National Climatic Data Center

DATA DOCUMENTATION

FOR

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GOES Data User's Guide

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Additional GOES Satellite information

http://www.oso.noaa.gov/goes/index.htm

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Chapter 1 - Introduction

1.0 Background

In September of 1961 the United States Congress passed a law establishing a satellite program that would enhance the United States' ability to monitor and predict weather. The Geostationary Operational Environmental Satellites (GOES) operated by the National Oceanic and Atmospheric Administration (NOAA) are a major component of that program. On December 6, 1966, the National Aeronautics and Space Administration (NASA) launched the first geostationary Applications Technology Satellite (ATS-1), which had the ability to see weather systems in motion. This dream was realized, thanks to the pioneering efforts of Dr.Verner Suomi of the University of Wisconsin, who conceived and designed the first Spin Scan Cloudcover Camera (SSCC). The ATS-1 was capable of imaging the entire face of the Earth every half hour. Within six years after the launch of ATS-1, operational use of satellite imagery began at the National Severe Storm Forecast Center (NSSFC) and the National Hurricane Center (NHC).

NASA's research and development work came to fruition with the launch of the first prototype GOES satellite, the Synchronous Meteorological Satellite (SMS-1) on May 17, 1974. NOAA's operation of the GOES series began with the launch of GOES-1 on October 16, 1975. The primary instrument on board the SMS and earliest GOES satellites was the Visible and Infrared Spin Scan Radiometer (VISSR). Since the launch of the first SMS, there have been 14 launches of the geostationary weather satellites at the time of this writing. Table 1-1 provides the launch dates and periods of data archived.

1.1 Mission Summary

Over the last 35 years, environmental service agencies have emphasized a need for continuous, dependable, and high-quality observations of the Earth and its environment. The GOES satellites have fulfilled this need by providing frequent radiometric observations over large portions of the western hemisphere. The instruments on board the satellites measure Earth emitted and reflected radiation from which atmospheric temperature, winds, moisture and cloud cover are derived. GOES carries two critical earth observation instruments, an Imager and a Sounder, both of which simultaneously acquire high resolution visible and infrared data, as well as temperature and moisture profiles of the atmosphere. The Imager and Sounder continuously transmit these data to ground terminals where the data are processed for rebroadcast to primary weather services in the United States and around the world, including the global research community. The data are archived in the Comprehensive Large Array-data Storage System (CLASS). The GOES system performs the following basic functions:

- Acquisition, processing, and dissemination of imaging and sounding data.
- Acquisition and dissemination of Space Environment Monitor (SEM) data.
- Reception and relay of data from ground based Data Collections Platforms that are situated in carefully selected urban and remote areas to NOAA's Command and Data Acquisition (CDA) station.

- Continuous relay of Weather Facsimile (WEFAX) and Low Rate Information Transmission (LRIT) and other data to users, independent of all other functions.
- Relay of distress signals from people, aircraft, or marine vessels to the search and rescue ground stations of the Search and Rescue Satellite-Aided Tracking (SARSAT) system.

The GOES series of satellites is owned and operated by NOAA. NASA manages the design, development, and launch of the spacecraft. Once the satellite is launched and checked out, NOAA assumes responsibility for the command and control of the satellite, transmission of data, and the archive and dissemination of the data and its derived products to the user community.

The NOAA National Climatic Data Center (NCDC) is responsible for archiving and servicing requests for GOES retrospective data with the CLASS system. The National Environmental Satellite, Data, and Information Service (NESDIS) operates the satellites and oversees the processing and distribution of data in real time. The primary user is the NOAA National Weather Service (NWS), which uses real time satellite data and derived products for creating accurate weather forecasts and warnings for the public community. Another important user is the NOAA National Hurricane Center, which uses the data to monitor tropical cyclone activity in both the Atlantic and Eastern Pacific Basins and to provide timely tropical storm watches and warnings. Other users include the Federal Aviation Authority (FAA), private weather forecasting industry, the media, international agencies and other government agencies.

Since the dawn of Internet access, GOES data and images are used by a broad range of users interested in historical and near real-time data. Many government agencies and universities are providing GOES images and movies on the Internet at no cost to the user, who range from the casual home user to researchers in the field.

GOES satellites provide continuous monitoring necessary for intensive data analysis. They circle the Earth in a geosynchronous orbit on Earth’s equatorial plane, which means that the satellite’s rotation matches exactly that of the Earth’s rotation. This configuration allows the satellite to view the same areas of the Earth at all times. The geosynchronous plane is about 35,800 km (22,300 miles) above the Earth’s surface, high enough for the satellites to view the entire Earth. The obvious advantage is the capability to watch for atmospheric conditions that may lead to severe weather such as tornadoes, flash floods, hail storms, and hurricanes. When these conditions develop, the GOES satellites can monitor storms and track their movements on a minute to minute basis.

GOES satellite imagery is also used to estimate rainfall during thunderstorms and hurricanes for flash flood warnings, as well as estimate snowfall accumulations and overall extent of snow cover. Such data help meteorologists issue winter storm warnings and spring snow melt advisories. Satellite sensors can also detect ice fields and map the movements of sea and lake ice and slower moving icebergs. With the improved resolution on the infrared channels, GOES satellites can detect forest fires, fog formation, volcano plumes, and distinguish between water and ice clouds.

Table 1-1 GOES Launch Dates and Periods of Data Acquisition

Satellite Name	Launch Date	Period of Record Archived (MM/DD/YY)	Archive Form*	Instrument Data archived at NCDC
ATS-1	12/06/66	01/01/67 - 10/16/72	I	Spin Scan Cloud Camera
ATS-3	11/05/67	03/02/68 - 09/02/74	I	Spin Scan Cloud Camera
SMS-1	05/17/74	06/27/74 - 01/07/76	I	VISSR
SMS-2**	02/06/75	03/10/75 - 08/04/81	I/D	VISSR
GOES-1	10/16/75	01/08/76 - 03/15/80	I/D	VISSR
GOES-2	06/16/77	08/15/77 - 09/15/80	I/D	VISSR
GOES-3	06/16/78	07/13/78 - 03/05/81	I/D	VISSR
GOES-4	09/09/80	03/05/81 - 06/01/83	I/D	VAS
GOES-5	05/15/81	08/05/81 - 07/30/84	I/D	VAS
GOES-6	04/28/83	06/01/83 - 01/29/89	I/D	VAS
GOES-7	02/26/87	03/25/87 - 01/17/96	I/D	VAS
Meteosat-3#	06/15/88	01/01/93 - 05/30/95	I/D	VAS
GOES-8	04/13/94	09/01/94 - 04/01/03	D	Imager/Sounder
GOES-9	05/23/95	01/09/96 - 07/21/98 04/23/03 - present	D	Imager/Sounder
GOES-10	04/25/97	07/21/98 - present	D	Imager/Sounder
GOES-11	05/03/00	In space storage mode		
GOES-12	07/23/01	04/01/03 - present	D	Imager/Sounder

Legend

I = Printed Images
D = Digital Format
VISSR - Visible and IR Spin Scan Radiometer
VAS - VISSR Atmospheric Sounder

* Most pre-1978 images are archived at the Federal Records Center
**SMS-2 operation was intermittent
Loaned to U.S. by EUMETSAT
ϕLoaned to Japan Meteorological Agency for GMS-5 replacement over western Pacific

1.2 Geographic Coverage

The GOES spacecraft is positioned 35,790 km (22,240 statute miles) above the equator allowing it to view a major portion of the Western Hemisphere including southern Canada, the contiguous

48 states, major portions of the eastern Pacific Ocean and western Atlantic Ocean, and Central and South America. Because the Atlantic and Pacific basins strongly impact the weather over the United States, coverage is typically provided by two GOES spacecraft, one at 75° west longitude (GOES East) and the other at 135° west longitude (GOES West).

The combined footprint (radiometric coverage and communications range) of the two spacecraft encompasses Earth's full disk about the meridian approximately in the center of the continental United States. Figure 1-1 illustrates two possible satellite configurations, the top shows a single GOES system positioned at 100° west longitude. This configuration would occur if either GOES-EAST or GOES-WEST fails prematurely. The remaining satellite would then be centrally positioned and may be seasonally shifted eastward or westward during the hurricane season and winter season, respectively. The bottom illustration shows an optimal two satellite configuration with adequate coverage well beyond the east and west coasts of the continental United States. No longitudinal adjustment would be necessary in any season.

1.3 GOES Today

The latest generation of GOES satellites commenced with the launch of GOES-8 on April 13, 1994. This generation of GOES satellites is totally redesigned from the ground up. They are three-axis body stabilized and equipped with a separate Imager and Sounder, replacing the old VAS (VISSR Atmospheric Sounder) instrument on the older spinning GOES satellites. Since GOES-8, four more GOES satellites have been launched. The latest, GOES-12, replaced GOES-8 on April 1, 2003, bringing with it several new features such as adding channel 6 (13.3 µm), broadening of the water vapor band (channel 3), and improving the water vapor resolution from 8 km to 4 km in the north to south direction. Channel 5 was removed from GOES-12 to make room for the new channel. The new channel improves measuring the heights of the steering winds around 500mb.

Table 1-2 gives a complete comparison between the old spin stabilized GOES and the current 3-axis stabilized GOES. Chapter 3 describes the GOES Imager and Sounder instruments in more detail.

GOES Geographic Coverage

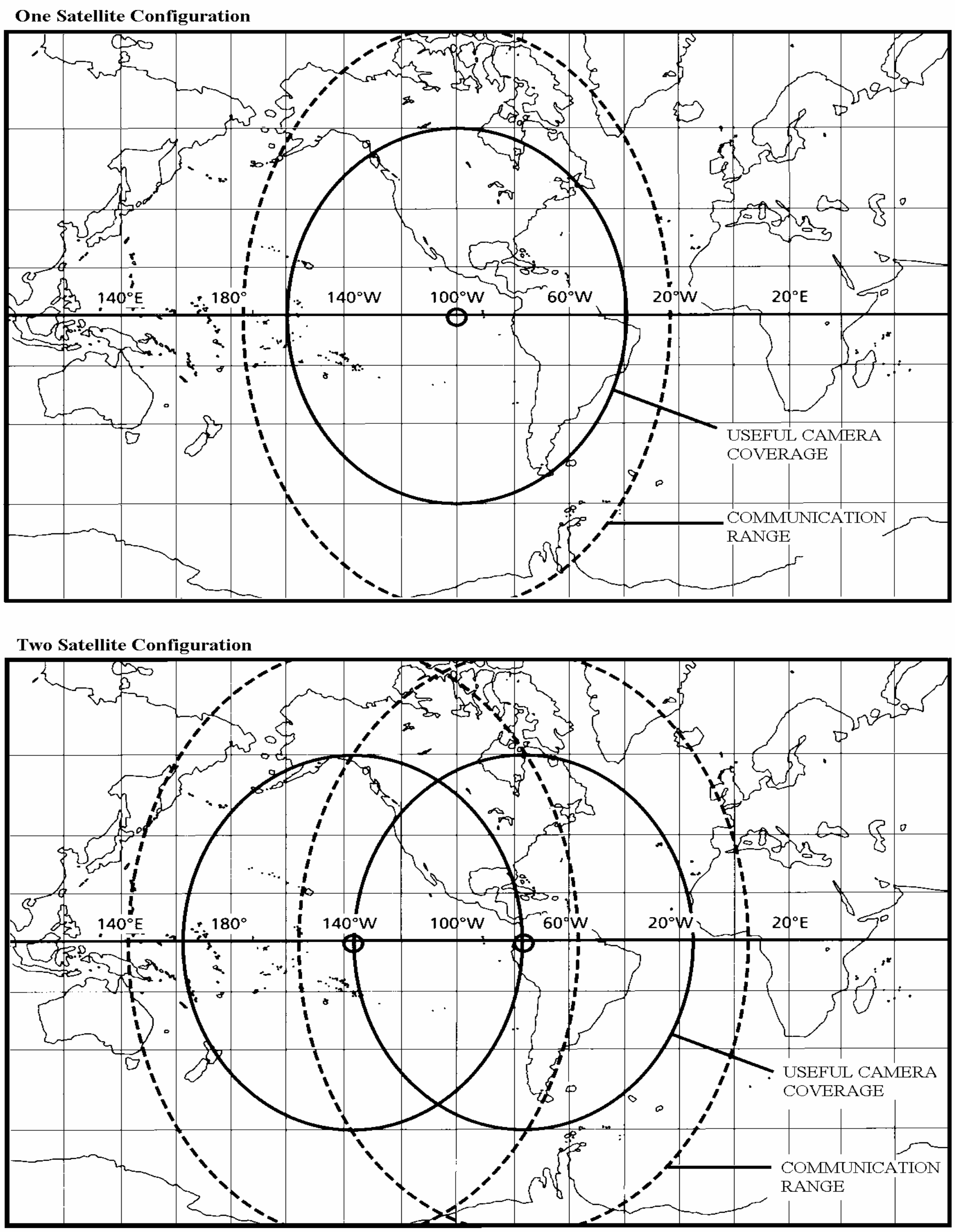


Figure 1-1 GOES Geographic Coverage

Table 1-2 GOES Comparison

Characteristics	GOES 4 through 7	GOES 8 through 12
SPACECRAFT		
Stabilization	Spin stabilized	3-axis body
Instrumentation	Combined Imager and Sounder (VAS), single telescope and scan mirror	Independent Imager and Sounder, each with its own telescope and scan mirror
INSTRUMENT SCANNING		
Scan mechanism	Scans performed by spinning of the satellite, each rotation equals one scan	2-axis gimbaled scan mirrors, which slew east to west, then west to east
Areas scanned	Full or partial disk scans-fixed width.	Full disk, sector, or small area scans
Frame limits	Selectable NS within 20 EW by 20 NS	Selectable NS and EW within 19.2 EW by 19 NS
Scan direction	Always west to east	Alternating between scans
IMAGING		
Scan Characteristics		
Priority scanning	N/A	Priority scan available
NS stepping	192 μr steps	224 μr step for an 8 line visible swath
EW scan width	Fixed	Variable from image to image
Radiometrics		
Vis Detectors	PMT	Solid State
Visible resolution	0.89km at nadir (25μr×21μr)	1km at nadir (28μr×16μr)
Vis signal quantization	6 bits	10 bits
IR detectors	Dual-element IR detectors, offset in NS plane (192μr×384μr squares)	Multi-element IR detectors, no offset in NS plane (112μr and 224μr squares)
IR Spectrum	12 bands, filter wheel selectable	4 bands, fixed
Images per frame	Up to 4, selectable (interleaved)	4 non-selectable (not interleaved
IR resolution	Selectable 7km or 13km	Band-fixed, 4km and 8km
IR signal quantization	10 bits	10bits
Calibration		
Spacelook (S/L)	Every spin (scan)	Every other scan for wide frames; on 36.6 sec or 9.2 sec interval timer for narrow frames; data timed at two minute interval
Blackbody (BBCAL)	BBCAL on each spin (scan)	Timed or commanded-operationally commanded every 30 minutes
Electronic (ECAL)	Before every frame	With each BBCAL33

Table 1-2 GOES Comparison (continued)

Characteristics	**GOES 4 through 7**	**GOES 8 through 12**
Navigation		
Earth location	By ground system	By ground system
Earth pointing	Not actively controlled	1) By instruments 2) Star sensing through instrument visible array. Operationally commanded every 30 minutes. 3) Ranging 4) Landmarking (daytime only)
SOUNDING		
Sounding Characteristics		
Mechanism	Multiple-spin line sampling	Step and settle column sampling
Dwell	Up to 255 spins per band	Selectable 0.1, 0.2, 0.4 seconds at each step- all bands sampled
Line skipping	Every line with alternating band options	True line skipping; available at 0.2 sec dwell on GOES-8, at 0.1 sec dwell on GOES-9.
NS Stepping EW Stepping	192 μr/line-line commandable 3822 samples-full widths, no ground control	1120 μr with skip line capability 280μr sample, 1,2, or 4 samples
Radiometrics		
IR detectors	Dual-element, offset in N-S plane	Quad-element, short, medium, and long wave, offset in NS and EW planes
Spectrum	4 of 12 bands, filter wheel selectable	18 IR bands, 1 visible, non-selectable
IR Resolution	13 km at nadir	8 km at nadir
IR Signal quantization	10 bits	13 bits
Calibration		
Spacelook (S/L)	Before every scan	By timer, every 2 minutes
Blackbody (BBCAL)	Before every frame	Timed or commanded-operationally commanded approx every 20 minutes
Electronic (ECAL)	Before every scan	With each spacelook
Earth Location Earth Pointing	By ground system Stability not actively controlled	By ground system 1) By instrument 2) Star sensing 3) Ranging 4) Landmarking

Chapter 2- GOES System Description

2.0 Introduction

Discussion in this chapter will cover the three basic satellite systems, the GOES Spacecraft System, the GOES Spacecraft Support Subsystem, and the Product Generation and Distribution Subsystem. This is a generalized view to enable clearer understanding of the processes involved in acquiring GOES VARiable (GVAR) data and the production of its products. Technical information regarding these systems and other subsystems are found in documents listed in Appendix D.

2.1 GOES System Overview

The NESDIS GOES system has three major functional components, as illustrated in Figure 2-1: the GOES spacecraft, the Spacecraft Support System (SSS), and the Product Generation and Distribution system (PG&D). All three parts of this system are operated by the National Environmental Satellite, Data, and Information Service (NESDIS), which is a part of NOAA.

The spacecraft senses Earth and space with its instruments and sends raw sensor data to the Spacecraft Support System (SSS) on earth. The SSS processes these instrument data into GVAR format and is sent back to the GOES satellite with sensor calibration and image navigation information. From the satellite, the calibrated and navigated GVAR data are rebroadcast to receiving stations throughout the Western Hemisphere. The spacecraft also sends health and status telemetry to the SSS.

The SSS is physically divided between the Command and Data Acquisition (CDA) at Wallops Island, Virginia, and the Satellite Operations Command Center (SOCC) at Suitland, Maryland. The CDA Station is the main point of communication with the spacecraft. The functions performed at the CDA include those most closely associated with the real-time production of the formatted spacecraft data derived from the raw instrument data, and with the retransmission of these processed data through the spacecraft to the user community. The SOCC's functions include providing for continuous monitoring and supervision of the spacecraft and CDA systems. The SOCC plans and schedules spacecraft and ground system activities and commands these systems to satisfy mission requirements.

The GOES Product Generation and Distribution (PG&D) system generates real-time meteorological products from preprocessed GOES satellite data, and distributes these products to various National Weather Services Offices (NWS), the National Centers for Environmental Prediction (NCEP), and to many other users needing operational data for further analyses.

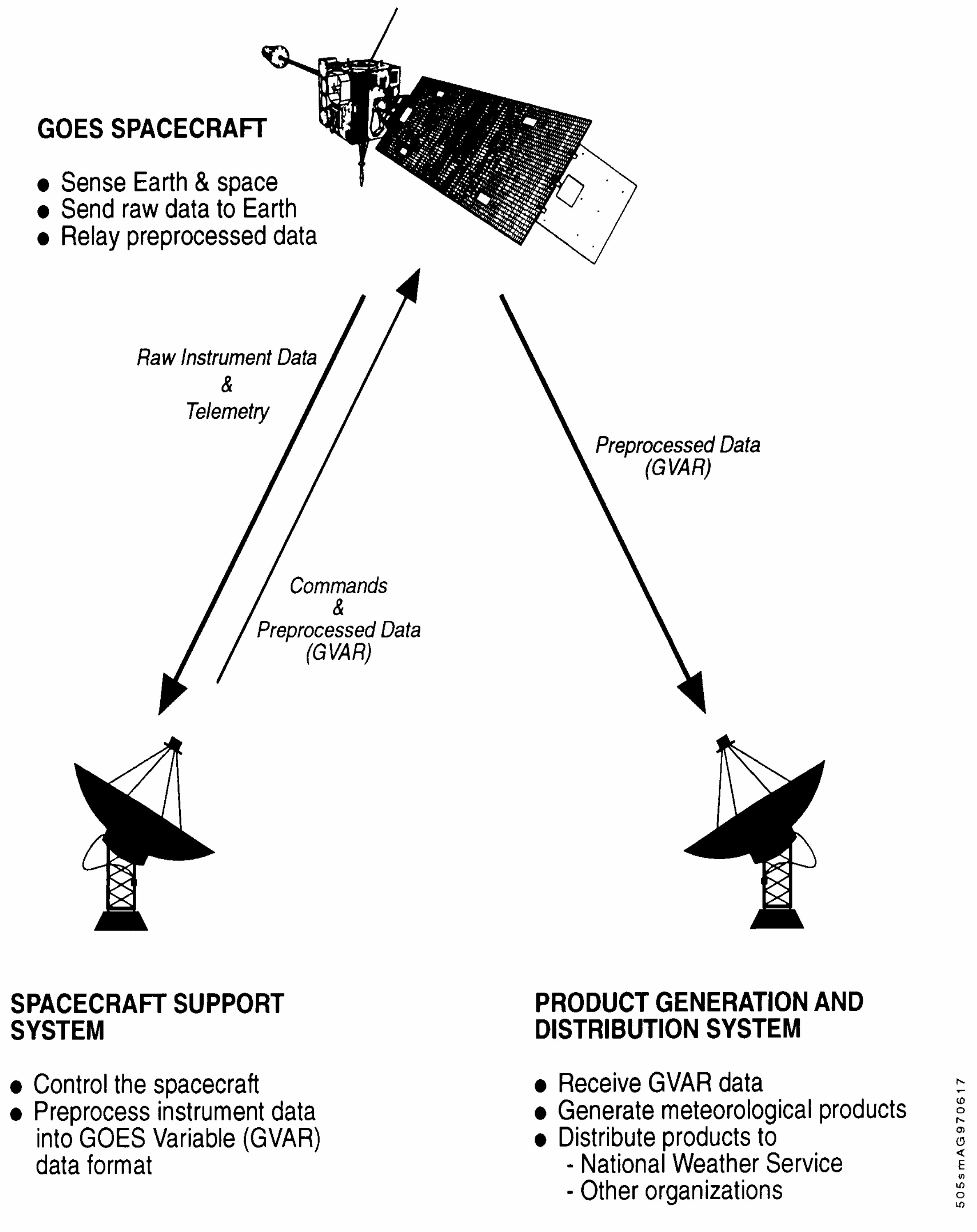


Figure 2-1 GOES System

2.2 GOES Spacecraft System

As mentioned earlier, GOES satellites are three-axis body stabilized, meaning that the three axes (pitch, yaw, and roll) of the satellite remain stationary relative to the nadir. Satellite spacecraft stabilization is performed by internal momentum wheels to provide attitude control and require corrective action from the ground to compensate for the effects of thermal gradients and solar winds. Unlike the previous GOES series, the current GOES spacecraft's Imaging and Sounding instruments can be operated simultaneously and independently of one another.

The spacecraft's configuration is essentially a compact six sided main body that carries the operational instruments, a continuous drive solar array attached to the south panel through a yoke assembly, a solar sail mounted off the north panel to offset solar pressure torques, a Telemetry and Command (T&C) antenna boom-mounted on the east end for full omni-directional coverage, and the Space Environment Monitor (SEM) magnetometer on a boom off the anti-earth side of the satellite (Figure 2-2).

The main body of the spacecraft accommodates the five-channel visible and infrared Imager and the nineteen-channel Sounder. Both instruments sample radiance from earth and atmosphere by identical two-axis scan systems and nearly identical two-axis telescopes in each unit. Scan control and data collection for the instruments are independent of each other and most other activity on the spacecraft.

Also supported by the spacecraft's main body are the space monitoring instruments. All of the communication antennae, excluding T&C, are fixed to the earth-facing panel for unobstructed earth coverage.

The solar sail and boom are used to balance the solar array. The solar array is a two panel assembly attached to a continuously rotating solar array drive assembly that also provides sun tracking for the SEM's Solar X-ray Sensor (XRS).

2.3 GOES Spacecraft Support Subsystem

The GOES Spacecraft Support System (SSS) has three major ground sites: the Command and Data Acquisition (CDA) station in Wallops Island, Virginia, the Satellite Operations Control Center (SOCC) in Suitland, Maryland, and the NOAA Science Center in Camp Springs, Maryland. Each site has a unique combination of spacecraft control, processing, and product generation functions, as explained below.

The GOES Spacecraft Support portion of the ground system consists of the hardware and software required to command, control, and receive information from the GOES spacecraft. These spacecraft support functions are provided by the Operational Ground Equipment (OGE), the T&C subsystems, the RF transmit/receive subsystems, and ground communications. Components of the OGE are located at both the SOCC and the CDA.

GOES Spacecraft System

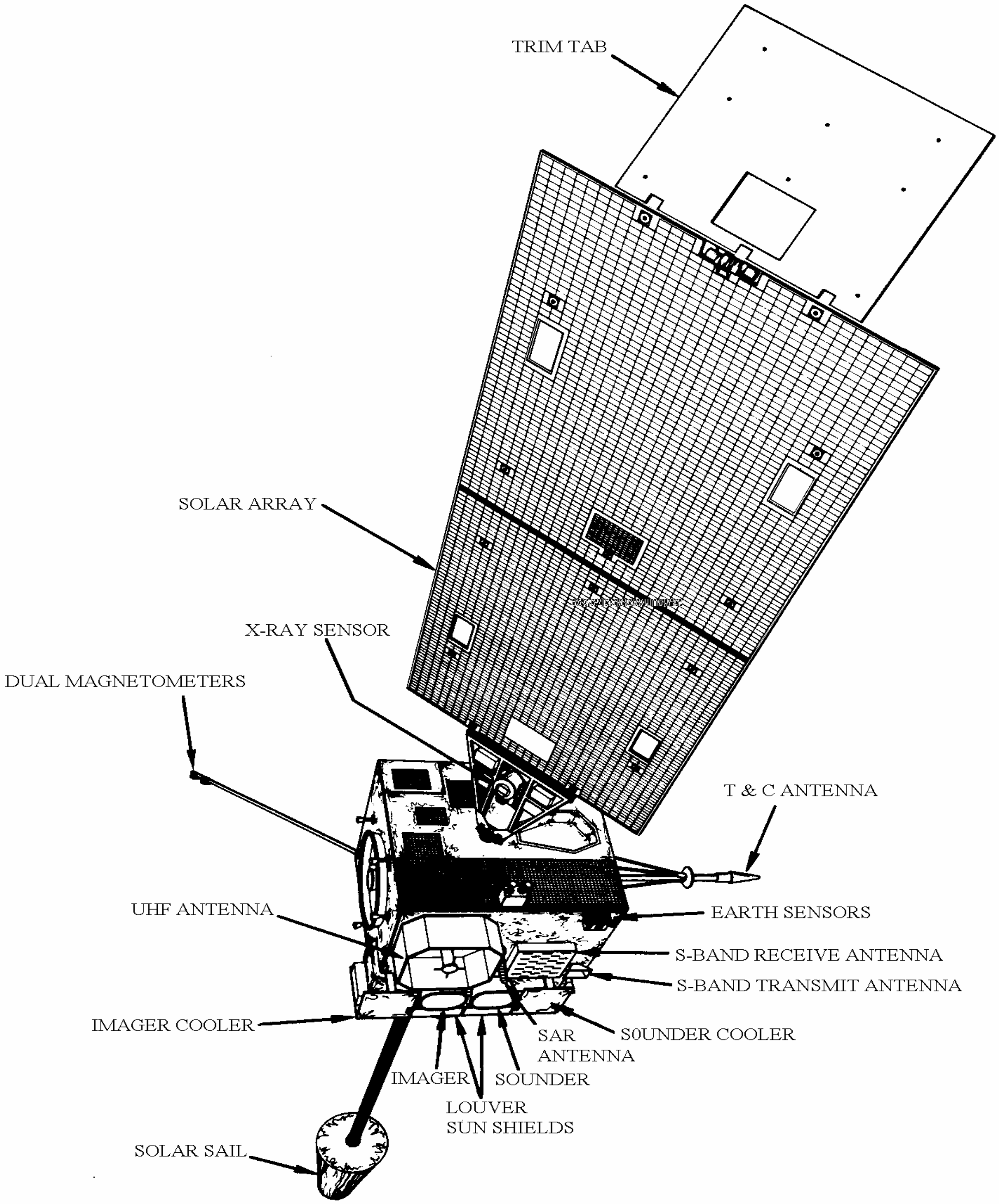


Figure 2-2 GOES Spacecraft

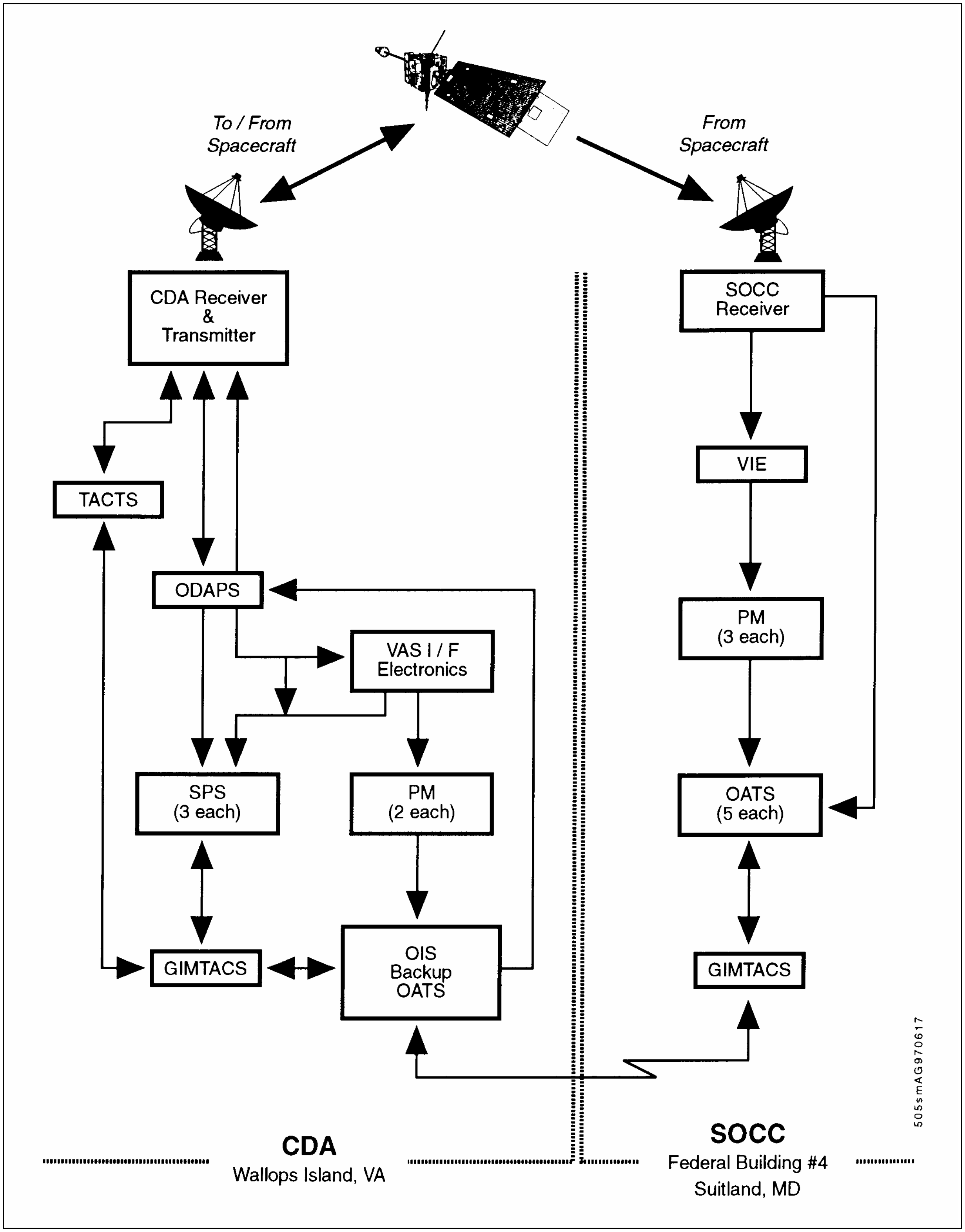


Figure 2-3 GOES Spacecraft Support Subsystem

The SOCC is responsible for continuous monitoring and supervision of the spacecraft and the CDA systems. The CDA provides the principal terrestrial interface with the satellite. In general, those components closely associated with the raw instrument data processing and re-transmission are located at the CDA. The remaining components, primarily those associated with scheduling, planning, and off-line engineering and analysis functions, are located at SOCC for normal operations, but are backed up by redundant copies at the CDA during ground communication outages or SOCC failure.

The T&C subsystem is divided into the Telemetry Acquisition and Command Transmission System (TACTS) and the GOES I-M Telemetry and Command System (GIMTACS). TACTS performs the baseband down to Intermediate Frequency (IF), up conversion of the commands to the spacecraft, the IF to baseband down conversion of the spacecraft telemetry data stream, and data formatting. The remainder of the T&C functions is performed by GIMTACS. These include controlling and monitoring the spacecraft and supporting ground systems, providing spacecraft operator control, scheduling and generating commands, processing and displaying telemetry information, and providing the communication links between the SOCC and the CDA.

2.4 Product Generation and Distribution Subsystem

The GVAR satellite data are received at the Wallops Island, Virginia, CDA station and relayed to SOCC in Suitland, Maryland, for data monitoring at SOCC and product generation at the Office of Satellite Data Processing and Distribution (OSDPD) Central EnvironMental Satellite Computer System (CEMSCS). SOCC also forwards its GVAR data via microwave line-of-sight communications to the NOAA Science Center in nearby Camp Springs, Maryland, for product processing. Figure 2-4 is a simplified diagram of the GOES Product Generation and Distribution (PG&D) System. There are six functional subsystems used to produce GOES products. The names and locations of the processing and distribution systems are found in parentheses; selected output products are listed to the right of the PG&D System block. The PG&D system generates meteorological products in real-time mode from preprocessed GOES satellite data, and distributes these products in real-time mode to National Weather Services Offices (NWS) and other government agencies and cooperative institutions. Also, many of the GOES products, both operational and experimental, can be accessed via the Internet. See Appendix B for a comprehensive list of WEB addresses offering a host of GOES products.

2.4.1 Real Time Remapped Imagery

The GOES Ingest and NOAAPORT Interface (GINI) system generates a suite of real-time GOES
products from "raw" GVAR imager and sounder data. The GINI processing system involves sectorizing, scaling, and remapping digital products in various projections such as Lambert-Conformal, Mercator, and Polar Stereographic. GINI is the central remapping system for NWS Advanced Weather Interactive Processing System (AWIPS), a data display and applications platform. Remapped image files (sectors) are relayed from the GINI to a NOAAPORT interface that distributes the products to more than 200 NWS Weather Forecast Offices (WFOs) via a point to-multipoint satellite broadcast. Satellite relay of GINI products via NOAAPORT enables

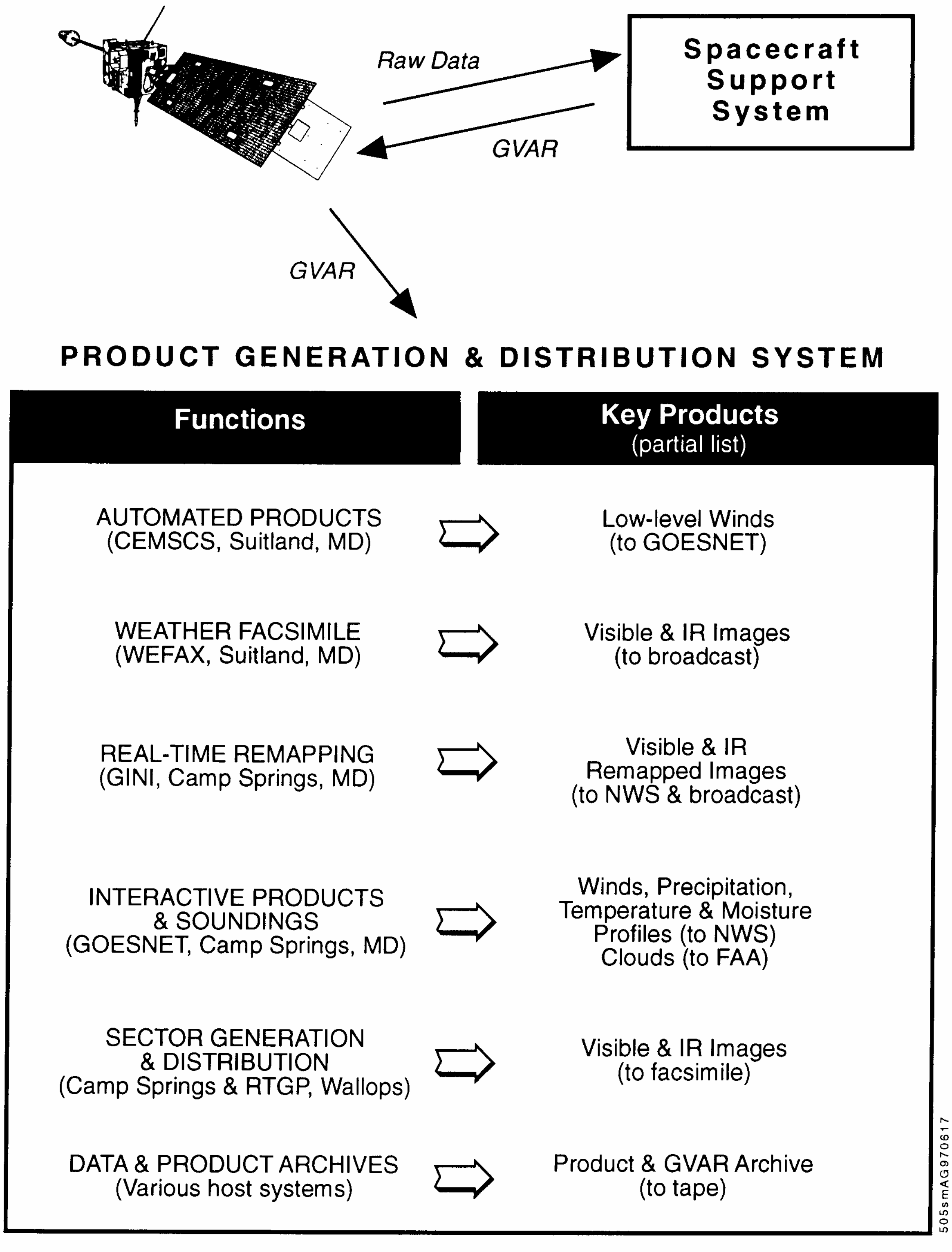


Figure 2-4 PG&D Function and Products

access by the general public. Utilizing all GOES imager channels, up to 120 remapped digital sectors can be generated concurrently. The process of sector generation and remapping is data driven, not scheduled like the former GOES-TAP service. A predefined sector is generated when most of the data covering the specified geographic area is received. GINI does not superimpose grids on the imagery prior to dissemination, but provides navigational data in the AWIPS header to enable local generation of a local grid map database. The output sectors are transmitted serially. Transmission of the highest priority sector begins immediately after the first data for that sector is received; lower priority sectors are then transmitted. An overview of the NOAAPORT program can be found on the Internet at:

http://www.nws.noaa.gov/noaaport/html/noaaport.shtml

2.4.2 Weather Facsimile

The Weather Facsimile (WEFAX) Distribution System is a communications transponder service provided through the GOES-12 and GOES-10 satellites. The low resolution analog image products are generated on the CEMSCS and then transmitted on the Facsimile Transmission System (FXTS) to the Wallops Island, Virginia, CDA via a broadband communication circuit. The CDA then sends the signal to the GOES satellites for final distribution to users. Each image takes 3.5 minutes to transmit.

This imagery is produced from the retransmitted GVAR data streams received at the facility. WEFAX involves the retransmission of low-resolution geostationary and polar orbiter satellite imagery or other meteorological data through the GOES satellites to relatively low cost receiving units within receiving range of the satellite. Three types of sectorized images are transmitted: (1) visible, (2) IR, and (3) WV. The images display sectorized portions of a full disk scan. There are a total of seven sectors available including an 8 km Northern Hemisphere IR sector transmitted hourly throughout the day and a visible Northern Hemisphere sector transmitted hourly during daylight hours. In addition, there are four 8 km sectors (NE, SE, NW and SW), a 4 km CONUS sector, and a 16 km full disk image transmitted every three hours. A full suite of 8 km WV sectors is transmitted twice daily. All sectors contain implanted geographic boundaries and latitude/longitude reference lines.

The present GOES WEFAX system, as described above, will be replaced with digital Low Rate Information Transmission (LRIT) by 2005. Users are in the process of replacing present WEFAX reception equipment. For more information on LRIT please go to http://noaasis.noaa.gov/LRIT/.

2.4.3 Data and Products Archives

The Data and Product Archives function retrieves the original GOES data (GVAR), NCEP model data, and product data from CEMSCS, and creates GOES Products. The GVAR data are ingested in near real-time into the NOAA Comprehensive Large Array-data Stewardship System (CLASS). Online access to limited GVAR data and some GOES products is available at: http://www.class.noaa.gov/

Chapter 3 - GOES Imager and Sounder

3.0 Overview

The GOES Imager and Sounder instruments have greatly increased capabilities compared with the instruments onboard the GOES D-H satellites. The GOES satellites carry a five-channel (four infrared and one visible) Imager and a 19-channel (18 infrared and one visible) Sounder. This system has increased atmospheric observing capabilities not available in the older GOES in that the GOES Imager has simultaneous imaging from all infrared and visible channels and higher IR resolution (4km) in the surface and cloud detection channels. GOES Sounder quality is improved by having: 1) total isolation and independence from imaging, 2) more and narrower spectral channels, 3) spatial resolution reduced to 8km, and 4) sufficient sensitivity for full quality soundings to be derived from each sampled atmospheric column.

A body-stabilized satellite with one surface continually oriented toward the earth provides the platform for the instruments. The full-time operation of the Imager and Sounder permits maximum sensitivity and flexibility of control, enhancing synoptic, aperiodic, and mesoscale observations.

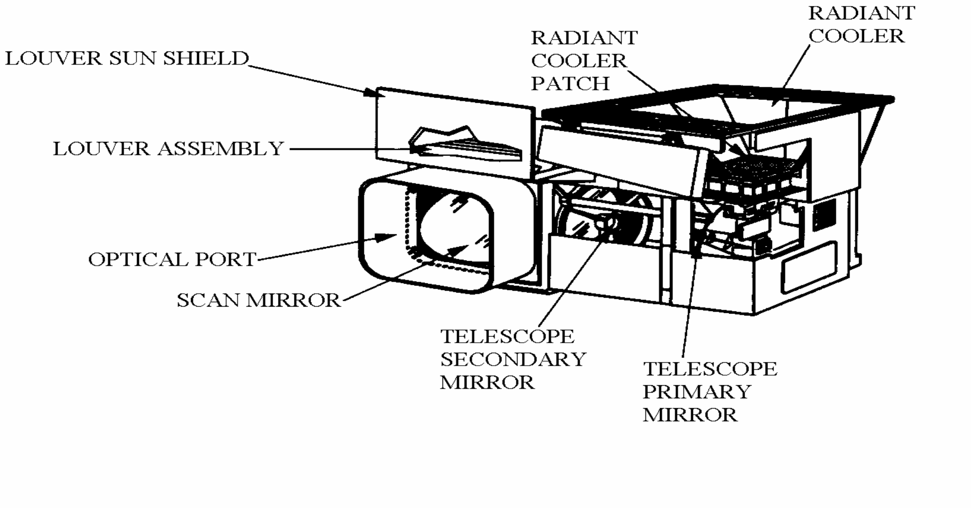
3.1 Instrument Description

The GOES Imaging and Sounding Subsystem shown in Figure 3-1 is made up of two instruments, each having very similar functional capability. Scan control and data collection for the instruments are independent of each other and of most other activity on the spacecraft. An on-board computer provides a method of automatic motion compensation unique to GOES.

Each instrument is under operator control to command the start time, location, and size of earth areas to be imaged or sounded. Radiance from the earth is sampled by identical two-axis scan systems and nearly identical telescopes in each unit. Spectral separation in the two instruments differs to meet their separate requirements. Separation in the Imager is by fixed dichroic beam splitters, permitting simultaneous sampling of all five spectral channels. In the Sounder, the visible spectrum and three IR bands are separated by dichroic beam splitters; the three IR bands then pass through three concentric rings of a filter wheel (see Figure 3-9) where channel filters provide sequential sampling of the seven longwave, five midwave, and six shortwave channels. The infrared detectors operate at three patch temperatures: 94°K for seven or eight months that include the winter season, 101°K for the four or five months that include the summer season, and 104°K for radiative cooler contingencies.

Each linear scan of the Imager samples an 8km North-South swath (at nadir). The Sounder has four detectors in each band. Each detector's Field of View (FOV) is 8km at nadir and a scan swath is 40km wide (N/S) at nadir. The Imager has a highly linear scan in the West-East or E/W direction at a rate of 20.021° per second. It then drops 224 ær (radians or 8km at nadir) to scan in the opposite direction to continue a frame. The Sounder steps at a fixed pattern rate of 0.1

Imager



Sounder

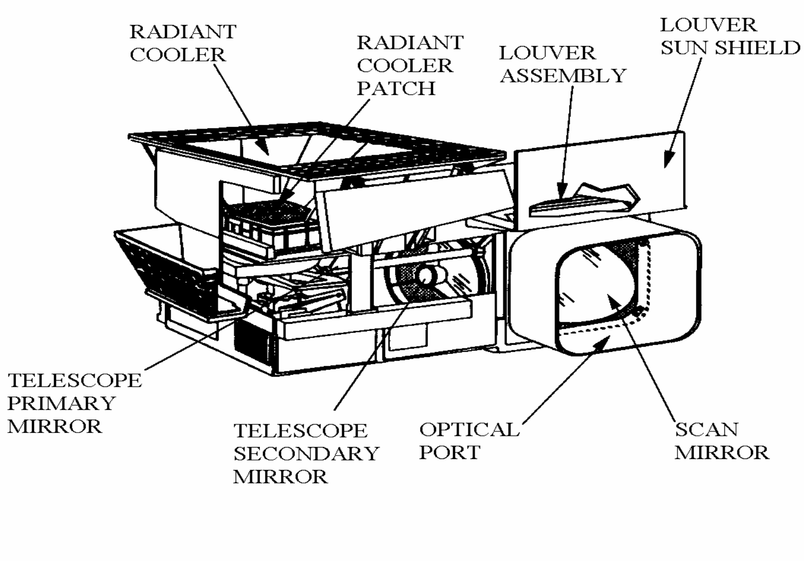


Figure 3-1 GOES Imager and Sounder Instruments

seconds for each 280 ær (10 km at nadir) in the West-East or East-West direction, then steps down (or up) 1120 ær (40 km) to the next contiguous scan to continue a frame.

Interactive operation of the instruments and spacecraft permits independent operation of the individual scan systems, yet maintains the pointing accuracy of each optical system. This is accomplished by a Mirror Motion Compensation (MMC) algorithm on the spacecraft which recognizes the scan mirror motions and their physical effect on the spacecraft. A counteracting signal is developed and fed to both instruments to apply the appropriate corrections that maintain the scan mirror angle accuracy with respect to the Earth.

Star reference data collection is performed by each instrument. This permits regular determination of optical references. These features that reduce pointing errors permit the total system to achieve high accuracies with respect to ground coordinates.

Each instrument's optical assembly measures approximately 18" x 18" x 42". A 9" long sun shield extends from the scan cavity and a 24" square by 12" extension shields the radiative cooler. The separate electronics module for each instrument, containing nearly all the control and signal processing circuitry, is located across from the optical assembly. Raw Imager data is transmitted at 2.6208 Mbps. The Sounder has a much lower rate at 0.040 Mbps.

3.1.1 Key Features

General features, characteristics, and each instrument’s performances are given in Tables 3-1 through 3-6. Figures 3-4 and 3-5 show the coordinate frames and scan limits for the instruments. The prime features of these instruments are as follows:

- Scan control

  1. On command frame size and location capability – can do rapid scans in short succession
  2. Independent Imager and Sounder – fully separate systems
  3. Motion compensation mechanisms against other instrument's movements allowing for superior pointing toward earth
  4. Repeat-frame option, similar to Rapid Interval Scan Operations (RISOPS)

- Position location and frame overlay accuracies

  1. Imager pixel geo-location accurate to 4 km at nadir, at noon ± 8 hours
  2. Registration between repeated images from 53μr and 210μr depending upon time of day and time between frames.
  3. Sounder sample locations accurate to 10 km at nadir, at all times; registration between repeated soundings of 280μr.

- Long term stability and calibration
  1. Space reference used for short term radiance reference.

2. Full aperture blackbody reference used for regular slope (radiance per output count)
3. Calibration of infrared channels approximately every half hour to offset diurnal variation.

Table 3-1 Imager Features (GOES 8 through 11)

CHANNEL	DETECTOR	# OF DETECTORS	IGFOV(nom km²)
Visible	Silicon	8	1
Shortwave	InSb	2	4
Water Vapor	HgCdTe	1	8
Longwave 1	HgCdTe	2	4
Longwave 2	HgCdTe	2	4
		Detector Beamsplitter (Simultaneous Output, all ch) 14 μr (0.5km) ground alignment	
Radiometric Calibration		Space and 290°K IR Blackbody (Varies with housing temperature)	
Space look		Every 9.2 sec, 36.6 sec, or every other scan depending on frame size	
Blackbody Calibration		Every 10 minutes, 40 sec duration, but operationally inhibited within a frame and commanded every 30 minutes between frames	
Detector Temperature Signal Quantizing		94°/101°/104°K, IR Channels 10 bits, all channels	
Downlink Data Rate		2.6208 Megabits per second (Mbps)	
Scan Speed (East-West) Scan Capability System Power Average		20.021°/sec optical +0.2 sec turnaround per scan Full Earth, Sector, Area 74 watts	
System Weight Sensor Assembly Electronics Module Total		 118 lb (53.6kg) 033 lb (15.0kg) 151 lb (68. Kg)	

Table 3-2 Sounder Features

Channel	Detector	Number	IGFOV (μr) Specified Maximums	Nominal
Longwave IR	HgCdTe	4	224	215 diagonal
Midwave IR	HgCdTe	4	224	215 diagonal
Shortwave IR	InSb	4	224	215 diagonal
Visible	Silicon	4	224	215 diagonal
Star	Silicon	8	No spec	22.8 square
FOV Defining Element			Field stop	
Telescope Aperture			31.1 cm (12.25 inches) diameter	
Channel Separation, LW-SW-MW			Dichroic	
Channel Definition			Interference filters	
Radiometric Calibration			Space and 290°K IR Blackbody	
Space Look			Every 2 minutes, 10 sec approx. duration	
Blackbody Calibration			Every 20 minutes, 55 sec approx. duration	
IR Detector Operating Temperatures			94°/101°/104°K	
Field Sampling			4 areas N-S on 10 km centers	
East-West Scan Step Angle			280 μr (10 km nadir) 560 μr optional	
Step and Dwell Time			0.1 second; 0.2 sec and 0.4 sec optional +0.1 second turnaround per scan	
Scan Capability			Full Earth (not in practice) and sector areas	
Signal Quantizing			13 bits - all channels	
Downlink Data Rate			40,000 bits per second (40 Kbps)	
System Power Average			74 watts	
System Weight				
Sensor Assembly			126 lb (57.5 kg)	
Electronics Module			031 lb (14.0 kg)	
Total			157 lb (71.5 kg)	

3.2 Imager Instrument

The Imager is a multi-channel instrument designed to sense radiant and solar-reflected energy from sampled areas of the Earth's surface and atmosphere.

The Imager's multi-element spectral channels simultaneously sweep an 8 km north-south (N/S) longitudinal swath along an east-west (E/W) latitudinal path by means of a two-axis gimballed mirror scan system. Position and size of an area scan are controlled by command. Beamsplitters separate the spectral channels to the various IR detector sets, which are redundant. The 1 km by 8 km visible detector array is composed of eight detectors all functioning at once. There is no redundancy built into the visible array.

Table 3-3 Imager Characteristics

Channel	Spectral Response	Spatial Resolution	Purpose
1	0.52-0.75µ (visible)	1 km	cloud cover
2	3.8-4.0µ	4 km	night cloud cover
3	6.5-7.0µ	8 km (4km G-12)	water vapor
4	10.2-11.2µ	4 km	sea surface temperature
5	11.5-12.5µ	4 km	sea surface temperature
6 (G-12)	13.0-13.7µ	8 km	carbon dioxide

3.2.1 Imager Detector Characteristics

The Imager instrument acquires radiometric data for five distinct channels. These five radiometric channels are characterized by a central wavelength denoting primary spectral sensitivity within these channels. The five channels are split into two distinct classes, visible and IR, and comprise a total of 22 detectors as follows (See Figure 3-2):

- Visible - Channel 1 of the Imager contains eight visible detectors arranged in a linear fashion (v1-v8). Each detector provides an Instantaneous Geometric Field of View (IGFOV) of 28 microradians on a side. At the sub-satellite point, this corresponds to a square pixel of one kilometer (km) per side.

- IR - Channel 3 (6.75 μm) contains two square detectors (GOES-8 through 11), one primary and one redundant. Each provides an IGFOV of 224 microradians corresponding to an eight kilometer resolution at the sub-satellite point. GOES-12 and higher contain two primary and two redundant detectors with a 4km x 8km (n-s) resolution at the satellite nadir.

Table 3-4 Imager Performance (GOES-8 through 11)

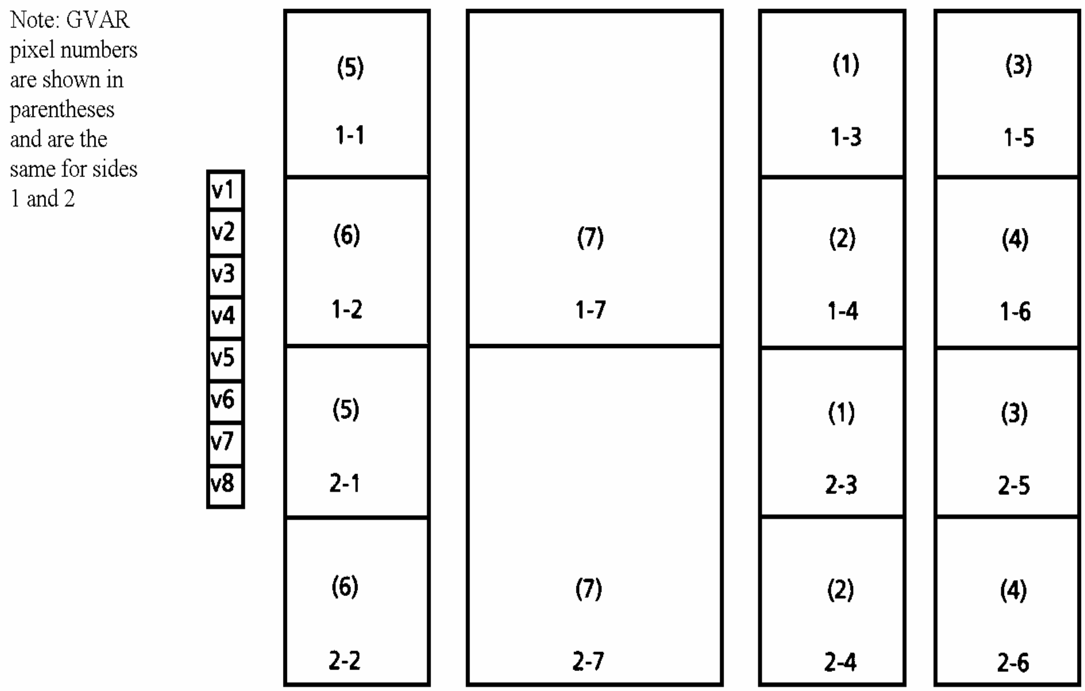
SENSITIVITY					
Channel	Spectrum (μm)	IGFOV (μr)	NEΔT or S/N Spec	Actual	At Scene Temperature
1	.52 to .75	28	150:1	248:1 min	100% Albedo
2	3.8 to 4.0	112	1.4 °K	0.2 °K	300°K
3	6.5 to 7.0	224	1.0 °K	0.2 °K	230°K
4	10.2 to 11.2	112	0.35°K	0.14°K	300°K
5	11.5 to 12.5	112	0.35°K	0.30°K	300°K

OPTICAL CAPABILITY				
Channel	IGFOV (μR) North-South	East-West	Channel-to-channel co-registration (μr)	MTF @ x cycles/radian
1	26.8-27.3	27.4 - 27.9	39 max. Vis-to-IR; ground corrected to 14μr vis to IR	0.49 @18,000
2	A 86.9	103.2	20 max. IR to IR	0.35 @4490
	B 86.2	103.0		
3	214	200	14	0.41 @4490
4	A 127	105	14	0.29 @4490
	B 126	106		
5	A 101	110	14	0.28 @4490
	B 103	106		

- IR - Channels 2 (3.9 μm), 4 (10.7μm), and 5 (12.0 μm) each contain four detectors; two of these are the primary detectors and the other two provide redundancy. Each of these detectors is square, providing an IGFOV of 112 microradians. At the sub-satellite point, this corresponds to a square pixel having dimensions of four km per side. Starting with GOES-12, channel 5 is replaced with a channel 6 (13.3µm), which contains two detectors, one primary and one redundant at a IGFOV of 112 mircroradians (8 km pixel size).

Although the detectors are physically separated in the instrument, they are optically collocated as shown in Figure 3-3.

The five channels are configured in either primary or redundant mode. In the primary mode, the IR channels have only their upper detectors (P1-P7 enabled. In the redundant mode, the IR channels have their lower detectors (R1-R7) enabled. In both modes, the entire visible channel array is always enabled. In either of these configurations, radiometric data are sampled across a scan line whose vertical boundaries equal those of the 8 km water vapor detector or two 4 km of channels 2,4, and 5.



CHANNEL	1	2	3	4	5
CENTRAL WAVELENGTH (μm)	0.65	3.9	6.75	10.7	12.0
DETECTOR IGFOV (nominal, μrad)	28	112 Insb	224 HgCdTe	112 HgCdTe	112 HgCdTe

Figure 3-2 Imager Detectors

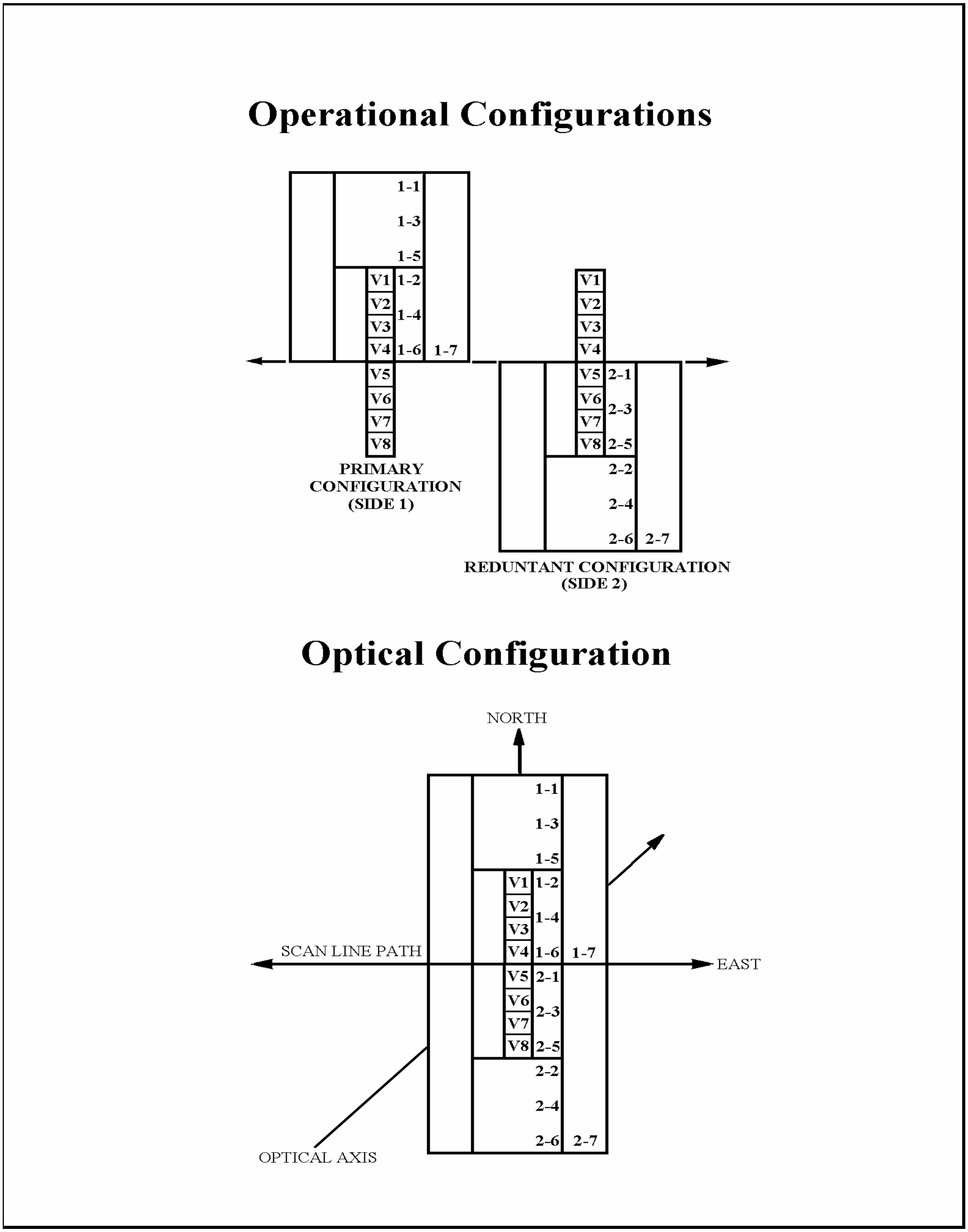


Figure 3-3 Imager Configurations

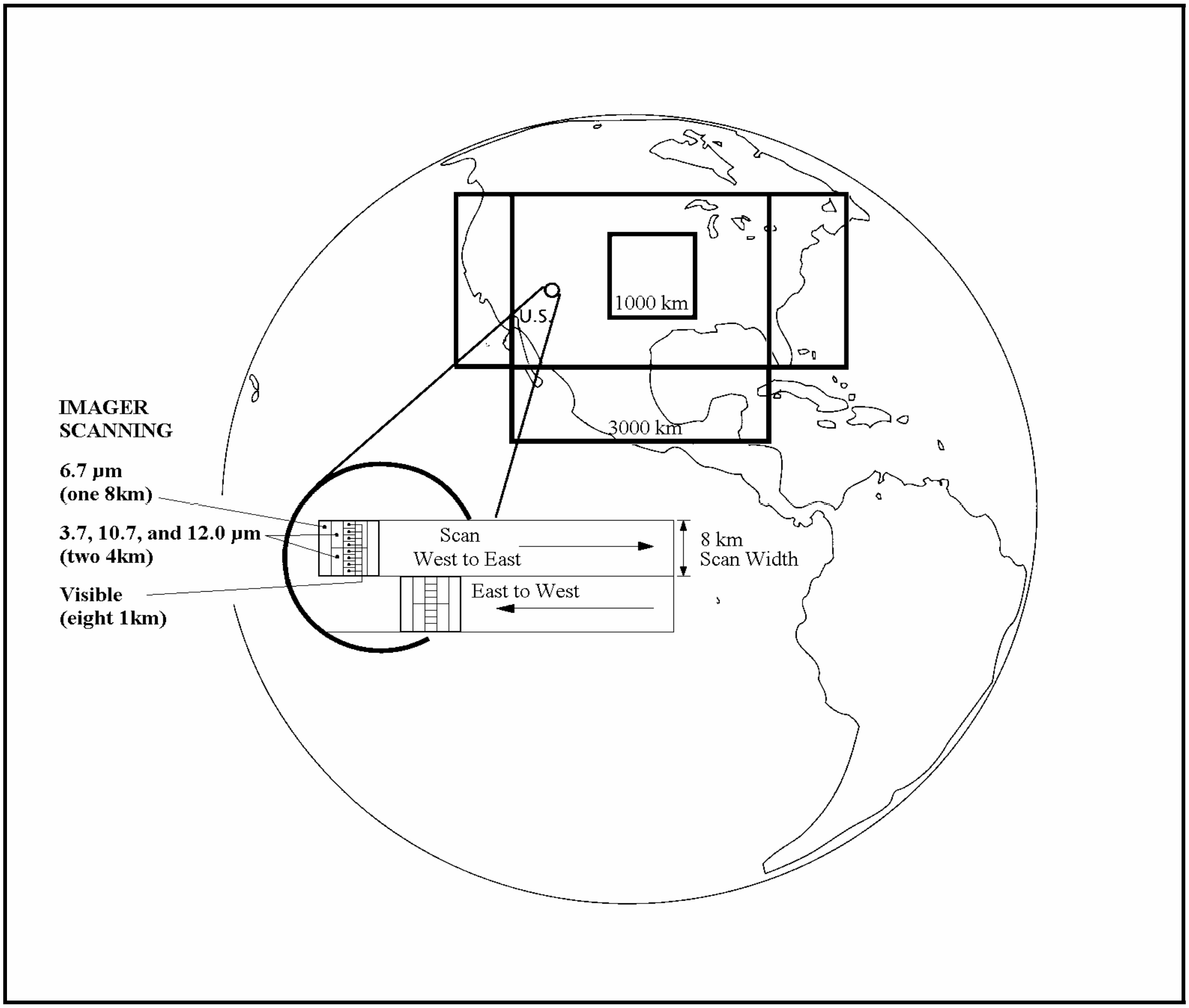


Figure 3-4 Area Scan

3.2.2 Scanning Characteristics

The Imager scans the selected image area in alternate directions on alternate lines (Figure 3-4). The imaging area is defined by a coordinate system related to the instrument's orthogonal scan axis, as shown in Figure 3-5. During imaging operations a scan line is generated by rotating the scanning mirror in the east-west direction while concurrently sampling each of the active imaging detectors. At the end of the line, the Imager scan mirror performs a turnaround, which involves stepping the mirror to the next scan line and reversing the direction of the mirror. The next scan is then acquired by rotating the scanning mirror in the opposite, west-east direction, again with concurrent detector sampling. Detector sampling occurs within the context of a repeating data block format. In general, all visible detectors are sampled four times for each data block (four times 1km wide), while each of the active IR detectors is sampled once per data block (one times 4 km wide).

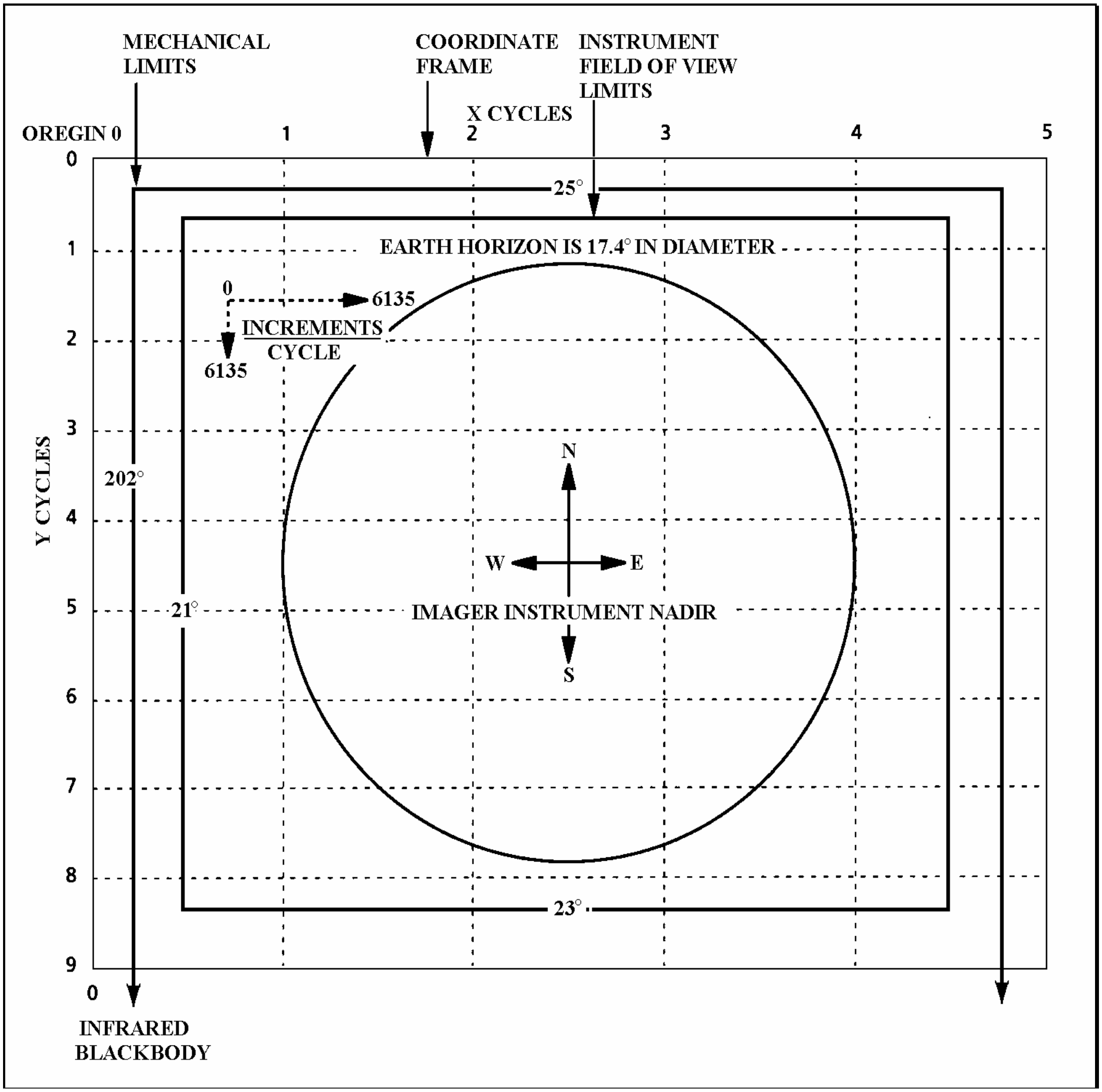


Figure 3-5 Imager Coordinate Frame

3.2.3 Imager Data Format Characteristics

The Imager instrument output data are continuously transmitted at a rate of 2.6208 Mbps in 480 bit data blocks. This rate corresponds to a transmission of 5460 blocks per second. Each block transmitted contains a 15 bit synchronization code used to synchronize the boundaries of the data block upon receipt by the OGE. A five bit identification code is included immediately following the synchronization code to identify the contents of the data blocks received. A typical data block format is shown in Figure 3-6. The six different data block formats transmitted to the ground equipment are as defined below.

- Header - A header data block precedes a string of active scan data blocks. The header provides flags to signal what operation is currently in progress and provides the current address.

- Trailer - A trailer data block is always found within a scan reversal sequence. The trailer provides flags to foretell what the next scan sequence is going to be and also provides the current address.

- Active Scan Block - An active scan data block is utilized to transmit radiometric data when the Imager is performing normal frame, priority frame, star sense, BB calibration, or space look operations.

- Telemetry - A telemetry data block is the means by which to transmit Imager T&C register data to the OGE. There are two telemetry words and eleven command register words of information per block.

- Electronic Calibration (ECAL) - An ECAL data block is very similar in format to the active scan block. It differs in that the Image Motion Compensation (IMC) and servo error data words are omitted and the ECAL step number has been added.

- Fill - The fill data block is used as a filler. It contains all zeroes except for the data block ID. The fill data block is used by the OGE to determine the bit error rate of the integrated data.

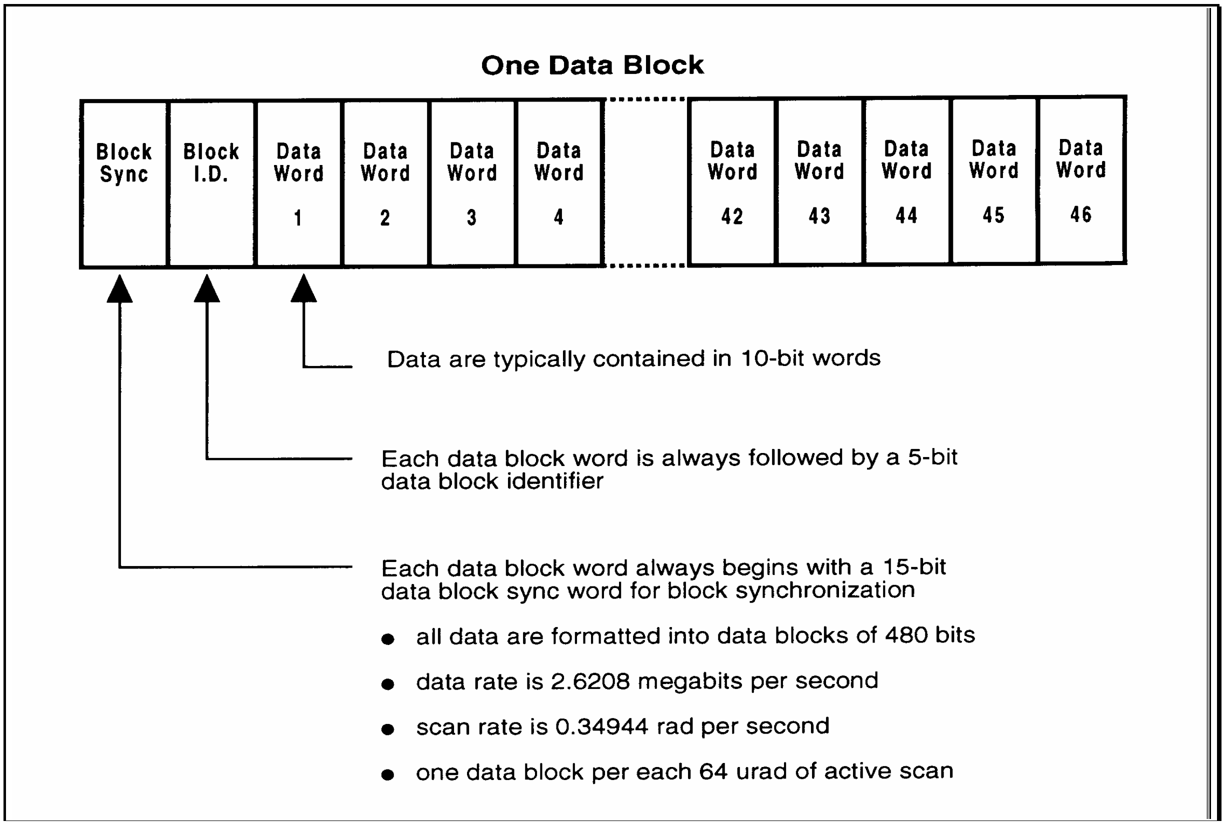


Figure 3-6 Typical Imager Block Transmission

Combinations of these six blocks are transmitted due to the different operational modes of the Imager.

3.2.4 Instrument Operational Modes

At any given time, each instrument is in one of six modes:

- Normal Scan Frame -- The instrument is scanning some portion of the earth/space within commanded rectangular scan limits.

- Priority Scan Frame -- Scanning in this mode is identical to scanning in a normal scan frame. However, a priority scan frame may be started when the instrument is in idle mode or when it is in normal scan frame mode. That is, a priority scan frame may interrupt a normal scan frame. If a priority frame interrupts a normal frame, then, when the priority scan frame is completed, the normal scan frame resumes from the point of interruption. In the Imager, upon returning to a normal frame from a completed priority frame, scanning is resumed at the beginning of the scan line that was interrupted.

- Star Sense/Sequence -- The instrument slews to just beyond the location of a star, and holds that position for a commanded period of time as the star drifts across the field of view.

- Space Look -- Based on the expiration of a timer, the ongoing operation, e.g., frame scan, is interrupted while the instrument slews to space, collects data for a fixed period of time, and resumes the interrupted operation.

- Blackbody Calibration -- Based on the expiration of a timer (10 minutes for the Imager and then only out of frame; 20 minutes for the Sounder, either in or out of frame), the instrument performs a space look followed by a view of the internal blackbody. Operationally the timer is disabled and blackbody calibrations are commanded approximately every 30 minutes for the Imager between scan frames, and every 15 minutes for the Sounder.

- Idle -- The instrument remains in idle mode whenever no other operation is being performed.

Any of the above modes can be terminated by a scan reset command. In response to a scan reset, the instrument slews to nadir, performs a blackbody calibration, returns to nadir, and enters idle mode, and performs system reinitialization.

3.2.5 Data Block Sequences

During the different operational modes, there are two basic sequences that are transmitted, scan sequence (Figure 3-7) and a scan reversal sequence (Figure 3-8). The scan sequence is used to transmit radiometric data samples. A scan consists of the following data blocks:

- Header Block

- Active Scan Blocks

- Trailer Block

The header block always precedes the active scan blocks containing radiometric data. The number of active scan data blocks varies depending on the current mode. Although the trailer is included in this scan sequence, some of the active scan blocks in the trailer are actually part of the scan reversal sequence.

The scan reversal sequence is generally output when the Imager has not been commanded to perform any scan, or when it is moving to or from a position where it will output radiometric data, such as when moving from one Imager scan line to the next. A scan reversal sequence consists of groups of data blocks, where each group consists of multiple blocks all of the same type. The data block group sequence in the scan reversal sequence is as follows:

- Active Scan Blocks
- Trailer Blocks
- Active Scan Blocks
- Telemetry Blocks

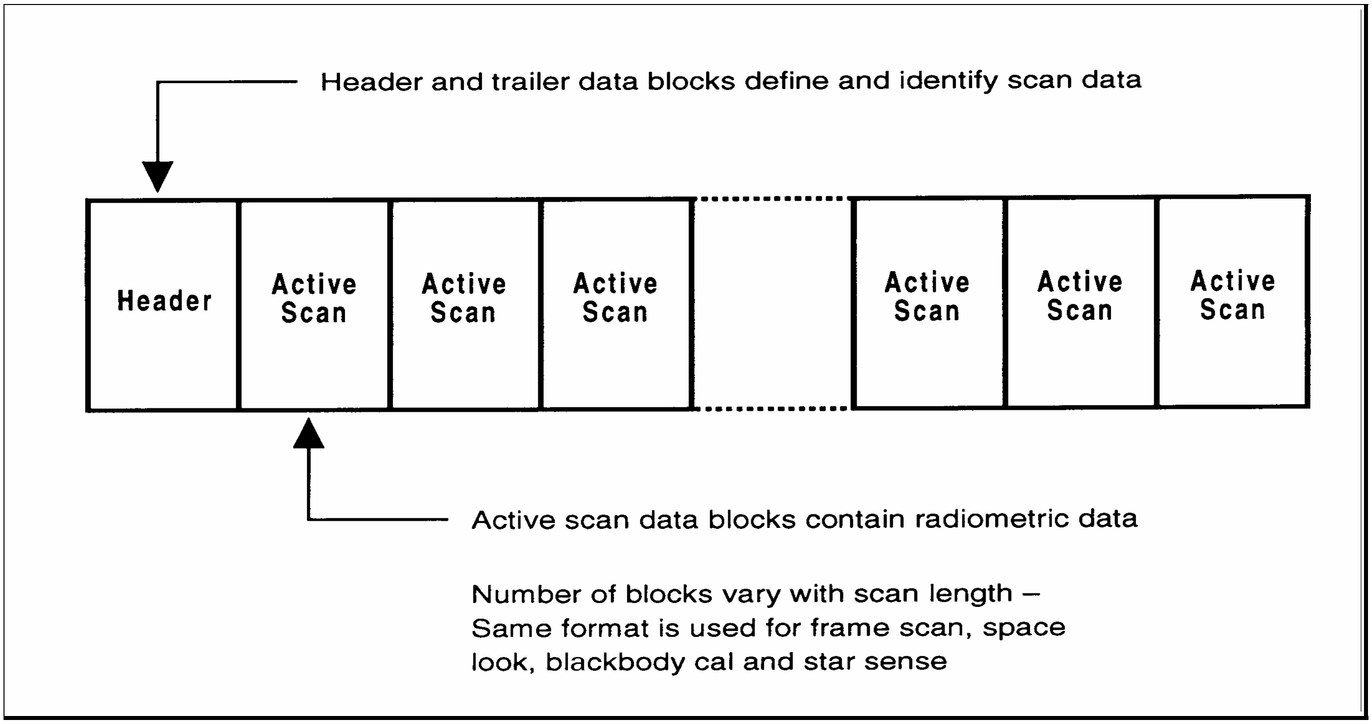


Figure 3-7 Typical Imager Raw Data Scan Line Format

- Fill Blocks
- ECAL Blocks
- Fill Blocks

Of these data blocks, the trailer and telemetry blocks always contain some valid information. The ECAL and the two separate portions of active scan blocks only contain valid information during certain modes. The ECAL data are valid only during the space look which precedes a BB calibration sequence. It is the responsibility of the scan reversal sequence to foretell what type of radiometric data is to be output in the next scan sequence. During normal or priority frame operation, the direction of the scan alternates with each scan from west-to-east to east-to-west. The radiometric data from each scan are output in a series of active scan data blocks. A header data block precedes each scan and provides control that defines the location of the scan within the frame along with other instrument status. When the end of the scan is reached, the

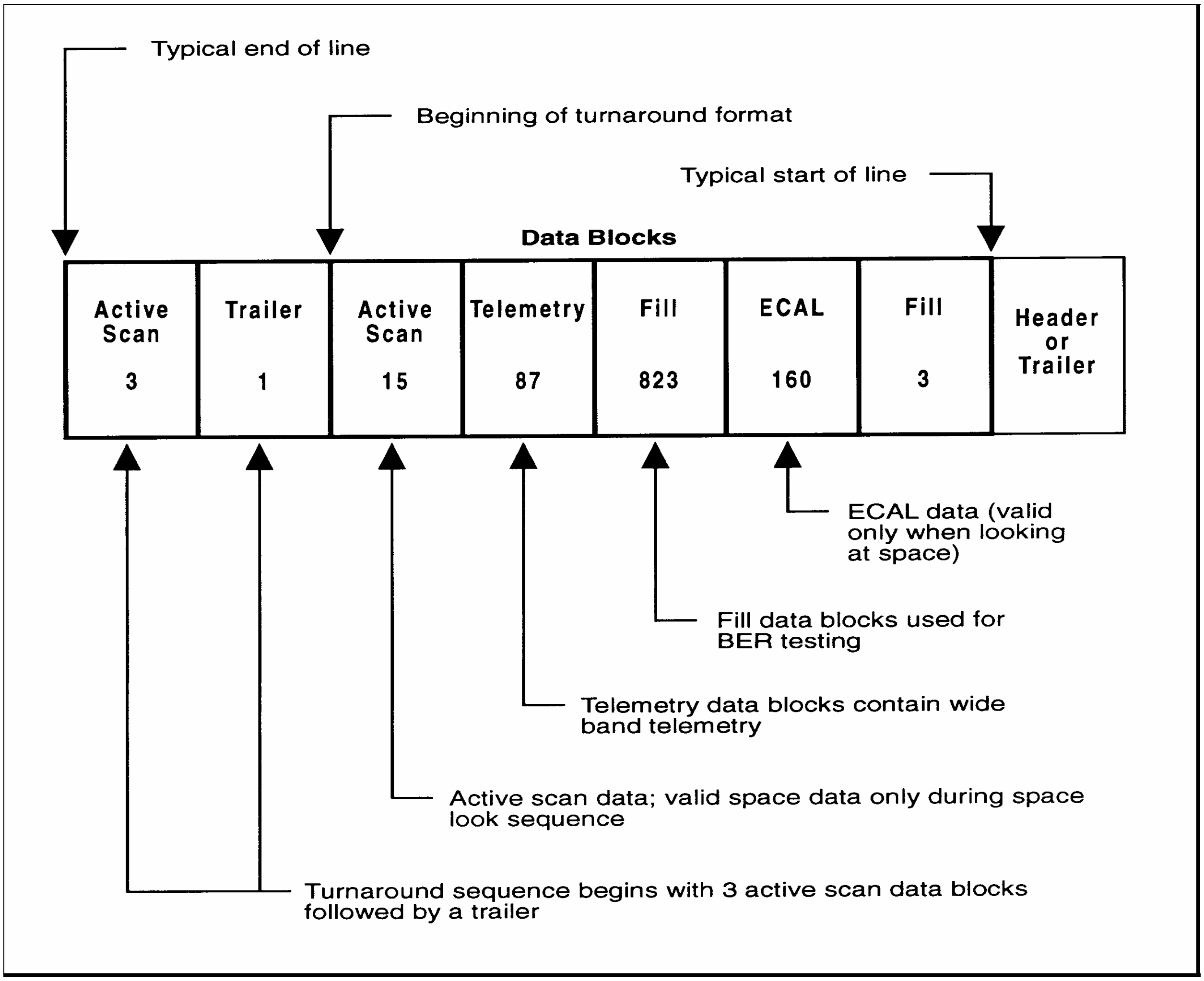


Figure 3-8 Imager Turnaround Sequence

Imager scan mirror performs a turnaround. During this sequence, the mirror steps to the next scan line while reversing its direction. Interruption of a normal and priority frame operation by a higher priority operational mode can only occur at the end of a scan prior to a turnaround; however, this feature is not used operationally. During the turnaround a scan reversal sequence as described previously is output. A scan reversal sequence is also transmitted whenever the instrument is slewing to a new location to perform a space look or star sense and when returning to the commanded destination. This sequence is also generated when the instrument is in the idle mode and when the mirror is settling prior to a star sense or BB calibration.

3.3 Sounder Instrument

The Sounder, shown earlier in Figure 3-1, consists of three major modules. The sensor assembly is mounted on a baseplate external to the spacecraft with shields and louvers for radiation and heat control. The electronics module provides a structure for mounting and interconnecting the electronics boards with proper heat dissipation. The power supply module converts and distributes spacecraft bus power to the Sounder circuits. The electronics and power supply modules are mounted on the equipment panel of the spacecraft.

The Sounder is intended to provide data for atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. The Sounder's multi-element detectors simultaneously sample four locations of the atmosphere. These four fields of view are sampled at 0.1, 0.2, or 0.4 second intervals, each provided output from the 19 spectral channels in each sample period. The infrared spectral definition is provided by a rotating filter wheel (see Figure 3-9) that brings selected filters into the optical path of the detector assembly. Filters in three spectral bands, longwave (12μm to 14.7μm), midwave (6.5μm to 11μm), and shortwave (3.7μm to 4.6μm), are arranged on the wheel for efficient use of sample time and optimal channel co-registration. The rotation of the filter wheel is synchronized with the stepping motion scan mirror. As commanded from the ground, the scan system will generate frames of any size or location using W-E stepping and E-W stepping of 280 μrads, with a N-S step of 1120 μrads until the desired frame is complete. The visible channel (0.67μm) is not part of the filter wheel but is a separate set of uncooled silicon detectors having the same field of size and spacing. These detectors are sampled at the same time as IR channels 3, 11, and 18, providing registration of all sounding data.

Radiometric quality of the Sounder is maintained by frequent (two minute interval) views of space for reference. Less frequent views of the full aperture BB occur every 20 minutes, interrupting the area sounding pattern as required. This establishes a high temperature baseline for instrument calibration in orbit. In addition, the amplifiers and data stream are checked during each BB reference cycle by means of a 16 level precision step signal applied to the amplifier input.

Control of the Sounder comes from a defined set of command inputs. The instrument is capable of full earth soundings; however, the completely flexible scan location capability will generally be used to sound selected areas of the earth. Area scan size may be as small as one sounding location. Sounding dwell at each step may be chosen to be 0.2 or 0.4 seconds in place of 0.1 second. Another option permits skipping scan lines to increase area sounding rate at a dwell time of 0.2 second per sounding.

The Sounder also provides star sensing capability. The time and location of a star are predicted very accurately and are related to the spacecraft location and optic field. From a set of this data, the ground system chooses a location and time that is convenient within the sounding scenario. The Sounder scan is pointed to any space location within its 21° N-S by 23° E-W view and the scan is stopped (This frame size is used for star sensing only. Sounding limits are 19° N-S by 23° E-W).

Table 3-5 Sounder Characteristics

Channel	Detector	Spectral Peak	Spatial Resolution	Purpose
1	Longwave	14.71µ	8 km (10 km step)	temperature sounding
2		14.37µ	8 km (10 km step)	temperature sounding
3		14.06µ	8 km (10 km step)	temperature sounding
4		13.64µ	8 km (10 km step)	temperature sounding
5		13.37µ	8 km (10 km step)	temperature sounding
6		12.66µ	8 km (10 km step)	temperature sounding
7		12.06µ	8 km (10 km step)	surface temperature
8	Midwave	11.03µ	8 km (10 km step)	surface temperature
9		9.71µ	8 km (10 km step)	ozone
10		7.43µ	8 km (10 km step)	water vapor sounding
11		7.02µ	8 km (10 km stpe)	water vapor sounding
12		6.51µ	8 km (10 km step)	water vapor sounding
13	Shortwave	4.57µ	8 km (10 km step)	temperature sounding
14		4.52µ	8 km (10 km step)	temperature sounding
15		4.45µ	8 km (10 km step)	temperature sounding
16		4.13µ	8 km (10 km step)	temperature sounding
17		3.98µ	8 km (10 km step)	surface temperature
18		3.74µ	8 km (10 km step)	surface temperature
19	Visible	0.67µ (visible)	9 km (10 km step)	cloud cover
	Star Sense	0.65µ (visible)	1 km equivalent	only for star sense

A separate linear array of eight silicon detectors is provided, having a nominal 229 μrad N-S coverage. As the star image passes through one or two detectors, the signal is sampled four times during each 0.1 second sounding interval. This signal is encoded to 13 bit resolution and is included in each Sounder data block for extraction and use at the ground station.

3.3.1 Sounder Detector Characteristics

The Sounder instrument acquires radiometric data from 19 distinct channels through the use of four separate detector arrays and a rotating filter wheel. The radiometric data are comprised of one visible channel, one star sense visible channel, and 18 IR channels. Sounder IR channels are divided into three logical channel classifications which are the longwave, midwave, and shortwave channel groups. These are referred to as channel groups since each one provides IR data from a number of channels assigned to a particular class of IR wavelengths (See Table 3-5).

The Sounder detector configuration consists of five sets of detectors provided on the Sounder instrument as illustrated in Figure 3-9. Detector sets and their general characteristics are as follows:

- Three sets of four IR detectors. Each set of detectors is dedicated to sampling one of the three IR channel groups. Each detector is square in shape and provides an IGFOV of 224 μradians corresponding to eight kilometers per side at the satellite subpoint.

- One set of four visible detectors comprising the visible channel. The detectors are square in shape, with an IGFOV of 224 μradians on a side, yielding a pixel of eight km per side.

- One set of eight visible detectors (used for star sensing) linearly ordered along the N-S axis. Each detector provides an IGFOV of 21.6μ radians.

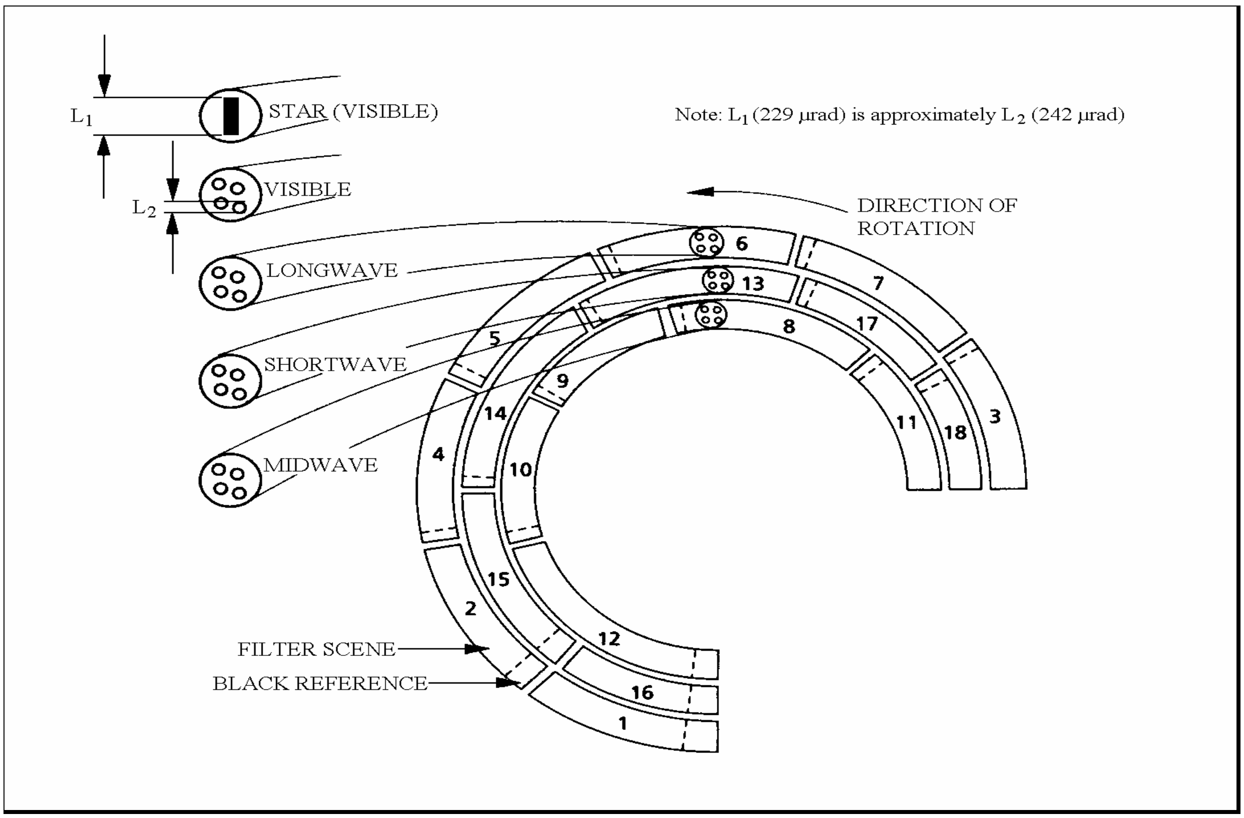


Figure 3-9 Sounder Filter Wheel

Channel assignments for the channel groups are as follows:

- Longwave - Channel 1 - 7

- Midwave - Channel 8 - 12

- Shortwave - Channels 13 - 18

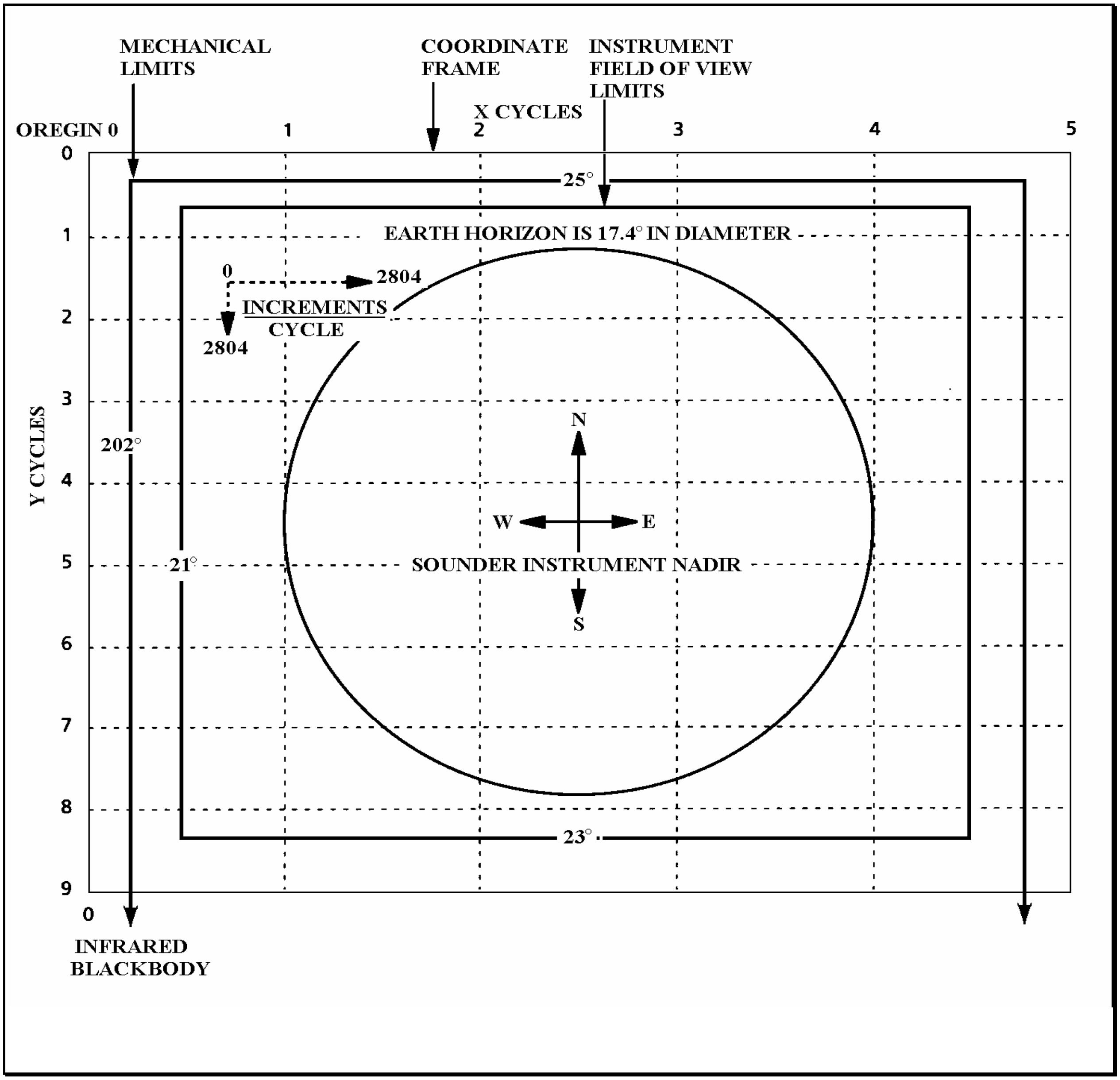
Table 3-6 lists the Sounder's channels and their performance characteristics. The particular wavelength characteristic of an IR channel within a channel group is provided by the Sounder's filter wheel. The filter wheel rotates within the FOV of the three sets of IR detectors, which are strategically located along the filter wheel to provide four samples for every channel each time the filter wheel completes one revolution. Therefore, 72 IR plus four visible samples are included in one Sounder data block each time the filter wheel completes one revolution. This occurs at a rate of once every 0.1 seconds.

Table 3-6 Sounder Spectral and Sensitivity Performance

Channel	Central Wavenumber (cm-1)	Half PWR BW (cm-1)	MAX BR Temp (°K)	NE△N (mW/m-2sr-1cm)	
				Specified	Actual
Long Wave					
1	680	13	260	0.66	1.99
2	696	13	260	0.58	1.27
3	711	13	270	0.54	1.09
4	733	16	290	0.45	0.89
5	748	16	300	0.44	0.79
6	790	30	315	0.25	0.38
7	832	50	330	0.16	0.23
Med Wave					
8	907	50	335	0.16	0.16
9	1030	25	310	0.33	0.19
10	1345	55	300	0.16	0.10
11	1425	80	285	0.12	0.09
12	1535	60	265	0.15	0.13
Short Wave					
13	2188	23	310	0.013	0.018
14	2210	23	295	0.013	0.014
15	2245	23	275	0.013	0.015
16	2420	40	330	0.0080	0.006
17	2513	40	335	0.0082	0.007
18	2671	100	335	0.0036	0.003
Visible					
19	14,367	1000	N/A	0.10%A	0.099%A

3.3.2 Sounder Scanning Characteristics

Like the Imager, the Sounder scans the selected image area in alternate directions on alternate lines. This area is defined by scan coordinates which relate to the latitude and longitude for the northwest corner and southeast corner (Figure 3-10). The Sounder, however, provides additional scanning features that are not employed on the Imager. This instrument provides the capability to dwell on a particular location for a pre-programmed time period. These dwell times are 0.1, 0.2, or 0.4 seconds for one, two, or four data blocks. The Sounder also employs two N/S



scanning modes referred to as the single and double-step modes. When in the single-step mode, the scan mirror steps the equivalent of one output scan line in the N-S direction each time an E-

W or W-E scan completes. In the double-step mode, the scan mirror steps two output scan
Figure 3-10 Sounder Coordinate Frame
lines in the N-S direction for each E-W or W-E scan. This mode is also referred to as the skip-line mode and will only scan an image area with a dwell of 0.1 second. The single-step mode of operation is considered the normal mode for the Sounder and can scan an image area at any of the three dwell selections.

A Sounder scan is acquired via a repeating sample-step-settle sequence which constitutes the 100 millisecond interval. During the 75 millisecond sampling portion of the interval the 19 channels of radiometric data are acquired. In the remaining 25 milliseconds the scanning mirror is stepped 280 micro radians in the E-W direction and allowed to settle before the start of the next interval. This procedure is repeated until the end of the scan line is reached. Upon reaching the end of the scan line, 100 millisecond interval is executed in which the mirror is stepped 1120 micro radians in the N-S direction. Following this, the acquisition of the scan line is initiated in the opposite direction using the same sequence. Figure 3-11 depicts the pixel pattern acquired for a short scan line.

3.3.3 Sounder Data Format

A raw Sounder data block is transmitted during the time it takes for the filter wheel to complete one revolution. Unlike the Imager, there is no concept of multiple data block types which are formatted differently as a function of their data block content. All of the raw data from the Sounder are contained in one Sounder block format. Each block contains 250 16 bit words and is transmitted at a rate of 40 kbps. The following describes the data contained in the Sounder data block:

- Synchronization code (4 words)- used by the ground equipment to synchronize the incoming data.

- Header data (6 words)- contains instrument command status and identification.

- Sounding data (76 words)- consists of radiometric data from the visible channel and the 18 IR channels. Four samples are collected from each channel and formatted into this data block. The radiometric data in this field are produced from scans of the earth FOV, space look, or BB calibration sequences.

- Star Sense data (32 words)- four samples from each visible star detector.

- Sounder telemetry (69 words)- various instrument telemetry values.

- Scan position (4 words)- report of the current position of the Sounder scan mirror.   E-W/N-S scan positions.

- Attitude/Orbit Control Electronics (AOCE) data (11 words)-data defining the attitude of the spacecraft.

- Scan control (16 words)- consists of the echoed contents of the Sounder command registers along with additional status defining current Sounder operations and data validity.

- Spare (32 words)

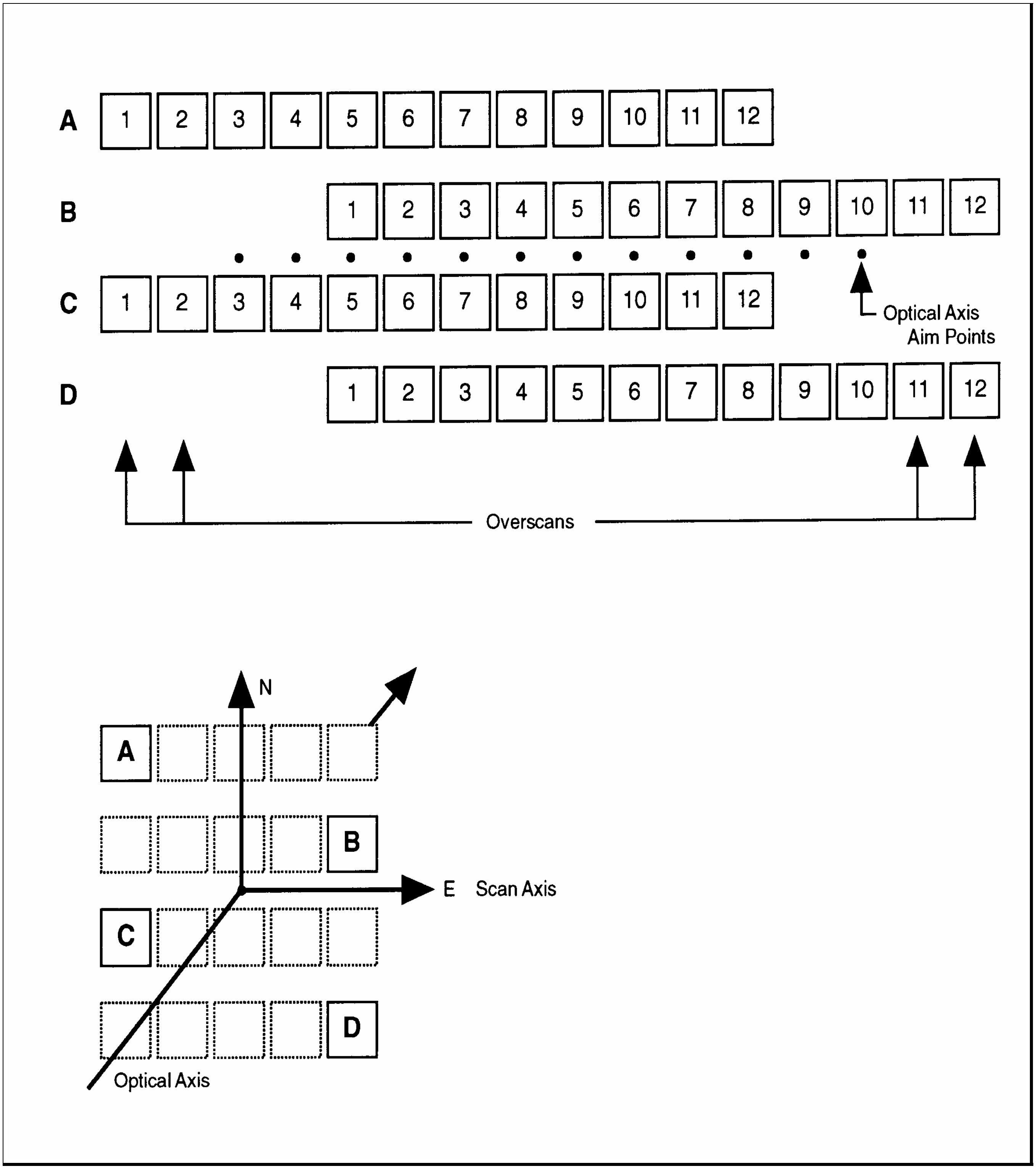


Figure 3-11 Sounder Scan Line Pixel Pattern

3.3.4 Sounder Scan Sequences

During normal or priority frame operation, a series of Sounder data blocks is output with valid sounding data when scanning the defined image area between west and east frame limits. The Sounder data block format is shown in Table 3-7. Like the Imager, the Sounder performs a turnaround when the programmed west or east frame limits are reached and prior to the next scan direction. Invalid sounding data are indicated in the scan control status for data blocks output during the turnaround. This sequence is detected by the OGE by checking the N/S step flag which is also provided in the scan control status and is active whenever a step occurs. As in the Imager, the normal mode of operation can be interrupted by higher priority operation. However, the Sounder checks for interruptions after sounding each location. Whenever the Sounder is slewing to begin a new operation, a series of valid data blocks is output. A slew flag provided in the scan control status allows the OGE to detect the scan mirror slew. During this period, the only data that are valid are the command and scanner status, telemetry, and AOCE.

Table 3-7 Sounder Data Format

SYNC 4	TLM 1	COMMAND STATUS, ID 3	SCAN POSITION 4	BB & SPACE TIMERS 2	COMMAND ECHO 16	STAR SENSE #2 8	CHANNEL 1 (LW) 4
CHANNEL16 (SW) 4	TLM 17	CHANNEL12 (MW) 4	CHANNEL 2 (LW) 4	SPARE 1	TLM 7	SPARE 1	CHANNEL15 (SW) 4
SPARE 1	TLM 3	SPARE 1	CHANNEL 3 (LW) 4	STAR SENSE #2 8	CHANNEL 8 (MW) 4	SPARE 3	TLM 7
SPARE 1	CHANNEL14 (SW) 4	CHANNEL 4 (LW) 4	SPARE 1	TLM 8	SPARE 1	CHANNEL11 (MW) 4	SPARE 1
TLM 6	SPARE 1	CHANNEL 5 (LW) 4	CHANNEL13 (SW) 4	SPARE 1	STAR SENSE #3 8	SPARE 1	TLM 3
SPARE 1	CHANNEL10 (MW) 4	CHANNEL 6 (LW) 4	CHANNEL17 (SW) 4	SPARE 1	TLM 18	SPARE 1	CHANNEL 7 (LW) 4
SPARE 6	CHANNEL18 (SW) 4	CHANNEL 9 (MW) 4	STAR SENSE #4 8	CHANNEL20 (VIS) 4	SPARE 1	AOCE 11	SPARE 7
BLANK 1							

3.4 GOES VARiable Format

This section defines the structure and content of the GOES I-M VARiable (GVAR) processed instrument data transmission format. This format is primarily used to transmit meteorological data measured by the Imager and Sounder instruments. Additionally, parameters associated with the measuring instrumentation are transmitted in this format, as are auxiliary products.
The GVAR format has its origins in the Operational VAS Mode AAA (Triple A) format. The AAA format featured a fixed length format composed of 12 equal size blocks. These blocks were transmitted synchronously with the spin of the earlier GOES, i.e., one complete 12-block sequence occurred for each rotation of the satellite.

With the advent of the three-axis stabilized GOES, employing separate and independent sounding and imaging instruments, the range and flexibility of satellite operations are increased. The use of a fixed length transmission format would have required that operational limitations be placed on the satellite's capabilities. The GVAR format was developed to permit full use of the new capabilities while maintaining as much commonality with AAA reception equipment as possible. GVAR is generated by the Sensor Processing System (SPS), a portion of the OGE. Each SPS, one per spacecraft, generates a separate GVAR data stream. GVAR does not contain an earth location array for the Imager due to bandwidth limitations. An earth location array is provided with GVAR Sounder data that maps each pixel into a specific latitude-longitude point. An algorithm to convert Imager scan line and pixel coordinates to Earth latitude-longitude is available in software programmed in Fortran 77. The software, and its accompanying documentation, known as the Earth Location User's Guide (ELUG), was produced by Integral Systems, Inc. (ISI - Lanham, Maryland).

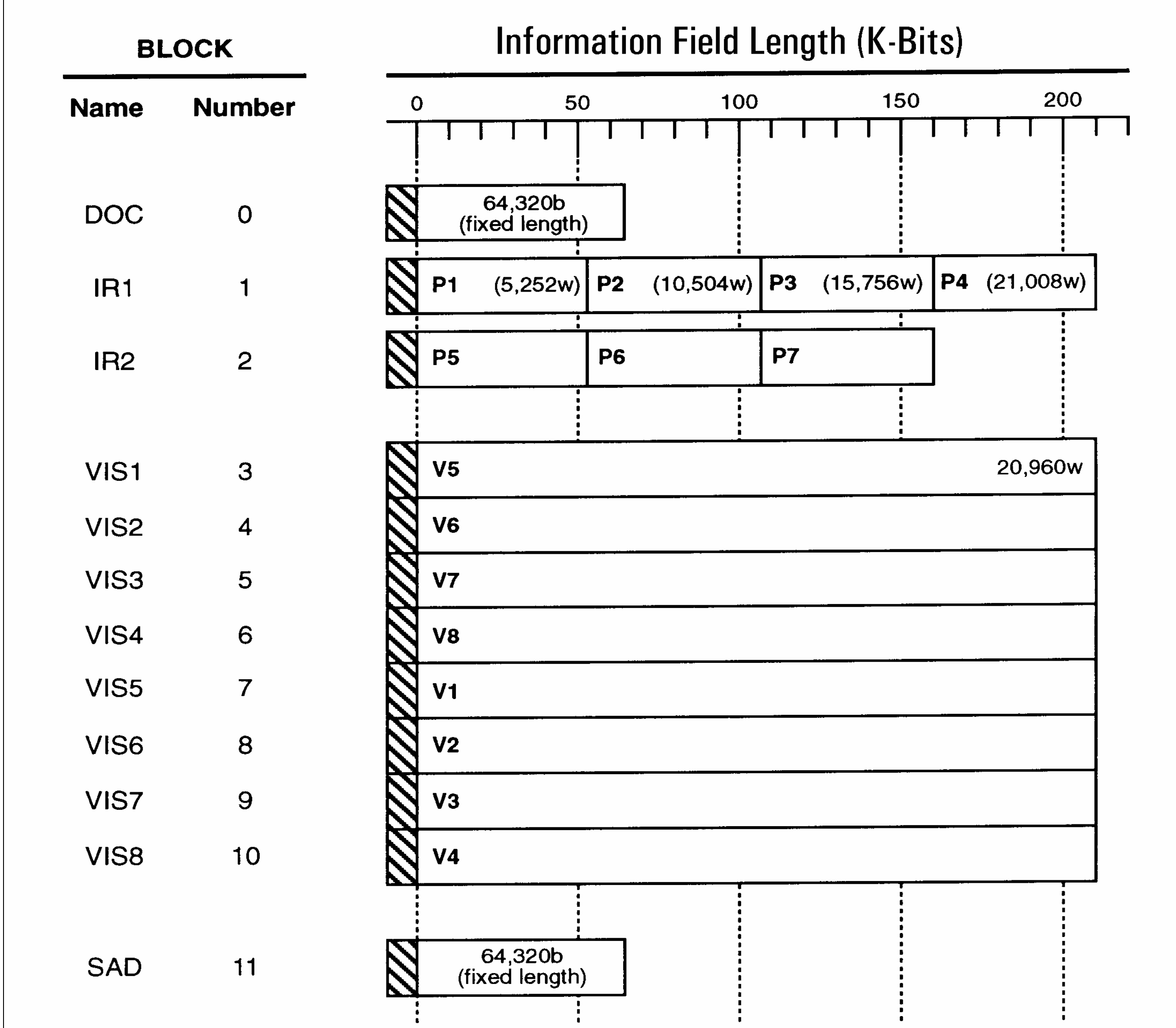
GVAR data words are in Gould floating point format.

3.4.1 GVAR Scan Format

The GVAR transmission sequence is depicted in Figure 3-12. It consists of 12 distinct blocks numbered 0 through 11. Blocks 0 through 10 are transmitted as a contiguous set for each Imager scan swath (eight lines). Block 10 will be followed by a variable number of Block 11's according to what data are available for transmission. Each GVAR Block is transmitted with a 10,032-bit synchronization code, a 720-bit header (3 copies of a 240-bit sequence), the variable length information field containing 1-4 records and a 16-bit Cyclic Redundancy Check (CRC) trailer. Blocks 0 and 11 are fixed, equal length blocks of 64,320 bits each in the information field.

The information fields in Blocks 1 through 10 vary in length directly in accordance with the width of the Imager scan line. The formula for computing the total number of bits downlinked in GVAR Blocks 0-10, including synchronization fields, headers and trailers, in a single scan is 185,168 + 390 x N, where N is the number of mirror 4-pixel groups (4 x 16 μr pixels) in the scan line. The formula for computing the number of words in the Information Fields only in GVAR Blocks 0-10 for a single scan is 8,280 + 39 x N, yielding a range of 8,280 to 212,484 words. Table 3-8 provides further details about the structure of the GVAR format information field.

The Block 1-10 formats are shown with a maximum of 5,236 4-pixel groups, corresponding to a 19.2° field of view (FOV), an operational limit imposed by the shield around the optical port. This accommodates scans wider than a full disc (earth edge to earth edge at the equator is 17.4°). Operationally, the instruments are limited to a N-S scan of 19° for earth viewing and 21° for star viewing. These scan limits would normally be earth centered, but not necessarily centered within the 23° x 25° instrument aperture (see Figure 3-10). A North-South scan of 19° equates to 1480 swaths (11,840 visible lines) for the Imager and 296 swaths (1184 lines) for the Sounder.



LEGEND

b = bits

w = 10-bit words

Synch 10,032b
+3 x 240 header
= 10,752b

NOTES:

1. Each Imager record (P1 - P7 in Blocks 1 - 2 and V1 - V8 in Blocks 3 - 10) includes a leading 16w documentation line.
2. Each block is appended with a 16b CRC trailer (not shown).
3. Blocks 1 - 10 are shown in maximum length.

Figure 3-12 GVAR Scan Format

Block #	Contents	# of Records	Record Structure	Record Length Formulation	Record Length Range	Block Length Range
0	Documentation	1	8,040 8-bit words	64,320 bits	64,320 bits	64,320 bits
1	IR Detectors P1-P4	4	Doc[1] + Data - I[2]	16+ N[4] words[5]	17 - 5,252 wrds	68 - 21,008 wrds
2	IR Detectors P5-P7	3	Doc + Data - I	16+ N words	17 - 5,252 wrds	51 - 15,756 wrds
3	Visible Detector V5	1	Doc + Data - V[3]	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
4	Visible Detector V6	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
5	Visible Detector V7	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
6	Visible Detector V8	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
7	Visible Detector V1	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
8	Visible Detector V2	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
9	Visible Detector V3	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
10	Visible Detector V4	1	Doc + Data - V	16 + 4 N wrds	20 - 20,960 wrds	20 - 20,960 wrds
11	Sounder/Auxiliary Data	1	10,720 6-bit words or 8040 8-bit words or 6,432 10-bit words	64,320 bits	64,320 bits	64,320 bits

Notes
1. Each Imager record begins with 16 10-bit words of line documentation.
2. In a scan line, i.e. in a Block 1-2 set, each Data-I contains the same number of pixels and therefore each IR record is the same length, namely, one word per pixel times one pixel-per-group = one word-per-group.
3. In a scan line, i.e. in a block 3-10 set, each Data-V contains the same number of pixels and therefore each Vis record (identical with theVis block) is the same length, namely, one word-per-pixel times four pixels per group = 4 words-per-group.
4. Imager operational scanning range is 1 to 5,236 4-pixel groups (64 μr pixels) in a scan line.
5. Blocks 1-10 contain 10-bit words.

:

3.4.2 Imager Data--Blocks 0-10

During any frame the Imager detectors will be active in either a primary or a redundant (corresponding to Side 1 and Side 2 of the instrument electronics) configuration as illustrated in Figure 3-3. In both configurations the visible detector group (V1-V8) and one of the two infrared groups are active. The resultant swath on the earth's surface generated by either of these two configurations is misaligned in the infrared and visible bands. This misalignment is removed in the GVAR format by lagging data from appropriate detectors. The lagged data is combined with detector data from a subsequent scan, forming earth scan swaths in which the visible and infrared detector data are coincident.

In the primary detector configuration, data from visible detectors V5 through V8 is lagged. This lagged data will be combined with infrared (P1 through P7) and visible (V1 through V4) detector data gathered during the next scan to create a GVAR block sequence. For the redundant detector configuration, data from visible detectors V5 through V8 and infrared detectors R1 through R7 are lagged. The lagged data are combined with data from visible detectors V1 through V4 gathered during the next scan to create a GVAR block sequence. In the cases of scan-type calibration sequences of space look and blackbody, no data lagging is performed.

Co-registration of the VIS and IR detectors is performed on the ground by the SPS. Co-registration of the VIS and IR detectors is necessary because of thermal distortion of IR FOV relative to VIS FOV. Additional leading/lagging of data are possible depending on the co-registration requirements, e.g., ±8 visible pixels N-S, ±64 visible pixels E-W.

3.4.3 Non-Imager Data--Block 11

A scan by the Imager instrument will result in the generation of GVAR Blocks 0-10. The transmission of Blocks 0-10 will be followed by the transmission of a variable number of Block 11's (0 to n) according to the nature of the data available for transmittal.

When the Imager is actively scanning, there is not always sufficient time to transmit all of the generated Block 11's between consecutive Block 0-10 sets. There is always sufficient time for all Sounder data Block 11's generated during simultaneous operation of both instruments. The number of Block 11's that appear contiguously is the number there is time for, i.e., until the next Block 0-10 set is ready for output.

The total effective rate of generation of nonfill Block 11's is about 80 per minute (1.3 per second) when both instruments are actively scanning. A full width Imager scan takes 1.16 seconds including turnaround. So, while Block 11's are being generated at about the same rate as Block 0-10 sets, and while it is true that the SPS will generate fill Block 11's in otherwise idle time between Block 0-10 sets, it is NOT true that a Block 11 will necessarily appear every few Block 0-10 sets. Rather, because the SPS buffers many scan lines of Imager data before assembling and outputting GVAR Block 0-10 sets, the GVAR data stream can contain many consecutive Block 0-10 sets without any intervening Block 11's.

3.5 Imaging and Sounding Support System Functions

An overview of some of the support system functions as it relates to the GOES data has been included in this section. A full description of the support functions are found in other NESDIS documentation referenced in Appendix E.

3.5.1 Relativization/Calibration/Normalization

All radiometric image data produced by the Imager and Sounder instruments must undergo relativization, calibration, and normalization processing. The relativization function was added to the GOES data stream processing in spring of 1996 and occurs before the data are normalized. The calibration/normalization function can be described in terms of those functions that occur during on-line processing and those that are performed during non real-time operating modes.

3.5.1.1 Relativization

The signal from any scene is the instrument's output while viewing the scene minus its output when viewing space. Up until the spring of 1996, however, the data in the visible sensors were transmitted in absolute counts (i.e. scene counts plus space counts) in keeping with the practice with other NOAA satellites past and present. It was observed that visible imagery from the GOES satellites experienced occasional incidents of severe striping believed to be caused by space clamp noise in one of the eight visible detectors.

3.5.1.2 Real-Time Calibration/Normalization

The real-time calibration and normalization of Imager and Sounder data can be divided into a continual application process and a periodic calibration coefficient generating process (See Figure 3-13). In the real-time continual application process, factory measured detector response characteristics together with inflight measurements made while viewing space and BB targets are used by the SPS to convert raw Imager and Sounder sensor data to theoretical target radiance. The visible data normalization is performed so that all detectors of the same instrument produce the same readings when viewing an area of uniform brightness. This is done to prevent image striping. The SPS maintains a current calibration data base for each satellite to be used in the real-time calibration of raw Imager and Sounder sensor data. In addition, the data base contains the current calibration coefficients for the IR channels, which are based on the space and BB measurements. The periodic calibration coefficient generating process is performed to insure the best possible coefficient values are used when calibrating Imager and Sounder IR data.

The Imager and Sounder in the spacecraft perform periodic inflight sequences that support IR calibration processing in the OGE. The instrument information generated includes space look, blackbody calibration, and Electronic Calibration (ECAL). A space look sequence provides radiometric data for all detectors from a view of space located beyond the edge of the Earth. For the Imager, a space look occurs every two minutes, based on the expiration of an internal timer. At the appropriate time, the Imager suspends its current process, slews to space, collects data, and then resumes the interrupted operation. This process, however, can occur at the end of any scan line, or during the idle mode. For the Sounding instrument, a space look is performed every two minutes. In normal and priority modes, after each location is sounded, a timer is examined to see if a space look is necessary. The Sounder then saves the current address and slews to the space location. Upon completion, the Sounder checks to determine if ECAL and blackbody calibration should be performed. If not, the instrument returns to the original location.

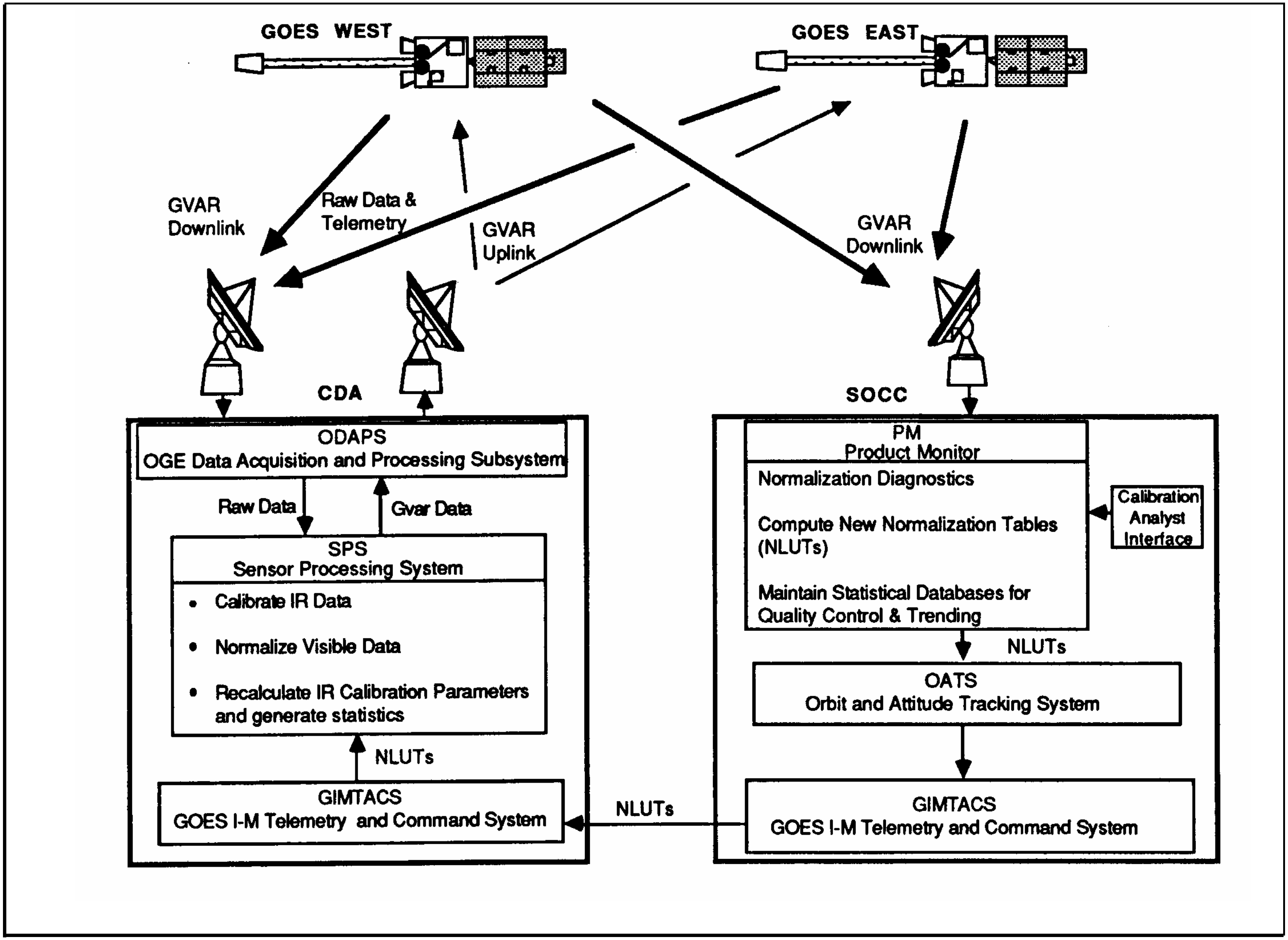
A blackbody calibration consists of data samples from a view of the instrument's internal blackbody. In the Imager, the blackbody calibration is normally performed every 10 minutes. At the most, the Imager may go 25 minutes between blackbody views. The blackbody calibration process does not interrupt any other operation and cannot occur during a frame. In the Sounder, a blackbody calibration sequence is performed after every 20 minutes. For both the Imager and Sounder, the in-flight calibration data generated, together with the raw spacecraft sensor data, are transmitted to the OGE at the CDA for use in IR calibration processing. The calibration data, ECAL, space look, and blackbody measurements are extracted from the Imager and Sounder data, and used for calculation of the IR calibration equations.

Upon completion of the real-time data processing, the SPS formats the calibrated infrared and normalized visible Imager and Sounder data into GVAR processed data streams. The newly computed IR calibration coefficients and the space look and blackbody statistics generated during their calculation are also included in GVAR for transmission to the OGE Product Monitor (PM) and the user community (Figure 3-13).

3.5.1.3 Non Real-Time Calibration/Normalization

The non real-time calibration/normalization process includes the generation of visible normalization coefficients and the production of short and long term history files of data and archive.

The visible Normalization Look-Up Tables (NLUTs) are used in the SPS for the normalization of Imager and Sounder visible data. These NLUTs are generated periodically through an analyst-interactive histogram matching technique performed with the PM.


GOES WEST
GOES EAST
GVAR
Downlink
Raw Data &
Telemetry
GVAR
Uplink
GVAR
Downlink
CDA
SOCC
ODAPS
OGE Data Acquisition and Processing Subsystem
Raw Data
Gvar Data
SPS
Sensor Processing System
• Calibrate IR Data
• Normalize Visible Data
• Recalculate IR Calibration Parameters and generate statistics
NLUTs
GIMTACS
GOES I-M Telemetry and Command System
NLUTs
PM
Product Monitor
Normalization Diagnostics
Compute New Normalization Tables (NLUTs)
Maintain Statistical Databases for Quality Control & Trending
Calibration Analyst Interface
NLUTs
OATS
Orbit and Attitude Tracking System
GIMTACS
GOES I-M Telemetry and Command System

To generate new NLUTs, a raw visible data transmission from the SPS is scheduled. This is done by disabling the normalization process in the SPS. From the displayed raw image data, for NLUT cumulative histograms are automatically generated and displayed. A reference detector is selected generation. New NLUTs are then calculated for the other detectors by matching the target and reference detector's cumulative histograms. Once approved by the analyst, the newly generated NLUTs are sent to OATS and transmitted to the SPS, through GIMTACS, for use.

3.5.2 Image Navigation and Registration

The Imaging and Sounding functions of the GOES satellites demand accurate control of the satellite's orbit and attitude. The Image Navigation and Registration (INR) function performed by the satellite system has two primary purposes. The first is navigation, i.e., being able to determine the Earth latitude and longitude of each pixel. The second is registration, which is maintaining the pointing accuracy of each pixel to the same Earth location from one image to another. The con-cept of image registration implies that over the registration interval, all images are made to appear as though they were taken from a satellite at a fixed position relative to the Earth and with instru-ments having a fixed optical direction with no variations. Navigation and Registration combine to result in fixed gridding; the preassignment of latitude and longitude to each pixel for images to be taken of the same Earth area over a 24 hour interval. Table 3-9 lists the image navigation and registration requirements.

The basic spacecraft navigation functions include ranging, star sensing, and landmarking to provide the principle means of establishing the spacecraft position with respect to the Earth. The computation of the spacecraft range establishes the spacecraft position to usually within 10 meters. The star viewing process is done by both the Imager and Sounder on a routine basis. The sensed data are then compared to a catalog of 850 stars whose positions are based on an epochal star catalog. Landmarking is a daytime operation where the observation is the determination, on the ground, of observing instrument's line and pixel location of an earth landmark with a known latitude and longitude.

3.6 GOES Operational Scanning Modes

The GOES Imager and Sounder operations provide meteorological imagery and sounding data coverage that meet NWS requirements. The following section describes the three operational modes which are employed under specific static or evolving weather conditions**.** In Routine Scan Mode, there will be four sectors an hour over the continental U.S. from each satellite. Contact the NCDC Satellite Data Services Group to determine if additional satellite imagery were made during times of severe or significant weather events for your study area.

3.6.1 GOES Imager/Sounder Standard Scan Sectors

The Imager/Sounder scan areas (frames), their boundaries, scan durations, including space looks, and beginning scan times for GOES-East and GOES-West are given in Tables 3-10 and 3-11, respectively. These sector definitions apply when the satellite is in the **routine** mode of operation and are subject to change. Examples of image sectors on a typical 8 x 10 inch print are provided in Chapter 4. Note that for greater areal coverage, the resolution is reduced by several factors.

However, there are no size (limited only by the scheduled frame size) and resolution restrictions on digital media. The Sounder schedule varies between summer and winter season. Current Imager/Sounder schedules may be obtained from the NOAA Satellite Information System (NOAASIS) Bulletin Board (See Appendix B for URL).

Table 3-9 Image Navigation and Registration Requirements

	DAYTIME (+/- 8 hours from local noon)	NIGHTTIME (+/- 4 hours from local midnight)
Image Navigation Accuracy (km at nadir)	4	6
Registration within an image 25 minute (micro radians)	42	42
Registration between repeated images (micro radians) - 15 min - 90 min - 24 hour - 48 hour	42 84 168 210	70 105 168 210
Channel-to-channel co-registration (micro radians)	28	28
Fixed Grid Duration (hour)	28	24
Navigation Accuracy (km at nadir)	10	10
Registration within a sounding 120 minute (micro radians)	84	112
Registration between soundings 24 hours (micro radians)	280	280
Channel-to-channel co-registration referred to channel 8 (micro radians)	22	22

3.6.2 Imager Operational Scanning Modes

The imaging of a specific group of standard sectors executed in a particular sequence constitutes a GOES imaging operational scenario. The NOAA NESDIS/NWS Study Group has defined a set of sectors of the imager full-earth field of view and three imager operational scenarios that satisfy NWS requirements for the collection of Imager data. The operational modes are designated Routine, Rapid Scan and Full Disk. Tables 3-10 and 3-11 depict GOES in Routine operational mode.

The three imaging modes correspond, respectively, to operation of the GOES system under normal or typical meteorological conditions, operation under conditions of one or more evolving severe weather or tropical storm conditions, and operation during periods of degraded GOES system performance, such as during system component failure or maintenance, or during the spring and fall eclipse season when GOES scanning is halted to avert solar intrusion on the radiometer.

In the GOES routine schedule scan mode, two views at approximately 15 minute intervals of the CONUS (GOES-East) or PACUS (GOES-West) are provided in a half hour period. A northern hemisphere scan is also included in the 30 minute cycle.

Table 3-10 GOES-EAST Scan Sectors in Routine Mode

Frame Name	Boundaries	Duration (mm:ss)	Scan Times(UTC)
IMAGER SECTORS			
Full Earth	Earth Edge	26:16	0245, 0545, etc
Extended. N. Hemisphere	20S-66N/45-120W	14:16	xx15, xx45
Southern Hemisphere	20-50S/30-120W	4:53	xx10, xx40
CONUS (Continental US)	14-60N/60-125W	4:45	xx00, xx30
SOUNDER SECTORS			
Full Regional N Hem.	23-53N/64-121W	49:00	xx05 (hourly)
Limited Regional N Hem.	26-50N/66-120W	38:00	4X daily
Full Regional S Hem.	27-41S/64-120W	49:00	4X daily (winter)
Mesoscale Tropics	11-23N/93-115W	12:00	4X daily (summer)

Table 3-11 GOES-WEST Scan Sectors in Routine Mode

Frame Name	Boundaries	Duration (mm:ss)	Scan Times(UTC)
IMAGER SECTORS			
Full Earth	Earth Edge	26:10	0000, 0300, etc
Northern Hemisphere	0-66N/90W-170E	9:00	xx00, xx30
Southern Hemisphere	0-45S/115W-170E	7:00	xx22, xx52
PACUS	12-60N/90-175W	5:00	xx15, xx45
SOUNDER SECTORS			
Regional (ASOS1)	22-50N/128-175W	32:00	xx24 (hourly)
Regional (ASOS2).	21-50N/109-125W	20:00	xx01 (hourly)
Limited (ASOS2)	31-50N/128-175W	20:00	4X daily
Hurricane Sector (Area1)	06-23N/102-137W	32:00	4X daily (summer)
Hurricane Sector (Area2)	06-23N/137-178W	32:00	4X daily (summer)

During GOES Rapid Scan Operations (RSO), four views of the CONUS (GOES-8) or Sub-CONUS (GOES-9) are provided at approximately 7.5 minute intervals in a half hour period. A northern hemisphere scan for both GOES is also included in the 30 minute cycle. This yields eight views of the continental U.S. per hour.

During GOES Super Rapid Scan Operations (SRSO), approximately 10 one-minute interval scans are provided every half hour using prescribed 1000 km x 1000 km sectors. The remaining time in the half hour cycle is devoted to scans of the northern hemisphere and CONUS (GOES-East) or Sub-CONUS (GOES-West).

When GOES RSO or SRSO is utilized, most of the southern hemisphere is not scanned.

3.6.3 Sounder Operational Scanning Modes

The sounder scan areas, their boundaries, and the time to sound, including space looks, is given in Tables 3-10 and 3-11 for GOES-EAST and GOES-WEST, respectively. The scan durations in the tables do not include either star sequence or BB calibration operations. Those operations may be scheduled between frames at approximately half hour intervals or may be allowed to occur during frame scanning. The mesoscale definitions in the tables are representative of a number of mesoscale frames that may be defined. These sector definitions are for illustration purposes only and are subject to change. During Full Disk or Routine mode operations of the Imager, the Sounder executes a series of sectors over a six-hour cycle of which the Full Regional-Northern Hemisphere sector is the primary sector scanned. At six-hour intervals, the Sounder changes from scanning the Full Regional-Northern Hemisphere sector to scan either the Full Regional-Southern Hemisphere sector (December-May for GOES-EAST) or the Limited Regional and a selected mesoscale sector (June-November for GOES-EAST and WEST). During Rapid Scan mode operation of the Imager, the Sounder will scan a selected mesoscale sector, interrupted at three-hour intervals by the Limited Regional and mesoscale sector sequence.

The NESDIS Office of Research and Applications, Forecast Products Development Team has specified a set of sounder scanning scenarios. The basic GOES-EAST sounder sector, Full Regional Northern Hemisphere, covers the continental United States and the adjacent Atlantic and Gulf of Mexico areas. The Limited Regional sector is similar to the Full Regional-NH sector but somewhat reduced in size to provide a shorter scan time to allow time for a mesoscale sounding. The mesoscale sectors are variable in boundary definition as appropriate for severe weather or tropical storm areas. The basic GOES-WEST sounder sectors, WEST ASOS1 and WEST ASOS2, cover the western third of the continental United States and adjacent Pacific Ocean every hour, respectively. The Limited ASOS2 sector occurs every six hours over a smaller region of the northern Pacific Ocean. During the hurricane season, the WEST ASOS2 sector is replaced by two consecutive hurricane sectors every six hours (see Table 3-11).

Chapter 4 – GOES Data and Products

4.0 Introduction

The NCDC environmental satellite database is an element of the overall National Environmental Satellite Data and Information Service (NESDIS) environmental database. There are over 230 terabytes of digital satellite information and countless hard copies of satellite imagery collected from the National Oceanic and Atmospheric Administration (NOAA) operational environmental satellites. The GOES environmental satellite data base is a unique source of data and information containing film imagery and digital data collected since the beginning of the GOES program in the early 1970’s. Table 4-1 provides a listing of geostationary satellites, launch dates, archive dates, and instrument data archived at NCDC.

4.1 Ordering Satellite Data and Products

Requests for data are serviced by the Satellite Services Group located at NCDC in Asheville, North Carolina. In light of the explosive activity on the Internet, NCDC’s satellite services are meeting the needs of the research and educational community by providing an increasing amount of qualitative and quantitative products on-line free of charge.

To meet the varied demands of its worldwide user community, NCDC offers GOES data in a variety of formats. Users requesting satellite data should make every effort to supply as accurate and as much information as possible concerning their needs. Frequently, orders contain ambiguous information, which results in delays or improper filling of orders. The following points should be considered and such information furnished in preparing orders for data. Users are encouraged to speak directly with the user service personnel to discuss their individual requirements.

After identifying a particular image or set of images, the final product supplied to the requester can be in several formats. Please specify as much of the following information as possible:

- Date(s) of interest
- Time(s) in UTC (+5 hours from EST)
- Type of Product (i.e. colorized, black & white, mapped, full disk, sector, etc.)
- Geographic Areas (best described using lat/long coordinate box)
- Satellite id (if known)
- Channel (i.e. visible, infrared, or water vapor)
- Resolution (1 km is best possible for the visible channel and 4 km is best possible for IR)
- Physical features(s) to be shown or enhanced
- Map projection (i.e. Mercator, polar stereographic, or Lambert-conformal)
- Political and/or state boundaries
- Media type: hard copy or digital (please enquire for details for options)

Table 4-1 GOES Launch Dates and Periods of Data Acquisition

Satellite Name	Launch Date	Period of Record Archived (MM/DD/YY)	Archive Form*	Instrument Data archived at NCDC
ATS-1	12/06/66	01/01/67 - 10/16/72	I	Spin Scan Cloud Camera
ATS-3	11/05/67	03/02/68 - 09/02/74	I	Spin Scan Cloud Camera
SMS-1	05/17/74	06/27/74 - 01/07/76	I	VISSR
SMS-2**	02/06/75	03/10/75 - 08/04/81	I/D	VISSR
GOES-1	10/16/75	01/08/76 - 03/15/80	I/D	VISSR
GOES-2	06/16/77	08/15/77 - 09/15/80	I/D	VISSR
GOES-3	06/16/78	07/13/78 - 03/05/81	I/D	VISSR
GOES-4	09/09/80	03/05/81 - 06/01/83	I/D	VAS
GOES-5	05/15/81	08/05/81 - 07/30/84	I/D	VAS
GOES-6	04/28/83	06/01/83 - 01/29/89	I/D	VAS
GOES-7	02/26/87	03/25/87 - 01/17/96	I/D	VAS
Meteosat-3#	06/15/88	01/01/93 - 05/30/95	I/D	VAS
GOES-8	04/13/94	09/01/94 - 04/01/03	D	Imager/Sounder
GOES-9	05/23/95	01/09/96 - 07/21/98 04/23/03 - present	D	Imager/Sounder
GOES-10	04/25/97	07/21/98 - present	D	Imager/Sounder
GOES-11	05/03/00	In space storage mode		
GOES-12	07/23/01	04/01/03 - present	D	Imager/Sounder

Legend

I = Printed Images
D = Digital Format
VISSR - Visible and IR Spin Scan Radiometer
VAS - VISSR Atmospheric Sounder

* Most pre-1978 images are archived at the Federal Records Center
**SMS-2 operation was intermittent
Loaned to U.S. by EUMETSAT
ϕLoaned to Japan Meteorological Agency for GMS-5 replacement over western Pacific

Requests for GOES and other environmental satellite data, products and documentation should be addressed to:

National Climatic Data Center
Attn.: Satellite Services Group
151 Patton Avenue, Room 120
Asheville, North Carolina 28801-5001
U.S.A.

Phone number: 828-271-4850
Facsimile number: 828-2714876
E-mail address: satorder@ncdc.noaa.gov

4.2 Retrospective GOES Imagery Available to Users

Since the publication of the last GOES Data User's Guide (e.g.1984), many changes in the methods in which satellite data are retrieved, archived and serviced have occurred, It is no longer feasible to maintain a complete paper archive of all of the sectors that were produced by the NWS Satellite Field Services Stations. In the past these images were loosely maintained at the NOAA Science Center Library in Camp Springs, Maryland, from which former requests for imagery were filled. Since the volume of hard copy images had become increasingly unmanageable, many of these sector facsimile images and negatives were shipped to the Federal Records Center (FRC) for permanent storage. Image requests prior to the digital archive (i.e. about July 1978), in some cases, will be transferred to the FRC, which in turn, will ship the appropriate set of boxes containing the requested image to NCDC. Because of the unwieldy nature of this interaction between the FRC and NCDC, only those requests of significant research potential will be considered.

Within just the last few years, digital storage capabilities have evolved to the point where most satellite image requests can be efficiently generated from the raw satellite data and no longer requires the use of facsimile or negative images, as had keen the case for the previous three decades. At NCDC satellite imagery are created using McIDAS (Man-computer Interactive Data and Access System), developed by the Space Science Engineering Center at the University of Wisconsin. McIDAS offers users the flexibility of receiving custom imagery based on unique user specifications. The specifications can include: a geographic region of any size, choice of spectral channels, choice of spatial resolution, exact time, and map projection. Along with these specifications, users can request latitude/longitude gridding at any interval, political boundary overlays, temperature contouring, annotations pointing to a particular spot on the image, and many types of visual enhancements. Additional enhancements such as blending in-situ weather data with satellite imagery are planned.

Currently, NCDC provides hard copy prints in 8" x 10" format and 11" x 17" format. Larger prints will require special photolab services of which none are contracted at this writing. Until such a photolab, that will meet NCDC's criteria is found, NCDC will not offer poster services. Customers are advised to contact a local photolab service to obtain information on acceptable medium upon which an enlarged image can be made. An increasing number of labs will accept a digital graphical image in one of the common formats (i.e. GIF, TIFF, JPG, BMP, etc.) which NCDC can supply.

4.2.1 Types of Imagery Products Available from NCDC

A growing number of imagery products are available from NCDC. There are basically two types of imagery products, custom images and reproduction images. Custom images are those images which are created specifically for customer defined areas, times, and channels. These images are processed from the original digital files using proprietary image display and processing software. The second type of image are reproduction images, which are images that have already been created from the raw satellite data and electronically archived in a common graphics format for quick access and printing. Many of these images were created either by the NCDC satellite services staff or by several offices within NESDIS, which are creating images in response to potential natural disaster events such as hurricanes, tornadic supercells, blizzards, volcano eruptions, forest fires, floods, and etc. The best of the reproduction images are made freely available to the user via the NCDC web site and can be freely downloaded to your computer storage disk; or NCDC can print selected imagery on photographic quality paper for a fee.

There are also a number of specialized image products produced in real-time mode in support of the National Weather Service forecast offices. These products are considered operational and will be archived at NCDC as soon as NCDC receives its own NOAAPORT. There are also a number of experimental products, which are not being archived at NCDC, but may be available directly from the office creating the product. A complete treatment of all GOES image products is found in the NESDIS document entitled, GOES Products and Services Catalog. A copy may be obtained from NCDC.

The series of figures in the following sections offer the user an opportunity to learn more about the availability of GOES sectors, the geographical extent of each sector, and the times they are normally available. Examples of spectral channels, resolutions with corresponding coverage, on a typical 8”x 10” print, and special enhancements for the IR channel are also provided. The published document will show all examples in black and white, however, the HTML version of this document, which is located at the NCDC web site (http://www.ncdc.noaa.gov/oa/ncdc.html) provides some examples in color.

4.2.1.1 Examples of Imager Sectors in Routine Mode

Figures 4-1 through 4-4 and Figures 4-6 and 4-9 illustrate typical geographical coverages scanned by GOES-EAST and GOES-WEST satellites, respectively, while in Routine Mode of operation. The routine scan sectors include Full Earth every three hours, Extended Northern Hemisphere every half hour, Northern Hemisphere every half hour, and mid-latitudes Southern Hemisphere every half hour. The beginning scan times are indicated on each figure’s caption. GOES-EAST Full Earth (also known as Full Disk) is available every three hours starting at 0245 UTC, whereas GOES-WEST Full Earth scans are normally available every three hours starting at 0000 UTC. Since the Full Earth Scans require approximately 26 minutes to complete, the CONUS (GOESEAST) and PACUS (GOES-WEST) sectors normally scheduled for the next slot are skipped. Figures 4-3 and 4-8 illustrate CONUS and PACUS coverages, respectively, which are part of the Northern Hemisphere scan times (see Figures 4-4 and 4~7), thus, the point that they are available every fifteen minutes is valid. As pointed out earlier and illustrated in Figure 4-5, the user has the freedom to choose any sub-sector of a major scan area for purposes of detailed analyses in a geographic information and display system.

4.2.1.2 Examples of Resolution

Figures 4-10 through 4-15 illustrate approximate coverages on a typical 8 x 10 inch print based on resolution. The highest resolution possible is 1 km for the visible channel and 4 km for the IR channels (except 8 km for the water vapor channel). Figure 4-10 is an example of GOES-EAST visible at best resolution. Coverage at mid-latitudes extends about 50 degrees north to south and 70 east to west. When resolution is reduced to 24 km much of the Earth can be shown within an 8 x 10 inch print. The largest print size NCDC offers is 11 x 17 inch, which will allow more coverage.

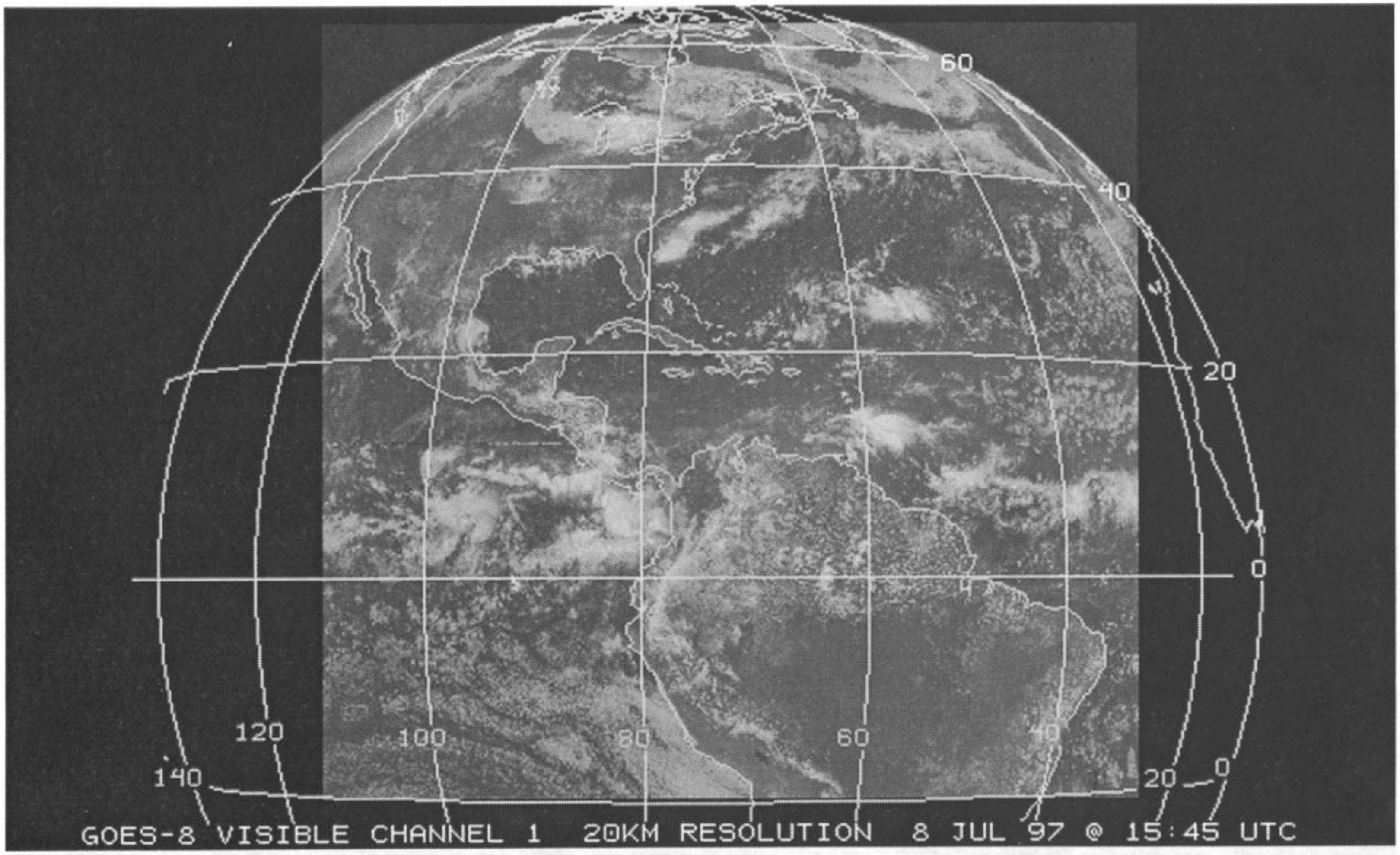


Figure 4-2 GOES-EAST Northern Hemisphere sector. Available every half hour at xx:15 and xx:45 UTC

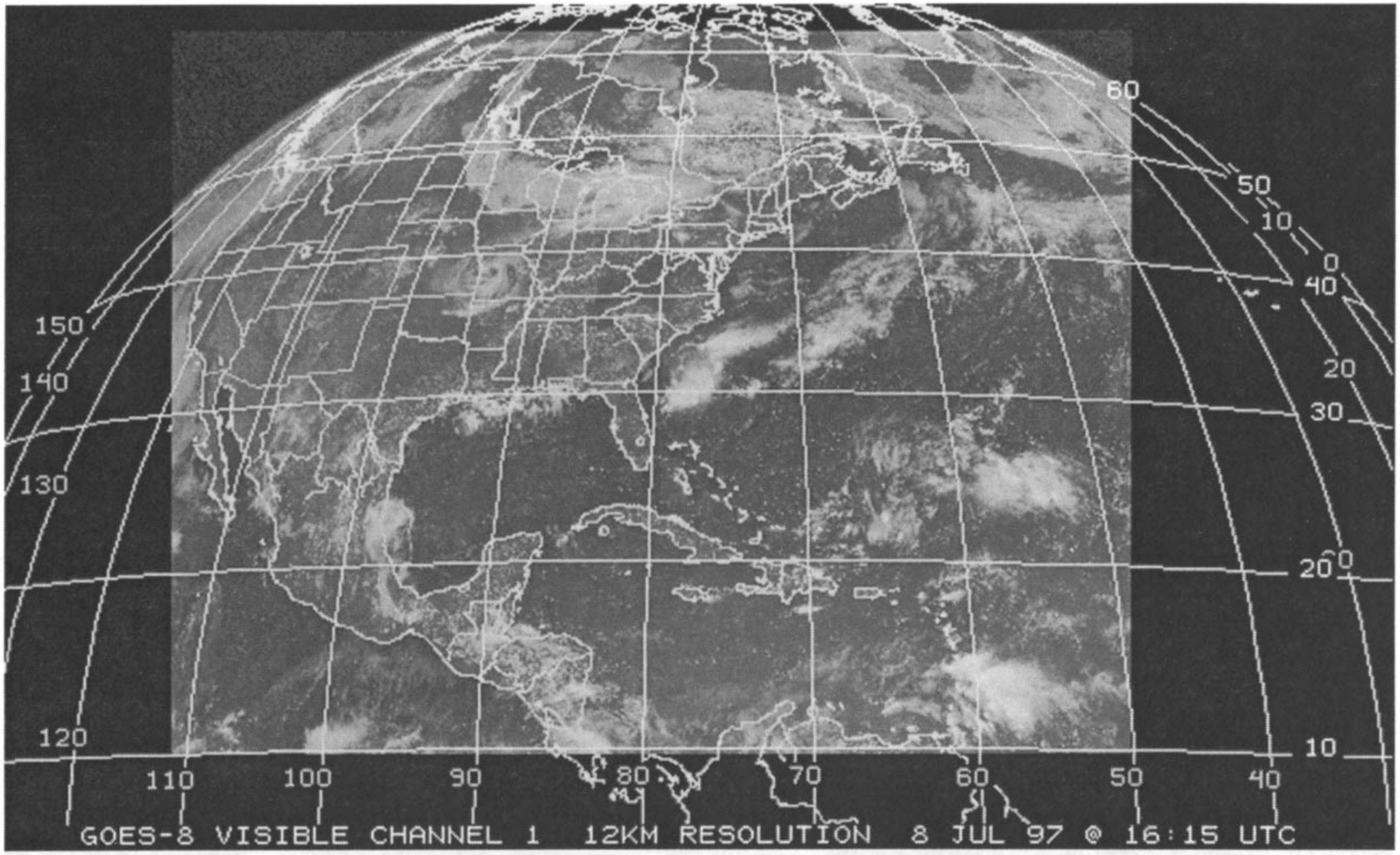


Figure 4-3 GOES-EAST CONUS sector. Available every 15 minutes at xx:00, xx:15, xx:30, and xx:45 UTC.

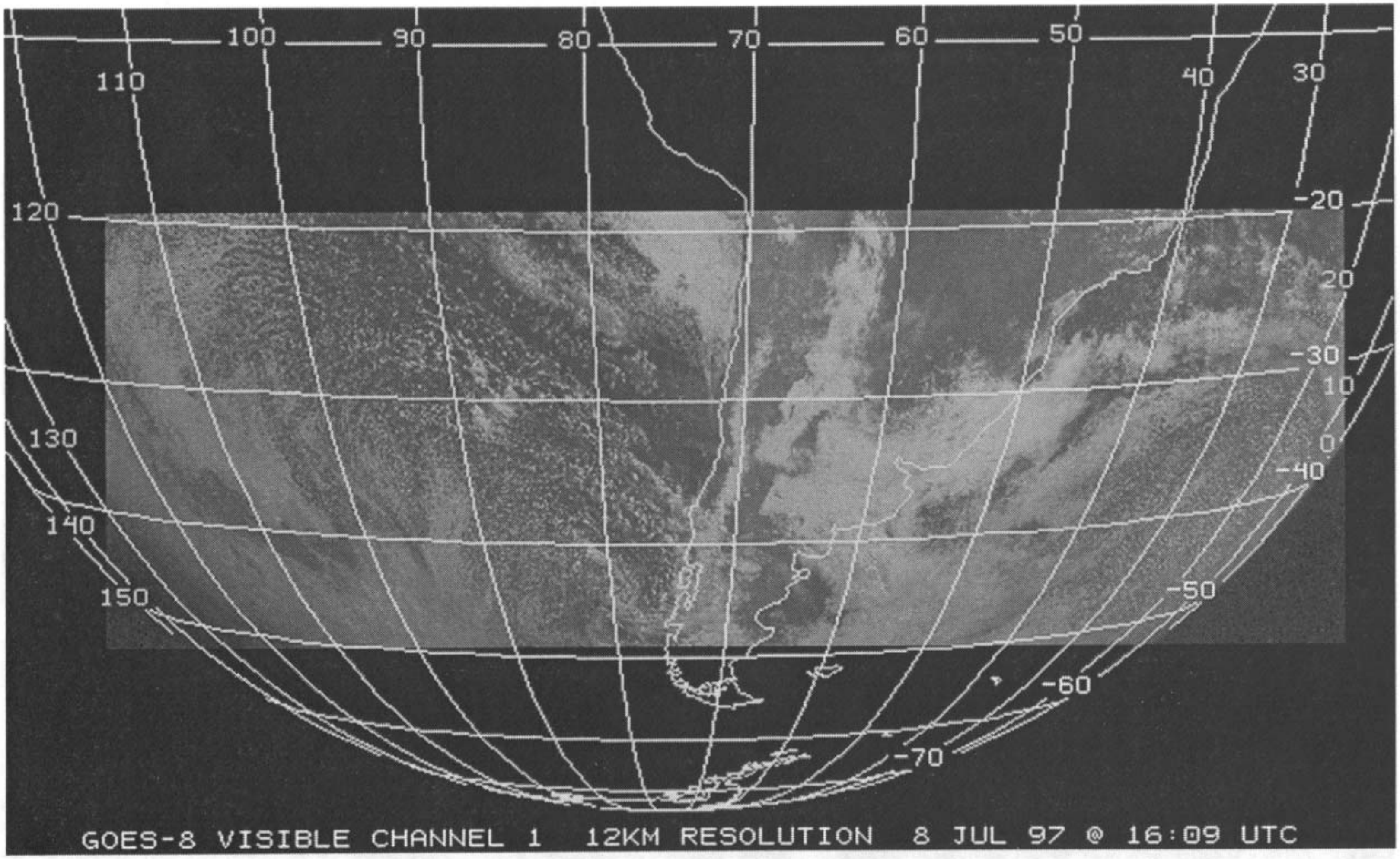


Figure 4-4 GOES-EAST Southern Hemisphere sector. Available every half hour at xx:10 and xx:40 UTC.

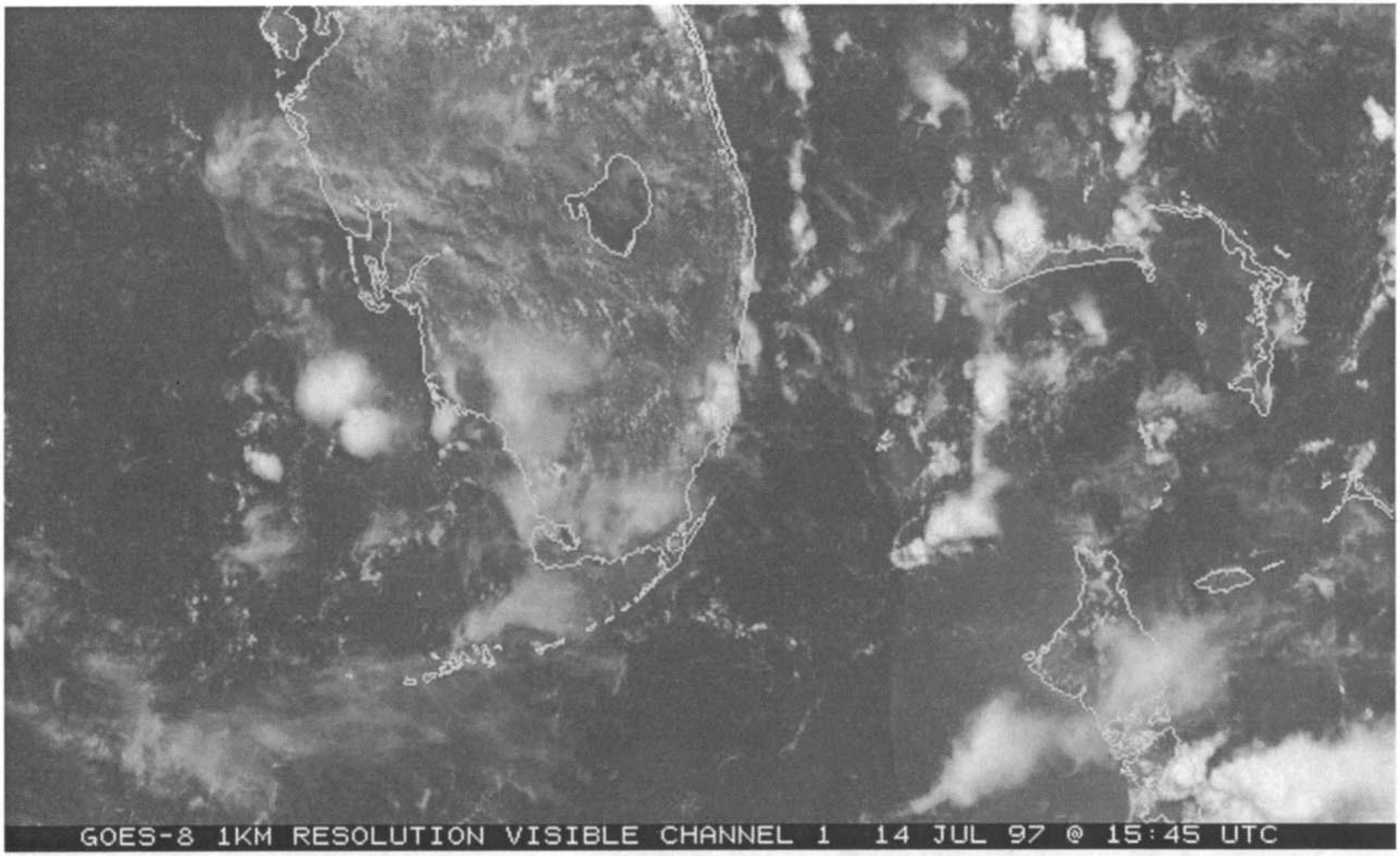


Figure 4-5 GOES-EAST full resolution sector centered over West Palm Beach, Florida.

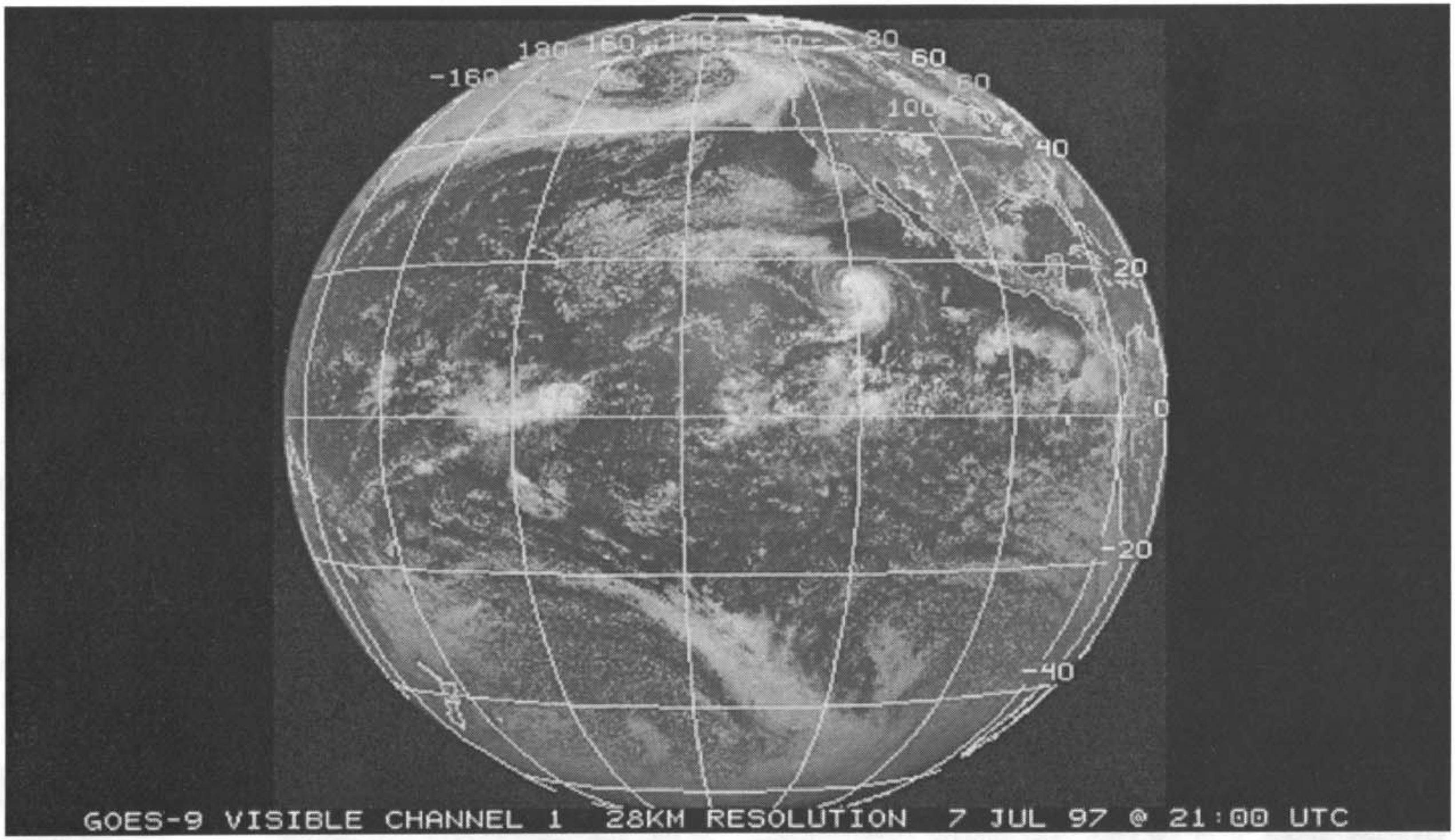


Figure 4-6 GOES-WEST Full Earth scan. Available every three hours at 00:00, 03:00, ..., 21:00 (UTC).

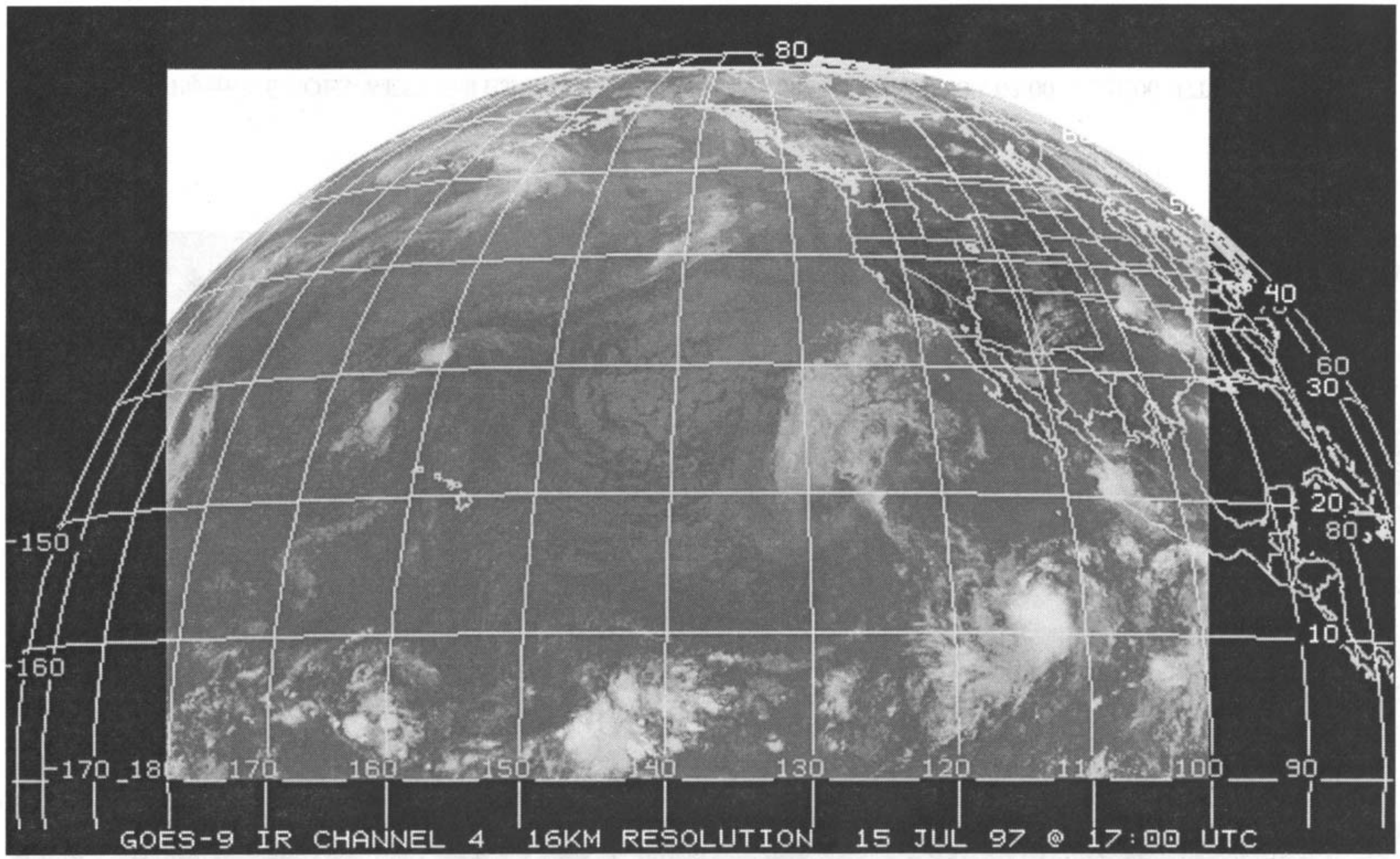


Figure 4-7 GOES-WEST Northern Hemisphere sector. Available every half hour at xx:00 and xx:30 UTC.

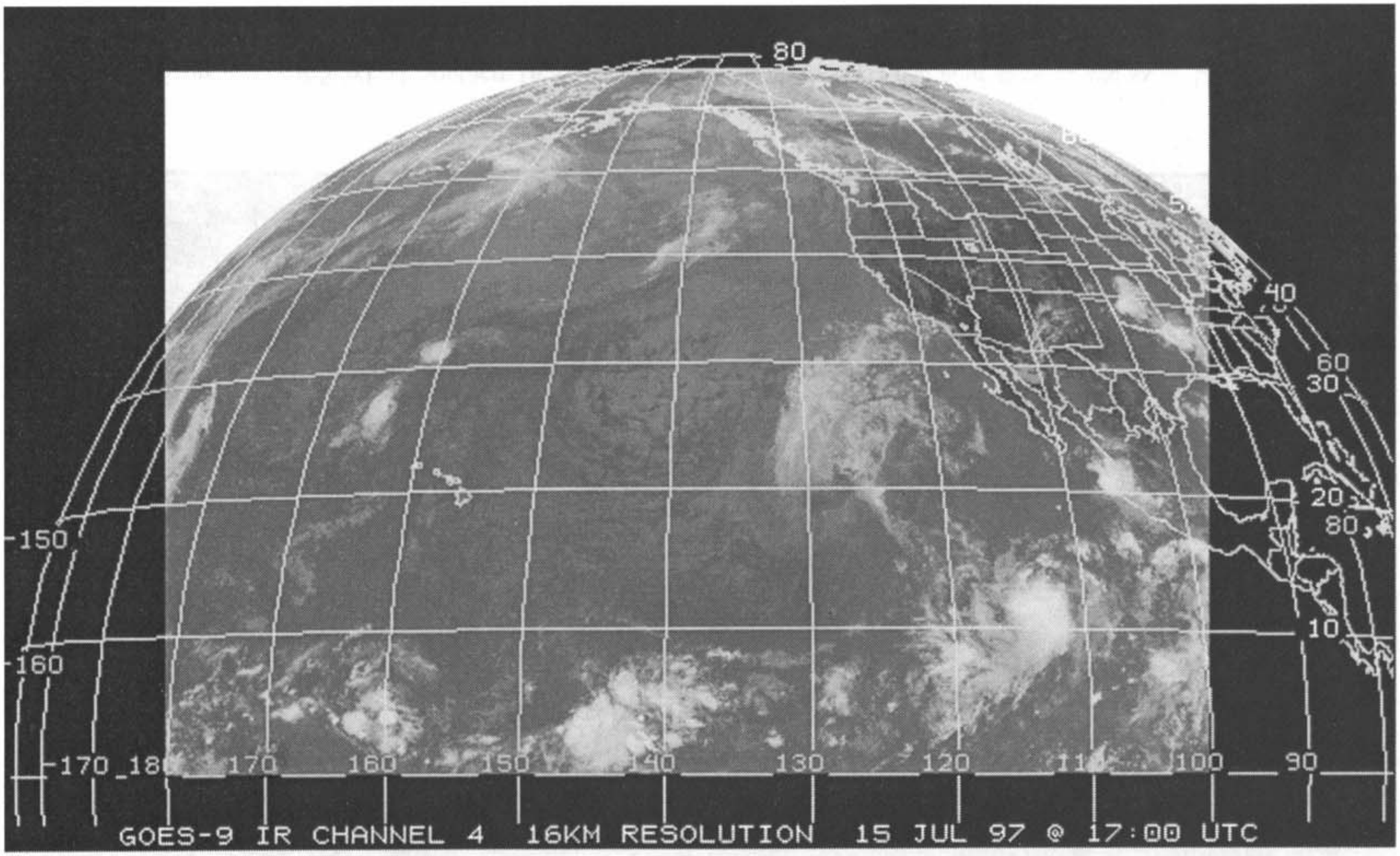


Figure 4-8 GOES-WEST PACUS sector. Available every 15 minutes at xx:00, xx:15, xx:30, and xx:45 UTC.

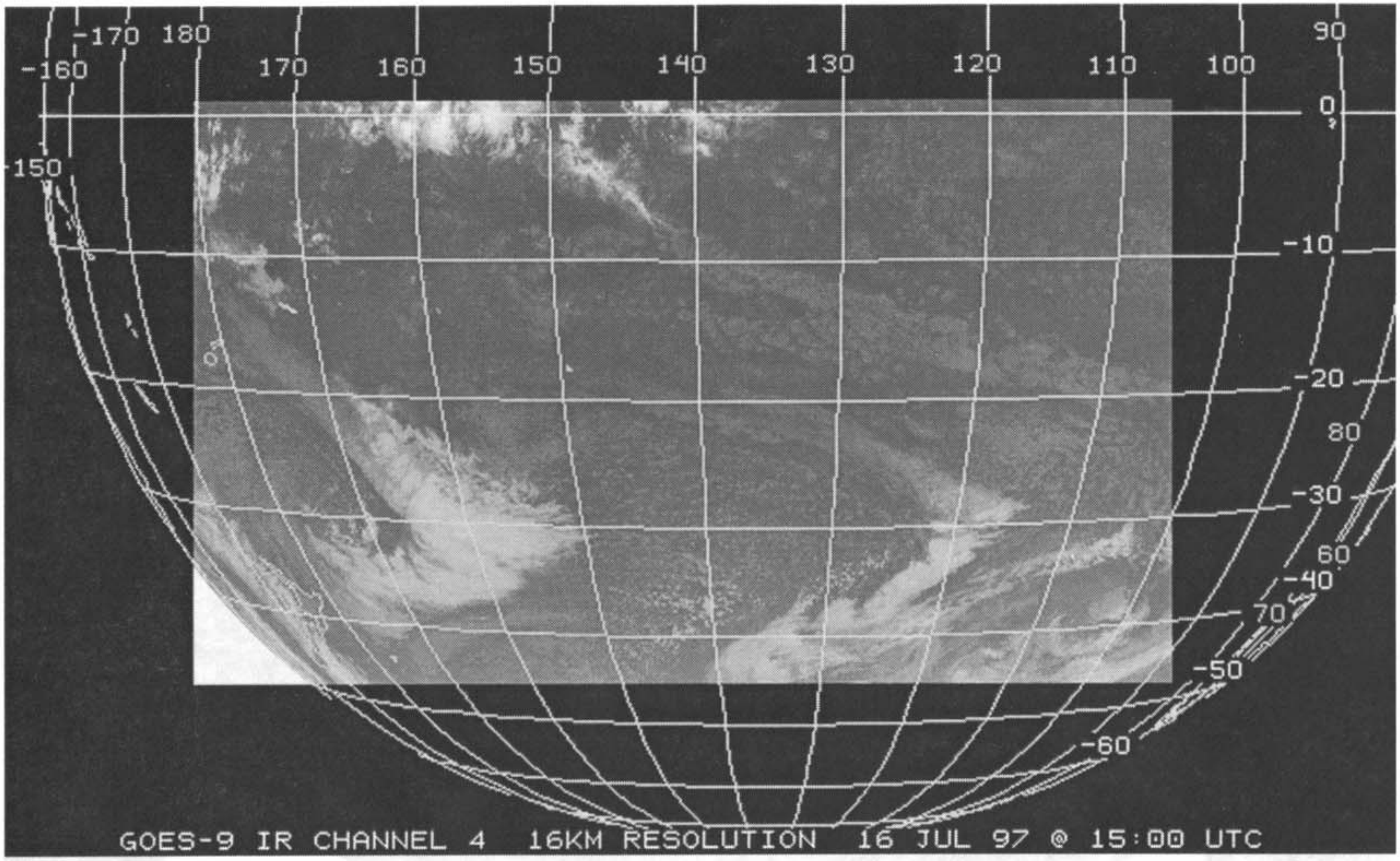


Figure 4-9 GOES-WEST Southern Hemisphere sector. Available every half hour at xx:22 and xx:52 UTC.

4.2.1.3 Examples of Imager Channels

Figures 4-16 through 4-20, show examples of satellite imagery for channels 1 through **5,** respectively. The channels range from the visible in channel 1 to the shortwave infrared in channel 2, to the midwave infrared in channel 3, to the longwave infrared in channels 4 and **5.** A brief explanation of the characteristics and benefits of each channel is provided.

In the visible channel (Figure 4-16) highly reflective surfaces such as clouds, fog, snow and sand will appear brightest. Vegetation is more reflective than water surfaces, thus, the surface of water appears almost black, except in cases where seas are smooth, a phenomenon called sun glint occurs.

Channels 2 through 5 measure the amount of radiation received by the satellite sensors for a specific spectral wave length. Since these channels are not dependent on reflected light energy to detect clouds and other features, their advantage over the visible channel was immediately apparent since the first radiometer was used in outer space. Since then, scientists have been discovering new advantages of using these various infrared sensors. The radiation sources are clouds, aerosols, gases, and surfaces. The IR channels measure heat that has escaped from the earth's surface. Some of this heat is absorbed by the greenhouse gases and readmitted at different wavelengths. Since the atmospheric gases absorb and re-admit radiation at specific wavelengths the sensor can be calibrated to measure various atmospheric components. For example, channel 3 on the Imager, known as the water vapor channel, has a central wavelength at 6.7ptm. At this wavelength the sensor detects atmospheric moisture which reveals the moisture's associated large scale motions within, the atmosphere. Bright white areas indicate a high volume of water vapor throughout the mid and upper ranges of the troposphere and are usually indicative of intense convectively produced rain. Medium grey areas indicate a lower concentration of water vapor in the atmosphere which in many cases occur in cloud-free regions. See Figures 4-16 and 4-18 for comparison.

Channel 2 (3.9ptrn) is unique in that it detects reflected energy as well as radiant energy. It can provide important data on the extent and phase (liquid vs. ice) of clouds during day and night hours and is used in conjunction with channel 4 to detect nighttime fog and stratus development. Channel 2 has also demonstrated its usefulness in detecting sub-pixel fires, especially at night.

4.2.1.4 Special Image Products

NCDC is offering more in the way of specialized image products, which could be as simple as color enhancing a single infrared channel to recreating an increasing number of operational products developed by the National Environmental Satellite Data Information and Services (NESDIS) for improving short range and long range computer forecast models.

Figures 4-21 and 4-22 are examples of the GOES Water Vapor Movement Wind (WVMW) and GOES Cloud Drift Wind (CDW) products, respectively. Each product is created every six hours at 0000, 0600, 1200 and 1800 UTC using three consecutive, half-hourly images. Automated pattern recognition software is used to detect and track features. Each wind vector, consisting of speed and direction, is assigned a height above the earth's surface based on the infrared energy signatures and guidance from corresponding numerical weather forecast parameters. There are three height categories where each vector is assigned one of three colors according to the height interval in which it belongs (The black and white examples do not explicitly show this). Table 4-2 gives the heights and corresponding colors that are assigned to each vector for the two wind products.

Table 4-2 GOES Winds Levels

Product	Low Level (Yellow)	Mid Level (Green)	High Level (Red)
Cloud Drift Winds	Below 700hPa <10,000 feet	400hPa to 700hPa 10,000 to 23,000 feet	100hPa to 400hPa 23,000 to 52,000 feet
Water Vapor Winds	400hPa - 700hPa 10,000 to 23,000 feet	25OhPa - 400hPa 23,000 to 33,000 feet	l00hPa - 25OhPa 33,000 to 52,000 feet

Figure 4-23 shows an example of the GOES Temperature Contour Plot for infrared images only. The plot generally covers an area of about 500 km x 300 km. which is used for highlighting the coldest cloud top temperatures. The contour intervals are selective and are chosen based on the complexity of the surfaces being contoured. The actual values are in degrees Kelvin only.

The GOES Fog Product (See Figure 4-24) is new for the GOES I-M series, especially since the resolutions on the IR channels have improved significantly enough to create this product. The Fog Product is simply the measure of the difference of emissivity measured between channels 2 and 4, which is found to be useful for detecting nighttime fog and stratus. Channel 2's lower emissivity in the presence of low level water clouds results in a lower brightness temperature than the longwave IR, while cloud-free areas show little temperature difference. The maximum information is obtained by taking the difference in brightness temperatures between channels 4 and 2(ch4-ch2).

Since the early 1970's, the National Weather Service has applied GOES infrared enhancement curves on its analog images which were transmitted to GOES-Tap users. These enhanced images helped the user to easily identify specific cloud top temperature ranges. They really are not curves at all, but a series of line segments that describe how the image brightness value varies according to input brightness temperature ranges. Today some of the original enhancement curves are still used in the NWS Advanced Weather Interactive Processing Systems (AWIPS) image displays. Probably the most popular enhancement curve to date is the so called "thunderstorm curve" or more formally known as the MB enhancement curve (see Figure 4-25). This curve isolates the coldest cloud tops by correlating brightness temperature values with a series of predefined gray scale values, in this case, gradually going to white for cloud top temperatures lower than -64.2^{o} C. For a complete listing, description, and graphs of enhancement curves, please refer to the previous edition of the GOES Data User's Guide.

4.2.1.5 Examples of Mapping

Figures 4-26 through 4-28 illustrate various map projections over same area for comparison. Mercator projection (see Figure 4-26) preserves direction and is useful for navigation. This projection has straight meridians and parallels that intersect at right angles. Scale is true at the equator or at two standard parallels equidistant from the equator. The projection is often used on marine navigation maps because all straight lines on the map are lines of constant azimuth.

Polar Stereographic projection (Figure 4-27) is used for navigation in polar regions. Directions are true from the center point and scale increases away from the center point as does distortion in area and shape.

The Lambert-Conformal projection (Figure 4-28) is often used for North America and other large countries with a larger east-west than north-south extent. Area and shape are distorted away from standard parallels. Directions are true in limited areas.

Figure 4-29 illustrates a GOES EAST-WEST composite creating a seamless view of all of North America and the northeastern Pacific Ocean. These composites can be made in any of the three projections covered above. The example shown is in polar stereographic projection.

Table 4-5 ASOS Cloud Height/Amount Record Format

Record Pos.	No. Of Integer	Element Name	Description
01	5	WBAN	Unique ID number assigned to station
02	2	SAT ID	O1=GOES-7, 02=GOES-8, 02=GOES-9, etc.
03	4	YEAR	Year of satellite scan
04	2	MONTH	Month of satellite scan (range of values is 1-12)
05	2	DAY	Day of satellite scan (range of values is 01-31)
06	2	HOUR	Hour (LST) of satellite scan over station (range of values is 00-23)
07	2	MIN	Minute (LST) of the satellite scan over station (range of values is 00-59)
08	3	LAT DEG	The latitude of the station in degrees, minutes, and seconds. Northern hemisphere latitudes are positive (no '+' sign) and southern hemisphere latitudes are negative with a '-' negative sign entered.
09	2	LAT MIN	
10	2	LAT SEC	
11	3	LONG DEG	The longitude of the station in degrees, minutes, and seconds. Eastern hemisphere longitudes are positive (no '+' sign) and western hemisphere longitudes are negative with a '-' negative sign entered.
12	2	LONG MIN	
13	2	LONG SEC	
14	3	CLD HGT	The height and amount indicators of up to three cloud layers detected by the satellite. The CLD HGT element is designated as CLR, HGH, or MID. The CLD AMT indicator can have SCT, BKN, OVC or blank (when CLD HGT=CLR). Low clouds are excluded.
15	3	CLD AMT	
16	3	CLD HGT	
17	3	CLD AMT	
18	3	CLD HGT	
19	3	CLD AMT	
20	3	LOWEST	The lowest and highest FOV cloud top in hundreds of feet. Low clouds are excluded.
21	3	HIGHEST	
22	3	EFFECTIVE AMT	The average FOV effective cloud amount (%). This is the sum of the amounts in each FOV divided by the number of FOVs (normally 25) with data in the matrix. Low clouds are excluded.
23	2	HGT & AMT	This field is repeated 25 times. See remarks below.

48	4	CLD TOP PRSSR	This field is repeated 25 times. See remarks below.
73	3	EFFECTIVE CLD AMT	This field is repeated 25 times. See remarks below.

Appendix A Abbreviations and Acronyms

AOC	Attitude and Orbit Control
AOCE	Attitude and Orbit Control Electronics
AOCS	Attitude and Orbit Control Subsystem
AOS	Acquisition Of Signal
APT	Automatic Picture Transmission
ASOS	Automated Surface Observing System
ATS	Applications Technology Satellite
AWIPS	Advanced Weather Interactive Processing Systems
BB	Black body
BDR	Bi-Directional Reflectance
BUFR	Binary Universal Form for Representation of meteorological data
C	Celsius
CDA	Command and Data Acquisition
CEMSCS	Central Environmental Meteorological Satellite Computer System
Ch	Channel
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CMW	Cloud Motion Winds
cm	Centimeter
CONUS	CONtinental United States
dB	Decibel
DCP	Data Collection Platform
DCS	Data Collection System
ECAL	Electronic Calibration
ELUG	Earth Location User's Guide
E/W	East/West
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FOV	Field Of View
GIMTACS	GOES I-M Telemetry And Command System
GINI	GOES Ingest NOAAPORT Interface
GMS	Geostationary Meteorological Satellite (Japan)
GOES	Geostationary Operational Environmental Satellite
GSAS	Geostationary Satellite Archive System
GSS	GOES Sectorizer System
G/T	Gain-to-Noise Temperature Ratio, dB/K
GVAR	GOES VARiable data format
HgCdTe	Mercury Cadmium Telluride (mercadtelluride)
Hz	Hertz
IF	Intermediate Frequency
IFC	In-Flight Calibration
IGFOV	Instantaneous Geometric Field Of View
IMC	Image Motion Compensation
INR	Image Navigation and Registration
InSb	Indium Antimonide
IR	Infrared
K	Degrees Kelvin
kb/s	Kilobits per Second
kHz	Kilohertz
km	Kilometer
L	Liter
LI	Lifted Index
LW	Longwave
m	Meter
Mb/s	Megabits per Second
McIDAS	Man-computer Interactive Data and Access System
MHZ	Megahertz

mm	Millimeter
MMC	Mirror Motion Compensation
MW	Midwave
MW	Momentum Wheel
mW	micro-Watts
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NEΔT	Noise Equivalent Change in Temperature
NESDIS	National Environmental Satellite Data and Information Service
NEΔN	Noise Equivalent Radiance Difference
NH	Northern Hemisphere
NHC	National Hurricane Center
NLUT	Normalization Look-Up Table
NOAA	National Oceanic and Atmospheric Administration
NOAASIS	NOAA Satellite Information System
NSSFC	National Severe Storms Forecast Center
N/S	North/South
NWS	National Weather Service
OATS	Orbit and Attitude Tracking System
OGE	Operations Ground Equipment
PACUS	PACific-United States
PG&D	Product Generation & Distribution
PM	Product Monitor
PMT	Photo Multiplier Tube
rad	Radians
RISOPS	Rapid Interval Scan Operations
RSO	Rapid Scan Operations
RTGP	Real Time GOES Processors
RW	Reaction Wheel
SARSAT	Search and Rescue Satellite-Aided Tracking
SEC	Space Environment Center
SEM	Space Environment Monitor
SFSS	Satellite Field Service Station
SH	Southern Hemisphere
SMS	Synchronous Meteorological Satellite
S/N	Signal-to-Noise Ratio
SOCC	Satellite Operations Control Center
SPS	Sensor Processing System
sr	Steradian
SRSO	Super Rapid Scan Operations
SSCC	Spin Scan Cloud Camera
SSS	Spacecraft Support System
SW	Shortwave
T&C	Telemetry and Command
TACTS	Telemetry And Command Transmission System
TC&R	Telemetry, Command and Ranging
UTC	Universal Time Coordinated
VAS	Visible and Infrared Spin Scan Radiometer Atmospheric Sounder
VISSR	Visible and Infrared Spin Scan Radiometer
W	Watts
WEFAX	Weather Facsimile
WVMW	Water Vapor Movement Winds
XRS	X-ray Sensor
m	Micro (10^{-6})

Appendix B Satellite Resources on the World Wide Web

Please note that there are many other resources for satellite data on the World Wide Web. This list emphasizes resources of GOES data and products, both real-time and retrospective, that are primarily distributed by NOAA agencies. However, included are a few non-NOAA sites which are worth mentioning below. If you know of a web site that should be included, please contact the National Climatic Data Center Satellite Services Group at satorder@ncdc.noaa.gov.

General Educational Information on Remote Sensing

University of Illinois - Basic Online Guides for GOES and POES Satellites
http://ww2010.atmos.uiuc.edu/(Gh)/guides/rs/sat/home.rxml

University of Massachusetts - Remote Sensing Imagery for Natural Resources Monitoring
A Guide for First-time Users
http://www.columbia.edu/cu/cup/catalog/data/023107/0231079281.HTM

NOAA/NESDIS Regional and Mesoscale Meteorology Branch (RAMMB) -
Introduction to GOES-8
http://www.cira.colostate.edu/ramm/G8INTRO/g8modpg1.htm

NASA - The Remote Sensing Tutorial by Nicholas M. Short
http://rst.gsfc.nasa.gov/Front/overview.html

Near real-time Satellite Images, Movies and/or Data

NOAA's Geostationary Browse Server
http://lwf.ncdc.noaa.gov/servlets/GoesBrowser

Space Science Engineering Center GOES Imagery
http://www.ssec.wisc.edu/data/index.html

NASA's GOES Project Science
http://rsd.gsfc.nasa.gov/goes/index.html

Naval Research Lab Monterey Satellite Meteorology
http://www.nrlmry.navy.mil/sat_products.html

NOAA-CIRA Realtime Satellite Data Animations
http://www.cira.colostate.edu/ramm/rmsdsol/main.html

Global Hydrology and Climate Center
http://wwwghcc.msfc.nasa.gov/GOES/

Composite Satellite Image of the World by Intellicast
http://www.intellicast.com/Local/USNationalWide.asp?loc=usa&seg=IntlSat&prodgrp=World&product=World&prodnav=none

Weather Underground of Hong Kong
http://www.underground.org.hk/

Retrospective On-line Satellite Images/Data

NCDC Historical GOES Browse Server
http://www5.ncdc.noaa.gov/plwebapps/plsql/goesbrowser.goesbrowsemain

Satellite Active Archive
http://www.saa.noaa.gov/

The University of Rhode Island Graduate School of Oceanography
http://dcz.gso.uri.edu/

Special Sensor Microwave/Imager (SSM/I)
Global Gridded Products
http://www.ncdc.noaa.gov/ol/satellite/ssmi/ssmiproducts.html

Special Sensor Microwave/Imager (SSM/I)
Global and North American Monthly Anomaly and Full-field Images
http://lwf.ncdc.noaa.gov/servlets/SSMIBrowser

JPL-PODAAC - Multi-channel SST Data
http://podaac.jpl.nasa.gov/cgi-bin/dcatalog/fam_summary.pl?sst+mcsst

NOAA/NASA Long Term Archive (TOMS and UARS)
http://jwocky.gsfc.nasa.gov/
http://umpgal.gsfc.nasa.gov/uars-science.html

Special Events Satellite Images/Movies

National Climatic Data Center
Images/Movies of Hurricanes and Special Events
http://www5.ncdc.noaa.gov/cgi-bin/hsei/hsei.pl?directive=welcome

NOAA's Operational Significant Event Imagery Homepage
http://www.osei.noaa.gov/updaterecent.html

GOES 8/9 Scrapbook from NASA's GOES Project
http://rsd.gsfc.nasa.gov/goes/index.html

Satellite Image Interpretation/Discussions

The GOES Gallery at Cooperative Institute for Meteorological Satellite Studies
http://cimss.ssec.wisc.edu/goes/misc/interesting_images.html

NCDC's Satellite's Eye Art Gallery
http://www.ncdc.noaa.gov/ol/satellite/satelliteseye/satelliteseye.html

Regional And Mesoscale Meteorology Team
Archived Satellite Discussions from the Cooperative Institute for the Research of the Atmosphere
http://www.cira.colostate.edu/ramm/picoday/archive.html

Near Real-time Satellite Products: Sea-Surface Temperatures

NOAA/NESDIS/OSDPD Environmental Products
http://www.osdpd.noaa.gov/PSB/EPS/SST/SST.html

Johns Hopkins University/Applied Physics Lab
http://fermi.jhuapl.edu/avhrr/sst.html

NOAA Coastal Services Center
http://www.csc.noaa.gov/

Near Real-time Satellite Products: GOES

NOAA/NESDIS/Office of Research and Applications
GOES Products
http://www.ssd.noaa.gov/PS/index.html

NOAA/NGDC's Space Physics Interactive Data Resource (SPIDR)
http://spidr.ngdc.noaa.gov/spidr/

NOAA's Information Processing Division
http://psbsgi1.nesdis.noaa.gov/IPD/IPD.html

Remotely Sensed Natural Hazards Monitoring

NOAA's El Niño - Southern Oscillation (ENSO) Home Page
http://www.ogp.noaa.gov/enso/

NASA's Global Fire Monitoring Homepage
http://www.ssd.noaa.gov/PS/FIRE/Layers/MODIS/modis.html

Michigan Technological University - Remote Sensing of Volcanic Eruption Clouds http://www.geo.mtu.edu/volcanoes/research/avhrr/

Climate Change and Weather Extremes
http://www.ncdc.noaa.gov/ol/climate/climateextremes.html

CEOS/NOAA Disaster Management Support Project
http://www.ceos.noaa.gov/

Appendix C   McIDAS Area Format Information

Storing Satellite Imagery in McIDAS Data Structures

February 1997

Space Science and Engineering Center
University of Wisconsin - Madison
1225 West Dayton Street
Madison, WI 53706

Additional signal transmission reference materials:
METEOSAT High Resolution Image Dissemination, 1992, EUMETSAT.
Operations Ground Equipment, Internal Specification, DRL 504-02-1 Part 1, Specification No E007020, released February 9, 1994, Space Systems/Loral, 3825 Fabian Way, Palo Alto, CA, 94303-4604.

Introduction

Satellite imagery is collected by instruments on geostationary or earth orbiting satellites. These instruments make a series of parallel scans over a section of the Earth. Ingestors collect and store the scanned data in area files. In addition to the image data, area files include information about the image's geography and physical characteristics, and modifications to the data. This document describes the structure of McIDAS area files and how image data is stored and accessed. Since this is a only a reference document, no information is provided about how to manipulate data in the structures described. If you plan to build area structures, it is important that you are familiar with the data structure formats described here and the signal transmission formats described in the reference documents on page 2. Currently, this document contains information about METEOSAT PDUS, GVAR and GOES-7 data structure formats only. Future revisions will include other satellites. This document includes the following information:

Description of McIDAS area file components including the Area Directory and image data descriptions of area file characteristics specific to METEOSAT, GVAR and GOES-7 satellites.

Area File Description

In McIDAS, satellite imagery data and supplemental information are stored on disk in data structures called areas. Each area is a binary file containing all the information necessary to display and navigate the image. Area files are named AREAnnnn, where nnnn is a four-digit number between 0000 and 9999. This number is referred to as the area file number. For example, AREA0013 is the name of the file that contains area 13. Complete images are often too large to be stored completely in an area file. An area may be a geographic portion of the image or a subset produced by sampling or averaging the image data. Any point in the area can be described with image coordinates, its position in the full satellite image, or with area coordinates, its position in the area or subset of the image.

Area files consist of six sections, or blocks:

<u>Area Directory Block</u> describes the area data and the image from which the area was created. It also contains pointers used for locating other blocks and data in the file.

<u>Auxiliary (AUX) Block</u> contains information created by the user such as histograms or long comments.

<u>Navigation (NAV) Block</u> contains information used to associate earth coordinates with the image pixels.

<u>Calibration (CAL) Block</u> contains information that relates sensor data to meaningful physical units such as temperature, albedo or visible brightness.
<u>Digital Data (DATA) Block</u> contains the actual data values for the image.

<u>Comment Records (AUDIT) Block</u> documents modifications to the file data.

Area Directory Block

The first 256 bytes of every area file are the Area Directory block for the image. The Area Directory describes the kind of data in the area and contains pointers used for locating the remaining blocks and other subsets of data in the file. It also contains information about the image from which the area was created. The data in the Area Directory is stored as 32-bit (4-byte) twos complement binary integers or as ASCII character data. The directory is divided in 64 words. Each word is described below. Some words are satellite specific. See the next section for specific satellites. All byte offsets are zero-based.

Word Description

W1 - contains zeros if the record is valid

W2 - area format: always 4 (as of June 1985)

W3 - sensor source number; see Appendix A within this document

W4 - nominal start date; scheduled date for image data collection; YYDDD

W5 - nominal start time; scheduled time for image data collection; HHMMSS UTC

W6 - image line coordinate of area line 0, element 0

W7 - image element coordinate of area line 0, element 0

W8 - not used

W9 - number of lines in the area

W10-number of elements in each line

W11-number of bytes per element (1, 2 or 4)

W12-line resolution; number of image lines between consecutive area lines

W13-element resolution; number of image elements between consecutive area elements

W14-maximum number of bands per line of the area
W15-length of the DATA block line prefix, in bytes; sum of W49, W50, W51 (+ 4 if W36 validity
code is present)

W16-McIDAS user project number under which the area was created

W17-actual ingest date; date the area was created; provided by the ingesting computer; YYDDD

W18-actual ingest time; time the area was created; provided by the ingesting computer; HHMMSS

W19-32-bit filter band map for multichannel images; if a bit is set, data exists for the band; band 1 is the least significant byte (rightmost)

W20-24-satellite specific information

W25-32-memo; 32 ASCII characters available for comments

W33-area file number; last four digits of the file name

W34-byte offset to the start of the area file's DATA block

W35-byte offset to the start of the area file's NAV block

W36-validity code; contains zeros if this area does not have validity codes; if these bytes are non-
zero, they must match the first four bytes of each DATA block line prefix or the line's data is ignored; this word is usually constructed from the date and time of the Area Directory creation; DDDHHMMSS

W37-45-satellite specific

W46-actual image start date; date the ingestor begins receiving image data; YYDDD

W47-actual image start time; time the ingestor begins receiving image data; HHMMSS

W48-actual starting scan line; the first scan line received by the ingestor

W49-length of the DATA block line prefix documentation region, in bytes

W50-length of the DATA block line prefix calibration region, in bytes

W51-length of the DATA block line prefix level map region, in bytes

W52-image source type; for example, VISR, VAS, AAA, ERBE, AVHR

W53-calibration type; units in which the digital data is stored; for example, RAW, TEMP, BRIT

W54-59-internal use only; initialized to 0

W60-byte offset to the beginning of the area file's AUX block

W61-length of the area file's AUX block, in bytes

W62-not used

W63-byte offset to the beginning of the area file's CAL block

W64-number of comment records in the area file's AUDIT block

Auxiliary (AUX) Block

This block contains information like histograms or long comments created by the user to describe or explain the area data. Word 60 of the Area Directory contains the number of bytes from the beginning of the area file to the beginning of the AUX block. Word 61 contains the total number of bytes in the block. If the area file does not contain an AUX block, Words 60 and 61 are both zero. Ordinarily, when an image is first ingested there is no AUX block in the area file.

Navigation (NAV) Block

This block contains the navigation data for the image. This information is used to associate earth coordinates, usually latitude and longitude, with the pixels of the image. Word 35 of the Area Directory contains the number of bytes from the beginning of the area file to the beginning of the NAV block. If there is no navigation for the image, Word 35 is zero. The NAV block's last byte is the byte before the CAL block, pointed to in Area Directory Word 63. If Word 63 is zero, the NAV block's last byte is the byte before the DATA block, pointed to in Word 34. The navigation block format varies with each satellite. See the next section for specific satellites.

Calibration (CAL) Block

This block contains the calibration data for the image. It is present in the area file if the data must be calibrated before it can be displayed. Calibration data is used to relate the sensor data to meaningful physical units such as temperature, albedo and visible brightness. Word 63 of the Area Directory contains the number of bytes from the beginning of the area file to the beginning of the CAL block. If the area file does not contain a CAL block, Word 63 is zero. The CAL block's last byte is the byte before the DATA block, pointed to in Area Directory Word 34. The calibration block format varies with each satellite. See the next section for specific satellites.

Digital Data (DATA) Block

This block contains the actual data values for the image. These values are stored in the area file in a series of lines and elements.

Coordinate Systems

Any point in an area can be described with image coordinates, its position in the full satellite image, or with area coordinates, its position in the area or subset of the image. Regardless of the source, a satellite image is a sequence of lines numbered from top to bottom. Each line is a sequence of elements numbered across the line from left to right. This line/element numbering scheme determines the coordinates for each element, called the image coordinates. The top line and leftmost element have image coordinates (1,1). This coordinate system is defined only by the satellite/camera combination and is independent of how the data is stored. The data stored in an area file is also arranged in a sequence of lines and elements, like the image from which it was created. The line/element pair determines the coordinates for the elements in the area, called the area coordinates. The top line and leftmost element have area coordinates (0,0). If entire satellite images could be stored in a single area, there would be no point in distinguishing between image and area coordinates. However, images are usually too large to process efficiently in their entirety. For example, a GOES VISSR image in the visible-light band contains 14568 lines with 15288 elements per line. This image requires over 200 megabytes of storage. The data actually stored in an area file is a subset of the image. An area may be a geographic portion of an image, the USA taken from a global image for example.

Resolution

An area file may be produced from an image by sampling or averaging the data. In the case of multiband images, an area may include only a portion of the measured spectral bands, so that each element contains fewer data values than are contained in the original image. To map an area back to the original image the following formulas are used:

Image Line = UpperLeftLine + (Area Line x LineResolution)
Image Element = UpperLeftEle + (Area Element x ElementResolution)

UpperLeftLine is the image line coordinate of the first area line. UpperLeftEle is the image element coordinate of the first area element. When LineResolution and ElementResolution are both 1, the area is said to be at Resolution 1 or Full Visible Resolution. If the area is at Resolution 4, every fourth line and element of an image originally at Resolution 1 are included in the area. Resolutions are relative to full resolution. The coverage of a pixel at full resolution will vary with each satellite.

Data Structure

The DATA block may be viewed as a continuous stream of bytes numbered from zero. The area data is arranged line after line, first to last. If a line of data is missing, the corresponding place in the data file must be either filled with zeros or flagged using non-matching validity codes.

```
  line prefix 1    line data 1    line prefix 2    line data 2    etc
|_______________|_____________|________________|_____________|___...
0                      byte numbers increase >>
```

Figure 1. Area File DATA Block Structure

Each line is divided into two parts: the line prefix and the actual line data (image elements). See Figure 1 above. The line prefix contains documentation about the image and the particular line. Although the size and content of the line prefix depend on the image source type defined in Area Directory Word 52, each line in an area has the same prefix length. Area Directory Word 15 contains the length of the prefix, in bytes. If no line prefix exists, Word 15 is zero.

The line prefix may contain any of the following regions. The lengths of these regions, when present, are multiples of four bytes.

- Validity Code
- Documentation
- Calibration
- Level Map

If present, the validity code is the first four bytes of the line prefix. When this code is present, Area Directory Word 36 contains a non-zero value. If the line prefix's validity code does not match the value in Word 36, the line is invalid and is ignored. The documentation region contains information specific to a particular satellite line (such as the VISSR IR documentation). Area Directory Word 49 contains the region's length, in bytes. The calibration region contains a set of calibration coefficients for each band in the line. For example, AAA Sounder images contain 13 bands per line, each with 8 bytes of calibration information. With an additional 12 bytes of information, an AAA Sounder calibration region has 116 bytes. Calibration regions in a line prefix are useful when coefficients change for individual bands during the course of a transmission. Area Directory Word 50 contains the region's length, in bytes. The level map region contains a 1-byte entry for each band/channel in the line. These are only meaningful if they are greater than zero. For an image containing a single band, the level map region is optional; for multiband areas, it must be present. Area Directory Word 51 contains the region's length, in bytes.

```
   validity code      documentation       calibration       level map
|______________|_______________|_____________|___________|
0                         byte numbers increase >>
```

Figure 2. Area Line Prefix Structure

Calculating Prefix, Line, and DATA Block Sizes

Area Directory Word 34 contains the number of bytes from the beginning of the area file to the beginning of the DATA block. Each line in an area has the same length. This length is a multiple of four bytes. The length of a line prefix, line data section, or the entire DATA block can be determined from information in the Area Directory. Use the information and the formulas that follow to calculate the sizes.

Area Directory Information
Word

validity code length (valcode)
4 bytes if W36 is not 0, otherwise 0

documentation length (doc)
W49

calibration length (cal)
W50

level map length (level)
W51

number of bands per line (nbands)
W14

number of elements per line (nele)
W10

number of bytes per element (nbytes)
W11

number of lines in the area (nlines)
W9

line prefix length = valcode (0 or 4) + doc + cal + level
line data section length = nbands × nele × nbytes
line length = line prefix length + line data section length
DATA block length = nlines × line length

Comment Records (AUDIT) Block

Comment records may be included in an area file. These records are usually used to keep an audit trail of modifications made to data in the file. Each comment record is 80 ASCII characters. Area Directory Word 64 contains the number of comment records. Ordinarily, when an image is first ingested there is no AUDIT block in the area file.

Satellite Specific Characteristics of McIDAS Area Files

Some aspects of McIDAS area files are satellite specific. This section describes characteristics specific to the following satellites:

METEOSAT PDUS

GVAR IMAGER
GVAR BLOCK 11
GVAR SOUNDER
GVAR VISSR
GOES-7

Future revisions of this document will include other satellites.

METEOSAT PDUS

Because METEOSAT PDUS images are remapped and calibrated at the ground station before the stretched signal is disseminated, the navigation and calibration data sections are simpler. This data is eight bits and each band is stored in a separate area file. For more information on METEOSAT labels and headers, see the EUMETSAT document, METEOSAT High Resolution Image Dissemination.

PDUS Area Directory Block

Word
Value and Description

W14
1; each band is stored separately

W19
band filter map values:
0 for visible image
128 (eighth bit from right) for IR
512 (tenth bit from right) for WV

W22
MIEC absolute calibration band value (IR or WV) from the calibration section of the METEOSAT header; stored as scaled integer xxxxx, value is .xxxxx

W23
space count corresponding to calibration value from the calibration section of the METEOSAT header; stored as scaled integer xxx, value is xx.x

W24
1 or 2; physical sensor number from the METEOSAT header

W37
line offset of the southeast corner of the area in image coordinates; 16-bit value from the METEOSAT header, right justified plus 1

W38
element offset of the southeast corner of the area in image coordinates; 16-bit value from the METEOSAT header, right justified plus 1

W39
satellite center longitude of rectification; 16-bit value from the METEOSAT header and right justified

W44
0

W49
24; length of the DATA block line prefix documentation, in bytes

W50
0; length of the DATA block line prefix calibration, in bytes

W51
0; length of the DATA block line prefix level map, in bytes

W52
MSAT; image source type

W53
RAW; calibration type
W54
0 if data was ingested as sent (full resolution);
1 if data was sampled down (every other pixel);
VIS is sent as Resolution 1 in some images and Resolution 2 in others

W55
bitmap indicating types of data included in the original image; bits are numbered right to left (least significant to most significant bit)
bit 0: 1 if VIS was included in transmission, 0 if not
bit 1: 1 if IR was included in transmission, 0 if not
bit 2: 1 if WV included in transmission, 0 if not
all other bits = 0

PDUS DATA Block

Line Prefix

Validity code: Optional but recommended to flag missing data. Missing data cannot be simply omitted; it must have zeros as placeholder data or a validity code that does not match the value in Area Directory Word 36.

Documentation: 24 bytes. This is a copy of the label that arrives with every subframe.
Calibration: 0 bytes. Not used.
Level map: 0 bytes. Not used. Each METEOSAT band is stored in a separate area.

Line Data.

Each value is transmitted as eight bits and is stored west to east and north to south in the area, the opposite of how it is transmitted.

PDUS NAV Block

A PDUS navigation block is divided into 256 words:

Word
Value and Description

W1
MSAT; navigation type

W2
Julian day of this navigation, YYDDD

W3
time of this navigation, HHMMSS

W4
0; reference position for the telescope

W5
0; line number corresponding to the telescope reference position

W6
1250; center scan line

W7
center longitude of rectification (west positive), DDMMSS

W8
0; not used

W9
0; not used

W10

Julian day of this navigation, YYDDD

W11-256
0; not used

PDUS CAL Block

No calibration information is needed for PDUS.

GVAR IMAGER

The tables mentioned in the line prefix, line data, calibration and navigation descriptions in this section are from Operations Ground Equipment, Internal Specification, DRL 504-02-1 Part 1, Specification No E007020. This document describes data formatted by the ground station and then retransmitted. It is referred to in this document as the OGE.

Imager Documentation (Block 0)
The GVAR Imager documentation, Block 0, is supplemental control information about an image, not image data. Some of the information is also contained in Imager sensor data. For each line of GVAR Imager sensor data transmitted, one line of Block 0 documentation is transmitted and stored in a separate area.
Area Directory Block

Word
Value and Description

W12
8; line resolution

W13
1; element resolution

W14
1; number of bands

W19
1; band number

W25-32
ordinarily contains the ASCII string RT IMGR DOC

W49
44; length of the DATA block line prefix documentation region, in bytes

W50

0; length of the DATA block line prefix calibration region, in bytes

W51
0; length of the DATA block line prefix level map region, in bytes

W52
GVAR; image source type

W53
RAW; calibration type

Line Prefix

Validity Code: 4 bytes
Documentation: 44 bytes. The documentation region consists of the following:
- Block Header CRC: 2 bytes (OGE Table 3-5)
- Scan Status: 4 bytes (OGE Table 3-6)
- Year, Day, Time from Block 0: 8 bytes (OGE Table 3-6)
- Block Header: 30 bytes (OGE Table 3-5)
- Bytes 17-24 now contain the time the block was disseminated from the ground station.

The rest of the line is made up of 8040 bytes of 8-bit data. (OGE Table 3-6)

Imager Area DIRECTORY Block (For blocks 1-10, bands 1-5)

Word
Value and Description

W5
1; size of the z-dimension

W14
1; number of bands requested

W19
band filter map; 1 for VIS; 2, 4, 8 or 16 for IR bands; only one bit should be set

W25-32
RT IMGR IR; (ASCII string)
RT IMGR VIS if the band is visible

W49
76; length of the DATA block line prefix documentation region, in bytes

W50

0; length of the DATA block line prefix calibration region, in bytes

W51
0; length of the DATA block line prefix level map region, in bytes

W52
GVAR; image source type

W53
RAW; calibration type

W55
1

Imager area DATA Block

GOES Variable Imager data (GVAR) is transmitted in five spectral bands: VISIBLE (VIS) and four INFRARED (IR) bands. An area contains only one of these five bands. Area Directory Word 19 contains a band filter map indicating the area file's band. The highest resolution (lowest values of line and element resolution in the Area Directory) possible for a visible area is 1. The highest resolution for an IR area is 4 because longer wavelengths inherently have less resolution. For a GVAR satellite, Resolution 1 means approximately 1 km resolution at the satellite subpoint.

Every element in a GOES-8 area contains one 10-bit pixel representing raw data from the instrument. Each pixel is stored as two bytes in the McIDAS area file. The hardware shifts the data so that the 10 bits are formatted as follows:

| 0 | x | x | x | x | x | x | x | x | x | x | 0 | 0 | 0 | 0 | 0 |

The x represents a data bit and the rest is 0-filled after shifting.

Line Prefix

Validity Code: 4 bytes
- Documentation: 76 bytes. The documentation region consists of the following:
- Block Header CRC: 2 bytes. Last three bits only; bit is set if Block Header copy is good. This data is usually 00,07.
- Scan Status: 4 bytes (OGE Table 3-6)
- Year, Day, Time from Block 0: 8 bytes
- Block Header: 30 bytes (OGE Table 3-5)

Bytes 17-24 now contain the time the block was disseminated from the ground station.

Additional Line Documentation: 32 bytes. Sixteen 10-bit fields, right-justified (OGE Table 3-7).

The 6 bit field on the left hand side is not zero filled. To get the 10 bit field a logical AND against 03FF (hex) must be used.

Data

The rest of the line consists of up to 41920 bytes of data. Because it is 2-byte data, half that many pixels are represented.

Imager NAV Block

Navigation blocks are divided into 640 words. Unless otherwise noted, words are twos complement binary integers. This navigation information comes from Block 0 records. Bytes designated R*4 in OGE Tables are in Gould format. They must be scaled and then converted to integers; or converted to Real on the machine doing the decoding, scaled as designated below, and then converted to integer.

Word
Value and Description

W1
GVAR; navigation type

W2
ASCII string; usually a letter followed by three integers, for example, U001

W3
imager scan status; bits 0-15 are right justified, bit15 is the least significant bit; IMC active flag is bit 8, counting from the least significant bit; 1=active; see OGE Table 3-6, bytes 3-6

W4-5
0; not used

W6-62
see OGE Table 3-6, bytes 295-522

W6
reference longitude, rad * 10000000

W7
reference distance from nominal, km * 10000000

W8
reference latitude, rad * 10000000

W9

reference yaw, rad * 10000000

W10
reference attitude roll, rad * 10000000

W11
reference attitude pitch, rad * 10000000

W12
reference attitude yaw, rad * 10000000

W13-14
epoch date/time, BCD format

W15
delta from epoch time, minutes * 100

W16
image motion compensation roll, rad * 10000000

W17
image motion compensation pitch, rad * 10000000

W18
image motion compensation yaw, rad * 10000000

W19-31
longitude delta from reference values, rad * 10000000

W32-42
radial distance delta from reference values, rad * 10000000

W43-51
geocentric latitude delta values, no units * 10000000

W52-60
orbit yaw delta values, no units * 10000000

W61
daily solar rate, rad/min * 10000000

W62
exponential start time from epoch, minutes * 100

W63-117

roll attitude angle information; see OGE Table 3-6, bytes 523-742

W63
exponential magnitude, rad * 10000000

W64
exponential time constant, minutes * 100

W65
mean attitude angle, rad * 10000000

W66
number of sinusoids/angles, no units

W67
magnitude of first order sinusoid, rad * 10000000

W68
phase angle of first order sinusoid, rad * 10000000
•
•
•
W95
magnitude of fifteenth sinusoid, rad * 10000000

W96
phase angle of fifteenth sinusoid, rad * 10000000

W97
number of monomial sinusoid, no units

W98
order of applicable sinusoid, no units

W99
order of first monomial sinusoid, no units

W100
magnitude of monomial sinusoid, rad * 10000000

W101
phase angle of monomial sinusoid, rad * 10000000

W102

angle from epoch at daily solar rate, rad * 10000000

W103-107
repeat of Words 98-102 for second monomial

W108-112
repeat of Words 98-102 for third monomial

W113-117
repeat of Words 98-102 for fourth monomial

W118-127
reserved
W128
MORE; 4-byte ASCII

W129
GVAR; 4-byte ASCII

W130-239
attitude angles

W130-184
repeat of Words 63-117 for pitch attitude angle; see OGE Table 3-6, bytes 743-962

W185-239
repeat of Words 63-117 for yaw attitude angle; see OGE Table 3-6, bytes 963-1182

W240-255
reserved

W256
MORE; 4-byte ASCII

W257
GVAR; 4-byte ASCII

W258-367
misalignment angles

W258-312
repeat of Words 63-117 for roll misalignment angle; see OGE Table 3-6, bytes 1183-1402

W313-367
repeat of Words 63-117 for pitch misalignment angle; see OGE Table 3-6, bytes 1403-1622

W368
year and Julian day, YYDDD

W369
nominal start time of image, HHMMSS

W370
1; Imager/Sounder instrument flag; 1 = Imager,
2 = Sounder

W371-379
reserved

W380
instrument nadir, north/south cycles; see OGE Table 3-6, byte 6305

W381
instrument nadir, east/west cycles; see OGE Table 3-6, byte 6306

W382
instrument nadir, north/south increments; see OGE Table 3-6, byte 6307-6308

W383
instrument nadir, east/west increments; see OGE Table 3-6, byte 6309-6310

W384
MORE; 4-byte ASCII

W385
GVAR; 4-byte ASCII

W386-511
reserved

W512
MORE; 4-byte ASCII

W513
GVAR; 4-byte ASCII

W514-640
reserved

Imager CAL Block

There are two instruments on the GOES-8 through GOES-12 series of satellites: the Sounder and the Imager. Even sensor source numbers represent Imager data and odd sensor source numbers represent Sounder data. Area Directory Word 52 contains the image source type:

1) **GVAR** for GVAR data as it is ingested (2 byte)
2) **VISR** for 1-byte visible or infrared imagery

VISR data cannot be ingested; GVAR data can be transformed to VISR with a McIDAS utility such as AA or SENAA.

Area Directory Word 53 contains the units in which the data is stored:

1) **RAW** for 2-byte raw GVAR data
2) **BRIT** for 1-byte visible or infrared values

Area Directory Word 14 contains the number of spectral bands present in an Imager area. The filter band map in Area Directory Word 19 describes the bands in an area. A bit is set for each band appearing in the area. The number of bands must match the value in Word 14.

The Imager calibration block is made up of 128 words (512 bytes). The data is in the Gould format.

Word
Value and Description

W1-W8
visible bias coefficients; one per detector (OGE Table 3-6, bytes 6399-6430)

W9-W16
visible first order gain coefficients; one per detector (OGE Table 3-6, bytes 6431-6462)

W17-W24
visible second order gain coefficients; one per detector (OGE Table 3-6, bytes 6463-6494)

W25
visible radiance to albedo conversion factor (OGE Table 3-6, bytes 6495-6498)

W26-W29
det side 1 IR bias scaling factors; one per IR channel (OGE Table 3-6: bytes 6667-6670 Ch 4, Side 1; bytes 6675-6679 Ch 5, Side 1; bytes 6683-6686 Ch 2, Side 1;
bytes 6691-6694 Ch 3, Side 1)

W30-W33
det side 2 IR bias scaling factors; one per IR channel (OGE Table 3-6: bytes 6695-6698 Ch 4,

Side 2; bytes 6703-6706 Ch 5, Side 2; bytes 6711-6714 Ch 2, Side 2;
bytes 6719-6722 Ch 3, Side 2)

W34-W37
det side 1 IR gain scaling factors; one per IR channel (OGE Table 3-6: bytes 6723-6726 Ch 4, Side 1; bytes 6731-6734 Ch 5, Side 1; bytes 6739-6742 Ch 2, Side 1;
bytes 6747-6750 Ch 3, Side 1)
W38-W41
det side 2 IR gain scaling factors; one per IR channel (OGE Table 3-6: bytes 6751-6753 Ch 4, Side 2; bytes 6759-6762 Ch 5, Side 2; bytes 6767-6770 Ch 2, Side 2;
bytes 6775-6778 Ch 3, Side 2)

W42-W128
0

BLOCK 11

Block 11 Holding areas contain data for Sounder images. This data cannot be easily accessed. A decoder must reformat the raw Block 11 data and place it in Sounder image areas, where it is available for analysis and display.

Block 11 Holding Area DIRECTORY Block

Word
Value and Description

W11
number of bytes per element; 1 or 2 depending on the element size of the desired band; a holding area cannot contain both 1- and 2-byte data.

W14
1; number of bands in the image

W19
block type filter; positions of set bits correspond to the block types requested; the least significant bit is the right hand bit; a value of 787968 translates to 0c0600 hex with bits set in positions 20, 19, 11 and 10 W25-32 ordinarily contains the ASCII string RT BK11 BYT1

W49
40; length of the DATA block line prefix documentation region, in bytes

W50
0; length of the DATA block line prefix calibration region, in bytes

W51

0; length of the DATA block line prefix level map region, in bytes

W52
BK11; image source type

W53
RAW; calibration type

Block 11 Holding Area DATA Block

GVAR transmits 22 types of Block 11 data. This can be 6-, 8-, or 10-bit data. The user can specify any type to be stored in a single holding area. Control fields in the line prefix or the first portion of the data (called the SAD ID) are used by post-processes, such as the Sounder decoder, to determine the block type. Each DATA block line consists of a single Block 11 sector (or block). All blocks are 8040 bytes. Refer to the OGE, sections 3.3.7 - 3.3.7.14 for a detailed breakdown of the contents of each block type. The 10-bit data is formatted as follows:

| 0 | x | x | x | x | x | x | x | x | x | x | 0 | 0 | 0 | 0 | 0 |

The x represents a data bit and the rest is zero-filled after shifting.

The 8-bit data is formatted as follows:

| x | x | x | x | x | x | x | x |

The 6-bit data is formatted as follows:

| 0 | 0 | x | x | x | x | x | x |

Line Prefix

Validity Code: 4 bytes

Documentation: 40 bytes. The documentation region consists of the following:

- Block Header CRC: 2 bytes (OGE Table 3-5)
- Current Year, Day and Time from Block 0: 8 bytes (OGE Table 3-6)
- Block Header: 30 bytes (OGE Table 3-5)

Bytes 17-24 now contain the time the block was disseminated from the ground station. The rest of the line consists of up to 8040 bytes of data, depending on block type. WARNING: The Block Header CRC field is overwritten in the mainframe by a 2-byte counter. This is used to check sequencing of the data flow.

GVAR SOUNDER

Sounder areas are decoded from Block 11 holding area data.

Block 11 Decoded Sounder Area DIRECTORY Block

Word
Value and Description

W12
line resolution; 10 is the base resolution; if lines are sampled or averaged, the resolution is in multiples of 10.

W13
element resolution; 10 is the base resolution; if pixels are sampled or averaged, the resolution is in multiples of 10.

W14
19; number of bands

W19
54287; band filter map; translates to 0007ffff hex; bits set for bands 1-19

W25-32
ordinarily contains the ASCII string PRIORITY COMPLETED

W49
36; length of the DATA block line prefix documentation region, in bytes

W50
0; length of the DATA block line prefix calibration region, in bytes

W51
24; length of the DATA block line prefix level map region, in bytes

W52
GVAR; image source type

W53
RAW; calibration type

Block 11 Decoded Sounder Area DATA Block

The GVAR Sounder Decoder reads Block 11 Holding areas, which contain blocks of type 32 (20hex) and type 35 (23hex) as well as others. These blocks are documented in OGE, section 3.3.7.2 and section 3.3.7.3. Navigation and calibration data is read from type 32 blocks (Sounder documentation blocks). Sensor data is read from type 35 blocks (Sounder scan data blocks) and then reformatted and placed in the Sounder image area. All Sounder data fields are 13 bits and are placed in 2-byte (16-bit) fields. There are 23 bands of data for each pixel in a Sounder scan data block. The pixels correspond to a geographic area 11 pixels west-east and 4 pixels north-south. For each image line, the decoder produces 11 sets of 23 interleaved fields of data. Bands 20-23 of this data are not displayable; they hold the latitude and longitude of the first 19 bands. The latitude and longitudes are 32-bit values. Since the actual Sounder data is 16 bits, the latitude and longitude values must be split in half to store them in the area structure. Band 20 holds the two most significant bytes and band 21 holds the two least significant bytes of the latitude. Band 22 holds the two most significant bytes and band 23 holds the two least significant bytes of the longitude. These latitude and longitude values are in the Gould floating point format. See OGE, section 3.5.4. For example, if the latitude of a pixel is 100.1640625, the hex representation is 42642A00; band 20 holds 4264, and band 21 holds 2A00. No code is provided in this package to use these latitudes and longitudes; they are included only for reference purposes. There are four Sounder sensors: A through D. Each DATA block line contains information from only one sensor. The first line contains sensor A information, the second line, sensor B, etc. This pattern is repeated for the entire DATA block.

Line Prefix

Validity Code: 4 bytes

Documentation: 36 bytes. The documentation region consists of the following:

- First 9 words of SAD Block ID: 9 bytes (OGE Table 3-8)
- Year, Day, Time of scan line start: 8 bytes (OGE Table 3-11)
- Sounder scan status: 2 bytes (OGE Table 3-11)
- Number of Block 11 blocks in the scan: 2 bytes (OGE Table 3-11)
- O&A Location: 2 bytes. No longer used.
- Detector status: 10 bytes (OGE Table 3-11)
- Detector used in this area line: 1 byte
- padding: 2 bytes

Level map; indicates band order for this line: 24 bytes. The rest of the line is made up of the interleaved Sounder data.

Block 11 Decoded Sounder Area NAV Block

Navigation blocks are divided into 640 words. Unless otherwise noted, words are twos complement binary integers. This navigation information comes from Block 11 records, type 32. Bytes designated R*4 in the OGE Tables are in Gould format in the holding areas. They must be scaled and then converted to integers; or converted to Real on the machine doing the decoding, scaled as designated below, and then converted to integer.

Word

Value and Description

W1
GVAR; navigation type

W2
ASCII string; usually a letter followed by three integers, for example, U001

W3
imager scan status; bits 0-15 are right justified, bit 15 is the least significant bit; IMC active flag is bit 8, counting from the least significant bit; 1=active; see OGE Table 3-11, bytes 3-6

W4-5
0; not used

W6-62
see OGE Table 3-11, bytes 323-550

W6
reference longitude, rad * 10000000

W7
reference distance from nominal, km * 10000000

W8
reference latitude, rad * 10000000

W9
reference yaw, rad * 10000000

W10
reference attitude roll, rad * 10000000

W11
reference attitude pitch, rad * 10000000

W12
reference attitude yaw, rad * 10000000

W13-14
epoch date/time, BCD format

W15
delta from epoch time, minutes * 100
W16

image motion compensation roll, rad * 10000000

W17
image motion compensation pitch, rad * 10000000

W18
image motion compensation yaw, rad * 10000000

W19-31
longitude delta from reference values, rad * 10000000

W32-42
radial distance delta from reference values, rad * 10000000

W43-51
geocentric latitude delta values, no units * 10000000

W52-60
orbit yaw delta values, no units * 10000000

W61
daily solar rate, rad/min * 10000000

W62
exponential start time from epoch, minutes * 100

W63-117
roll attitude angle information; see OGE Table 3-11, bytes 551-770

W63
exponential magnitude, rad * 10000000

W64
exponential time constant, minutes * 100

W65
mean attitude angle, rad * 10000000

W66
number of sinusoids/angles, no units

W67
magnitude of first order sinusoid, rad * 10000000

W68
phase angle of first order sinusoid, rad * 10000000
•
•
•
W95
magnitude of fifteenth sinusoid, rad * 10000000

W96
phase angle of fifteenth sinusoid, rad * 10000000

W97
number of monomial sinusoid, no units

W98
order of applicable sinusoid, no units

W99
order of first monomial sinusoid, no units

W100
magnitude of monomial sinusoid, rad * 10000000

W101
phase angle of monomial sinusoid, rad * 10000000

W102
angle from epoch at daily solar rate, rad * 10000000

W103-107
repeat of Words 98-102 for second monomial

W108-112
repeat of Words 98-102 for third monomial

W113-117
repeat of Words 98-102 for fourth monomial

W118-127
reserved
W128
MORE; 4-byte ASCII

W129
GVAR; 4-byte ASCII

W130-239
attitude angles see OGE Table 3-11, bytes 771-1210

W130-184
repeat of Words 63-117 for pitch attitude angle; see OGE Table 3-11, bytes 771-990

W185-239
repeat of Words 63-117 for yaw attitude angle; see OGE Table 3-11, bytes 991-1210

W240-255
reserved

W256
MORE; 4-byte ASCII

W257
GVAR; 4-byte ASCII

W258-367
misalignment angles

W258-312
repeat of Words 63-117 for roll misalignment angle; see OGE Table 3-11; bytes 1211-1430

W313-367
repeat of Words 63-117 for pitch misalignment angle; see OGE Table 3-11; bytes 1431-1650

W368
year and Julian day, YYDDD

W369
nominal start time of the image, HHMMSS

W370
2; Imager/Sounder instrument flag; 1 = Imager, 2 = Sounder

W371-379
reserved

W380
instrument nadir, north/south cycles; see OGE Table 3-6, byte 3005

W381

instrument nadir, east/west cycles; see OGE Table 3-6, byte 3006

W382
instrument nadir, north/south increments; see OGE Table 3-6, byte 3007-3008

W383
instrument nadir, east/west increments; see OGE Table 3-6, byte 3009-3010

W384
MORE; 4-byte ASCII

W385
GVAR; 4-byte ASCII

W386-511
reserved

W512
MORE; 4-byte ASCII

W513
GVAR; 4-byte ASCII

W514-640
reserved

Block 11 Decoded Sounder Area CAL Block

Sounder calibration blocks are made up of 128 words (512 bytes):

Word
Value and Description

W1-W4
visible bias coefficients; one per detector (OGE Table 3-11, bytes 3075-3090)

W5-W8
visible first order gain coefficients; one per detector (OGE Table 3-11, bytes 3091-3106)

W9-W12
visible second order gain coefficients; one per detector (OGE Table 3-11, bytes 3107-3122)

W13
visible radiance to albedo conversion factor (OGE Table 3-11, bytes 3123-3126)

W14-W31
IR bias scaling factors; one per IR channel (OGE Table 3-11, bytes 3127-3414)

W32-W49
IR gain scaling factors; one per IR channel (OGE Table 3-11, bytes 3415-3702)

W50-W128
0

GVAR VISSR

Brightness to Temperature Conversion Algorithm

The following description is for image source type VISR from Area Directory Word 52. GVAR VISSR areas can be made with the McIDAS commands AA and ARAGET. Every element in a VISSR area contains one 8-bit pixel, representing raw data from the instrument. If the area contains IR data, the observed temperature may be calculated from the pixel value using the following formulas:

T = 418 - B (B>176 OR B=176)
T = 330 - (B / 2) (B<176 OR B=176)

T is the brightness temperature (degrees K). B is the pixel value (0 to 255). For IR data, the highest pixel values correspond to the coldest temperatures (space is white).

The line prefix in a VISSR area may be absent or it may contain only the 4-byte validity code. The highest resolution, lowest values of line and element resolution in the Area Directory, possible for a visible area is 1. The highest resolution for an IR area is 4 because longer wavelengths inherently have less resolution. For a GOES satellite, resolution 1 means approximately 1 km resolution at the satellite subpoint.

GOES-7 Area NAV Block

Unless otherwise noted, the words in the navigation block are twos complement binary integers.
Word
Value and Description

W1
GOES; navigation type

W2
satellite ID, year, and Julian day, SSYYDDD

W3
nominal start time of image, HHMMSS

Orbit parameters

W4
1; orbit type

W5
epoch date (ETIMY), YYMMDD

W6
epoch time (ETIMH), HHMMSS

W7
semimajor axis (SEMIMA), Km * 100

W8
orbital eccentricity (ECCEN) * 100000

W9
orbital inclination (ORBINC), Deg * 1000

W10
mean anomaly (MEANA), Deg * 1000

W11
argument of perigee (PERIGEE), Deg * 1000

W12
right ascension of ascending node (ASNODE), Deg * 1000

Attitude parameters

W13
declination of satellite axis (DECLIN), DDDMMSS (+ = NORTH)

W14
right ascension of satellite axis (RASCEN), DDDMMSS

W15
picture center line number (PICLIN)

Spin

W16
spin period (SPINP); the satellite period, in microseconds, or the spin rate in revolutions/minute.

Frame geometry

W17
total sweep angle, line direction (DEGLIN), DDDMMSS

W18
number of scan lines (LINTOT), NNLLLLL where NN is number of sensors, LLLLL is number of scans; total number of actual lines is NN * LLLLL

W19
total sweep angle, element direction (DEGELE), DDDMMSS

W20
number of elements in a scan line (ELETOT)

Camera geometry

W21
forward-leaning (PITCH), DDDMMSS

W22
sideways-leaning (YAW), DDDMMSS

W23
rotation (ROLL), DDDMMSS

W24
reserved

W25
east-west adjustment value (IAJUST), in visible elements (+ or -)

W26
time computed by IAJUST from the first valid landmark of the day (IAJTIM), HHMMSS

W27
reserved

W28
angle between the VISSR and sun sensor (ISEANG), DDDMMSS

W29
0; reserved for later implementation of *SKEW*

W30
reserved

Betas for this area

W31
scan line of first the beta

W32
time of first beta’s scan line (beginning), HHMMSS

W33
time of first beta’s scan line (continued), milliseconds * 10

W34
beta count 1

W35
scan line of second beta

W36
time of second beta’s scan line (beginning), HHMMSS

W37
time of second beta’s scan line (continued), milliseconds * 10

W38
beta count 2
Gammas for this area

W39
gamma, element offset * 100; this is the nominal offset at time zero of this day

W40
gamma-dot, element drift per hour * 100

W41-120
reserved

W121-128
memo; up to 32 ASCII characters of comments

Sensor Source Numbers

Use this table to find the number used by McIDAS software to identify sensors.

Number Sensor Source:

0 Non-Image Derived Data
2 Graphics
3 MDR Radar
4 PDUS METEOSAT Visible
5 PDUS METEOSAT Infrared
6 PDUS METEOSAT Water Vapor
7 Radar
8 Miscellaneous Aircraft Data (MAMS)
9 Raw METEOSAT
12 GMS Visible prior to GMS-5
13 GMS Infrared prior to GMS-5
14 ATS 6 Visible
15 ATS 6 Infrared
16 SMS-1 Visible
17 SMS-1 Infrared
18 SMS-2 Visible
19 SMS-2 Infrared
20 GOES-1 Visible
21 GOES-1 Infrared
22 GOES-2 Visible
23 GOES-2 Infrared
24 GOES-3 Visible
25 GOES-3 Infrared
26 GOES-4 Visible (VAS)
27 GOES-4 Infrared and Water Vapor (VAS)
28 GOES-5 Visible
29 GOES-5 Infrared and Water Vapor (VAS)
30 GOES-6 Visible
31 GOES-6 Infrared
32 GOES-7 Visible
33 GOES-7 Infrared
41 TIROS-N (POES)
42 NOAA-6
43 NOAA-7
44 NOAA-8
45 NOAA-9
46-49 MARINER X Spacecraft
50 Hubble Space Telescope
54 METEOSAT-3
55 METEOSAT-4
56 METEOSAT-5
57 METEOSAT-6

60 NOAA-10
61 NOAA-11
62 NOAA-12
63 NOAA-13
64 NOAA-14
70 GOES-8 (Imager)
71 GOES-8 (Sounder)
72 GOES-9 (Imager)
73 GOES-9 (Sounder)
74 GOES-10 (Imager)
75 GOES-10 (Sounder)
76 GOES-11 (Imager)
77 GOES-11 (Sounder)
78 GOES-12 (Imager)
79 GOES-12 (Sounder)
80 ERBE
82 GMS-4
83 GMS-5
84 GMS-6
85 GMS-7
87 DMSP F-8
88 DMSP F-9
89 DMSP F-10
90 DMSP F-11
91 DMSP F-12
95 FY-1b
96 FY-1c
97 FY-1d

GVAR Calibration Tables

Imager Sensor Characteristics

The IMAGER produces observation data for a given spatial location in four different IR spectral bands and a visible band. The characteristics of the Imager bands are given below:

Band No.
Wavelength Range (μm)
Range of Measurement
Meteorological Objective And Maximum Temp. Range

1
00.55 - 00.75
1.6 to 100 % albedo
Cloud Cover

2
03.80 - 04.00
4 to 320 K
Night clouds (space - 340 K)

3
06.50 - 07.00
4 to 320 K
Water vapor (space - 290 K)

4
10.20 - 11.20
4 to 320 K
Surface Temp (space - 340 K)

5
11.50 - 12.50
4 to 320 K
Sea surface temp and water vapor (space - 335 K)

Sounder Detector Characteristics

The Sounder produces data for a given spatial location in 18 IR spectral bands and a visible band. The characteristics of the Sounder bands are listed below:

Band No.
Central Wavelength (um)
Wave No. (cm -1)
Meteorological Objective And
Maximum Temp. Range

Longwave

1
14.71
680
Temperature (space - 280 K)

2
14.37
696
Sounding (space - 280 K)

3

14.06
711
Sounding (space - 290 K)

4
13.64
733
Sounding (space - 310 K)

5
13.37
748
Sounding (space - 320 K)

6
12.66
790
Sounding (space - 330 K)

7
12.02
832
Surface temp. (space - 340 K)

Midwave

8
11.03
907
Surface temp (space - 345 K)

9
9.71
1030
Total ozone (space - 330 K)

10
7.43
1345
Water vapor (space - 310 K)

11
7.02
1425
Sounding (space - 295 K)

12
6.51
1535
Sounding (space - 290 K)

Shortwave

13
4.57
2188
Temperature (space - 320 K)

14
4.52
2210
Sounding   (space - 310 K)

15
4.45
2248
Sounding   (space - 295 K)

16
4.13
2420
Sounding   (space - 240 K)

17
3.98
2513
Surface temp (space - 345 K)

18
3.74
2671
Temperature (space - 345 K)

Visible

19
0.70
14367
Cloud cover

The number of spectral bands present in Imager and Sounder areas is contained in Area Directory Word 14. The filter map in Word 19 describes the bands in an area. A bit is set for each band in the area. The number of bands must match the value in Word 14.

Storing Satellite Imagery in McIDAS Data Structures
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