[b]	IMAGING	>1	3.5	6.9	8	↓	10	↓	126	4.4	100
SOUNDING	SOUNDING	>1	3.5	13.8	12	↓	↓	↓	15.5	36	811 (13 hrs)

[a] Mode for operational use where VAS looks like a VISSR.

[b] Low data rate mode for VAS Experiment.

VASS SYSTEM MEMORY ALLOCATION

	DBM	APP	TCP
PROCESSOR TYPE	7/32	8/32	6/16
OPERATING SYSTEM			
TYPE	OS-32-MT	OS32-MT	Custom
CORE	64KB	64KB	10KB
System Task	Ingestion Service Data Request 50KB	Request Data Aquire Commands Disburse products 50KB	Accept Com Route Com Accept Products Route Products 20K
Applications Prog.	—	aver 36KB/prog aver 4 prog 145KB	—
Data Files	120 KB	4 x 50KB files 200 KB	30KB
Extra (used for faster data	22KB	53KB	4KB
Total memory	256KB	512	64KB