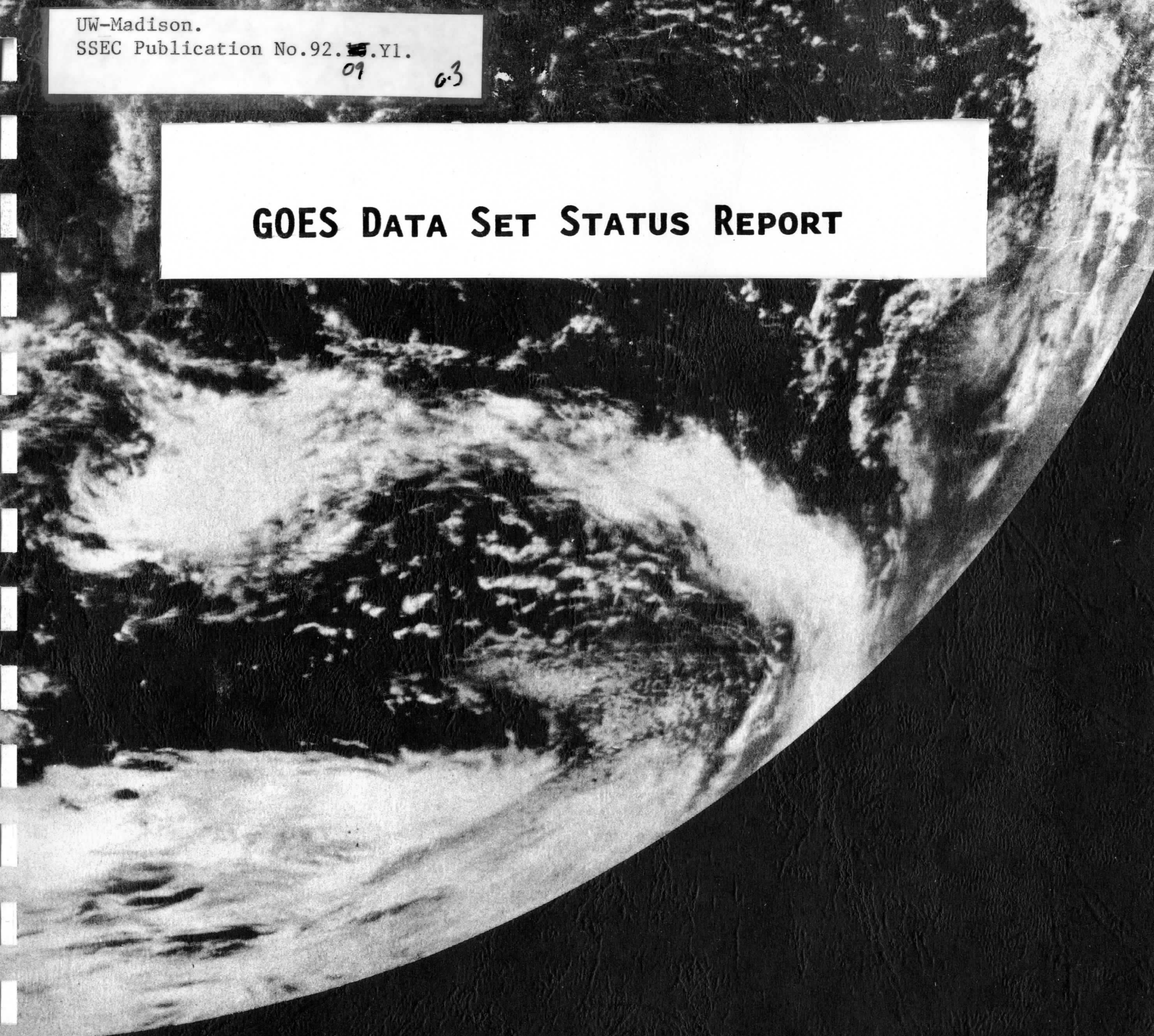
GOES Data Set Status Report



A REPORT

from the space science and engineering center
the university of wisconsin-madison
madison, wisconsin

GOES Data Set Status Report

Sponsored Jointly by

National Oceanic and Atmospheric Administration (NOAA)

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I. INTRODUCTION

A. Purpose

This report has been prepared to document the history and the state of the GOES Data set held at the University of Wisconsin (UW). It is intended to provide background to the GOES Pathfinder Science Working Group (SWG) to assist them in their recommendations to NOAA and NASA. The information which is included is not comprehensive, but represents a summary of the state of our knowledge at this time.

The report gives a general overview of the system primarily to establish a common understanding of concepts and terms. Much of the overview was taken from the GOES DATA USER'S GUIDE (Gibson, 1984) with significant updates by this author. This is followed by a section on known problems which is the primary focus of the report.

II. GOES SYSTEM OVERVIEW

The GOES system includes the satellite (with the GOES instrumentation and direct down-link data transmission capability), the NESDIS facility at Wallops Island, Virginia (that receives the direct transmission and generates the "stretched VISSR" transmission), and the ground systems at NESDIS and at SSEC.

A. The GOES Satellites

The original GOES instrument was the Visible and Infrared Spin Scan Radiometer (VISSR), which was an outgrowth of the spin scan radiometer flown aboard several of the Applications Technology Satellite (ATS) series of NASA research satellites. The VISSR was first flown aboard SMS-1 and SMS-2 (Synchronous Meteorological Satellite), also NASA satellites, that were turned over to NOAA for operational use. GOES-1, GOES-2, and GOES-3 were operational satellites that flew the original VISSR instrument.

1. Visible and Infrared Spin Scan Radiometer (VISSR) Instrument

The VISSR instrument consists of a scanning system, telescope, and Infrared and Visible sensors.

The scanning system consists of a mirror that is stepped mechanically to provide North to South viewing, while the rotation of the GOES satellite provides West to East scanning. The mirror is stepped following each West to East scan. The mirror position is controlled by one of two optical encode wheels attached to the axis. Each step of the mirror causes a change of 192 microradians in the scan angle, representing a distance of 6.9 km near nadir. A sequence of 1,821 scans is performed to provide a "full disk" view from just beyond the Northern Earth horizon to just beyond the Southern Earth horizon.

The scanning mirror reflects the received radiation into a sixteen inch diameter telescope. A fiber-optics bundle is used to couple the telescope to eight VIS detectors (sensitive to the .54 to .70 micrometer band). The fiber optics bundle is configured such that each of the eight VIS sensors has a 20 (W-E) by 25 (N-S) microradians (mr) field of view on GOES-5 to -7. On SMS-1 through GOES-4, each VIS sensor is 21mr square. The sensors are arranged in a linear array oriented "North-South" (i.e., perpendicular to the scan direction), thus sweeping out eight parallel scan line paths as the satellite rotates. The field of view provides a ground resolution of .9 km (normally referred to as 1 km or 0.5 nautical miles). The system thus provides eight parallel VIS data lines per West to East scan, covering the 6.9 km (normally referred to as 8 km or 4 mile) band scanned by each step of the scanning mirror. In addition, germanium relay lenses are used to pass received radiation to two

HgCdTe IR detectors by way of a 10.5 to 12.6 micrometer bandpass filter. The field of view of the IR detectors is 192 microradians (equal to the North-South scan step angle), and thus the IR sensors provides equivalent coverage to the 8 visible sensors.

The output from the eight VIS detectors and from one of the two IR detectors (or an average of both IR detectors) are digitized on board the satellite and transmitted down to Earth in real time. The visible data is sampled every 2 microseconds, which yields visible samples spaced at increments of satellite rotation of 20.9 microradians (assuming a nominal satellite spin rate of 100 RPM), a near nadir spacing of 0.9 km. The IR data is sampled every 8 microseconds, which yields IR samples spaced at increments of satellite rotation of 83.6 microradians, a near nadir spacing of 3.0 km. Since the IR detector field of view is 192 microradians, the IR data is, therefore, oversampled in the scan direction. The quantitization of the IR data is 8 bits, and of the VIS 6 bits. The visible sensors are digitized with a square root digitized for better signal to noise. The oversampling of the IR data leads to the designation of IR data as "4 X 2" IR data (4 mile resolution North-South, 2 mile resolution West-East).

2. VISSR Atmospheric Sounder (VAS) Instrument

The VAS instrument system is an expansion of the VISSR system with improved structural design and some additional capabilities. It consists of the same type of scanning system, a telescope with lighter weight optics made from beryllium instead of conventional materials (glass, steel), 8 visible detectors (25 X 24 mr IGFOV) and 6 infrared detectors.

When the VISSR/VAS is installed in the spacecraft, its optical axis becomes parallel to the spacecraft spin axis, which must be parallel to earth's axis. The VAS optical axis is thus perpendicular to the direction of the earth scene. The optically flat scan mirror of the VAS, placed at a 45^o angle to the VAS optical axis, directs the earth scene into the VAS. The spinning motion of the satellite scans the earth scene West-to-East. North-to-South scanning is accomplished by stepping the scan mirror from 40^o, representing the North polar extreme, to 50^o, representing the South polar extreme. An angle position encoder integral with the mirror stepping mechanism converts the position information to electrical signals, which are sent to CDA station to aid in reassembly of the earth scene. The 10^o of mirror motion (resulting in 20^o of optical angle due to doubling of the optical angle at the mirror) is divided into 1821 steps, each representing 192 mr optically.

At the image plane, a relatively large field of view (FOV) is available. Each detector element is dimensioned to define the FOV which its signal is intended to represent. For example, the smallest IR field is 192 mr defined by a square detector 0.00315 inch on each side. (At synchronous altitude, 192 mr is equivalent to 5 miles along the earth's surface at the satellite's suborbital point.)

Two focal planes are used in the VAS. Visible spectrum signals are obtained at the principal focus. An optical fiber for each of the eight FOVs defines the field to be measured (25 by 24 mr) and conveys the impinging light within that FOV to a photomultiplier tube, which converts the light intensity to a proportional electrical current.

IR radiation must be sensed by solid state detectors which are cooled to a low temperature to reduce their intrinsic electrical noise to a level below the electrical equivalent of the least intense radiation to be measured. This cooling is provided by a radiation cooler which radiates excess heat into space. Because of spacecraft design constraints, the cooler must be located away from the prime focal plane. The relay optics provide an appropriate location for an IR focusing mechanism and filter assembly out of the visible light path. The filter assembly contains a 11.2 centimeter diameter disc, called a filter wheel, that houses 12 spectral passband filters. During each scan, one filter is placed in the IR path to acquire data in the desired spectral band. Any one of the filters can be positioned in the IR optical FOV within 350 milliseconds (i.e., during the time that the VAS telescope is not viewing the Earth during a given spin). Filters are inserted in the IR path only, and used in the MSI (MultiSpectral Imaging) and sounding modes. While 38 channels are possible with the filter wheel detector combinations, only 13 bands can be transmitted. Figure 1 below shows the GOES scanning geometry and sensor geometry. See Table 1. below for a description of each band, and Table 2. below for a description of the design features for each band.

The scanning schedule and the various modes of operation are uploaded to an electronics module in the satellite. The satellite including an onboard controller which can itself be reprogrammed via the spacecraft command link. A typical daily schedule for GOES-7 is listed in Table 3. The key for interpreting the schedule is in Table 4.

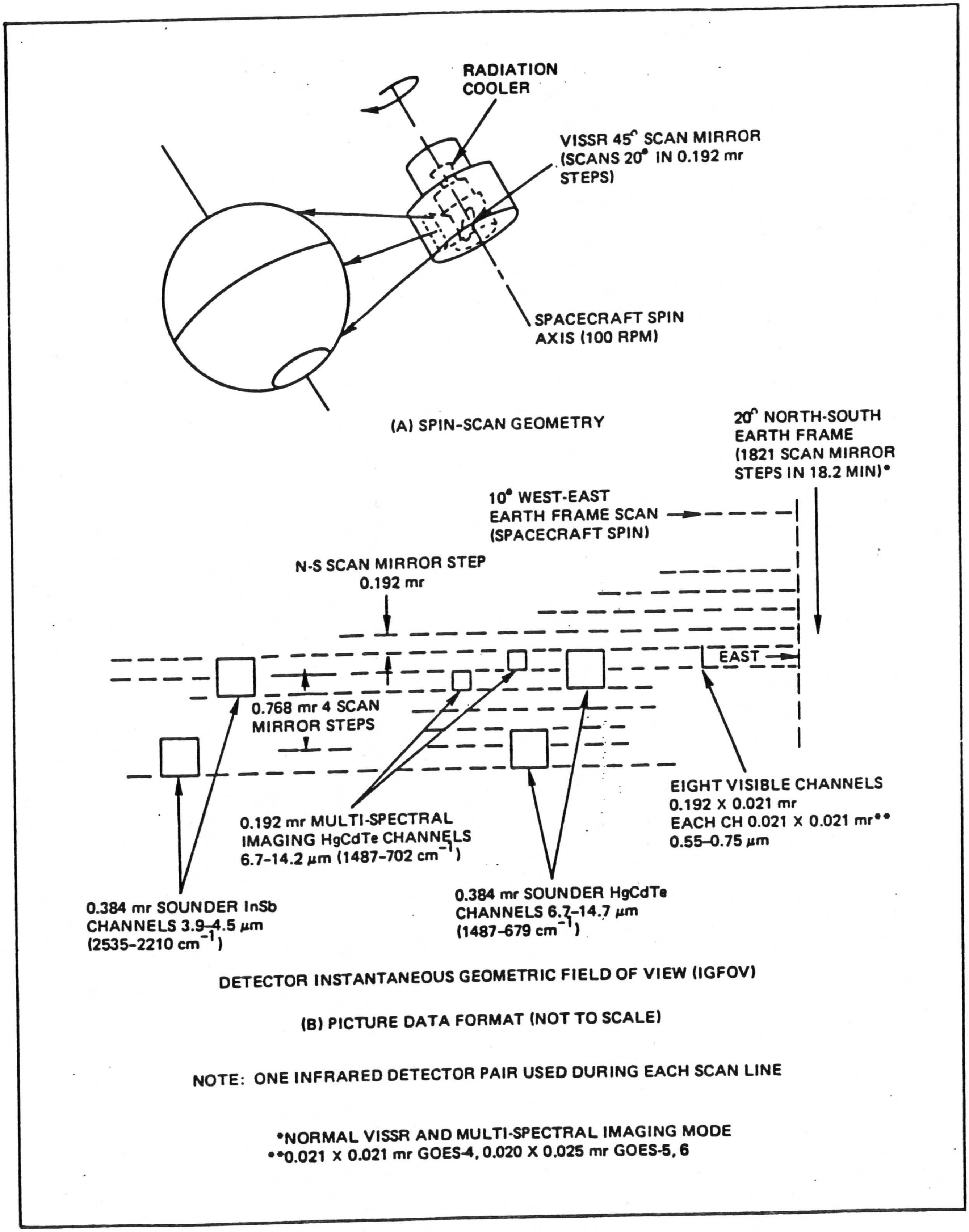

Figure 2-1. VAS/Spacecraft Spin-Scan Geometry and Image Data Format Arrangement

Figure 1

VAS Infrared Spectral Bands

Spectral Band	Atmos. Press. (mb)	ν (cm^{-1})	λ (μm)	$\Delta\nu$ (cm^{-1})	Nominal Single-Sample S/N for 320 K Scene Temperature: 6.9-km IGFOV	13.8-km IGFOV	Remarks: Band	Detector Type
1	70	678.7	14.73	10	NA	37.4	CO_2	HgCdTe
2	125	690.6	14.48	16	NA	92.3	CO_2	HgCdTe
3	200	701.6	14.25	16	50.4	100.8	CO_2	HgCdTe
4	500	713.6	14.01	20	65.3	130.6	CO_2	HgCdTe
5	920	750	13.33	20	64.1	128.3	CO_2	HgCdTe
6	850	2210	4.525	45	NA	108.9	N_2O	InSb
7	Surf.	790	12.66	20	60.7	121.4	H_2O	HgCdTe
8	Surf.	895	11.17	140	607.1*	953.5	Window	HgCdTe
9	600	1377.2	7.261	40	24.2	48.5	H_2O	HgCdTe
10	400	1487	6.725	150	73.7	147.4	H_2O	HgCdTe
11	300	2250	4.444	40	NA	83.7	N_2O	InSb
12	Surf.	2535	3.945	140	NA	111.1	Window	InSb

*For 340 K scene temperature.

Table 1.
(Table 2-1 of Montgomery and Endres, 1985)

Design Features of the VAS Channels

VAS Ch. No.	Spectral Filters: Center μm	Center cm^{-1}	Width cm^{-1}	Purpose for Sounding	Main Absorbing Gas	Other Significant Effects
1	14.730	0678.7	10.0	temp	CO_2	O_3
2	14.480	0690.6	16.0	temp	CO_2	O_3
3*	14.250	0701.6	16.0	temp	CO_2	O_3
4*	14.010	0713.6	20.0	temp	CO_2	O_3
5*	13.330	0750.0	20.0	temp	CO_2	O_3
6	04.525	2210.0	45.0	temp+cloud	N_2O	Sun
7*	12.660	0790.0	20.0	moisture	H_2O	CO_2+dust
8*	11.170	0895.0	140.0	surface	H_2O	CO_2+dust
9*	07.261	1377.0	40.0	moisture	H_2O	CO_2
10*	06.725	1487.0	150.0	moisture	H_2O	–
11	04.444	2250.0	40.0	temp+cloud	N_2O, CO_2	Sun
12	03.945	2535.0	140.0	surface	H_2O	Sun+dust

*Available at 6.9 km as well as 13.8 km IGFOV

Table 2.
(Table 2-2 of Montgomery and Endres, 1985)

Table 3.
Typical Daily Schedule for GOES-7

6 May 1991

TIME UTC	ACTIVITY NOMINAL	RISOP
0000	7-10(16), DSSP(5)	7-10(16), DI(8)
0030	10(14), DSN1(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0100	7-10(14), DSS1(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0130	10(14), DSB(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0200	7-10(14), DSNN(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0230	10(14), DSSS(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0300	7-10(16), D23NH(8)	7-10(16), DI(8)
0330	5-10(16), DSN(8)	5-10(12), 7-12NH(12)
0400	7-10(16), DSS(8)	7-10(12), DSH2O(12)
0430	5-10(16), 5(8) w	5-10(12), 5(12)
0500	7-10(16), DSN(8)	7-10(12), 7-10(12)
0530	5-10(16), DSS(8)	5-10(12), 7-10(12)
0600	7-10(16), 7-12SH(8)	7-10(16), DI(8)
0630	7-10(14), DSN(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0700	7-10(14), DSS(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0730	7-10(14), DSB(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0800	7-10(14), DSNN(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
0830	9-10(14), DSSS(10)	9-10(8), 7(4),5-10(4),7-12(4),7(4)
0900	7-10(16), 7-12NH(8)	7-10(16), DI(8)
0930	5-9(16), DSN(8)	5-9(12), 7-12SH(12)
1000	7-10(16), DSS(8)	7-10(12), DSH2O(12)
1030	5-9(16), 5(8) w	5-9(12), 5(12)
1100	7-10(16), DSN(8)	7-10(12), 7-10(12)
1130	5-10(16), DSS(8)	5-10(12), 7-10(12)
1200	7-10(19), DSNP(5)	7-10(19)
1230	10(14), DSN1(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1300	7-10(14), DSS1(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1330	10(14), DSB(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1400	7-10(14), DSNN(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1430	10(14), DSSS(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1500	7-10(16), D23SH(8)	7-10(16), DI(8)
1530	5-10(16), DSN(8)	5-10(12), 7-12NH(12)
1600	7-10(16), DSS(8)	7-10(12), DSH2O(12)
1630	5-10(16), 5(8) w	5-10(12), 5(12)
1700	7-10(16), DSN(8)	7-10(12), 7-10(12)
1730	5-10(16), DSS(8)	5-10(12), 7-10(12)
1800	7-10(16), 7-12SH(8)	7-10(16), DI(8)
1830	7-10(14), DSN(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1900	7-10(14), DSS(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
1930	7-10(14), DSB(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
2000	7-10(14), DSNN(10)	7-10(8), 7(4),5-10(4),7-12(4),7(4)
2030	9-10(14), DSSS(10)	9-10(8), 7(4),5-10(4),7-12(4),7(4)
2100	7-10(16), 7-12NH(8)	7-10(16), DI(8)
2130	5-9(16), DSN(8)	5-9(12), DSH2O(12)
2200	7-10(16), DSS(8)	7-10(12), DSH2O(12)
2230	9-10(16), 5(8) w	5-9(12), DSH2O(12)
2300	7-10(16), DSN(8)	7-10(12), 7-10(12)
2330	5-10(16), DSS(8)	5-10(12), 7-10(12)

w indicates fifteen minute wind loop

Table 4.
Schedule Key

MSI

	A B C D E F G H	
5	08-13-05-13-08-13-05-13	S
7	08-13-07-13-08-13-07-13	S
10	08-13-10-13-08-13-10-13	S
5-9	08-05-08-05-08-09-08-09	S
5-10	08-05-08-05-08-10-08-10	S
7-8	08-07-08-07-08-08-08-08	S
7-10	08-07-08-07-08-10-08-10	S
7-12	08-07-08-07-08-12-08-12	S
9-10	08-09-08-09-08-10-08-10	S

PDL	HSZ	CEN	TIM	COV	COMMENT
5(8)	400	501	8.0	90N-EQ	CO2 heights
5(12)	600	701	12.0	90N-27S	CO2 heights
5-9(12)	600	701	12.0	90N-27S	RISOP 15min loop
5-9(16)	800	901	16.0	full	water vapor winds loop
5-10(4)	170	411	3.5	50N-22N	RISOP 5min loop
5-10(12)	600	701	12.0	90N-27S	RISOP 15min loop
5-10(16)	800	901	16.0	full	
7(4)	170	411	3.5	50N-22N	RISOP 5min loop
7-8(4)	170	411	3.5	50N-22N	RISOP 5min loop
7-10(8)	400	501	8.0	90N-EQ	
7-10(12)	600	701	12.0	90N-27S	
7-10(14)	700	801	14.0	90N-42S	
7-10(16)	800	901	16.0	full	
7-10(19)	910	911	18.2	full	
7-12(4)	170	411	3.5	50N-22N	RISOP 5min loop
7-12NH(8)	400	501	8.0	90N-EQ	NH SST
7-12SH(8)	400	1301	8.0	EQ-90S	SH SST
7-12NH(12)	600	701	12.0	90N-27S	RISOP NH SST
7-12SH(12)	600	1101	12.0	27N-90S	RISOP SH SST
9-10(8)	400	501	8.0	90N-27S	RISOP only
9-10(12)	600	701	12.0	90N-27S	RISOP only
10(14)	700	801	14.0	90N-42S	

Table 4 con't.

DS

	SPINS 1-2-3-4-5-6-7-8-9-A-B-C	IGFOV 3456789	S1,S3	HSZ	CEN	TIM	COV
DSN(8)	0-1-2-2-2-2-2-1-2-1-1-1	SSSLSLLL	4,4	77	291	8.0	50N-35N
DSS(8)	0-1-2-2-2-2-2-1-2-1-1-1	SSSLSLLL	4,4	77	441	8.0	36N-23N
DSN1(10)	0-1-2-2-3-2-2-1-2-2-2-1	SSSLSLLL	4,4	85	329	10.1	50N-33N
DSS1(10)	0-1-2-2-3-2-2-1-2-2-2-1	SSSLSLLL	4,4	85	495	10.1	33N-21N
DSN(10)	0-1-2-2-3-2-2-1-2-2-2-1	SSSLSLLL	4,4	85	279	10.1	50N-33N
DSS(10)	0-1-2-2-3-2-2-1-2-2-2-1	SSSLSLLL	4,4	85	445	10.1	33N-21N
DSNN(10)	0-1-2-2-3-2-2-1-2-2-2-1	SSSLSLLL	6,2	85	279	10.1	50N-33N
DSSS(10)	0-1-2-2-3-2-2-1-2-2-2-1	SSSLSLLL	6,2	85	445	10.1	33N-21N
DSB(10)	1-1-1-2-2-4-2-1-4-2-1-1	SSSLSLLL	4,4	79	951	10.1	02N-07S
DSNP(5)	2-3-3-2-1-1-0-0-0-0-0-0	SSSLSLLL	2,2	30	101	4.2	N pole
DSSP(5)	2-3-3-2-1-1-0-0-0-0-0-0	SSSLSLLL	2,2	30	1661	4.2	S pole
D23NH(10)	0-2-2-0-0-0-0-0-0-0-0-0	LLLLLLLL	8,8	160	361	10.0	NH Strat
D23SH(10)	0-2-2-0-0-0-0-0-0-0-0-0	LLLLLLLL	8,8	160	1261	10.0	SH Strat
DI(8)	0-1-2-2-1-2-1-1-2-1-1-1	SSSLSLLL	4,4	85	319	8.0	46N-31N
DSH2O(12)	0-0-0-0-0-0-0-0-4-3-0-0	SSSLSSSS	2,2	130	441	12.0	55N-23N

Table 4 con't

UTC	NOMINAL	RISOP
0000	WEX,PW,LI,STRAT	WEX,PW,LI,ASOS
0030	H20S, ASOS	SW,H20L, 5 MIN LOOP OF 4
0100	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
0130	H20S, BRAZIL	SW,H20L, 5 MIN LOOP OF 4
0200	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
0230	H20S, ASOS'	SW,H20L, 5 MIN LOOP OF 4
0300	WOP,PW,LI,STRAT	WOP,PW,LI,ASOS
0330	WOP,CO2, ASOS	WOP,CO2, SST,FOG(NH)
0400	WOP,PW,LI,ASOS	WOP,PW,LI,15 MIN LOOP
0430	W15, W15,CO2	W15, W15,CO2
0500	WEX,W15, ASOS	WEX,W15, 15 MIN LOOP
	PW,LI	PW,LI
0530	WEX,CO2, ASOS'	WEX,CO2, 15 MIN LOOP
0600	WEX,PW,LI SST,FOG(SH)	WEX,PW,LI,ASOS
0630	SW,H20L, ASOS	SW,H20L, 5 MIN LOOP OF 4
0700	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
0730	SW,H20L, BRAZIL	SW,H20L, 5 MIN LOOP OF 4
0800	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
0830	WH20, ASOS	WH20, 5 MIN LOOP OF 4
0900	WOP,PW,LI,SST,FOG	WOP,PW,LI,ASOS
0930	WOP,WH20, ASOS	WOP,WH20,CO2
	CO2	ENH H20 LOOP
1000	WOP,PW,LI,ASOS	WOP,PW,LI, ENH H20 LOOP
1030	WH20,W15, W15,CO2	WH20,W15,CO2, ENH H20 LOOP
1100	WEX,PW,LI,ASOS,NHC	WEX,PW,LI,15 MIN LOOP
1130	WEX,CO2, ASOS,NHC	WEX,CO2
1200	WEX,PW,LI,STRAT	WEX,PW,LI,
1230	H20S, ASOS	SW,H20L, 5 MIN LOOP OF 4
1300	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
1330	H20S, BRAZIL	SW,H20L, 5 MIN LOOP OF 4
1400	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
1430	H20S, ASOS	SW,H20L, 5 MIN LOOP OF 4
1500	WOP,PW,LI,STRAT	WOP,PW,LI,ASOS
1530	WOP,CO2, ASOS	WOP,CO2, SST(NH)
1600	WOP,PW,LI,ASOS	WOP,PW,LI,15 MIN LOOP
1630	W15, W15,CO2	W15, W15,CO2
1700	WEX,W15, ASOS	WEX,W15, 15MIN LOOP
	PW,LI	PW,LI
1730	WEX,CO2, ASOS	WEX,CO2, 15 MIN LOOP
1800	WEX,PW,LI,SST(SH)	WEX,PW,LI,ASOS
1830	SW,H20L, ASOS	SW,H20L, 5 MIN LOOP OF 4
1900	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
1930	SW,H20L, BRAZIL	SW,H20L, 5 MIN LOOP OF 4
2000	PW,LI, ASOS	PW,LI, 5 MIN LOOP OF 4
2030	WH20, ASOS	WH20, 5 MIN LOOP OF 4
2100	WOP,PW,LI,SST	WOP,PW,LI,ASOS
2130	WOP,WH20, ASOS	WOP,WH20, SST(SH)
	CO2	CO2
2200	WOP,PW,LI,ASOS	WOP,PW,LI,15 MIN LOOP
2230	WH20,W15, W15	WH20,W15, W15,CO2
2300	WEX,W15 ASOS	WEX,W15, 15 MIN LOOP
	PW,LI	PW,LI
2330	WEX,CO2, ASOS	WEX,CO2, 15 MIN LOOP

B. NESDIS Command and Data Acquisition Facility (CDA)

This section describes the components of the GOES CDA at Wallops Island, VA pertinent to the archived data set.

1. Synchronous Data Buffer (SDB)

The real-time transmission of GOES VISSR and/or VAS data are received at the NESDIS CDA station directly from the satellites, and processed by the Synchronous Data Buffer. The SDB reformats the data, determines the start of each line, performs a calibration of the IR data, brightness enhances the visible datan, adds grid and orbit/attitude information (as will be described), and retransmits the data back to a transponder on the GOES satellite for broadcast to various user stations.

In reformatting the data, the SDB does an equal time to equal angle resampling to compensate for variations in the satellite spin rate. Therefore, the result is a constant number of data values per scan line corresponding to the nominal 100 rpm spin rate. The broadcast data rate is chosen such that the retransmission just occupies the time interval between real-time data bursts; i.e., the retransmission is accomplished while the instrument mirror on the satellite is viewing space between scans of the Earth (333 degrees of each spin is space view). The reduced bandwidth broadcast datastream is called the "stretched data". The format for the stretched data has changed 3 times during the archive period, and these formats are referred to as Mode A, AA, or AAA.

2. Retransmission Modes (Formats)

a. Mode A

Mode A data began in 1974 and continued until May 1, 1987. It supported 6-bit visible imagery and 8-bit IR imagery (11 micron window, sometimes water vapor imagery). The GOES SDB accepted the 14 or 28 Mbps downlink real-time datastream and performed the functions noted above. The GOES SDB had occasional firmware changes throughout it's life, correcting and causing some of the anomalies in the archived data set. At various times, modes A and AA or A and AAA were intermixed from the same satellite on a single archive tape.

b. Mode AA

Mode AA data began in 1980 and continued until May 1, 1987. It supported only data from the VAS instrument as 6-bit visible and 10-bit multichannel IR data. The VAS SDB accepted the 14 or 28 Mbps downlink real-time datastream and performed the functions noted above. The VAS SDB went through many changes over it's lifetime, but by July, 1981 had stabilized fairly well. Occasional firmware changes were still made throughout it's life.

It must be noted that Mode AA was never considered operationally supported, but was intended only to support research.

Mode AA was, on occasion, sent as a separate datastream (broadcast through a standby GOES spacecraft), and on other occasions sent 'between' mode A images (known as transparent VAS mode). Thus, for long periods of time, modes A and AA are intermixed on the archive tapes.

c. Mode AAA

Mode AAA began in May 1, 1987 and will continue until the demise of the currently active GOES-7. The primary motivations for this format change were to bring the VAS instrument data to operational status and to upgrade the ancient, failing GOES and VAS SDBs.

The mode AAA format is generated by the GOES Processor/Distribution Unit (P/DU) at the CDA. The GOES VAS Image Processor (VIP) inputs calibrated VIS and IR video data and the respective VIS and IR documentation and common documentation words to the P/DU. The central controller is yet another unit called the GOES Monitoring and Control System (GMACS). These units collectively are generally still referred to as the SDB in this report.

Again the SDB receives the 14/28 Mbps downlink real-time datastream and performs the functions noted above. This SDB supports both a mode A compatible signal, and the newer AAA signal. Mode AAA supports Multi-Spectral Imaging (MSI) and Dwell Sound (DS) spacecraft submodes. MSI submode supports 6-bit visible imagery and more organized, better calibrated 2 to 4 channel, 10-bit IR imagery. DS submode supports poorly calibrated 6-bit visible imagery and multi-spin, multi-channel 10-bit IR data (up to the full 12 channels of the instrument). These units were fairly stable by the time they were declared operational in May, 1987. Occasional software/firmware changes have occurred to date.

3. Navigation and Calibration Operation

This section provides information concerning the NESDIS operational navigation (earth location) process, in use since January 1980, and the calibration process.

a. NESDIS Operational GOES Navigation

The stretched VISSR datastream transmitted by NESDIS via broadcast from the SDB's at Wallops Island contains orbit and attitude parameters that are inserted by the SDB. These parameters are intended as inputs into the GOES navigation algorithm. It is important to recognize that these values are <u>predictions</u> made one to three days earlier rather than actual values measured for the time they are transmitted. The following is an outline of the process by which the orbit and attitude (O/A) parameters included in the datastream are produced:

a. Once a day, GOES data from both operational satellites, including O/A predictions made the previous day, are ingested by the VISSR Image Registration and Gridding System (VIRGS) (a version of the SSEC McIDAS).

b. NESDIS uses landmarks to compute actual attitude and orbit information for that day as needed or at least weekly.

c. From this day's actual O/A, NESDIS extrapolates a prediction for the next day's O/A.

d. The predicted O/A values are transmitted to Wallops Island to be inserted into the datastream for the next 24 hours.

As a result of this process, users may experience difficulty in obtaining a precise navigation using the predicted O/A values, especially if any kind of satellite maneuver has taken place.

SDSD receives from NESDIS the actual attitude and orbit information produced by NESDIS in the course of this process. This information is available from SDSD, starting with data from October 1979, in the form of listings. Digital information from July 1983 for 00 and 06 GMT are also available.

b. NESDIS Operational GOES Calibration

1) Pre GOES-4 Calibration

No calibration is performed on the raw VIS data (Ensor, 1978; Bristol, 1975). The 8 visible channels are designed to be non-linear. The analog-to-digital convertion is intended to be approximately equal to the square root of the intensity of the incident radiation. No on-board calibration was included in the instrument design.

The IR data values included in the VISSR datastream are calibrated values. The SDB uses a look-up table to replace the original IR data values transmitted from the satellite to calibrated values which are intended to correspond to a predetermined data value vs. temperature table. The look-up table is computed by NESDIS weekly, based on calibration parameters received from the instrument. The accuracy of this process is limited, especially for satellites prior to VAS (i.e., prior to GOES-4). In fact, on earlier satellites the calibration may drift sufficiently that by the end of the week a good calibration may be off by several degrees. Generally, the accuracy of these temperatures is limited to 2^{o}K to 4^{o}K, generally nearer 2^{o}K in the Winter and nearer 4^{o}K in the Summer. During eclipse periods, three weeks on either side of the equinoxes, an additional 4^{o}K error can occur due to thermal fluctuations on board the satellite as it moves through the Earth's shadow, (data are generally unavailable during this period). Note that the accuracy problems described above do not include the effects of atmospheric attenuation, etc., and arise within the instrument system only.

2) VISSR/VAS Calibration

The VAS data requires a more rigorous calibration for it to be of value for atmospheric sounding retrievals. The IR calibration scheme was changed to include the raw digital data with a set of calibration coefficient in the datastream documentation. The application of these coefficients was left to the user's processing system.

The VAS calibration is based on space view (assumed no radiation) and an internal blackbody source. The effect of the fore-optics of the instrument (not in the internal blackbody path) must be modelled, based on preflight measurements and calibration coefficients determined during prelaunch thermal-vacuum tests. For mode AA data, parameters related to this model were included in the datastream. When combined with the Blackbody measurement and the space view data (both included in the datastream documentation), the raw data can be calibrated on a line-by-line basis. Mode AAA data has had the fore-optics effects removed in the SDB, which greatly simplifies the user's processing algorithm.

a) Mode AA Calibration Algorithm

Transformation of VAS mode AA raw IR values into brightness temperatures is accomplished via the intermediate computation of calibrated VAS radiometric values ("radiances") using the following formula:

$$R = (P - YSUBZ) * 2^{(-N)} * 2^{(F + DELTAF)}$$

where:

R = radiance in ergs / (sec*steradians*cm)

N = number of bits used from the pixel values. The satellite transmits 10 bit values, but by averaging in dwell-sound mode the effective precision is raised to 15 bits. For maximum accuracy n is set to 15.

P = the N most significant bits, not including the sign bit, of the raw pixel value.

YSUBZ = the N most significant bits, not including the sign bit, of the space view value (from the calibration section of common doc).

F = the "Channel Scale Factor", a function of the spectral band is provide by a table look up.

DELTAF = "Line Scale Factor". This is a value between -5 and 5 obtained from a table look up using the 4 least significant bits of RAWDELTAF

b) Mode AAA Calibration Algorithm

Transformation of VAS mode AAA raw IR values into brightness temperatures is accomplished via the intermediate computation of calibrated VAS radiometric values ("radiances"), but for mode AAA the algorithm is simplified by using SDB generated coefficients and scale factors for each channel which are included in the datastream. The Radiance Equation Coefficients array contains 2 coefficients for each of the 38 channels, and a Radiance Equation Coefficients Scale Factors array contains 1 scale factor for each channel.

Once the mode AA or AAA raw IR values are converted to radiance values, the conversion of radiance to brightness temperature is accomplished using the inverse Planck function.

$$T = (C2 * V) / LN((C1 * V^3 / B) + 1)$$

Where:

T = temperature (degrees K)

V = wave number of the radiation (1/CM)
This is the median of the response characteristic of the filter used for a particular spectral band.

B = the radiance in (WATTS * CM) / (M^2 * STERADIANS)
This is 1000 times the radiance calculated above due to the difference in units.

C1 = 1.191066E-8 WATTS/(M^2 * STERADIANS * CM^{-4})

C1 = 2*H*C^2, where H is Planck's constant (6.63E-34 Joules*secs).

C2 = 1.438833 CM * Degrees K

C2 = H*C/K, where K is the Boltzmann constant (1.281E-23 Joules/Degree)

C. SSEC Archive system

The full resolution GOES archive system is operated by SSEC under contract to SDSD, and is based on unique GOES data handling and recording technology developed by SSEC.

SSEC has three antenna/receiver systems, and receives the stretched VISSR transmissions from the operational GOES satellites. The data are demodulated and recorded on 3M's U-MATIC video-cassette tapes at high density by means of the technique described below. SSEC uses an interactive display system, McIDAS (Man-computer Interactive Data

Access System) to perform archive retrieval, data quality checks, navigation functions and to produce reformatted sectors for distribution to the User community.

1. Recording Subsystem

The SSEC recording subsystem operates as a totally standalone system. The subsystem for each satellite consists of four recorders, four recorder electronic, a data logger, quality control display, and a recorder switcher. The fourth recorder and electronics are spares. During operational recording, the switcher automatically routes the datastream to the next recorder when a tape nears the end. Thus the system runs unattended except for the daily tape replacement. In the event of a recorder or electronics failure, the spare unit can be easily switched into operation to replace the bad unit.

The cassette archive machine is a modified 3/4-inch U-MATIC recorder that records digital satellite data. Except for high density machines, nothing mechanical is modified. The modifications for high density machines include the use of a separate electronics package that is specific to the signal. The electronics provide the servo reference timing, tape signal formatting/decoding, and the transport control functions.

High density operation doubles the recording density. It is accomplished by changing the scanner and slowing down the capstan another factor of two. High density operation eliminates the guard bands between head scans on tape. Azimuth recording allows separating the head scan information. The two scanner heads have different gap azimuths relative to the scan direction which allow independent magnetic tracks to be adjacent without interference. The slower tape speed changes the scan angle relative to tape allowing twice as much data to be recorded on the same length of tape. All recording is done at real time rates. That means the scanner and tape speed servos must be slowed down. For GOES low density, the factor is 3.6. The high density recording factor is 7.2.

The data logger collects information from the real-time datastream documentation and routes it to the data logger printer. The data logger provides the image start and stop times, image first and last scan count number, the number of observed errors in a portion of the IR documentation, and the beginning and ending beta values as an independent record. The archive operator uses these data in the inventory creation, and as a flag for the quality assessment processing.

The quality control display provides a means for viewing image quality in real time. A continuously scrolling visible or infrared image can be displayed at several resolutions. The display also allows viewing selected portions of the image at high resolution or the full globe at reduced resolution.

2. Archive Retrieval Subsystem

The playback subsystem consists of a video cassette player, playback electronics, data switcher, search track display, ingestor for the IBM mainframe computer, and a quality control display. The search track display allows the operator to quickly find the specific data desired on a tape. Recently, a universal playback electronics unit was developed which allows a single piece of hardware to play back the signals from all data types handled by the record subsystem. This development greatly simplifies operation and maintenance of the playback subsystem and provides improved backup with less hardware.

Once the start point is located and the playback started, the playback electronics presents the datastream to the appropriate ingestor housed in the Multisourcerer (SSEC IBM channel interface) which then passes the data through the IBM channel and onto disk.

Simultaneously, the signal is routed to a Display device, allowing the retrieved data to be quality controlled as it is recovered from the archive tape.

The data switch allows the operator to match the data being recovered for a specific satellite signal type, e.g. Mode A, Mode AA, Mode AAA, Meteosat, etc., with the appropriate ingestor. This capability improves throughput by allowing the operator to use more than one playback subsystem to process data requests. This flexibility would not exist if specific playbacks were "hard wired" to specific ingestors.

An ingestor is a combination of hardware and software which receives real-time or archived played-back signal and converts it to a number of imagery sectors in the McIDAS database. Since the signal is noisy, having many erroneous bits, including in the control fields, considerable interpretation of what data is good, bad, or good-but-misreported needs to take place in the ingestor in real time. Applications, such as AutoNav, can then use the data from the database to create the metadata or products.

3. Inventory

The GOES data inventory is an inventory by exception. The schedule for each satellite day is identified, and exceptions to the schedule are explicitly included. Each video cassette is assigned a unique library number for the purpose of identification. Information describing the content and quality (if known) of each cassette is entered into the on-line inventory. Presently, the on-line inventory can only be accessed by workstations running the McIDAS software. The following items are included in the SSEC archive inventory:

- Tape ID
- Schedules for each day
- seasonal change of station,
- satellite sub-point as of 12:01z of that day,
- special events (hurricanes, major severe storms), and
- Anomalies
    - flawed/bad/poor/unuseable/missing scans,
    - lost or cancelled images,
    - early or late starts,
    - scans other than those scheduled,
    - bad navigation,
    - visible calibration images,
    - maneuvers,
    - new start lines for the MSI's, and
    - planned anomalies.

The schedule information includes the scheduled start times, scan lines viewed, band/spin information, PDL numbers, and small or large detector information. For most of the anomalies, cause is assigned if known (satellite, ground station, operator, etc). The Archivist uses the data logger, the tape recorder log, listings created by the real-time ingestor, the daily summary from the CDA, the daily summary from the Satellite operations Control Center (SOCC), and the QC display to evaluate anomalies.

4. Archive Media Status

On January 22, 1991, NESDIS and SSEC staff visited the National Media Lab (NML) in Minneapolis, MN to discuss archival quality storage media.

a. Background

The National Media Lab (NML) is a Government-funded Center of Excellence for Government recording programs. It has a staff of 46, some provided by 3M. It is also partially funded by 3M. NML is working in five areas; media technology, advanced system concepts, theory and modelling, measurements, operations support. The NML includes the Magnetic Media Measurement Lab which is available to users at no charge. NML also provides consulting on operational issues at no charge.

NML provides quarterly reports to the government, industry, and general public. One day is allotted to the report, a second day is allotted to industry demos, and a third is a classified briefing for invited executives. The next report was given on 29 January in McLean, Virginia.

b. Summary

SSEC representatives presented a review of our current archive system and our understanding of the requirements for the Climate Product Generation System.

NML recommended that:

> SSEC stick with our present system, (U-MATIC tape) since nothing as reliable is available on the market today.
>
> SSEC should plan to use U-Matic for the next 5-8 years. The new technologies are in considerable turmoil at this time. They all suffer from major problems from an archive point of view.

In addition, NML recommended that:

1. The U-MATIC tape should be retentioned on the reel at 3-5 year intervals.
2. SSEC keep recorder and playback units close to the state of the industry for maintenance and spare parts availability.
3. SSEC closely monitor tension on our present recorder and playback units.
4. SSEC review tape handling and environmental conditions.

Temperature	70 degrees	+/- 5 degrees
Humidity	50%	+/- 5 %

5. SSEC should annually reassess the state of the archive system industry by attending one of the quarterly reviews.

NML provided the following explaination. Many of the new technologies are based on video recording industry requirement which doesn't have archive requirement. The primary candidates in our investigation to that point (D-2 and Exabyte) were strongly discouraged; both require tensilized, metal particle tape.

The metal particles (iron) are very easily corroded and are moisture and pollution sensitive.

The tape is tensilized to 1,000,000 psi in the longitudinal direction, and 300,000 psi in the transverse direction. This is done to make the tape thinner and stiffer for better performance in the transport. The substrate polymers have a memory and try to return to the original dimensions. Temperature is of most concern in the dimensional stability of the tape. When the temperature of the tape exceeds 120^{o}F. The tape becomes unstable. Over time, this dimensional instability changes the track to track distance, and data loss results. In some cases, dimensional instability has caused complete data loss after only six months.

These problems are present in most of the new formats:

DAT	8mm	Super VHS
D-1	D-2	Exabyte

Recently, A new magnetic pigment tape has been distributed to beta test sites. The pigment is Barium Ferrite. It is known to be very stable in the presence of oxidizing agents, but the dimensional instability remains a problem.

5. SSEC Navigation

Most navigation methods in use for GOES are based on a first principles algorithm which models the satellite orbit, the spacecraft spin axis attitude, and the scan mirror geometry. The first of these systems was developed by Smith and Phillips, 1974. The system in use at SSEC is an updated version of the same system.

The original system used a combination of externally derived orbital parameters and landmark measurements from the images to determine the best fit attitude for the satellite spin axis to minimize the landmark errors (residuals). The accuracy of the Smith and Phillips system was limited by the quality of the input orbit parameters. Prior to 1980, the orbital parameter quality varied widely. The orbital parameters were updated weekly. Major (100+ elements) discontinuities in navigation accuracy occurred when orbital parameters were updated.

a. Pre May 1980

Prior to 1980, the navigation information included in the GOES datastream was nonexistent or of poor quality. The only reasonable quality navigation information available covering the period 1978 to 1980 is that on file at SSEC. NESDIS has keep recorders of the navigation data sent in the GOES datastream from January 1979 to the present. These duplicate records on file at SSEC.

b. Post May 1980

During the first quarter of 1980, the datastream navigation was compared with SSEC generated predicts. By May 1980, the two were of similar accuracy. On May 13, 1980, SSEC discontinued manual daily navigation of the data, and used the datastream parameters.

c. AutoNav

In 1987, SSEC began development of the AutoNav system. AutoNav has three components, auto-landmarking, orbit and attitude computation, and parameter prediction for future days. AutoNav was used operationally at SSEC beginning January 11, 1988. AutoNav has been demonstrated to produce navigation parameters precise to 0.93 pixels RMS in the N-S direction and 0.98 pixels RMS in E-W direction. Due to system loading, AutoNav was discontinued on August 17, 1988.

III. GOES DATA SET STATISTICS

A. Satellite history

SMS/GOES SATELLITES
HISTORIES, STATION, & ARCHIVED INFORMATION

Name	Launch Date	Operational	Deactivated	IR sensor Failure	VAS Failure	Encoder Failure 1st	Encoder Failure 2nd	VAS Demo	Operational Life (mo)	Spacecraft Life	Station	Period of Record	SAT DAYS
SMS-1	5/17/74	11/15/74	1/29/81						1yr, 10mo	6yr, 8mo	EAST	06/27/74-01/07/76 01/26/79-04/19/79 (21:30z) - (18:00z)	84
SMS-2	2/6/75	3/10/75	8/5/82			1/23/81	8/5/81		5yr, 5mo	7yr, 6mo	EAST	03/10/75-08/04/81 04/19/79-08/05/81 (18:30z) - (04:00z)	840
GOES-1	10/16/75	1/8/76	3/7/85	3/24/79		10/7/84	2/3/85		3yr, 10mo	9yr,5mo	WEST	01/08/76-03/15/80 11/29/82-05/31/83 (14:15z) - (05:45z)	184
GOES-2	6/16/77	8/15/77				12/18/78	1/26/79		1yr, 5mo		EAST	08/15/77-09/15/80 02/20/78-01/26/79 (01:00z) - (21:00z)	337
GOES-3	6/16/78	7/13/78				9/14/79	3/5/81		2yr, 8mo		WEST	07/13/79-03/05/81 11/20/78-03/05/81 (??:??z) - (16:45z)	837
GOES-4	9/9/80	3/5/81			11/26/82			10/15/80	2 yr, 1mo		WEST	03/05/81-06/01/83 (17:52z) - (04:15z)	632
											VAS-AA	01/05/81-02/27/81 (18:02z) - (20:42z)	
GOES-5	5/22/81	8/5/81	7/18/90			7/22/82	7/30/84	6/15/81	3yr		EAST	08/05/81-07/29/84 (00:01z) - (00:31z)	1089
											VAS-AA	02/08/82-11/26/82 (14:01z) - (12:01z)	
											VAS-AA	04/15/83-11/28/83 13:00z) - (12:31z)	

Table 5

SMS/GOES SATELLITES
HISTORIES, STATION, & ARCHIVED INFORMATION

Name	Launch Date	Operational	Deactivated	IR sensor Failure	VAS Failure	Encoder Failure 1st	Encoder Failure 2nd	VAS Demo	Operational Life (mo)	Spacecraft Life	Station	Period of Record	SAT DAYS
GOES-6	4/25/83	6/1/83				8/6/85	1/21/89		5yr, 9mo		WEST	06/01/83-08/01/84 (00:15z) - (17:45z)	429
											VAS-AA	11/29/83-12/31/83 (10:46z) - (23:46z)	
											PRIME	08/01/84-03/25/87 (18:30z) - (16:00z)	1030
											VAS-AA	01/01/85-12/31/86	
											WEST	03/25/87-01/21/89 (17:15z) - (18:46z)	669
GOES-7	2/26/87	3/25/87									EAST	03/25/87-01/21/89 (17:00z) - (18:46z)	1010
											E/W	01/21/89-02/20/89 (18:46z) - (10:00z)	31
											PRIME	02/21/89-PRESENT (11:00z) - (??:??z)	736

B. Satellite location history

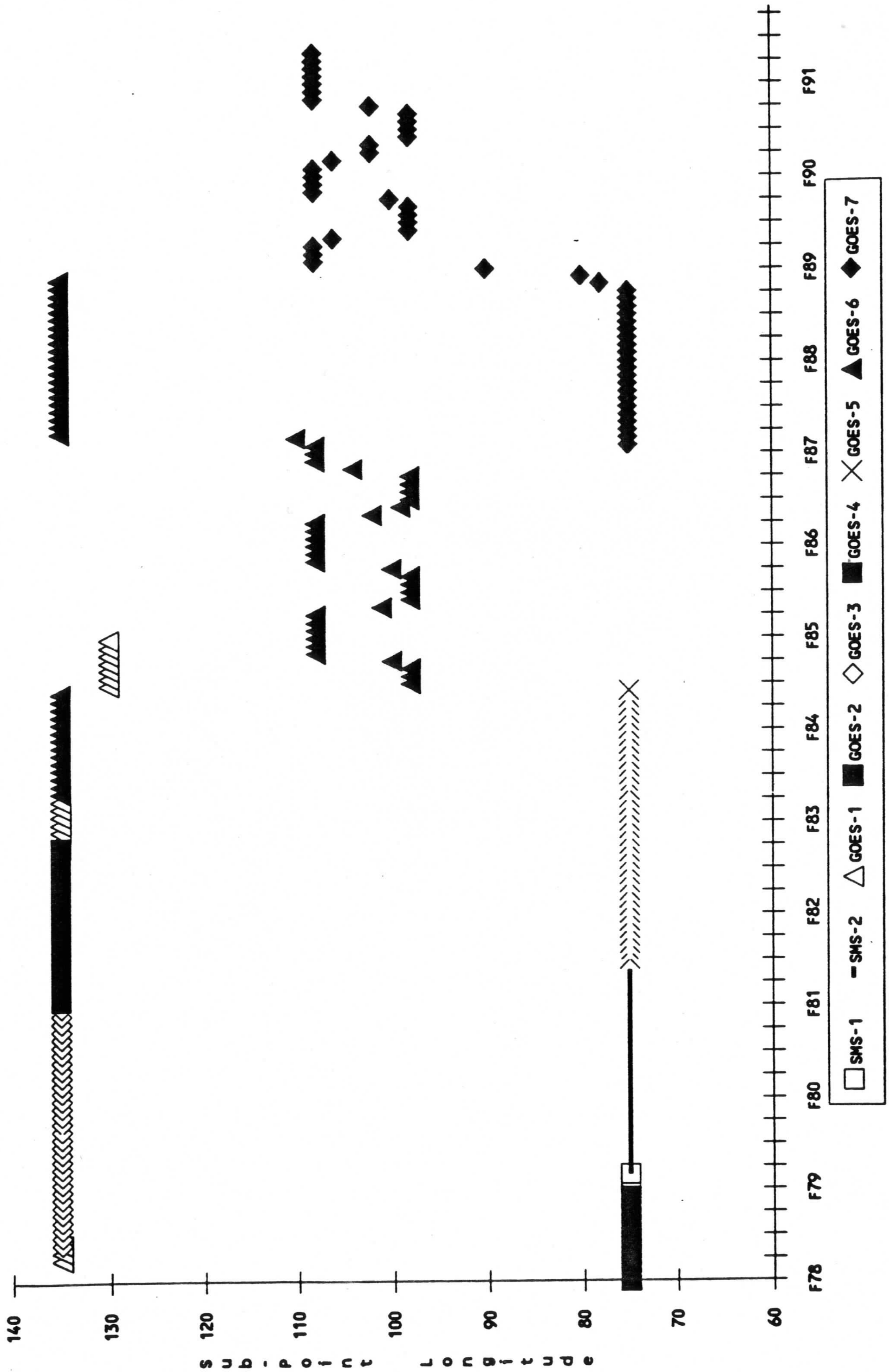

Figure 2

Table 6

GOES LOCATION HISTORY

SATID	SATID	FROM	TO	COMMENTS
		EAST		
16/01	SMS-1	74169	76008	
20/03	GOES-1	76009	77227	
22/04	GOES-2	77228	79015	
22/04	GOES-2	79016	79026	SWITCHED TO SMS-1 AT 2130Z
16/01	SMS-1	79027	79109	
18/02	SMS-2	79110	81217	
28/07	GOES-5	81218	83332	
28/07	GOES-5	83333	84049	
28/07	GOES-5	84050	84211	
		84212	84212	GOES5 ENCODER LAMP FAILED
		84213	84214	
32/09	GOES-7	87057	87057	GOES7 SUCCESSFULLY LAUNCHED
32/09	GOES-7	87084	87123	MODE-A DATA, SP 75
32/09	GOES-7	87124	88299	MODE-AAA/VAS DATA, SP 75W
32/09	GOES-7	88300	88355	MODE-AAA/VAS, BIRD DRIFTING WEST
32/09	GOES-7	88356	89020	MODE-AAA/VAS, SP 80W
32/09	GOES-7	89021	89051	MODE-AAA/VAS, DRIFTING WEST
		WEST		
18/02	SMS-2	75068	78093	
20/03	GOES-1	78095	78193	
24/05	GOES-3	78194	81063	
26/06	GOES-4	81064	82329	
20/03	GOES-1	82333	83151	NO IR
30/08	GOES-6	83152	83332	
30/08	GOES-6	83333	84214	
		84215	84242	
20/03	GOES-1	84243	84281	1745 -> 0245 Z VISIBLE IMAGES ONLY
		84282	84291	
20/03	GOES-1	84292	85033	1745 -> 0245 Z VISIBLE IMAGES ONLY
20/03	GOES-1	85034	85034	0015 -> 0345Z VISIBLE IMAGES ONLY
		85035	85035	GOES1 SCAN DRIVER FAILED
		85036	87083	
30/08	GOES-6	87084	87089	SP 108
30/08	GOES-6	87090	87120	DRIFTING WEST/MODE-AAA VISSR
30/08	GOES-6	87121	87292	MODE-AAA VISSR
30/08	GOES-6	87293	89020	MODE-AAA/VAS
30/08	GOES-6	89021	89021	GOES 6 ENCODER LAMP FAILED AT 1854

Table 6 Con't

GOES LOCATION HISTORY

SATID	SATID	FROM	TO	COMMENTS
		VAS		
26/06	GOES-4	80266	81063	VAS
28/07	GOES-5	81160	81217	VAS
28/07	GOES-5	81218	83332	EAST
30/08	GOES-6	83333	84049	WEST
28/07	GOES-5	84073	84211	EAST
30/08	GOES-6	84339	86322	PRIME
30/08	GOES-6	86330	87083	PRIME MODE-AAA TESTING
		INDIA		
20/03	GOES-1	78336	79335	SP=60E
		PRIME		
30/08	GOES-6	84215	84243	CHECK LOG FOR SP
30/08	GOES-6	84244	84298	SP=98
30/08	GOES-6	84299	84320	CHECK LOG FOR SP DRIFTINNNG WEST
30/08	GOES-6	84321	85169	SP=108
30/08	GOES-6	85170	85189	CHECK SP BIRD DRIFTING EAST
30/08	GOES-6	85190	85297	SP=98
30/08	GOES-6	85298	85324	CHECK SP BIRD DRIFTING WEST
30/08	GOES-6	85325	86169	SP=108
30/08	GOES-6	86170	86216	CHECK SP BIRD DRIFTING EAST
30/08	GOES-6	86217	86323	SP=98
30/08	GOES-6	86324	86345	CHECK SP BIRD DRIFTING WEST
30/08	GOES-6	86346	87084	SP=108
32/09	GOES-7	89052	89179	AAA/VAS GOES 7 SP=108
32/09	GOES-7	89180	89199	AAA/VAS, DRIFTING EAST
32/09	GOES-7	89200	89291	AAA/VAS, SP=98
32/09	GOES-7	89292	89333	AAA/VAS, DRIFTING WEST
32/09	GOES-7	89334	90115	AAA/VAS SP=108
32/09	GOES-7	90116	90211	AAA/VAS, DRIFTING EAST
32/09	GOES-7	90212	90290	AAA/VAS, SP=98
32/09	GOES-7	90291	90332	AAA/VAS, DRIFTING WEST .26/DAY
32/09	GOES-7	90333	91114	AAA/VAS, SP=108
32/09	GOES-7	91115		AAA/VAS, DRIFTING EAST .09/DAY

C. Archive statistics

ROUGH ESTIMATE OF SSEC ARCHIVED DATA

1974 - 1991
as of May 30, 1991

YEAR	Cassette Tape	GBytes
1974	134	763
1978	1,602	4,562
1979	4,458	12,696
1980	3,009	8,569
1981	2,317	6,598
1981	373	2,124
1982	1,790	10,195
1983	1,672	9,523
1984	1,591	9,062
1985	1,349	7,683
1986	1,322	7,530
1987	1,673	8,258
1988	1,815	8,959
1989	1,134	5,598
1990	1,091	5,385
5/31/91	454	2,241
Totals	25,784	tapes109,746

GBytes

Table 7

Scanner's note:

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IV. SUMMARY OF KNOWN PROBLEMS RELATED TO PATHFINDER EFFORT

A. GOES Radiance Data problems

1. VISSR

a. Satellite problems

1) Spontaneous gain step changes (detectable, maybe correctable)

On a number of occasions (probably 5-10) over a 3 month period, visible sensor gain step changes occurred spontaneously on board the GOES-4. The reason for this activity was never identified, and the problem stopped for no apparent reason. On some occurrences, 3 - 4 hours elapsed before the gain was corrected.

2) "Striping" of the visible sensors (detectable, correctable)

Throughout the history of the GOES, the visible data has experienced "striping". The 8 visible channels are designed to be non-linear. The analog-to-digital convertion is intended to be approximately equal to the square root of the intensity of the incident radiation. No on-board calibration was included in the instrument design. Therefore the gain is a decreasing function of intensity. Gains and offsets of the individual visible sensor photomultiplier tubes may vary slightly with time, and thus introduce artificial East-West "striping".

3) Loss of visible sensors (detectable, uncorrectable)

Throughout the GOES satellite series individual visible sensors have failed (due to photomultiplier tube power supply failures). The worst case was SMS-2 which lost 3 visible sensors during its operational life. These losses were not very evident because an adjacent good visible sensor's data was patched into the SDB's buffer for the lost sensor. In the SMS-2 case, the derivation of mesoscale cloud drift winds was impractical. The record of these patches was put into the datastream documentation. This and possibly the SDB operator's logs are the only record of these modifications.

4) Loss of IR channel (detectable, uncorrectable)

On March 24, 1979 (79083), while in operation over the Indian Ocean in support of FGGE, the GOES-1 IR sensors failed. Only visible imagery are available for the remainder of the FGGE period (to 79335). GOES-1 was pressed into service again in 1982 (82333), as GOES-West, following the failure of GOES-4. GOES-1 was replaced by GOES-6 on 83151. Therefore, the GOES-West position has a gap in IR coverage for 183 days (82333 to 83151).

5) Scan increment errors (detectable, correctable)

Scan increment errors (SIE) have been observed with GOES-6 and GOES-7. Scan increment errors are caused by an error in the satellite telemetry electronics, which causes the wrong scan number(s) to be downlinked. The encoder wheel is incrementing correctly. SIEs of short duration (< 10 scans) are corrected by the ingestor.

b. SDB problems

1) Data Buffer (SDB) errors (detectable, correctable)

The primary role of the buffers in the SDB are to store the decommutated visible sensor data in a one sensor line per buffer format, and hold the data until it is sent to the stretch data uplink. The early version of the SDB had hardware memory failures which occasionally modified the data for one sensor. The failure caused one of the 6 bits to be intermittently held in a one or zero state for that sensors data until the memory was reset or replaced by the operator.

2) Datastream documentation errors

a) IR sensor ID errors (detectable, correctable)

The first version of the SDB used until mode AAA was introduced required the operators to enter data with a set of thumb wheel switches. The cumbersome technique resulted in errors. One such error resulted in the use of one IR sensor while the calibration and offset parameters for the other IR sensor were applied to the data. This was reported to have occurred at least 3 times. One of these events lasted for about 30 days before it was detected. There is no written record of these events which can identify the specific occurrences, but they are known to have occurred in the 1979 - 1981 time frame. These are easily detectable with an IR-VIS offset algorithm.

b) Intermittent wrong year (detectable, correctable)

3) Planned anomalies

a) WV/IR substitution (detectable, uncorrectable)

Beginning in January, 1984 and continuing to may 1, 1987 certain IR images were replaced by WV images every 4 or 6 hours. No indication in the signal is given when this occurred. These events are recorded in the inventory

b) Partial scan image schedule (detectable, uncorrectable)

Throughout the history of the GOES satellites, the operational full globe scanning schedule has been interrupted to provide high time frequency imaging of mesoscale events.

2. VAS

a. GOES-6 filter wheel temp. regulation failed (~21 Dec 83)

The temperature regulation of the filter wheel assembly failed in the 3rd week of December 1983. It is estimated that the net effect is a 2^{o} brightness temperature meandering when the VISSR mode calibration (updated weekly) is used, and a 0.5^{o} brightness temperature meandering when the VAS mode calibration (updated line by line) is used. The drift in the filter wheel assembly temperature remained a problem for the 5.25 years left in the GOES-6 operational life.

b. GOES-4 large HgCdTe detector failed before launch

The failure of one of the large HgCdTe detectors causes alternating good and blank lines in the data sets or images which use this sensor since the scanning uses both sensors for one channel.

B. Ancillary data problems

1. Navigation

a. Parameter quality (detectable, correctable)

Two samples of the navigation quality were evaluated for a arbitrarily selected for a 62 day period in 1979 and 1988. SMS-1 data were used for the 1979 period (GOES-East). GOES-7 data were used for the 1988 period (GOES-East). In 1979, the manually measured landmarks and NOAA supplied orbit parameters were used. In 1988, AutoNav was in use. The landmarks were measured automatically, and the navigation parameters were recomputed using the landmark measurements.

The navigation analysis package provides the RMS errors for all landmarks for a day in the line direction (N-S) and in the element direction (E-W). The landmark line and element residual errors are computed as the difference between the measured location in visible image coordinates and the computed location for the ascribed latitude and longitude.

Table 9

Two Samples of Navigation Quality

	1979 (62)	1988 (62)
# days with nav parameters	52 (84%)	61 (98%)
Total number of landmarks (45.8/day)	385 (7.4/day)	2794
Avg. obs. RMS error for # days, N-S pixels	4.77 pixels	2.09
Avg. obs. RMS error for # days, E-W pixels	10.97 pixels	6.00
Max. obs. RMS error for period, N-S pixels	105.5 pixels	6.03
Max. obs. RMS error for period, E-W pixels	190.0 pixels	20.37

b. Spacecraft Maneuvers

1) Maneuver impact (known, correctable)

Spacecraft maneuvers would be of little consequence except that the navigation models for the data assume an unperturbed satellite. The impact of these maneuvers decreases as the energy used decreases. In the description below, the maneuvers are listed in order of decreasing impact.

Spacecraft maneuvers are executed aperiodically on the GOES satellites for one of five reasons. The Inclination (N-S) maneuver is used to keep the satellite near the equator. N-S maneuvers are usually done 2 or 3 times a year. In-track change of station moves the satellite to a new location the speed of the move is proportional to the duration of the burn. In-track stationkeeping are required every few months to keep the satellite within a nominal 1.5^{o} longitude window. Attitude are executed seasonally to keep the spin axis of the satellite close to parallel to the Earth's spin axis. This keeps the north-south daily excursions of the Earth in the image frame to a minimum. Attitude maneuvers are the most dramatic causing image jumps of up to 500 lines between consecutive images. Spin rate maneuvers are very weak maneuvers to change the spin rate of the satellite. It's effect is unnoticed unless one thruster malfunctions causing an asymmetrical burn as sometimes happens.

Following a maneuver, it is necessary to collect landmarks to determine the orbit and attitude parameters to recover good image navigation. See Appendix A. for a detailed maneuver history of the SMS/GOES satellites.

c. IR-Visible misalignment (detectable, correctable)

The IR and VIS sensors are mounted on a fiberglass plate that is known to be dimensional unstable in space vacuum. Post-launch measurements are required to determine the input parameters for the SDB. Until AutoNav, these measurements were made by intercomparing the visible data with all the other sensor data and manual shifting of the images for the best alignment. AutoNav uses cross-correlation on the same feature in all channels for a number of images around satellite noon. This method was used to determine the sensor displacement for the GOES-7 inputs to the SDB.

d. Nutation (detectable, uncorrectable)

Nutation of the satellite is a high frequency wobble of the spin axis. Much like a toy top. Nutation effects were first observed in the GOES data in March, 1975. Nutation in the GOES series is caused by mismanagement of the fuel manifold and chamber temperatures by the CDA operations. When the satellite nutates, the mirror scans at slightly different angles across the Earth on each scan. The resulting image shows that small portions of adjacent scans have overscanned or underscanned the same part of the Earth.

The magnitude of this problem is very small. The amplitude of the nutations is 2 pixels (~42mr) in the line direction. There is no effect in the element direction. The frequency has been measured 6 scans (period = 4.8 sec.). The effect has been on observed on all GOES series satellites to have the same amplitude and frequency.

When it occurred, several days to several weeks passed before it was detected and CDA operations corrected.

2. Calibration

No attempt has been made to assess or upgrade the calibration of the GOES data set as part of the Archive's holdings. Where the data were modified in the SDB, apparently, no record has been keep of the transformation functions. For a period of time in 1978-1981, the look up table values were stored as hard copy by NESDIS. These records have not been located to date.

C. Archive system problems

1. Recording system

a. No "read after write" verify capability (partially correctable)

The recording technology was, in 1978 and is still, at the state of the art in high density magnetic recording. The recording method does not allow read after write, which could be used to verify the quality of the recording process. Consequently, there are no data on the quality of the recording process itself, nor can deterioration of the media be assessed independently.

2. Playback system

a. Current system sometimes load dependent (correctable)

The present playback system depends on the McIDAS IBM mainframe to convert the data into computer form. The present McIDAS is overloaded with other applications unrelated to archive playback. The McIDAS mainframe system is poorly suited to climate product generation in any case.

b. Tape damage (detectable, uncorrectable)

Invariably, the use of the tapes to retrieve data for users has resulted in damage to some of the archive tapes. Of the 25,784 tapes, 6 have been damaged beyond repair. Partial tape damage has been successfully spliced out. Generally, this represents 100 to 200 scans of an image. It has been necessary to splice out damaged tape in less than 50 cases.

c. Real-time playback rate (correctable)

The present tape players play the data back at GOES real time rates. Since, we now have 23.6 satellite-years of data, the playback of the entire data set would be difficult and expensive.

3. Inventory

a. Spot check visual inspection (correctable)

The quality assurance effort for the archive has continually improved over the archive period, but still leaves much to be desired from an automated climate product generation prospective. The visual inspection only addresses gross impression of data integrity. The quality descriptions are general in nature (good, fair, poor, late start, missed lines, etc.) and do not address specific causality. The visual inspection is a spot check. All scans in all the data are not checked.

V. APPENDIX

A. Maneuver history

The following list describes the maneuver history for the SMS/GOES satellites.

Appendix A.

Maneuver History for the GOES Data Set

SMS-1

YrDay	Maneuver Type
79029	Stationkeeping Maneuver
79039	Attitude Maneuver
79067	Stationkeeping Maneuver
79074	Attitude Maneuver
79081	Stationkeeping Maneuver
79116	Attitude Maneuver

SMS-2

YrDay	Maneuver Type
80010	Attitude Maneuver
80031	Attitude Maneuver
80045	Attitude Maneuver
80059	Attitude Maneuver
80073	Attitude Maneuver
80087	Attitude Maneuver
80122	Attitude Maneuver
80136	Attitude Maneuver
80155	Attitude Maneuver
80171	Attitude Maneuver
80185	Attitude Maneuver
80201	Attitude Maneuver
80213	Attitude Maneuver
80227	Attitude Maneuver
80241	Attitude Maneuver
80255	Attitude Maneuver
80268	Attitude Maneuver
80331	Attitude Maneuver
81042	Attitude Maneuver
81078	Attitude Maneuver
81092	Attitude Maneuver
81106	Attitude Maneuver
81133	Attitude Maneuver
81162	Attitude Maneuver
81196	Attitude Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-1

YrDay	Maneuver Type
82342	Stationkeeping Maneuver
82350	Attitude Maneuver
82364	Stationkeeping Maneuver
83024	Stationkeeping Maneuver
83029	Stationkeeping Maneuver
83041	Stationkeeping Maneuver
83090	Attitude Maneuver
83104	Attitude Maneuver
84215	Change of Station Maneuver
84221	Attitude Maneuver
84241	Change of Station Maneuver
84263	Change of Station Maneuver
84306	Stationkeeping Maneuver
84354	Stationkeeping Maneuver
84355	Spin Rate Maneuver
85024	Stationkeeping Maneuver

GOES-2

YrDay	Maneuver Type
78010	Stationkeeping Maneuver
78200	Stationkeeping Maneuver
78222	Attitude Maneuver
78270	Attitude Maneuver
78284	Attitude Maneuver
78305	Attitude Maneuver
78349	Stationkeeping Maneuver
79002	Attitude Maneuver
79009	Orbit inclination Maneuver

GOES-3

YrDay	Maneuver Type
78283	Attitude Maneuver
78307	Attitude Maneuver
78342	Attitude Maneuver
78354	Attitude Maneuver
79023	Attitude Maneuver
79072	Attitude Maneuver
79089	Stationkeeping Maneuver
79172	Stationkeeping Maneuver
79228	Attitude Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-3 continued

79261	Attitude Maneuver
79291	Attitude Maneuver
79305	Stationkeeping Maneuver
79319	Attitude Maneuver
79353	Attitude Maneuver
80003	Stationkeeping Maneuver
80024	Attitude Maneuver
80058	Stationkeeping Maneuver
80108	Stationkeeping Maneuver
80120	Attitude Maneuver
80170	Attitude Maneuver
80190	Attitude Maneuver
80199	Stationkeeping Maneuver
80220	Attitude Maneuver
80269	Attitude Maneuver

GOES-4

YrDay	Maneuver Type
80366	
81026	Stationkeeping Maneuver
81049	Stationkeeping Maneuver
81057	Stationkeeping Maneuver
81063	Stationkeeping Maneuver
81077	Attitude Maneuver
81126	Stationkeeping Maneuver
81169	Attitude Maneuver
81176	Stationkeeping Maneuver
81190	Attitude Maneuver
81197	Stationkeeping Maneuver
81225	Attitude Maneuver
81239	Attitude Maneuver
81281	Attitude Maneuver
81292	Spin Rate Maneuver
81295	Stationkeeping Maneuver
81322	Stationkeeping Maneuver
81343	Attitude Maneuver
81364	Attitude Maneuver
82007	Stationkeeping Maneuver
82028	Stationkeeping Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-4 continued

82042	Attitude Maneuver
82056	Spin Rate Maneuver
82077	Attitude Maneuver
82084	Stationkeeping Maneuver
82098	Attitude Maneuver
82132	Attitude Maneuver
82154	Stationkeeping Maneuver
82161	Attitude Maneuver
82167	Stationkeeping Maneuver
82196	Attitude Maneuver
82216	Stationkeeping Maneuver
82224	Stationkeeping Maneuver
82238	Attitude Maneuver
82245	Stationkeeping Maneuver
82266	Stationkeeping Maneuver
82273	Stationkeeping Maneuver
82287	Spin Rate Maneuver
82294	Attitude Maneuver

GOES-5

YrDay	Maneuver Type
81236	Stationkeeping Maneuver
81253	Attitude Maneuver
81288	Attitude Maneuver
81314	Attitude Maneuver
81323	Stationkeeping Maneuver
82014	Attitude Maneuver
82021	Stationkeeping Maneuver
82035	Stationkeeping Maneuver
82049	Attitude Maneuver
82083	Attitude Maneuver
82105	Stationkeeping Maneuver
82112	Attitude Maneuver
82119	Attitude Maneuver
82124	Spin Rate Maneuver
82126	Stationkeeping Maneuver
82167	Attitude Maneuver
82189	Stationkeeping Maneuver
82203	Attitude Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-5 continued

82223	Attitude Maneuver
82273	Stationkeeping Maneuver
82301	Attitude Maneuver
82328	Attitude Maneuver
82343	Stationkeeping Maneuver
82350	Attitude Maneuver
83006	Attitude Maneuver
83027	Attitude Maneuver
83028	Stationkeeping Maneuver
83069	Stationkeeping Maneuver
83083	Attitude Maneuver
83153	Stationkeeping Maneuver
83181	Stationkeeping Maneuver
83265	Stationkeeping Maneuver
83293	Orbit inclination Maneuver
83300	Attitude Maneuver
83335	Stationkeeping Maneuver
83348	Attitude Maneuver
84012	Attitude Maneuver
84019	Stationkeeping Maneuver
84054	Stationkeeping Maneuver
84074	Attitude Maneuver
84089	Attitude Maneuver
84103	Orbit inclination Maneuver
84124	Stationkeeping Maneuver
84137	Spin Rate Maneuver
84158	Attitude Maneuver
84166	Orbit inclination Maneuver

GOES-6

YrDay	Maneuver Type
83196	Stationkeeping Maneuver
83209	Attitude Maneuver
83278	Stationkeeping Maneuver
83321	Attitude Maneuver
83341	Orbit inclination Maneuver
83349	Stationkeeping Maneuver
84026	Attitude Maneuver
84033	Orbit inclination Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-6 continued

84047	Stationkeeping Maneuver
84072	Spin Rate Maneuver
84082	Spin Rate Maneuver
84110	Attitude Maneuver
84117	Stationkeeping Maneuver
84131	Orbit inclination Maneuver
84172	Attitude Maneuver
84201	Orbit inclination Maneuver
84208	Stationkeeping Maneuver
84244	Change of Station Maneuver
84256	Attitude Maneuver
84298	Change of Station Maneuver
84321	Change of Station Maneuver
84341	Attitude Maneuver
84348	Orbit inclination Maneuver
85037	Attitude Maneuver
85045	Orbit inclination Maneuver
85052	Stationkeeping Maneuver
85115	Change of Station Maneuver
85136	Orbit inclination Maneuver
85150	Stationkeeping Maneuver
85170	Stationkeeping Maneuver
85177	Attitude Maneuver
85190	Change of Station Maneuver
85192	Attitude Maneuver
85212	Orbit inclination Maneuver
85232	Stationkeeping Maneuver
85290	Orbit inclination Maneuver
85297	Change of Station Maneuver
85324	Change of Station Maneuver
85353	Attitude Maneuver
86044	Orbit inclination Maneuver
86051	Stationkeeping Maneuver
86107	Orbit inclination Maneuver
86114	Stationkeeping Maneuver
86163	Orbit inclination Maneuver
86170	Change of Station Maneuver
86190	Change of Station Maneuver
86226	Orbit inclination Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-6 continued

86232	Attitude Maneuver
86310	Orbit inclination Maneuver
86324	Change of Station Maneuver
86345	Change of Station Maneuver
87015	Orbit inclination Maneuver
87071	Orbit inclination Maneuver
87090	Change of Station Maneuver
87091	Change of Station Maneuver
87119	Change of Station Maneuver
87119	Change of Station Maneuver
87154	Attitude Maneuver
87154	Orbit inclination Maneuver
87211	Orbit inclination Maneuver
87218	Stationkeeping Maneuver
87293	Stationkeeping Maneuver
87302	Orbit inclination Maneuver
87349	Stationkeeping Maneuver
87363	Stationkeeping Maneuver
88026	Orbit inclination Maneuver
88063	Attitude Maneuver
88091	Stationkeeping Maneuver
88138	Attitude Maneuver
88175	Stationkeeping Maneuver
88238	Stationkeeping Maneuver
88315	Stationkeeping Maneuver
89018	Change of Station Maneuver
89103	Stationkeeping Maneuver
89313	Change of Station Maneuver

GOES-7

YrDay	Maneuver Type
87175	Stationkeeping Maneuver
87190	Attitude Maneuver
87231	Attitude Maneuver
87295	Stationkeeping Maneuver
87314	Orbit inclination Maneuver
87337	Orbit inclination Maneuver
88020	Stationkeeping Maneuver
88035	Orbit inclination Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-7 continued

88036	Orbit inclination Maneuver
88049	Attitude Maneuver
88103	Stationkeeping Maneuver
88126	Orbit inclination Maneuver
88189	Orbit inclination Maneuver
88196	Stationkeeping Maneuver
88231	Stationkeeping Maneuver
88322	Orbit inclination Maneuver
88356	Change of Station Maneuver
89019	Orbit inclination Maneuver
89023	Stationkeeping Maneuver
89024	Stationkeeping Maneuver
89052	Change of Station Maneuver
89109	Orbit inclination Maneuver
89173	Orbit inclination Maneuver
89180	Attitude Maneuver
89199	Attitude Maneuver
89214	Attitude Maneuver
89221	Attitude Maneuver
89236	Orbit inclination Maneuver
89297	Attitude Maneuver
89320	Orbit inclination Maneuver
89334	Change of Station Maneuver
90011	Orbit inclination Maneuver
90038	Change of Station Maneuver
90109	Orbit inclination Maneuver
90116	Change of Station Maneuver
90142	Attitude Maneuver
90172	Orbit inclination Maneuver
90184	Change of Station Maneuver
90212	Stationkeeping Maneuver
90241	Attitude Maneuver
90291	Change of Station Maneuver
90304	Attitude Maneuver
90333	Stationkeeping Maneuver
90339	Orbit inclination Maneuver
90354	Stationkeeping Maneuver
91024	Orbit inclination Maneuver
91029	Orbit inclination Maneuver

Appendix A.

Maneuver History for the GOES Data Set

GOES-7 continued

91045	Change of Station Maneuver
91107	Orbit inclination Maneuver
91115	Change of Station Maneuver
91142	Attitude Maneuver
91162	Attitude Maneuver

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