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THE STATUS OF ENVIRONMENTAL SATELLITES AND AVAILABILITY OF THEIR DATA PRODUCTS

Job Order 75-225

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For

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SPACE AND LIFE SCIENCES DIRECTORATE

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

March 1977

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NOTE

The contents of this report represent the latest information available to the authors about unclassified environmental satellites flown by the United States. Many factors in satellite status, sensor status, and ground processing and data storage status can affect final data products available to the user. Some of the variables in this process are as follows:

- Satellites which have not been approved for flight may eithe change nomenclature before launch or may never be launched.
- Satellites may fail on launch
- Failure or partial failure of instrument or satellite in orbit can result in limited or no data
- Change in mode of operation of satellite upon command can change because of requirements
- Satellites can be put on stand-by because of obsolescence forced by improved satellites, time, or other factors
- Changes can occur in data products because of priorities, economics, reduced requirements, increased requirements, improvements, or other factors
- Changes can also occur in processing and storage facilities and locations of receiving sites

For these reasons, this report should be kept in loose leaf form in order that changes can be easily incorporated. Significant changes in available information about the status of environmental satellites and their data products will be reason for issuing a revision to this report.

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ACRONYMS

AASIR	Advanced Atmospheric Sounding and Imaging Radiometer
AEM	Application Explorer Mission
AFGWC	Air Force Global Weather Control
AFC	Air Force Communications
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
APT	Automatic Picture Transmission
ATC	Air Training Command
ATS	Applications Technology Satellite
AVHRR	Advanced Very High Resolution Radiometer
BSU	Basic Sounding Unit
CCT	Computer Compatible Tape
CDA	Command and Data Acquisition
CDC	Control Data Corporation
CDDS	Central Data Distribution System
CZCS	Coastal Zone Color Scanner
DAPAF	Data Processing and Analysis Facility (NOAA)
DCS	Data Collection System
DCS/RSE	DCS Receiving Site Equipment
DDHS	Digital Data Handling System
DDS	Data Display Segment
DIPS	Digital Image Preprocessing System
DPPS	Digital Image Processing System
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense

DS	Digital Subsystem
EBR	Electron Beam Recorder
EDC	EROS Data Center
EDR	Experimental Data Records
ERB	Earth Radiation Budget
EREP	Earth Resources Experiment Package (SKYLAB)
EROS	Earth Resources Observations Systems (Program)
ERTS	Earth Resources Technology Satellite
ESMR	Electrically Scanning Microwave Radiometer
FOFAX	Forecast Office Facsimile (Network)
FNWC	Fleet Numerical Weather Central (U.S. Navy)
GEOS	Geodynamic Experimental Ocean Satellite
GOES	Geostationary Operational Environmental Satellite
GOSSTCOMP	Global Operational Sea Surface Temperature Computations
GSFC	Goddard Space Flight Center
HCMM	Heat Capacity Mapping Mission (also AEM-A)
HCMR	Heat Capacity Mapping Radiometer
HDT	High Density Tape
HRIRS	High Resolution Infrared Radiation Sounder
HRPT	High Resolution Picture Transmission
IERG	Imagery Enhancement Review Group (NESS)
IFOV	Instantaneous Field of View
IIGS	Initial Image Generation System
IPF	Image Processing Facility
IPD	Information Processing Division (GSFC)
IPS	Image Processing System

IR	Infrared
ITOS	Improved TIROS Operational Satellite
ITPR	Infrared Temperature Profile Radiometer
KHz	Kilohertz
LAGEOS	Laser Geodynamics Satellite
LANDSAT	Land Satellite
LEST	Large Earth Survey Telescope (on SEOS)
LIMS	Limb Infrared Monitoring of the Stratosphere
LRIR	Limb Radiance IR Radiometer
MASR	Microwave Atmospheric Sounding Radiometer
MDHS	Meteorological Data Handling Station (GSFC)
MHz	Megahertz
MOCS	Mission Operations and Control System (GSFC)
MPP	MSS Preprocessor
MSS	Multispectral Scanner
MSU	Microwave Sounding Unit
NAFAX	National Facsimile (Network)
NASCOM	NASA Communications (Network)
NBTR	Narrow Band Tape Recorder
NCIC	National Cartographic Information Center
NDPF	NASA Data Processing Facility
NESS	National Environmental Satellite Service
NEMS	NIMBUS-E Microwave Spectrometer
NMC	National Meteorological Center
NOAA	National Oceanographic and Atmospheric Administration
NTTF	NASA Test and Training Facility

NWS	National Weather Service
OCC	Operations Control Center
OLS	Operational Linescan System
OFT	Operational Flight Test
PCM	Pulse Code Modulation
PCM-NRZL	Pulse Code Modulation - Non-Return to Zero Level
PDPS	Project Data Processing Subsystem (SEASAT)
PDR	Processed Data Records
PMR	Pressure Modulator Radiometer
RBV	Return Beam Vidicon
RTD	Real Time Data
SAC	Strategic Air Command
SAGE	Stratospheric Aerosol and Gas Experiment
SAMS	Stratospheric and Mesospheric Sounder
SAMSO	Space and Missiles Systems Organization
SAO	Smithsonian Astrophysical Observatory
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications (NOAA)
SBUV/TOMS	Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer
SCAMS	Scanning Microwave Spectrometer
SCMR	Surface Composition Mapping Radiometer
SCR	Selective Chopper Radiometer
SDSB	Satellite Data Services Branch (NOAA)
SDPS	SAR Data Processing Subsystem (SEASAT)
SEASAT	Sea Satellite
SEOS	Synchronous Earth Observations Satellite

SFSS	Satellite Field Service Station
SEM	Space Environmental Monitor
SINAP	Satellite Input to Numerical Analysis and Prediction
SIRS	Satellite Infrared Sounding
SLAR	Side Looking Airborne Radar
SMMR	Scanning Multi-frequency Microwave Radiometer
SMS	Synchronous Meteorological Satellite
SOCC	Satellite Operations Control Center (NOAA)
SSOS	Severe Storms Observational Satellite
SPM	Solar Proton Monitor
SR	Scanning Radiometer
SRR	Scanning Radiometer Recorder
SSE	Supplementary Sensor E
SSH	Special Meteorological Sensor-H
SSL	Supplementary Sensor-L
SST	Sea Surface Temperature
SSU	Stratospheric Sounding Unit
STDN	Space Tracking and Data Network (NASA)
STORMSAT	Storm Satellite
TDAS	Tracking and Data Acquisition Subsystem (NASA)
T&DRE	Tracking and Data Relay Experiment
THIR	Temperature Humidity Infrared Radiometer
TIROS	Television Infrared Observational Satellite
TM	Thematic Mapper
TWERLE	Tropical Wind Energy Conversion and Reference Level Experiment

USB	Unified S-Band
VAS	VISSR Atmospheric Sounder
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VIRR	Visible-IR Radiometer (SEASAT)
VISSR	Visible-Infrared Spin Scan Radiometer
VTPR	Vertical Temperature Profile Radiometer
VTR	Video Tape Recorder
WBVT	Wide Band Video Tapes
WBTR	Wide Band Tape Recorder
WEFAX	Weather Facsimile
WSFO	Weather Service Forecast Offices (NOAA)

1. INTRODUCTION

During the development of the Skylab program analyses as well as the ensuing Advanced Sensors Studies, it became apparent to the authors that a large number of environmental satellite data products were available to potential users. Unfortunately, very little of this available data and complimentary services were utilized by ourselves or by other researchers within the Earth Resources Community. This is not attributed to a lack of value in the data but can primarily be blamed on lack of education in the large variety and multitude of locations of these products and a lack of time during a given project to obtain knowledge about the data. The difficulty in obtaining this knowledge is compounded by several factors:

- Several government agencies collect environmental data
- Nomenclature of satellites is complicated and confusing
- Currently operational satellites are not always publicized
- Availability of data is sometimes through a multitude of sources within an agency
- Specific users of data are given little publicity
- Some agencies primarily address operational data products rather than research and development products
- Some products in the past have been classified
- Operational data products come in a variety of outputs including film and tapes.
- Data products are also available which require user inputs for their development
- Because of the magnitude of collected data, very little information is actually archived. This forces the user to have pre-knowledge of his needs if he wants to utilize environmental data taken during his project.

Because of these factors, it is apparent that a document is needed to survey available environmental satellite data in order to educate users within the Earth Resources Community. This document, then, will attempt this task by comprehensively surveying present and future environmental satellites, and the availabilities of their data products.

2. STATUS OF ENVIRONMENTAL SATELLITES

There are three types of environmental satellites which will be discussed in this study. These will be both unmanned (1) earth resource and (2) meteorological satellites and the (3) manned satellites which can act as a combination platform for instruments carried by either of the other two types of satellites. The status as to present and future operation of these three types of satellites are shown in figure 2-1.

There is considerable variety in the types of orbits in which each of these satellites are or can operate. For instance, the meteorological satellites are either near earth polar orbiting, sun-synchronous or are geosynchronous. Examples of the near earth polar orbiting, sun-synchronous satellites are NIMBUS, ITOS/NOAA, and the USAF/DMSP. Geosynchronous satellites are the SMS/GOES and STORMSAT. The primary consideration of the near earth meteorological satellites with reflective and infrared bands is to obtain data on a 12 hours basis of every part of the earth in order to monitor changing weather conditions. This requires that resolution be relatively gross in order that data rates are not excessively high.

The Landsat data, on the other hand, is near earth sun-synchronous but because of higher resolution requirements has only 18 day coverage. Several of the earth resource satellites whose sensors are primarily microwave are not sun-synchronous because microwave does not need sunlight for its operation. Examples of these satellites are GEOS-3 and SEASAT-A.

Each type of satellite from figure 2-1 will be given a brief description in the following sections.

Figure 2-1. Status of Environmental Satellite Platforms

	Currently Operational Satellites/Launch Date	Future Operational Satellite/ Projected Launch Date
Earth Resource Satellites	Landsat-1+/July 1972	Landsat C/1977*
	Landsat-2/January 1975	Landsat D/1980
	GEOS-3/April 1975	AEM-A/1978*
		AEM-B/1979*
	LAGEOS/March 1976	AEM-C/TBD
		Seasat-A/1978*
		SEOS-A/mid 1980's #
Meteorological Satellites	NIMBUS-5/December 1972	NIMBUS G/1978*
	NIMBUS-6/June 1975	
		TIROS N/1978*
	ITOS/NOAA-4/November 1974	
	ITOS/NOAA-5/July 1976	ITOS-I/Under review (as of December 1976)
	USAF/DMSP Block B/C	GOES-B/1977* #
	USAF/DMSP Block D/September 1976	GOES-C/1979* #
	SMS-1/May 1974 #	GOES-D/TBD #
	SMS-2/February 1975 #	GOES-E/TBD - New sensor configuration w/VAS #
	GOES-1/October 1975 #	STORMSAT/1982 #
Manned Satellites	Skylab/May 1973++	Space Shuttle*/First operational flight test 1979, operational mid 1980

+Both tape recorders inoperable, only real time data reception possible

++Mission terminated in February 1974

*NASA approved missions

#Geosynchronous

ACRONYMS

AEM - Applications Explorer Mission

GEOS - Geodynamic Experimental Ocean Satellite

GOES - Geostationary Operational Environmental Satellite

ITOS - Improved TIROS Operational Satellite

LAGEOS - LAser GEOdynamics Satellite

DMSP - Defense Meteorological Satellite Program

SEOS - Synchronous Earth Observations Satellite

SMS - Synchronous Meteorological Satellite

TBD - To be Determined

VAS - VISSR Atmospheric Sounder

2.1 LANDSAT

Landsat satellites are intended for earth resources. They are especially designed for agricultural uses, but also are useful for geology, pollution, water resources and oceanography. They are launched in sun-synchronous orbits. In January 1975 the name was changed from ERTS to Landsat.

2.1.1 LANDSAT 1 AND 2

Landsat 1 was launched July 23, 1972 and Landsat 2 was launched January 22, 1975. They circle the earth every 103 minutes and each covers the earth every 18 days. One follows the other's track with a time delay of 9 days. They have two imaging systems, a multispectral scanner (MSS) and Return Beam Vidicon (RBV). The RBV on Landsat I failed.

The MSS (Multispectral Scanner) has a large mirror which oscillates in order to perform the scan rather than a spinning mirror as for most satellites. The radiation goes through interference filters to fiber optics located in the focal plane and then to the detectors. There are 4 bands:

Band Number	Wavelength (Micrometers)
4	0.5 - 0.6
5	0.6 - 0.7
6	0.7 - 0.8
7	0.8 - 1.1

For each band there are 6 detectors, giving a total of 24 electronic channels. Thus 6 lines are scanned at a time. The detectors for the first three bands are photomultipliers and for the 0.8 - 1.1 micrometer band the detectors are photodiodes.

The swath width is 185 km. The instantaneous field of view (IFOV) is 79 x 79 meters. In the scan direction the sample rate is once every 56 meters. Thus the pixel size is 79 x 56 meters. Each pixel has 6 bits or 64 levels.

Attitude stabilization of the vehicle is obtained within 0.7° and attitude information is obtained accurate to 0.07° for correction of distortion of the imagery during data processing.

The RBV consists of 3 return beam vidicons. There are reseau marks on the face of each camera to aid in distortion correction and registration of the channels during data processing. The bands, using the 50% points, are:

Band	Wavelength Micrometers
1	0.49 - 0.58
2	0.59 - 0.66
3	0.68 - 0.73

Each frame covers 185 x 185 km. The three frames are exposed simultaneously every 25 seconds. There are 4125 scan lines per picture. The output of the RBV is analog although the output of the MSS is digital. The bandwidth during readout is 3.2 Mhz.

2.1.2 LANDSAT C

Landsat C is similar to Landsat 1 and Landsat 2 but a thermal channel will be added to the MSS and only two vidicons will be utilized for the RBV. It also will be in a near-polar, sun-synchronous orbit at 911.8 km. The scheduled launch date is September 1977.

The MSS has a thermal band added with the band limits at 10.4 and 12.6 micrometers. Two HgCdTe detectors are added for the thermal band, giving a total of 26 detectors. They sweep out the same area as the 6 detectors of the other bands. The IFOV for the IR band is 240 x 240 meters or 3 times the distance across the IFOV of the other bands.

There will be only two RBV cameras. They will be redundant cameras with a single band at 0.50 - 0.75 micrometers. The resolution is twice that of the MSS and also the RBV's on Landsat 1 and 2, or 40 meters. The primary design improvement over the previous cameras will be improved geometrical accuracy.

The equations for reformatting the data and correcting the radiometric and geometrical errors had not been decided at the time this was written.

2.1.3 LANDSAT D

Landsat D will be launched in 1980 in a near-polar, sun-synchronous orbit at 702.4 km. Two satellties will permit complete coverage every 9 days.

The sensor, a multispectral scanner, is called the Thematic Mapper (TM). The specifications were not definite at the time this was written, but tentatively the resolution of the visible and near IR bands will be 30 meters and the thermal IR 120 meters. Tentatively, there will be 6 bands at 0.45 - 0.52, 0.52 - 0.60, 0.62 - 0.69, 0.76 - 0.90, 1.55 - 1.75, and 10.4 - 12.5 micrometers.

2.2 SEASAT-A

Seasat-A is a NASA non-sun-synchronous satellite which is projected for launch in 1978 and will primarily be dedicated to the study of oceans. Such physical features as wave heights, lengths, and directions, surface wind velocities, currents, temperatures, and ice cover will be measured. In addition, the marine geoid will be measured with a special radar altimeter with a root mean square accuracy of ±10 cm.

The objectives of the SEASAT-A mission are, (1) to develop and validate means for predicting the general ocean circulation, surface currents, and their transports of mass, heat, and nutrients; (2) to develop and validate means for synoptic monitoring and prediction of transient phenomena on the ocean surface such as wave heights and directions, surface winds, temperature, and storm surges, with an emphasis on identifying marine hazards; and (3) to make precision determinations of the marine geoid.

These objectives will be accomplished by a host of sensors which are primarily microwave. These include three active microwave sensors, one passive microwave sensor and one passive optical sensor:

	Sensor	Abbreviation	Type
(1)	Radar Altimeter	(ALT)	active microwave/non-imaging
(2)	Synthetic Aperture Radar	(SAR)	active microwave/imaging
(3)	Radar Scatterometer	(SASS)	active microwave/non-imaging
(4)	Scanning Multifrequency Microwave Radiometer	(SMMR)	passive microwave/non-imaging
(5)	Visible-IR Radiometer	(VIRR)	passive optical/imaging

The characteristics of these sensors are shown in Table 2.2-1.

Seasat-A will orbit the earth fourteen times a day in a 790 km circular, retrograde polar orbit that will provide global coverage every 36 hours.

TABLE 2-1 SEASAT-A SENSOR CHARACTERISTICS*

CHARACTERISTICS	SYNTHETIC APERTURE RADAR (SAR)	RADAR SCATTEROMETER (SASS)	SCANNING MULTIFREQUENCY MICROWAVE RADIOMETER (SMMR)	RADAR ALTIMETER (ALT)	VISIBLE INFRARED RADIOMETER (VIRR)
GENERAL					
Type	Imaging L-band	Fan Beam	Bidirectional Scan	Pulse/Precision	Scanning
System Contractor	Hughes/JPL	GE[2]	JPL	APL[3]/Johns Hopkins	SBRC[4]
Contracting Organization	JPL[1]	NASA/Langley	JPL	Wallops Flt. Ctr.	GSFC[5]
SPECIFIC					
Frequencies	1.275 GHz	14.6 GHz	6.6, 10.69, 18.0, 21.0, & 37.0 GHz	13.5 GHz	0.47 - 0.94 μm 10.5 - 12.5 μm
Spatial Resolution	25m	50 km ±5%	Footprint axes: (6.6) 121 x 79 km (10.69) 74 x 49 km (18.0) 44 x 29 km (21.0) 38 x 25 km (37.0) 21 x 14 km	1.6 km diameter	Visible: 2 km Infrared: 4 km
Coverage	100 km (17 - 23° or 230 - 330 km from nadir, one side)	High and low winds: ±25°- 65°; 200 - 950 km near nadir roughness ± 70 km	638 km (±25° from nadir)	12 km (due to integration time)	2127 km
Polarization	H	VV & HH in sequences	dual linear	linear (antenna)	- - -
PRF[6]	1464, 1540, 1647 pps	38 pps	Non applicable	1030 pps	Non applicable
Data Rate	15.06 mbps	590 bps	2 kbps	8.15 kbps	(Vis) 6.26 kbps (IR) 3.31 kbps

1 Jet Propulsion Laboratory
2 General Electric
3 Applied Physics Laboratory
4 Santa Barbara Research Center
5 Goddard Space Flight Center
6 Pulse Repetition Frequency

*Table 2.2-1 from Bibliography 24, page 1-2.

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2.3 GEOS-3

GEOS-3 was launched 9 April 1975 from Vandenberg Air Force Base, California aboard a two-stage Delta rocket. The nominal orbital parameters were:

mean altitude	843 km
inclination	115 degrees
eccentricity	.006 (max)
period	101.7 minutes

The orbital parameters were chosen to provide orbital traces that cover the earth's surface in a prescribed grid work pattern.

The major instrument aboard the GEOS-3 is the radar altimeter which will measure time-varying behavior of the ocean's surface and the departure of the sea surface from the geoid. The mission objectives were to (1) determine the feasibility and utility of a space borne radar altimeter to map the topography of the ocean surface with an absolute accuracy of $\pm$ 5 meters, and with a relative accuracy of 1 to 2 meters, (2) determine the feasibility of measuring the reflection of the vertical at sea, (3) determine the feasibility of measuring wave height, and (4) contribute to the technology leading to a future operational altimeter satellite system with a 10 cm measurement capability.

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2.4 APPLICATION EXPLORER MISSION (AEM)

Several Applications Explorer Missions (AEM's) are planned by NASA in the late 1970's and early 1980's. AEM-A, the Heat Capacity Mapping Mission (HCMM), has been approved for launch in 1978 and AEM-B, the Stratospheric Aerosol and Gas Experiment (SAGE), has a projected launch in 1979. AEM-C, MAGSAT, had not been approved for flight as of December 1976. AEM-C will carry a magnetometer as its primary experiment.

The AEM's are small, standard, low-cost satellites carrying only a single experiment which will be launched by Scout missiles.

The Heat Capacity Mapping Mission (AEM-A) will have as its primary sensor the Heat Capacity Mapping Radiometer (HCMR). This is a modified spare Surface Composition Mapping Radiometer (SCMR) which was flown on NIMBUS-5 and failed shortly after launch. The HCMR will have two channels, one in the reflective (.55 - 1.1 μm) and another in the thermal (10.5 - 12.5 μm) regions with a resolution of 500 x 500 meters at nadir. The AEM-A satellite orbit will have an ascending daylight node with nominal equatorial crossing at 2:00 p.m., and will provide a 1:30 p.m. and 2:30 a.m. crossing over mid-latitudes. This will allow for continuous sensing of surface thermal and thermal inertia effects and allow for reflectance measurements during the daylight passes. Several experiments are planned with the instrument. These include:

- Discrimination of rock types
- Soil moisture measurements
- Plant canopy temperature measurements
- Thermal effluent determination
- Snowfield mapping
- Study of atmospheric heating over urban areas

The Stratospheric Aerosol and Gas Experiment (SAGE) to be flown on AEM-B will gather radiometric data at .38, .45, .60 and 1.0 μm for determining the concentration and optical properties of aerosols and ozone as a function of altitude.

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2.5 LAGEOS

LAGEOS (Laser Geodynamic Satellite) is a passive satellite with retroreflectors for laser ranging from the ground. It was launched May 4, 1976.

The design minimizes the ranging error. It is a sphere covered with retroflectors and the center of gravity is at the geometrical center. Between the retroreflectors, the surface has a diffuse reflectance. The diameter is 60 cm and the weight 411 kg. The purpose of the large weight is to minimize changes in location due to external forces, such as atmospheric drag, radiation pressure and magnetic effects.

The altitude is 5900 km and the inclination 110 degrees. The high altitude results in low atmospheric drag.

Ranging is obtained by flashing a laser beam off the satellite and measuring the time required for detecting the return beam. At least three stations at different places on the earth measure the distance to the satellite simultaneously in order to obtain useful data.

Because of the small changes in location of the poles of the earth, distortions due to tides and a small variation in the rotation of the earth, points on the earth are not suitable as bases for precise measurements. However, the center of gravity of the earth and the satellite are satisfactory base points and measurements of distances can be based upon them.

Applications of these measurements are continental drift and plate tectonics, the distortions of the earth due to tides and determination of the causes of the variability of the rotation of the earth and its axis. It is hoped that the precise measurements will enable the determination of crustal stresses, permitting the prediction of earthquakes. It is expected that these measurements showing tectonic motions will result in important improvements in our knowledge of geophysics.

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2.6 SEOS-A

All earth resource dedicated satellites that have previously been launched have been low orbiting and have had limited repetitive coverage (for instance LANDSAT has 18-day repeat coverage). This limited coverage is not conducive to sensing transient phenomena and 18-day coverage may not even be possible if an area under study has high probabilities of cloud cover. For these reasons, a geosynchronous satellite called the Synchronous Earth Observatory Satellite (SEOS) has been proposed by NASA for launch in the mid-1980's for nearly continuous coverage of earth resource subjects.

Several studies have been commissioned by the Goddard Space Flight Center to define application requirements and the instruments needed to meet those requirements. (See Bibliography 1 and 2.)

The basic instrument for this satellite will be LEST or Large Earth Survey Telescope. This telescope will be able to image relatively small areas on earth (200 km swath width versus 185 km for Landsat) and will have resolution approaching LANDSAT from a geosynchronous altitude.

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2.7 ITOS/NOAA

The Improved TIROS Operational Satellite (ITOS) series has had continuous operation since ITOS-1 was launched 23 January 1970. These satellites have essentially the same instrument payloads and after the newest launched satellite is checked out, the previous one is placed on stand-by. NOAA-4 was launched in November 15, 1974 and is presently the satellite providing weather data. NOAA-3 was placed on stand-by December 17, 1974. NOAA-5 was only recently launched on July 29, 1976 and will become the primary operational satellite after checkout. As of December 1976 ITOS-I, the follow-on satellite, had not been scheduled for future launch.

The objectives of the NOAA Polar Satellites are to monitor the environment day and night and transmit to local stations and the central facility to provide real-time and retrospective data. The data is especially useful for meteorological purposes because it describes the cloud cover, temperature and limited humidity profiles and oceanographic temperatures.

The orbits are sun-synchronous at altitudes around 1450 to 1500 km.

The satellite is normally launched in an ascending node, crossing the equator at 1500 hrs., or a descending node crossing at 0900 hours local solar time. (The ascending node is the longitude at which the satellite crosses the equator from south to north and the descending node is the longitude at which it crosses from north to south.) Each pass is approximately 28.8° westward of the previous one.

The orientation is 3-axis stabilized, aided by a momentum wheel controlling the pitch, and roll and yaw controlled by a magnetic torque with the earth's magnetic field.

The NOAA series of satellites contains three important instruments for earth environmental monitoring. These include the Scanning Radiometer (SR), Very High Resolution Radiometer (VHRR), and the Vertical Temperature Profile Radiometer (VTPR). The first two are visible/infrared scanning instruments and the latter is a sounder. Each instrument is redundant (double) and will be discussed in the following sections. In addition, a Solar Proton Monitor (SPM) is also aboard the NOAA satellites.

2.7.1 SCANNING RADIOMETER (SR)

The scanning mirror rotates at 48 rpm. Image data is obtained during 1/3 of a rotation. The optics consist of a Cassegrain collecting system and a dichroic beamsplitter reflecting the visible radiation to a photodiode and passing the IR to a thermistor bolometer. The visible (VIS) band extends from 0.4 to 1.1 micrometers (except for NOAA-2 where it is 0.5 - 0.7) and the IR band is 10.5 - 12.5 micrometers.

The IFOV is 2.8 milliradians for the visible and 5.3 for the IR, corresponding to 3.2 and 7.4 km respectively. Horizon-to-horizon cross track scan gives global coverage. The distance between scans is 6.4 km, creating a 3.2 km gap in the visible at the subpoint and achieving contiguity at 1,208 km at each side. The IR IFOV is 6.4 km at the subpoint where contiguity is achieved. Registration between data on successive orbits occurs at 1,449 km from the subpoint at the equator. At that distance the IFOV is 12.9 x 19.3 km in the IR and 6.4 x 12.9 in the visible.

Real time transmission is made via the Automatic Picture Transmission (APT) to APT ground stations which are user owned. Direct readout of cloud top temperatures may be made. Also, the data is recorded and transmitted to Command and Data Acquisition (CDA) stations.

2.7.2 VERY HIGH RESOLUTION RADIOMETER (VHRR)

The VHRR scans with a 45° mirror at 400 rpm. The optics include a Cassegrain system, dichroic beamsplitter, HgCdTe detector for the IR and silicon photodiode for the visible. The band in the visible 0.6 - 0.7 micrometers and in the IR 10.5 - 12.5 micrometers. The resolution in both channels is 0.87 km at the satellite subpoint and 1.33 km at the edge.

The two VHRR instruments are slaved together in a time sharing manner and 180° out of phase. Also, transmission between visible and IR are alternated. Registration between the two channels at the coincidence point is offset 8 km., but is measured preflight. Also registration offset with the grid lines is measured. The registration errors are reduced to 32 km in the data processing.

In case of a failure of one instrument, two backup modes exist. One is transmission of the single channel during data taking and backscan information during the otherwise alternate dead scan. A second method involves transmission of both channels in a frequency multiplexed mode at a lower signal-to-noise ratio.

The noise equivalent temperature difference, measured at the instrument output, is 0.5°C for a 27°C scene and 2.0°C for a -88°C scene.

Daytime and nighttime cloud cover data in both the IR and visible is multiplexed for direct transmission to VHRR ground stations through the satellite's High Resolution Picture Transmission (HRPT) system.

8.5 minutes of VHRR data can be programmed to be taken at any time. Playback can be made in command from a Command and Data Acquisition (CDA) station. Partial HRPT orbital segments are programmable in N out of 8 equal orbital partitions which need not be contiguous.

HRPT service is via an S-band transmitter at 1697.5 MHz.

2.7.3 VERTICAL TEMPERATURE PROFILE RADIOMETER (VTPR)

The Vertical Temperature Profile Radiometer (VTPR) samples the atmosphere twice a day over most regions of the earth. These samples are converted to temperature profiles by the National Environmental Satellite Service. This permits calculation of the humidity profile and atmospheric corrections to sea surface temperatures.

The two VTPR instruments measure energy in 8 IR spectral bands, six discrete channels within the 15-micrometer carbon dioxide absorption region, one in the 11 micrometer "window" and one in the 18-micrometer water absorption region. The instrument has a single optical system and pyroelectric detector. A filter wheel with 8 filters rotates at 120 rpm, bringing each filter into the optical path every 62.5 milliseconds.

It scans the ground in 23 equal steps. One scan covers 59 x 1,364 km. The ground resolution is 110 x 110 km at the subpoint.

The instrument is designed to have an absolute accuracy better than 0.5% and a relative accuracy between channels of 0.125%, except for one of the CO_2 channels.

The data is digitized to 10 bits and then recorded on the Scanning Radiometer Recorder (SSR) or phase modulated and transmitted on the 137.14 Mhz sub-band of the beacon transmitter. The stored data is played back in the S-band.

2.8 DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP)

The Program (DMSP) is managed within the Space and Missiles Systems Organization (SAMSO) of the Air Force Systems Command(AFSC). Technical and management functions are provided by the Deputy for Defense Meteorological Satellite Systems, SAMSO, command and control functions provided by the 4000th Aerospace Applications Group, SAC (Offutt AFB, Nebraska); launch activities provided by the 10th Aerospace Defense Squadron, ADC (Vandenburg AFB, California), logistics from AFLC; training ATC; and communications AFC. DMSP is a tri-service organization. The Air Force Global Weather Center, Offutt AFB, Nebraska, is the prime Air Force user of the satellite data.

2.8.1 BLOCK 5B/C SATELLITES

Present satellites are the Block 5B/C type. (A new generation of satellites, the Block 5D, is becoming operational.)

Two satellites at 830 km (450 nm) are in sun-synchronous orbits with an inclination of 98.747°. One has its ascending node in early morning and the other at noon. The maximum latitude of the nadir is 81.3°, but because of the width of the field of view imagery extends over the poles. The nodal period (time of a revolution) is 101.56 minutes. This gives 14.3 revolutions per day. Each crossing of the equator is 25.4° west of the previous crossing the day before.

2.8.1.1 Block B/C Primary Sensor

The primary sensor is a four channel scanner. Two channels are visible and two infrared. They are summarized as follows:

	Nadir Resolution	Spectral Band	Detector
HR	3.7 km	0.57 - 0.97	Silicon diode
IR or MI	4.4 km	9 - 12	Thermistor bolometer
VHR	0.63 km	0.57 - 0.97	Silicon diode
WHR	0.66 km	9 - 12	HgCdTe, 105°K

All channels scan the same field, 3,000 km across. HR stands for high resolution visible, VHR very high resolution visible, IR high resolution infrared and WHR very high resolution infrared. IR and MI are used for the same channel in different reports. In ordering data, the channel designation is abbreviated to the first letter, namely, H, I, V or W.

There are really two scanners with their rotating shafts mechanically linked with a gear ratio of 3 to 1. The HR and IR channels are obtained from detectors on the slower rotating lower resolution scanner, while channels VHR and WHR are associated with the higher resolution scanner. The higher resolution scanner has a double-sided mirror and six times the number of scan lines. The actual resolution is determined by the detector size and data rate as well as the scan rate. Each pair of channels is associated with the same shaft. Dichroic beam splitters separate the visible and IR radiation of each pair.

The lower resolution channels, HR and IR, have much higher sensitivity than the very high resolution channels. The HR channel can obtain useful imagery in the visible at night if the moon is shining or there are lights in the scene. The IR channel has a better signal-to-noise ratio and better accuracy than the WHR channel. Therefore, it is used for quantitative purposes, such as ocean temperature measurements and cloud height determination. The VHR and WHR channels are more useful for examining fine detail in clouds, especially in detecting small clouds which cause quantitative errors in the IR data but cannot be detected in the IR data.

The HR channel's night/day capability, especially for the case of crossing the terminator, results in severe dynamic range requirements. They are fulfilled by 16 automatic and 11 commandable along-track gain states and 93 automatic along-scan gain states to provide useful data over 7 decades of input radiance. Also, the HR channel utilizes a sun sensor to control channel gain, thereby providing an output signal which represents scene albedo. The VHR channel is also representative of scene albedo. It has 16 automatic and 3 commandable along-track gain states which provide data over 3 decades of input radiance.

The IR and WHR channels cover the range of blackbody temperatures from 210° K to 310 °K. The indicated ocean temperatures are 2- 10° K cooler than the thermometer temperatures. This error is caused by absorption in the wide band used and can be corrected. However, the sensitivity to temperature differences is very high and temperature gradients in the ocean are accurately measured.

2.8.1.2 SCANNING INFRARED RADIOMETER (SSE)

The Block 5 B/C satellites also have two supplementary sensors chosen from a group of four.

The SSE is a scanning spectroradiometer, also called supplementary sensor E. It is used for measuring vertical temperature profiles. It has 6 channels in the 15 micron carbon dioxide absorption band at 668.5, 677, 695, 708, 725, and 747 cm^{-1}, a channel at 535 cm^{-1} in a water vapor absorption band and a channel at 835cm^{-1} in the atmospheric window near 12 microns.

A scanning mirror steps across the subtrack of the satellite, allowing the SEE to view 25 separate columns of the atmosphere every 32 seconds over a cross-track ground swath of 185 km. For each IFOV the channel filters are rotated through the optical path. The detector is tri-glycine pyroelectric. At nadir the width (resolution) of the IFOV is 37 km.

2.8.1.3 Supplementary Sensor L (SSL)

Supplementary Sensor L (SSL) is a lightning sensor. It operates only at night to detect lightning flashes in the 0.4 to 1.1 micron range. The detection system is a 3 x 4 array of silicon photodiodes. The field of view is 2960 x 2220 km and the pixel size 740 x 740 km. The value of the peak pulse during each second and the number of counts per second for each detector is recorded.

2.8.2 BLOCK 5D SATELLITE

The Block 5D Satellite and sensor have specific objectives the same as for the Block 5B/C; however, the hardware is different. The sensor has a completely different design. The orbits are the same as for the Block 5B/C and the swath covered by the sensor is the same.

A Block 5D Satellite with a noon orbit was launched September 1976 but has had attitude problems and no data has been taken. It is expected that the bugs will be ironed out by Spring 1977. A second Block 5D satellite may be launched in late Summer 1977, but the launch date will be sooner if problems with the first are not solved.

2.8.2.1 Block 5D Primary Sensor

The primary sensor, the Operational Linescan System (OLS), is an image plane optical scanner. Compensation for the variation in ground resolution with distance off axis is performed in the sensor so that the resolution is constant as a function of scan angle. Compensation for the effect of the velocity of the vehicle in causing distortion is performed by switching detectors. Thus, the S-distortion of scanners is compensated in the vehicle and is not required in the data processing. Also, the high degree of stabilization of the vehicle (0.01°, 3 sigma, error; and roll rate of 0.03°/sec., 3 sigma, per axis) minimizes distortion due to the orientation of the vehicle.

There are three detectors, two for the visible and one for the IR, and two resolutions. The segmented infrared detector obtains high resolution infrared (TF) data (thermal-fine data), and during the daytime only the segmented silicon diode detector obtains high resolution visible (LF) data (visible-fine data) at a pixel size of 0.55 x 0.55 km. In order to improve the signal-to-noise ratio, smoothed (low resolution) infrared (TS) and visible (LS) data is obtained by averaging 5 high resolution pixels analog along the scan line and adding 5 pixels digitally in the flight direction for an overall smoothed resolution of 2.8 x 2.8 km.

At night under a quarter moon or brighter conditions, a photomultiplier collects visible (LS) data at a resolution of 2.8 km.

2.8.2.2 Block 5D Special Meteorological Sensor H (SSH)

The objectives of the Block 5D Special Meteorological Sensor H (SSH) are to measure the temperature profile, humidity profile and ozone content of the atmosphere. It measures the spectral radiance in 16 bands as shown in Table 2-2.

TABLE 2-2. - SSH CHANNEL CHARACTERISTICS

Center		Width	Species	Absorption	NESN*
μm	cm^{-1}	cm^{-1}			
9.8	1022	12.5	O_3		0.05
12.0	835	8	window		0.11
13.4	747	10	CO_2	least	0.12
13.8	725	10	CO_2		0.11
14.1	708	10	CO_2		0.11
14.4	695	10	CO_2		0.10
14.8	676	10	CO_2		0.09
15.0	668.5	3.5	CO_2	most	0.30
18.7	535	16	H_2O	least	0.15
24.5	408.5	12	H_2O		0.14
22.7	441.5	18	H_2O		0.09
23.9	420	20	H_2O		0.12
26.7	374	12	H_2O		0.18
25.2	397.5	10	H_2O		0.16
28.2	355	15	H_2O		0.25
28.3	353.5	11	H_2O	most	0.33

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

At the altitude of 450 km it scans from -48° to 48° in steps of 4° for a path width of 2040 km. The time per step is one second. There is one scan every 32 seconds and 25 meteorological data points. The 7 seconds not accounted for here are used for calibration, recording housekeeping data and dead time. The distance between scans is 207.2 km. Along the scan the pixels are 58.3 km apart at the nadir and 156.5 km at the edge of the field.

After passing the scanning mirror and Cassegrain collecting optics, the radiation passes through a chopper. A dichroic beamsplitter reflects all wavelengths greater than 20 microns and the radiation goes to the F channel detector. The F channel has a rotating filter wheel with 7 narrow band filters and a pyroelectric detector. The radiation at wavelengths less than 20 microns is transmitted by the first dichroic and strikes the second dichroic, which reflects wavelengths longer than 11 microns into the E channels. The E channels have a rotating filter wheel with narrow band filters which transmit the 12 micron window and 7 absorption bands. The detector is pyroelectric. Radiation at a wavelength shorter than 11 microns is passed by the second dichroic and goes to the Z channel which has a fixed narrow band filter at 9.8 microns to measure ozone. The detector is also pyroelectric.

During each one second interval corresponding to the pixel or footprint on the earth, the spectral data is sampled twice by each E and F narrow band channel and 12 times by the Z channel.

2.9 SMS/GOES

The SMS/GOES is a geosynchronous satellite with a follow-on design based on the earlier ATS-1 and ATS-3 (Applications Technology Satellites). There are presently three of the satellites in orbit; two of the three were commissioned by NASA and are called Synchronous Meteorological Satellites (SMS) and the third was ordered by NOAA and is called the Geostationary Operational Environmental Satellite (GOES). The three satellites have had several locations and their history as of September 1976 is as follows:

Nomenclature, Launch Date and Location Data for GOES/SMS Satellites

Name		Launch Date	Original Station		Current Station	
Prior to Launch	After Launch		Equator and	Date on Station	Equator and	Arrival on Station
SMS-A	SMS-1	5-17-74	45°W	6-07-74	105°W	2-16-76
SMS-B	SMS-2	2-06-75	115°W	2-22-75	135°W	12-19-75
GOES-A	GOES-1	10-16-75	75°W	12-18-75	75°W	12-18-75

In the near future SMS/GOES, or their replacements will form part of an international geosynchronous satellite system which will cover the entire earth except for the poles. The configuration is illustrated in figure 2-2.

After the launch of GOES-1, SMS-1 was placed on standby. SMS-2 and GOES-1 are both operational and SMS-2 is sometimes referred to as "West GOES" and GOES-1 is referred to as "East GOES."

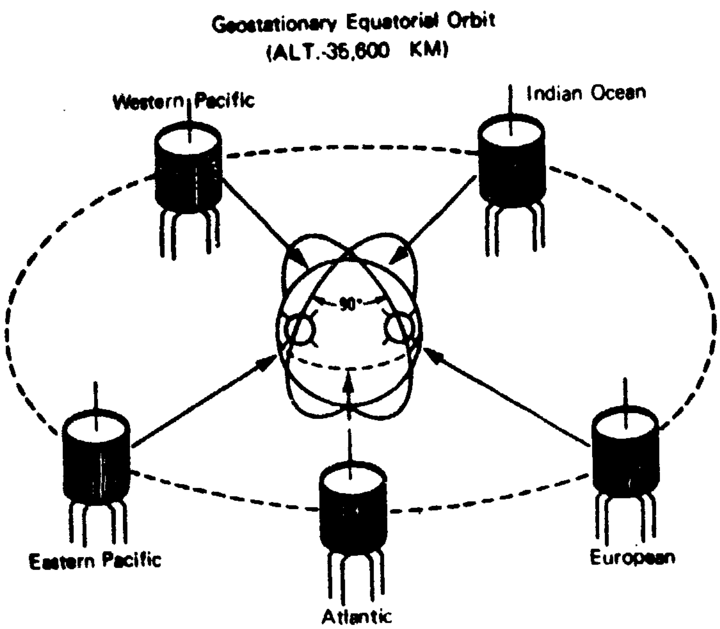

Figure 2-2. - The Global Geostationary Satellite System

The list below contains the latest information on the status of satellites other than those of the United States as of September 1976. These satellites will complete earth coverage.

Additional Geosynchronous Satellites Planned

To Be Launched By:	Satellite to Be Centered Over	Approximate Launch Date
European Space Agency (ESA)	Greenwich Meridian (Eastern Atlantic)	June/July 1977
U.S.S.R.	70^{o}E (Indian Ocean)	Mid 1978
Japan	140^{o}E (Western Pacific)	August 1977

GOES-B and GOES-C with the same scientific payloads in the previous GOES-1 have been given NASA mission approval and should be launched in the second quarter of 1977 and the last quarter of 1979, respectively.

The primary instruments on the SMS/GOES is the Visible/Infrared Spin Scan Radiometer (VISSR) which has two bands, one in the visible at .55 - .70 μm and another in the infrared at 10.5 - 12.6 μm. Resolution at nadir is 0.8 km for the visible channel and 8 km for the infrared. The SMS/GOES satellite turns at 100 revolutions per minute providing the cross track scanning for the radiometer. The radiometer performs 1821 steps in successive scans from North to South in forming an image of the earth disc in about 18.2 minutes. Successively received (input every 30 minutes) images of North and Central America from SMS/GOES are normally used in television newscasts to show the shift of fronts and the progress of cloud cover.

GOES-E, whose launch date is to be determined, is scheduled to have an improved VISSR for Atmospheric Sounding (VAS). Bands in this instrument are at .55 - .73, 3.73, 4.28, 6.71, 7.25, 11.1, 12.7 - 14.7 (7 channels) μm. Visible images will be produced in the .55 - .73 μm channel and infrared images in the 11.1 μm centered band. Radiometric data will be taken in the other channels. The purpose of the instrument will be to monitor day/night cloud movement, surface temperatures, cloud water, and temperature sounding.

The SMS/GOES also has a Space Environmental Monitor (SEM) which includes a magnetometer, a solar X-ray telescope, and an energetic particle monitor. These instruments provide important quantitative measurements of solar activity.

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2.10 TIROS-N

TIROS-N, a third generation satellite, will be launched for NOAA by NASA in January 1978. The first satellite will be an operational prototype of several follow-on systems and will eventually replace the ITOS-NOAA series of satellites.

Several newer sensor systems will be flown on TIROS-N. The TIROS operational vertical sounder will have a Basic Sounding Unit (BSU) of 14 infrared channels, a Stratospheric Sounding Unit (SSU) of three channels and a Microwave Sounding Unit (MSU) of four channels. Measurements of these instruments will provide accuracies in temperature soundings to 1^{o}C from the earth's surface to 50 km and water vapor sounding to 15 km. The Advanced Very High Resolution Radiometer (AVHRR) will provide data information channels better to delineate land, water, melting and non-melting snow and ice, and improve sea surface temperature measurements in partially cloudy areas. Resolution at nadir is 1 to 4 kilometers.

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2.11 STORMSAT

The greatest meteorological hazard to human life and property are severe storms. These include tornadoes, hail storms, tropical cyclones, extra tropical cyclones, and other large scale phenomena such as dust storms. While the spatial resolution of most polar orbiting satellites is adequate to identify the elements in the structure of those storms, their temporal coverages are inadequate in the study of storm development which could lead to early detection and prediction. A geosynchronous satellite called Severe Storms Observation Satellite (SOSS) was proposed for this purpose in 1975 to monitor severe storms on a near continuous basis. The official name of this satellite which is proposed for launch in 1983 has since been changed to Stormsat.

As of this writing, two instruments are planned for the satellite. These are the Advanced Atmospheric Sounding and Imaging Radiometer (AASIR) and Microwave Atmospheric Sounding Radiometer (MASR). The AASIR has both an imaging and sounding capability. Imaging will be performed in a reflective channel at .55 - 1.1 μm with a subsatellite resolution of .75 km and in a thermal channel around 11.1 μm with a subsatellite resolution of 4.5 km.

The sounding channels will be registered and will have subsatellite resolutions of 13.5 km. Sounding channels will include the following:

γ (cm^{-1})	$\Delta\gamma$ (cm^{-1})	No. of Channels
668.5 - 790	5 - 20	8
1380	60	1
1490	140	1
2190 - 2360	25 - 50	5
2700	440	1

The MASR will operate at several frequencies about both 118 GHz and 183 GHz and will have resolution in the order of 30 to 40 km. A large parabola of very exacting dimensions is one of the design limitations which must be overcome in order to qualify this instrument for flight.

The AASIR will measure localized temperatures, water-vapor content, wind speeds, and cloud motions. In addition, this instrument can image the earth disc or can image local disturbances in areas as small as 250 km square. The earth disc image will take about 20 minutes while an image covering 250 km square will take only 24 seconds. The MASR will complement the AASIR by taking similar measurements through heavy cloud cover, through which the AASIR cannot operate. Rain cell distribution may also be mapped.

Stormsat will offer a number of improvements over the spin-scan instruments on the geosynchronous satellite GOES. Stormsat's instruments will be three-axis stabilized giving improvement in resolution in the reflective and thermal imaging channels. In addition, a sounding capability in both the infrared and the "all weather" microwaves will give many additional parameters for identification of severe storm elements and structures.

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2.12 SKYLAB

2.12.1 SATELLITE AND SENSORS

Data was obtained on three Skylab missions from May 22, 1973, to February 8, 1974. The altitude was 430 km. Data were taken of selected areas from 50^{O}N to 50^{O}S. The Skylab Earth Resources Experiment Package (EREP) consisted of six remote sensing systems:

- The S-190A Multispectral Photographic Camera consisted of six cameras with registered formats and 70 mm film, black and white, color and false-color. Some of the cameras had narrow band filters. Each image covered 144 by 144 km.
- The S-190B Earth Terrain Camera was a high resolution camera with a 12.7 cm format and a 47.5 cm focal length lens. The film was black and white, color or false-color infrared. The area covered per frame was 96 by 96 km.
- The S-191 Spectrometer scanned from 0.4 to 1.3 micrometers and 6 to 15 micrometers simultaneously every 0.96 seconds. The spectra were taken of preselected points and targets of opportunity. The instantaneous field of view on the ground was about 0.4 km at the nadir.
- The S-192 Multispectral Scanner had 12 bands in the visible and near infrared and one thermal band. The swath width was about 41 km wide.
- The S-193 Microwave Radiometer/Scatterometer and Altimeter was non-imaging.
- The S-194 L-Band Radiometer was non-imaging.

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2.13 SHUTTLE

Shuttle is a manned vehicle which can fly into a satellite orbit and return to earth with a load of 14,600 kilograms (32,000 pounds). It can take off with about twice this load, but must leave the rest in space. The orbital altitude may be 160 to 900 km, but at the higher elevations the maximum payload is considerably less. The flight time is five to seven days for the earlier flights and later flights may be as long as thirty days. The advantages of shuttle are that a heavy load can be carried into space, even a satellite, and the payload may be returned to earth. However, the time of flight is relatively short. Shuttle will become operational about April 1980, after the first six flights which are operational flight tests (OFT). The earlier flights are more constrained with respect to payload weight, flight time, etc., than the later flights. Plans for the first six flights are definite with respect to the vehicle, but not the payloads. The only one of the first six flights expected to have earth resource sensors is OFT-2, which will fly in July 1979. Also, it is the only early flight where the bay will primarily face the earth. Sensors will be accepted only on a non-interference basis on the six flights.

The choice of sensors for OFT-2 has not been made, but the only earth resource sensor which has been given detailed integration planning is the engineering back-up unit of the SEASAT radar. The maximum payload will be 9000 kg., but this includes considerable test equipment. The flight time on OFT-2 may be only five days. The orbit will be 166 to 275 km in altitude with an inclination of 32^{o} to 40^{o}.

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2.14 NIMBUS

NIMBUS is the latin word for "cloud" and is a relatively large type of spacecraft utilized by NASA as a test bed for new and experimental instruments and associated data techniques. These instruments have primarily been used for development, test, and application of a variety of techniques in meteorological and geophysical areas. After these instruments are checked out and are operational, they may later be modified and orbited in another spacecraft and placed under the direction of NOAA. NIMBUS is sun-synchronous and polar orbiting in order to accommodate the 12-hour coverage required of the visible/infrared scanners.

NIMBUS-5 was launched 11 December 1972 and is still operational even though it is presently on standby. NIMBUS-6, launched on 12 June 1975, is the primary data collecting instrument being utilized at this time. NIMBUS-G is due for launch in the fourth quarter of 1978.

2.14.1 NIMBUS-5

The altitude of NIMBUS-5 is about 1112 kilometers. Its orbit is sun-synchronous having a local noon ascending and midnight descending equator crossing with an 81° retrograde inclination. Successive orbits are separated by 27° and time of orbit is about 107 minutes. The attitude control is ±0.5° in roll and yaw.

NIMBUS-5 is still operating, but the primary emphasis for data is NIMBUS-6 which is more completely described. Data is still being used from three instruments, the Electrically Scanning Microwave Radiometer (ESMR), the Selective Chopper Radiometer (SCR) and the NIMBUS-E Microwave Spectrometer (NEMS).

The ESMR on NIMBUS-G is an "improved version of the one on NIMBUS-5". See the description under NIMBUS-G which gives the most important differences.

The Selective Chopper Radiometer (SCR) is a filter wheel spectrometer for sounding the atmosphere. The temperature profile is determined up to 50 km. There are four filter wheels and detectors. They have the following filters:

Channel	Band Center (cm^{-1})	Pressure (CO_2) mb
A1	668.5	
A2	688.5	
A3	707.4	
A4	726.5	
B1	668.2	0
B2	668.2	40
B3	668.2	95
B4	668.2	310
C1	110 (edge)	
C2	202	
C3	536.4	
C4	859	
D1	3710	
D2	3805	
D3	4260 (edge)	
D4	2817	

Two of the filters are edge rather than band filters. The window channels at 11.6, 3.6 and 3.3 micrometers measure surface or cloud top temperatures. Eight channels in the 15 micrometer CO_2 band obtain data from which temperature profiles may be calculated. The B channels permit the differential transmission of different CO_2 paths to be measured, resulting in high sensitivity to CO_2. The FOV is 2.2° for the B channels and 1.5° for the other channels. The cycle of 16 measurements requires 4 seconds, during which time the sensor views the same location. This is accomplished by a forward and backward motion of the sensor.

The NIMBUS-E Microwave Spectrometer (NEMS) is the first step in the application of the microwave spectrum to global sensing of the atmospheric temperature structure. It can also obtain information about the atmospheric humidity, cloud water content over oceans, snow cover, ice type and soil moisture.

The channels and center frequencies are as follows:

Channel	Frequency (GHz)	Molecule Sensed
R_1	22.235	H_2O
R_2	31.40	H_2O
R_3	53.65	O_2
R_4	54.90	O_2
R_5	58.80	O_2

Each channel responds differently to the temperature profile, water vapor, precipitation clouds and surface, permitting information to be obtained about each one using simultaneous equations. The O_2 bands give primarily information on the temperature and the two H_2O bands enable the water vapor and cloud water content to be estimated separately.

The NEMS views the nadir only. The resolution is 200 km. The NEMS is used in conjunction with a similar instrument, except that it scans, on NIMBUS-6, called the ESMR.

2.14.2 NIMBUS-6

NIMBUS-6 is similar to NIMBUS-5 except for stabilization and instruments. It is biased +0.6° in pitch (nose-up). The yaw is stable to 1° and the pitch and roll to 0.5°.

The Temperature Humidity Infrared Radiometer (THIR) is a scanner with two bands. It measures the radiation in the 10.3 to 12.5 micrometer (11.5 micrometers) window to obtain an image of the clouds and to show the temperature of cloud tops, land and ocean surfaces. A 6.5 to 7.1 micrometer (6.7 micrometers) band provides information on the moisture content of the upper troposphere and stratosphere and the location of jet streams and frontal systems.

The scanning mirror rotates at 48 rpm and reflects the radiation to a Cassegrain system. A beamsplitter separates the two channels. The maximum practical scan angle for useful data is 50°. The IFOV is 8.2 x 8.2 km at the nadir and 35 x 15 km at 50° for the 11.5 micrometer channel. It is 22.5 x 22.5 km at the nadir and 95 x 41 km at 50° for the 6.7 micrometer channel.

The High Resolution Infrared Radiation Sounder (HRIRS) obtains data from which surface temperatures, atmospheric temperature profiles and water vapor profiles can be calculated. Also the outgoing radiant flux of the earth can be measured. The window channels 0.69, 3.71, and 11.0 enable clouds to be detected and the data for sounding ignored. The instrument is an improved version of the NIMBUS-5 ITPR.

The radiation enters a Cassegrain system and is incident upon a beamsplitter which passes the long wave radiation and reflects shorter wavelengths. Two choppers and two rotating filter wheels modulate the beams and provide the spectral resolution. A second beamsplitter separates the short wavelength radiation into the visible and IR before going to the detectors. There are 17 bands:

Wavelength (Micrometers)	Constituent Sensed
15.0	CO_2
14.7	CO_2

Wavelength (Micrometers)	Constituent Sensed
14.4	CO_2
14.2	CO_2
14.0	CO_2
13.6	CO_2/H_2O
13.4	CO_2/H_2O
11.0	Window
8.2	H_2O
6.7	H_2O
4.57	N_2O
4.52	N_2O
4.46	CO_2/N_2O
4.40	CO_2/N_2O
4.24	CO_2
3.71	Window
0.69	Window

The scan is from -36.9 to +36.9 degrees in 42 steps. Each step has a resolution of 25 km.

The Scanning Microwave Spectrometer (SCAMS) measures temperature and water vapor profiles, liquid water in the atmosphere, snow cover, ice type, soil moisture and ocean roughness. Clouds have a less adverse effect than in the IR.

There are three scanning systems with scanning reflectors and antennas. They scan in synchronism, completing a scan every 16 seconds. Data is recorded from -43.2 to +43.2°, giving a swath width of 2400 km. The sample rate is once per second. The ground resolution is 145 km at nadir and 330 km at 43°.

Channel 1 lies on a water vapor line at 22 GHz. Channel 2 is an atmospheric window near 32 GHz. Channels 3, 4 and 5 are on an oxygen band near 54 GHz and have the same antenna reflector. All of these channels respond differently to the terrestrial surfaces, clouds, precipitation, water vapor and atmospheric profile. Therefore, by simultaneous equations these parameters may be separated.

The instrument is similar to the NEMS on NIMBUS-5 except that it scans rather than following a nadir path.

The Electrically Scanning Microwave Radiometer (ESMR) is similar to the one on NIMBUS-5 except that both polarizations are measured separately instead of only one, the frequency is 37.0 GHz (0.81 cm) instead of 19.35 GHz (1.55 cm) and the scanning angle is approximately constant with respect to the ground because the scan is conical. It responds to water droplets as well as humidity and shows the brightness temperature of snow, permitting the mapping of snowfields.

The scan is electrical, in approximately a 35° half angle cone. Only the forward part of the scan is recorded, from azimuth +35° to azimuth -35° with respect to the flight direction. The beam is offset 5° with respect to the antenna. The angle between the ground and the received beam is constant at 60° within a degree. There are 71 samples per scan. The duration of each scan is 5 1/3 seconds.

The Earth Radiation Budget (ERB) Experiment is designed to make radiation measurements of the earth and sun with an accuracy of 1%. The measurement obtained will serve as an initial bench mark data set for the long term monitoring of the energy received from the sun and emitted and reflected by the earth.

There are 22 optical channels of which channels 1-10 monitor the sun, channels 11-14 are wide angle channels which monitor the whole earth and channels 15-22 are narrow IFOV channels which measure local variations of radiation from the earth. Channels 15-22 have several modes for scanning in order to obtain directional information of radiation coming from the earth. Their IFOV is 0.25 degrees by 5.12 degrees. Interference filters are used to narrow the bands on the narrow band channels. For the purpose of achieving high accuracy, with one channel checking the performance of the other, some of the channels are redundant. A summary of the channels is as follows:

ERB Channels:

Channel	Wavelength Limits (Micrometers)	Type
1	0.2 0 0.5	Solar
2	0.2 - 0.5	Solar
3	<0.2 - 70.5	Solar
4	0.530 - 3.0	Solar
5	0.695 - 3.0	Solar
6	0.394 - 0.505	Solar
7	0.345 - 0.460	Solar
8	0.300 - 0.408	Solar
9	0.264 - 0.340	Solar
10	0.243 - 0.312	Solar
11	<0.2 - >50	Earth Wide-Angle
12	0.2 - 50	Earth Wide-Angle
13	0.2 - 5.0	Earth Wide-Anlge
14	0.695 - 3.0	Earth Wide-Angle
15-18	0.2 - 5.0	Scanning Channels
19-22	4.5 - 5.0	Scanning Channels

Channels 15-22 are in four telescopes with their directions 12° apart.

The Pressure Modulator Radiometer (PMR) monitors the average structure of the atmosphere at 40 km to 85 km altitude and senses changes with latitude and season. In particular it senses large-scale atmospheric waves, especially stratospheric warming.

The system consists of two channels. Each channel has a cell with CO_2 which absorbs CO_2 radiation from the earth. The transmitted radiation is detected by a pyroelectric bolometer flake. A filter in front of each cell limits the incident radiation to a narrow band.

Changing the pressure in the cell shifts the wavelength for absorbing the radiation and thus modulates the beam in with a step function. Similarly, changing the doppler shift of the input radiation can also modulate the beam. This is accomplished by changing the angle of the mirror reflecting radiation into the cell so as to change the relative velocity of the atmosphere viewed with respect to the spacecraft. One cell, 1 cm long, has a pressure of 0.5 mb to 3 mb and covers the altitude 60 to 90 km. The other cell, 6 cm long, has a pressure 1 mb to 4 mb and covers 40 - 60 km.

The Limb Inversion Radiometer (LRIR) scans the atmosphere at the earth's limb in a vertical direction. An inversion of the spectral data gives the vertical distribution of temperature, ozone and water vapor from ~15 km to ~60 km. Measurements are made on a global scale as the satellite revolves around the earth. One advantage of using a horizontal or "tangent" path is that the optical density of the atmosphere is 60 times as great as for looking at the nadir. Also, with space as the background, there is a much less interference problem than looking at the earth. By integration of the temperature profile the geostrophic component of the wind can be obtained up to the 1 millibar (~48 km) level.

There are four bands: two in the 15 micrometer carbon dioxide band, one in the 9.6 micrometer ozone band and one at 23 - 27 micrometers in the rotational water vapor band.

The scan is ±1 degree. The vertical spatial resolution of the resulting parameters is 3 km for temperature, ozone and water vapor below 30 km and 4-5 km for water vapor above 30 km.

Random Access Measurement System (RAMS) receives data transmitted by platforms, digitizes it, records it and re-transmits the data to STDN stations.

An important application is the Tropical Wind Energy Conversion and Reference Level Experiment (TWERLE). The purposes of this experiment are to measure winds, temperatures and humidity from balloons. The data is useful for processing atmospheric sounder data. The balloon carries atmospheric sensors and a radio altimeter. The velocity of the balloon in the line of sight is sensed by the doppler shift.

Each platform transmits for one second each minute. RAMS can receive signals from eight stations simultaneously with an estimated reliability of 95%. The received signal is divided into 300 different frequency cells which are searched rapidly to determine if a signal is present. The data from up to eight cells is processed after acquisition.

2.14.3 NIMBUS-G

The NIMBUS-G observatory will be launched in a 955 km circular sun-synchronous polar orbit.

An important instrument on NIMBUS-G not on NIMBUS-6 is the Coastal Zone Color Scanner (CZCS). Its objectives are to map chlorophyll concentration, sediment distribution , gelbstoffe (yellow substance) concentration as a salinity indicator, and the temperature of coastal waters and the ocean.

To avoid sunlight, the field of view can be tilted. The pixel size will be 0.826 x 0.826 km. The bands and correspoinding measurements are as follows:

Channel	Band (μm)	Measurement
1	0.433 - 0.453	Chlorophyll absorption
2	0.510 - 0.5330	Chlorophyll correlation
3	0.540 - 0.560	Gelbstoffe
4	0.660 - 0.680	Chlorophyll absorption
5	0.700 - 0.800	Surface Vegetation
6	10.5 - 12.5	Surface Temperature

The Earth Radiation Budget (ERB) Experiment is similar to the one on NIMBUS-6 with minor changes, such as slightly different band limits.

The Limb Infrared Monitoring of the Stratosphere (LIMS) is similar to the LRIR on NIMBUS-6 except for a slower scan rate, different IFOV's and adding two channels. The bands are as follows:

Band (Micrometer)	Measurement
6.08 - 6.39	NO_2
6.41 - 7.25	N_2O
8.64 - 10.64	O_3
10.87 - 11.76	HNO_3
13.16 - 17.24	CO_2 (wide band)
14.71 - 15.75	CO_2 (narrow band)

The Stratospheric and Mesospheric Sounder (SAMS) is a pressure modulated spectrometer and is considerably improved over the PMR of NIMBUS-6. Its objective is to measure concentrations of gases, temperature to ~90 km, investigate departure from thermodynamic equilibrium between 80 and 130 km and the wind velocity along the line of sight. The earth's limb is viewed.

There are seven pressure modulated cells and six detectors. The cells are CO_2(2), NO, CH_4, and CO and H_2O. The bands are:

CO_2 - 15 micrometers

CO_2, CO, NO - 4.1 - 5.4 micrometers

H_2O - 2.7 and 2.5 - 100 micrometers

N_2O, CH_4 - 7.6 to 7.8 micrometers

The signal is chopped at 250 Hz. The IFOV is 10 km vertical by 100 km horizontal at the limb.

Stratospheric Aerosol Measurement II (SAM-II) measures the aerosol concentration of the earth from 10 km up by looking at the sun through the earth's limb.

A single band at 10 micrometers is monitored. The instrument scans up and down across the sun as it sets or rises. Any decrease in signal not caused by a clear atmosphere is ascribed to aerosols. The IFOV is 0.48 km at the limb.

The Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer (SBUV/TOMS) is similar to the BUV instrument on NIMBUS-4, except that it has cross-track scan capability, a wider wavelength range and special provisions for minimizing the background due to radiation. The SBUV measures the ozone profile at the nadir and the TOMS scanner maps the total ozone.

The central wavelengths in nanometers of the recorded band are as follows:

SBUV		TOMS	
Step No.	Wavelength (Nanometer)	Step No.	Wavelength (Nanometer)
0	339.8	1	312.5
1	331.2	2	331.2
2	317.5	3	317.5
3	312.5	4	339.8'
4	305.8	5	360.0
5	301.9	6	380.0
6	297.5		
7	299.2		
8	287.9		
9	283.0		
10	273.5		
11	255.5		

The SBUV is a tandem double Ebert-Fastie monochromotor to minimize off-band radiation. The detector is a photomultiplier. There is a step scan from 160 to 400 nanometers and 11 data points are recorded with a band width of one nanometer. Also, a parallel fixed photometer channel with a vacuum photodiode measures at 339.8 nanometers with a bandwidth of 3 nanometers. The IFOV on all channels is 0.20 radians (11.3°) square. The spectrometer scan time is 96 seconds. The SBUV can view the sun through a diffuser.

The TOMS scans latterally in 35 steps of 3°. The path width is 1.8 radians (11.3°). At each step a monochrometer scans and the spectral radiance is measured at 6 wavelengths. The band pass is 1 nanometer. The time of a geometrical scan is 7.95 seconds. In order to prevent confusion by clouds, a cloud photometer measures each scene in the near infrared.

The Scanning Multichannel Microwave Radiometer (SMMR) measures the speed of ocean surface winds by measuring the sea state and enables ice-covered areas to be determined. It differs from the previous microwave radiometers by having ten channels: five wavelengths and two polarizations. The 1.4 cm channel enables it to obtain atmospheric water vapor information and the other channels enable it to separate out the effects of liquid water vapor droplets from the competing surface effects. This will enable better discrimination between open water and multi-year ice where the IFOV is divided between them. The wavelengths are:

Wavelength (Micrometers)	Frequency (GHz)	Beam Width (Degrees)
0.8	37.00	0.71
1.4	21.00	1.19
1.7	18.00	1.46
2.8	10.69	2.45
4.0	6.60	3.98

The absolute accuracy of the radiometer is better than 2^{o}C in all the channels. The scan is ±0.4 radians (±25^{o}) in a circular scan with a half cone of 42^{o}. The scan time is 4.096 seconds.

The Temperature-Humidity Infrared Radiometer (THIR) measures IR radiation in two bands to provide pictures of cloud cover, temperature mappings of clouds, land and ocean surfaces, cirrus cloud content, contamination and relative humidity. It is similar to the one on NIMBUS-6.

3. DATA AVAILABILITY

There are three agencies within the United States Government which maintain facilities for ground controlling, tracking, data acquisition, and unclassified distribution of environmental satellite data. These are the National Aeronautics and Space Administration (NASA), the National Oceanic & Atmospheric Admistration (NOAA)*, and the United States Air Force. Satellites utilized by NOAA are under control of NASA until after launch and checkout. Both NOAA and NASA maintain facilities for near earth orbiting satellites as well as geosynchrounous satellites while the Air Force collects unclassified environmental data only from near earth polar orbiting satellites. In addition, NASA maintains an elaborate tracking network for manned spacecraft and planetary probes. These networks will not be discussed in this report.

Data availability from each of the three agencies from satellites under their control will be covered separately in this section. Some satellites mentioned in Section 2.0 are in the early developmental stage and data products have not been defined. Their data products will obviously be missing from Section 3.0.

*NOAA is part of the Department of Commerce. The branch of NOAA which handles satellite data is the National Environmental Satellite Service (NESS).

3.1 NASA CONTROLLED SATELLITES

3.1.1 LANDSAT

3.1.1.1 MSS and RBV Data Recording and Transmission

Data output from the MSS is a single Pulse Code Modulation-Non-Return to Zero Level (PCM-NRZL) encoded bit stream at a rate of 15.06 Mbps. The RBV is an analog video signal with a bandwidth of 3.2 Mhz. Data from the MSS and RBV may be transmitted in real time on the Wideband Payload S-Band or each recorded on a Wideband Tape Recorder (WBTR). Data from the Data Collection System (DCS) cannot be recorded but is retransmitted in real time.

There are four data recorders used with the payload, two WBTR's and two Narrow Band Tape Recorders (NBTR). Up to 30 minutes of data can be recorded on each WBTR. The data output from the WBTR's may be transmitted to ground at the high data rate. Alternatively, the output may be changed to a lower data rate, and up to 210 minutes stored on each of the NBTR's, from which it can be subsequently played back at a rate of 24 Kbps.

The Wideband Payload S-Band consists of two bands, at 2229.5 and 2265.5 Mhz., which transmit the MSS and RBV data in real time or from the WBTR's.

The Unified S-Band (USB) and VHF cannot transmit at the real time bit rate of the MSS and RBV. The USB transmits on separate subcarriers real time telemetry (768 KHz), playback data from the recorders (597 KHz), DCS data (1.024 MHz) and pseudo-random ranging information simultaneously over the same 2,287.5 MHz carrier. The playback data can come from either of the NBTR's or either of the auxiliary tracks of the WBTR's. Only real time telemetry or playback data from the NBTR's can be transmitted at one time over the 137.86 MHz VHF equipment.

The MSS has 6 bits per word (64 levels).

For the RBV the degradation in the signal-to-noise ratio during transmission is less than one dB. For the MSS the bit error rate during transmission is less than 1 in 10^5. These numbers apply to the worst case, namely, the satellite 2° above the horizon of the receiving station.

All three primary ground stations, namely Alaska, Goldstone (California) and the NASA Test and Training Facility (NTTF) at Goddard receive the Wideband Payload S-Band. Alaska receives both USB and VHF signals, while NTTF and Goldstone receive only the USB. Backup USB and VHF stations also exist, some in foreign countries.

The Wideband video data in the form of magnetic tapes is sent from Alaska and Goldstone by mail to the NASA Data and Processing Facility (NDPF) at Goddard. The video signals received at the NTTF are recorded in the Operations Control Center (OCC) rather than at the station and the tapes are sent to the NDPF directly. The USB and VHF data is transmitted in real time to the OCC via the NASA Communications (NASCOM) network.

See Figure 3-1 for a diagram of the communication system.

There are two parallel processes, one for film and the other for magnetic tape. The film production will be described first. The whole system is called the Image Processing System (IPS). (See Figure 3-2).

The MSS (Multispectral Scanner) data is recorded on the MSS video tape recorder (VTR). The data enters the Initial Image Generation System (IIGS), where it is reformatted. The calibration is applied and the digital-to-analog conversion is performed for input to the EBR (electron beam recorder) unit where the data is placed on film. (These are not the corrections applied to output tapes described elsewhere.)

Similarly the RBV data, which is analog, enters the IIGS via the RBV VTR. Radiometric and geometric corrections are applied. The geometric corrections come via an image correction tape from the General Purpose Image Processor.

In the IIGS, geometric corrections on the data are performed to compensate for the internal errors of the EBR. A tape is produced which is the input of the EBR. The RBV sensor takes frames every 163 km. This results in an overlap of approximately 22 km. for each 185 x 185 km frame. The film used is 70 mm. The continuous MSS data is also cut into sections approximately the same size in such a manner that the frame centers are coincident with those of the RBV, i.e., the RBV frame time is identical to the scan time at the center of the MSS frame. The overlap is 17 km for the MSS. The specifications for the EBR are given in Table 3-1.

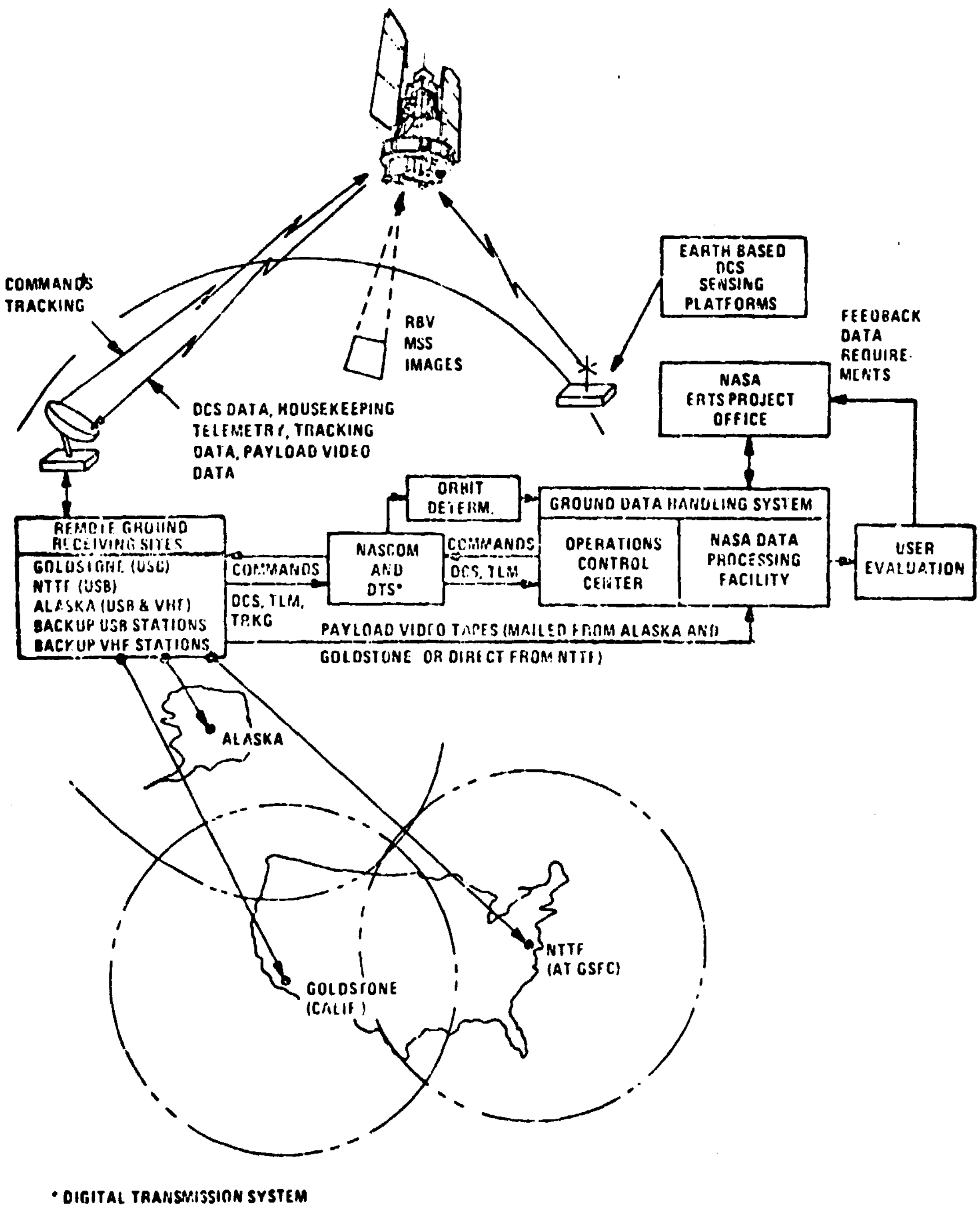


Figure 3-1. - Overall Landsat System

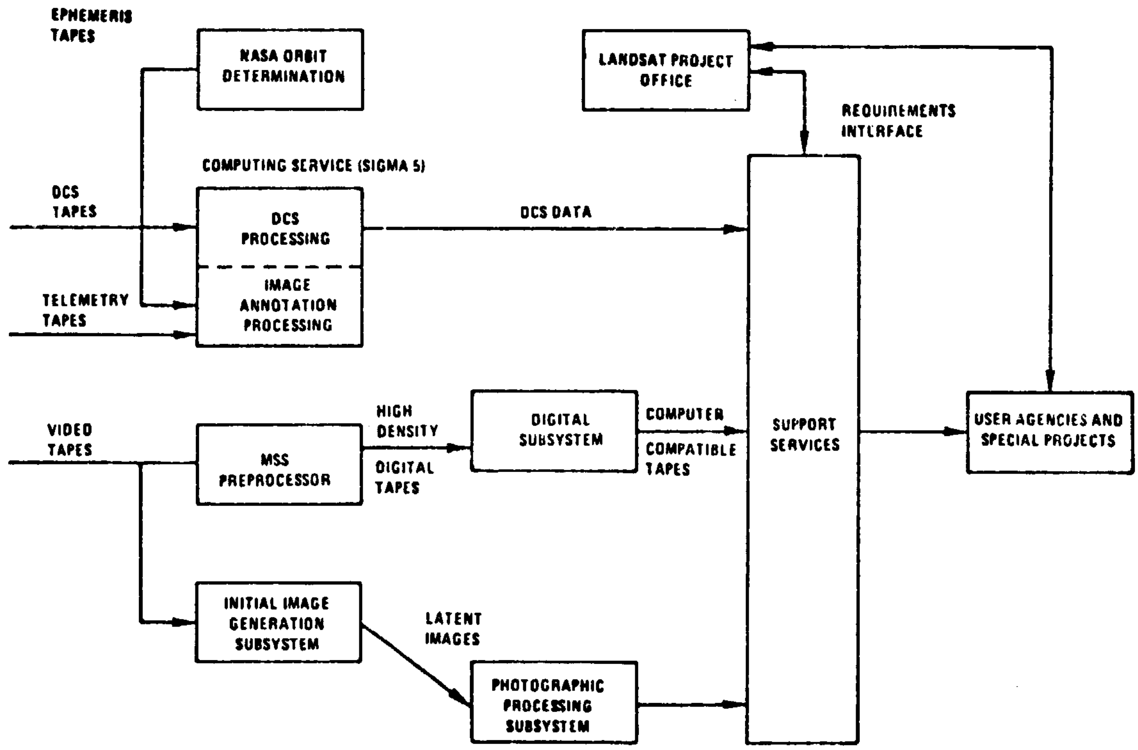


Figure 3-2. - NASA Image Processing Facility (IPF)

TABLE 3-1. - ELECTRON BEAM RECORDER PERFORMANCE DATA

Parameter	Performance
Video Bandwidth	0 to 8MHz at -3dB
Video Filter	RBV: passband 0 to 3.5MHz at -1dB MSS: passband 0 to 1.0MHz at -1dB
Line Scan Rate	RBV: 1250 lines/sec MSS: 326 lines/sec
Dynamic Writing Area	63 x 16 mm
Horizontal center: Frequency edge Response	8000 TV lines at 50% response 7200 TVL at 50% response
Vertical Lines per frame	RBV: 4125 (55 mm frame) MSS: 4512 (53 mm frame; after line doubling
Density Range	0.1 to 2.1
Transmission Range	100:1
Field Flatness	Max. density variation $< 1\%$ of D_{max}
Scan Jitter	peak-to-peak variation $< 0.01\%$ of 63 mm
Film Transport Jitter	rms variations line-to-line (non-cumulat[illegible] $< 20\%$ raster pitch
Repeatability	Peak error < 0.03 mm

The exposed film is developed in the Photographic Processing subsystem. The 70 mm. film is enlarged to 9.5 inch positive transparencies and prints. Triplet sets of 9.5 inch film are used to generate color composite negatives. Also, 70 mm negative and positive duplicate transparencies are made. In addition, 16 mm microfilm for archiving is produced.

The image correction tape utilized by the IIPS is made by the General Purpose Image Processor. 70 mm film from the EBR is compared with imagery with known ground control points using a viewer/scanner assembly. Matching is performed and a computer calculates the corrections required. A tape is generated which is an input to the EBR.

Parallel to the film processing described above, the Digital Image Preprocessing System (DIPS) (Figure 3-3) prepares radiometrically corrected tapes. The DPPS is divided into the Multispectral Scanner Preprocessor (MPP) and the Digital Subsystem (DS).

The input Wide Band Video Tapes (WBVT's) are screened at the MPP with a CRT. Selected scenes are recorded on high density tape (HDT). The data is reformatted in the process and the radiometric calibration is extracted and recorded on the HDT, but not applied at this stage. The purpose of the MPP is to prepare the data for input to the DS.

In the DS the radiometric corrections and other corrections are applied to the data. The output is a Computer Compatible Tape (CCT).

The output tapes and film go to the Data Services Laboratory, which has a central computer system. It controls the data flow in the above processes and uses a comprehensive data base for storage and retrieval. It fulfills user's requests, evaluates cloud conditions, production and shipping and generates catalogs of data products.

3.1.1.2 Availability of Data

The central source of Landsat data for users is the EROS (Earth Resources Observations Systems Program) Data Center (EDC), 25km northeast of Sioux Falls, South Dakota (an exception is that principal investigators of NASA approved projects request data before acquisition from NASA, Goddard).
The address is: User Services, EROS Data Center, Sioux Falls, South Dakota 57198, Phone: (605) 594-6511, x151, FTS 784-7511

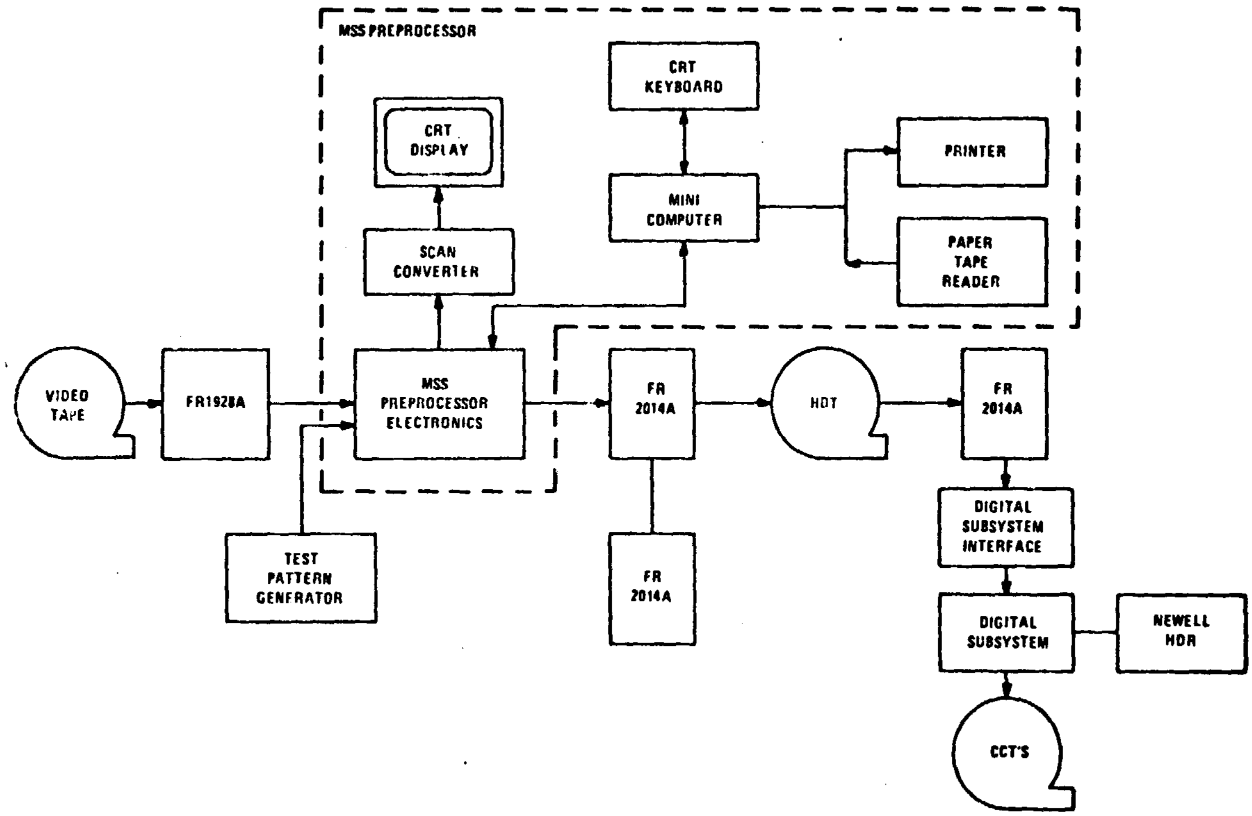


Figure 3-3. - Digital Imaging Processing System (DIPS) Overall System Configuration

The EROS Data Center is operated by the U. S. Geological Survey. It is an integral part of the National Cartographic Information Center (NCIC) system for those requesting information about available aircraft or spacecraft imagery and for those wanting to place orders for the data. The NCIC is headquartered in the Geological Survey National Center in Reston, Virginia. It is connected directly by terminal to EDC's computer data base. Inquiries and orders are transmitted daily. NCIC also has the following field offices with computer links:

Topographic Office
U. S. Geological Survey
900 Pine Street
Rolla, MO 65401
Phone: (314) 364-3680
Hours: 7:45 - 4:15

Air Photo Sales
U. S. Geological Survey
Federal Center, Building #25
Denver, CO 80225
Phone: (303) 234-2326
Hours: 7:45 - 4:15

NCIC Information Unit
National Center - Stop 507
12201 Sunrise Valley Drive
Reston, VA 22092
Phone: (703) 860-6045
Hours: 7:45 - 4:15

Map and Air Photo Sales
U. S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
Phone: (415) 323-2157
Hours: 7:45 - 8:15

There are several EROS Applications Assistance Facilities which maintain microfilm copies of data archived at the Center and provide computer terminal inquiry and order capability to the central computer complex at the EROS Data Center. Scientific personnel are available to assist in ordering. The addresses are:

EROS Applications Assistance Facility
U. S. Geological Survey
Room 202, Building 3
345 Middlefield Road
Menlo Park, California 94025
Phone: (415) 323-8111
Hours: 8:00 - 4:15

EROS Applications Assistance Facility
HQ Inter American Geodetic Survey
Headquarters Building
Drawer 934
Fort Clayton, Canal Zone
Phone 83-3897
Hours. 7:00 - 3:45

EROS Applications Assistance Facility
EROS Data Center
U. S. Geological Survey
Sioux Falls, South Dakota 57198
Phone: (605) 594-6511
Hours: 8:00 - 4:30

EROS Applications Assistance Facility
U. S. Geological Survey
Suite 1880
Valley Bank Center
Phoenix, Arizona 85073
Phone: (602) 261-3188
Hours: 8:00 - 5:00

U. S. Geological Survey
Room B-207-A, Building 1100
National Space Technology
Laboratories
Bay St. Louis, Mississippi 39520
Phone: (601) 688-3541
Hours: 8:00 - 4:30

EROS Applications Assistance Facility
U. S. Geological Survey
1925 Newton Square East
Reston, Virginia 22090
Phone: (703) 860-7871
FTS: (900) 860-7871
Hours: 8:00 - 4:15

EROS Applications Assistance
Facility
University of Alaska
Geophysical Institute
College, Alaska 99701 (Fairbanks)
Phone: (907) 470-7558
Hours: 8:00 - 5:00

In addition, several EROS Data Reference Files have been established throughout the United States which maintain microfilm copies of data available from the EROS Data Center. However, they do not have personnel for consultation. The addresses, telephone numbers and hours of operation are as follows:

EROS Data Reference File
Public Inquiries Office
U. S. Geological Survey
108 Skyline Building
508 Second Avenue
Anchorage, Alaska 99501
Phone: (907) 277-0577
Hours: 9:00 - 5:30

EROS Data Reference File
Topographic Office
U. S. Geological Survey
900 Pine Street
Rolla, Missouri 65401
Phone: (314) 364-3680
Hours: 8:00 - 5:00

EROS Data Reference File
Public Inquiries Office
U. S. Geological Survey
Room 7638, Federal Building
300 North Los Angeles Street
Los Angeles, California 90012
Phone: (213) 688-2850
Hours: 9:30 - 4:00

EROS Data Reference File
Water Resources Division
U. S. Geological Survey
975 West Third Avenue
Columbus, Ohio 43212
Phone: (614) 469-5553
Hours: 8:00 - 4:30

EROS Data Reference File
Water Resources Division
U. S. Geological Survey
Room 343, Post Office and Court
House Building
Albany, New York 12201
Phone: (518) 474-3107 or 6042
Hours: 8:00 - 4:30

EROS Data Reference File
University of Hawaii
Department of Geography
Room 313C, Physical Science
Building
Honolulu, Hawaii 96825
Phone: (808) 944-8643
Hours: 8:00 - 4:00

EROS Data Reference File
Bureau of Land Management
729 NE. Oregon Street
Portland, Oregon 97208
Phone: (503) 234-3361, ext. 400
Hours: 8:00 - 4:00

EROS Data Reference File
Public Inquiries Office
U. S. Geological Survey
Room 678, U. S. Court House Building
West 920 Riverside Avenue
Spokane, Washington 99201
Phone: (509) 456-2524
Hours: 9:00 - 4:30

EROS Data Reference File
U. S. Geological Survey
5th Floor
80 Broad Street
Boston Massachusetts 02110
Phone: (617) 223-7202
Hours: 9:00 - 5:00

EROS Data Reference File
Maps and Surveys Branch
Tennesse Valley Authority
20 Haney Building
311 Broad Street
Chattanooga, Tennessee 37401
Phone: (615) 755-2149
Hours: 8:00 - 4:00

In addition to the regular Landsat Facilities, the NOAA Satellite Data Services Branch (SDSB) has 16 mm browse files of Landsat data. The reason for this service is that Landsat data is often used in conjunction with NOAA satellite data. There are 21 SDSB browse files:

University of Alaska
Arctic Environmental Information and Data Center
142 East Third Avenue
Anchorage, Alaska 99501
Phone: 907-279-4523

Lake Survey Center - CLx13
630 Federal Building & U.S. Courthouse
Detroit, Michigan 48226
Phone: 313-226-6126

Inter-American Tropical Tuna Commission
Scripps Institute of Oceanography
Post Office Box 109
LaJolla, California 92037
Phone: 714-453-2820

National Weather Service, Central Region
601 East 12th Street
Kansas City, Missouri 64106
Phone: 816-374-5672

National Geophysical and Solar Terrestrial Data Center
Solid Earth Data Service Branch
Boulder, Colorado 80302
Phone: 303-499-1000, Ext. 6915

National Weather Service, Eastern Region
585 Stewart Avenue
Garden City, New York 11530
Phone: 516-248-2105

National Oceanographic Data Center
Environmental Data Service
2001 Wisconsin Avenue
Washington, D.C. 20235
Phone: 202-634-7510

National Climatic Center
Federal Building
Asheville, North Carolina 28801
Phone: 704-258-2850, Ext. 620

Atlantic Oceanographic and
Meteorological Laboratories
15 Rickenbacker Causeway,
Virginia Key
Miami, Florida 33149
Phone: 305-361-3361

National Weather Service, Pacific
Region
Bethel-Pauaha Building, WFP 3
1149 Bethel Street
Honolulu, Hawaii 96811
Phone: 808-841-5028

National Ocean Survey - C3415
Building #1, Room 526
6001 Executive Boulevard
Rockville, Maryland 20852
Phone: 301-496-8601

Atmospheric Sciences Library - D821
Gramax Building, Room 526
8060 - 13th Street
Silver Spring, Maryland 20910
Phone: 301-427-7800

National Environmental Satellite
Service
Environmental Sciences Group
Suitland, Maryland 20233
Phone: 301-763-5981

Northeast Fisheries Center
Post Office Box 6
Woods Hole, Massachusetts 02543
Phone: 617-548-5123

University of Wisconsin
Office of Sea Grant
610 North Walnut Street
Madison, Wisconsin 53705
Phone: 608 263-4836

National Severe Storms Lab
1313 Halley Circle
Norman, Oklahoma 73069
Phone: 405-329-0388

Remote Sensing Center
Texas A & M University
College Station, Texas 77843
Phone: 713-845-5422

National Weather Service, Southern
Region
819 Taylor Street
Fort Worth, Texas 76102
Phone: 817-334-2671

National Weather Service, Western
Region
125 South State Street
Salt Lake City, Utah 84111
Phone: 801-524-5131

Atlantic Marine Center - CAM02
439 West York Street
Norfolk, Virginia 23510
Phone: 804-441-6201

Northwest Marine Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112
Phone: 206-442-4760

Microfilm of the available imagery can also be viewed by NASA and approved personnel at the Earth Resources Research Data Facility, Code SF 121, NASA/ Johnson Space Center, Houston, Texas 77058.

Many factors are involved in determining the availability of data, such as acceptable cloud cover, time of year, location and acceptable quality. The following methods, catalogues and facilities of EROS may be used:

1. General references are Landsat Data Users Handbook (1976) and and Earth Resources Technology Reference Manual (ERTS) (No date). These documents describe the procedures of data production and ordering in more detail than described in this report.

2. A kit for ordering data is available from EROS. Prices are included.

3. Standing orders are advance requests for data acquisition. They are orders for bulk processed black and white imagery only.

4. Standard catalogues are issued every 18 days, describing data obtained in that interval. These are separate catalogues for U. S. and non-U. S. data. In addition there are cumulative catalogues of U. S. data up to July 23, 1973. Each cumulative catalogue has 4 volumes and is available from EROS.

5. Microfilms of all the imagery is available at the locations mentioned before. In addition, specific microfilms can be ordered.

6. A brouse facility is located in Building 23 at Goddard.

7. A computer search for the desired data may be initiated. It is necessary to specify the coordinates and other requirements as closely as possible in order to minimize the size of the printout.

8. Advice and consultation is available from EROS scientists pertaining to the acquisition of data. Information may be obtained by telephone, mail or visit. Seminars are often held at Sioux Falls on specific applications of the data. Regardless of the use of other methods, some consultation with EROS personnel is usually necessary until a person wanting data has established his procedure for obtaining the particular type of data he wants.

The general procedure for ordering data is first to contact EROS, explaining the type of data needed. They will send the forms, a list of prices, and descriptions of procedures. Next, the exact description of the data required is obtained by screening, using one or more of the above methods.

The following data outputs are available. They are subject to frequent change.

PHOTOGRAPHY (BULK)

Product format	Black and White		Color	
	Paper	Film	Paper	Film
Contact				
70 mm	-	X	-	X
5 x 5 inch	X	X	X	X
10 x 10 inch	X	X	X	X
Enlargements				
10 x 10 inch	X	X	X	-
15 x 15 inch	X	-	X	-
20 x 20 inch	X	-	X	-
30 x 30 inch	X	-	X	-
40 x 40 inch	X	-	X	-
Microfilm				
16 mm	-	X	-	X
35 mm	-	X	-	X

PRECISION DATA

Inquire at EROS

COMPUTER COMPATIBLE TAPES

Tracks	b.p.i.
7	800
9	800
9	1600

Bulk data is most useful for photointerpretation, precision data for mapping and computer tapes for quantitative radiometric work.

For MSS data, band 5, 0.6 - 0.7 micrometers, is usually the most useful for screening purposes.

There are two standing order options. In one case the data is sent automatically when data is obtained of the specified area. In the case of the other option, a list of the data obtained over the specified area is sent to the user and the user may order what he wants.

More detailed descriptions of the products, such as specifications, computer tape formats and interpretation of the annotation data are found in Landsat Data User Handbook, Section 4, Output Data Products.

3.1.1.3 Data Collection System (DCS)

A Data Collection Platform (DCP) collects data from a remote data collection site on either land or sea, encodes it and transmits it to Landsat, where it is re-transmitted to one of the receiving sites.

Each platform collects data from as many as eight sensors, supplied by the cognizant investigator, sampling such local environmental conditions as temperature, stream flow, snow depth or soil moisture.

Input may be analog or digital, serially or in parallel or a combination. Digital data is divided into 8 groups of 8 bits each for a maximum total of 64 bits. In the encoding, bits are added in the format to give up to 95 bits. For the purpose of reliability the message is made redundant, giving 190 bits before transmission. The transmission time is 68 milliseconds. A message is transmitted every 180 seconds.

The ERTS spacecraft merely acts as a relay and does not store the data. The data is transmitted from the satellite on the unified S-band. Line of sight between the platform and Landsat, and between Landsat and one of the three receiving stations is necessary. These stations are Goldstone, Alaska and the NTTF at Goddard. In addition, stations at Bay St. Louis, Mississippi, Waltham, Massachusetts and Colina, Chile receive data, but not as a general facility. At least one message is received from each platform every 12 hours with a reliability of at least 95%.

The received DCS data is extracted and inputted to special DCS Receiving Site Equipment (DCS/RSE). It is reformatted and transmitted by NASA Communications (NASCOM) to the Operations Control Center at Goddard. It is then sent to the NASA Data Processing Facility (NDPF). Requests are matched against received data and distributed to investigators by punched cards, magnetic tape teletype or computer listing within 24 hours.

Because each sensor, encoding method and format is different and calibration curves are required for converting into engineering units, only the primary user of the platform can convert the data. Therefore, data is not generally distributed by Goddard, but is usually obtainable from the platform owner. A list of platforms and addresses of owners is kept on computer tape at Goddard, but it is not generally kept up to date.

For additional information, contact:

J. Earle Painter
Code 952
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771
Phone: (301) 982-2823

If raw data is required on a regular basis it may be obtained from:

IPF Support Services
Code 563
Building 23, Room E409
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771
Phone: (301) 982-5406

BIBLIOGRAPHY

1. Earth Resources Technology Satellite, ERTS-2, Reference Manual, General Electric, Space Division, Valley Forge Space Center, Philadelphia, PA

2. ERTS Data User's Handbook (1976) NASA

3. Heaslip, George, B. (1976): Satellites Viewing Our World: The NASA Landsat and the NOAA SMS/GOES, Environmental Management, Volume I, No. 1, pp. 15-29.

4. Lansing, Jack C. Jr., and Cline, Richard W. (1975), Optical Engineering, Volume 14, No. 4, July/August 1975, pp. 312-322.

5. Horan, John J. et. al. (1975): In Orbit Calibration Performance of Landsat-2, Applied Optics 14, No. 9, pp. 2053-2054.

6. Paulson, Richard W. (1976): Use of Earth Satellites for Automation of Hydrological Data Collection, U. S. Geological Survey, Reston, Virginia.

7. (1975): The EROS Data Center, U. S. G. S. INF-74-43, Geological Survey, Department of the Interior.

3.1.2 SKYLAB

Data may be obtained from EROS. See comments on data acquisition under Landsat.

If a region of the earth is specified, EROS will state what, if any, data was obtained with the particular sensor. It will also state the scene numbers for photographs, by which the data may be ordered.

3.1.3 SEASAT-A*

3.1.3.1 Data Transmission

Seasat-A is a non-sun-synchronous NASA satellite which is projected for launch in 1978 and which will be primarily dedicated to the study of the oceans. The Seasat-A will orbit the earth fourteen times a day in a 790 km circular, retrograde polar orbit so designed that it will provide approximately global coverage every 36 hours. (See Figure 3-4). The following five Space Tracking and Data Network (STDN) stations are presently committed to provide telemetry, command and tracking support for Seasat-A.

(1) Fairbanks, Alaska (ULA)
(2) Goldstone, California (GDS)
(3) Merritt Island, Florida (MIL)
(4) Madrid, Spain (MAD)
(5) Orroral, Australia (ORR)

The STDN stations and their receiving areas are shown in Figure 3-4 with those areas covered by stations equipped for SAR data indicated with cross-hatching. The continental United States and its coastal waters are covered by the Goldstone (GDS) and Merritt Island (MIL) sites. The Fairbanks (ULA) site covers Alaska, western Canada and a large portion of the Arctic region north of both. The Madrid (MAD) site covers the British Isles, Europe and northwestern Africa. The Orroral (ORR) site covers the southeastern half of Australia and the western edge of New Zealand.

The first three of these STDN stations (ULA, GDS and MIL) will be equipped to receive and record the real time SAR data transmissions. The sites at Madrid (MAD) and St. John's, Newfoundland may eventually be added to these.

*Taken directly from Reference 3.1.3-1.

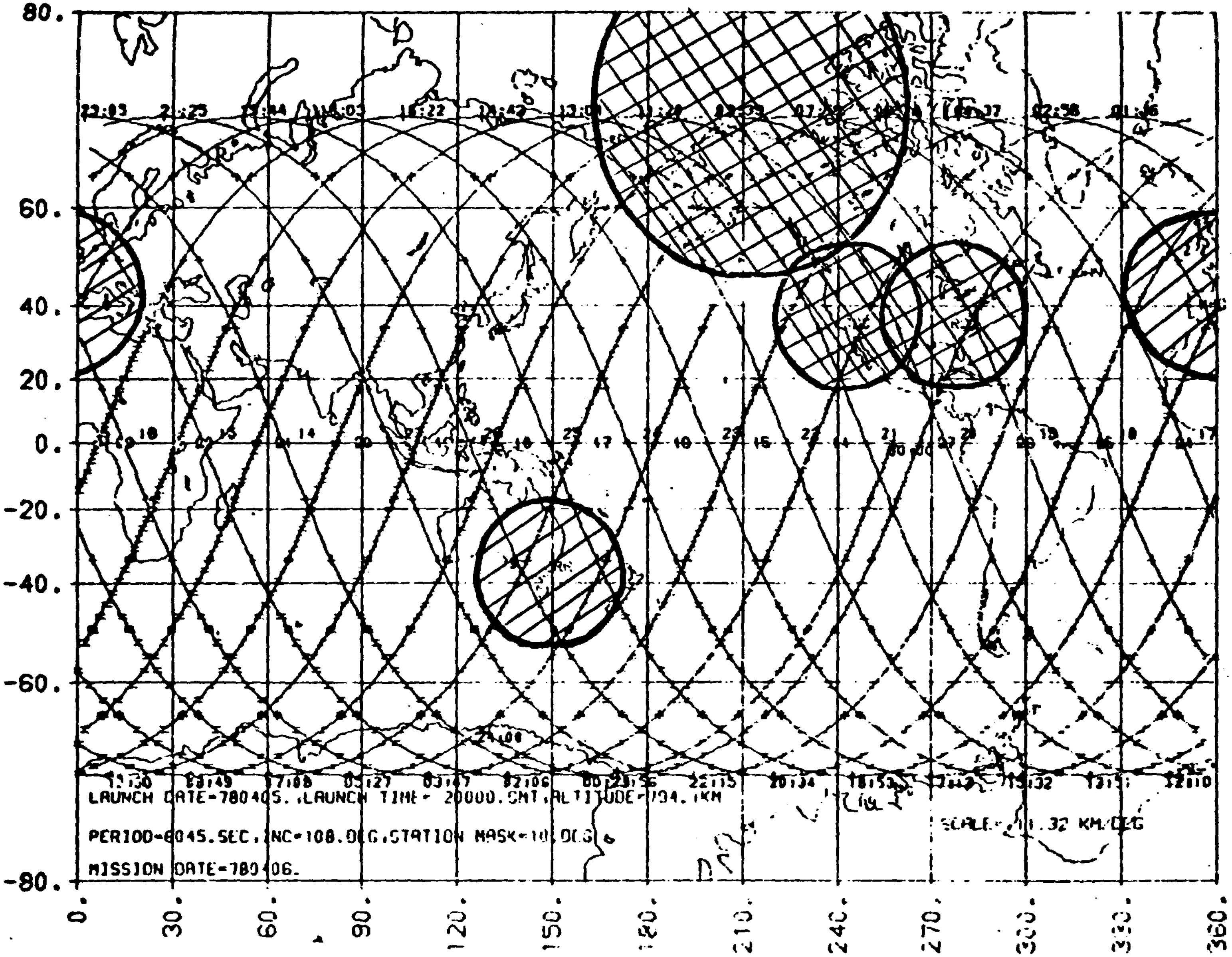


Figure 3-4. - Seasat-A STDN Receiving Sites (Shaded)
and Typical Ground Tracks

The following STDN sites are under consideration, to provide additional support to Seasat-A:

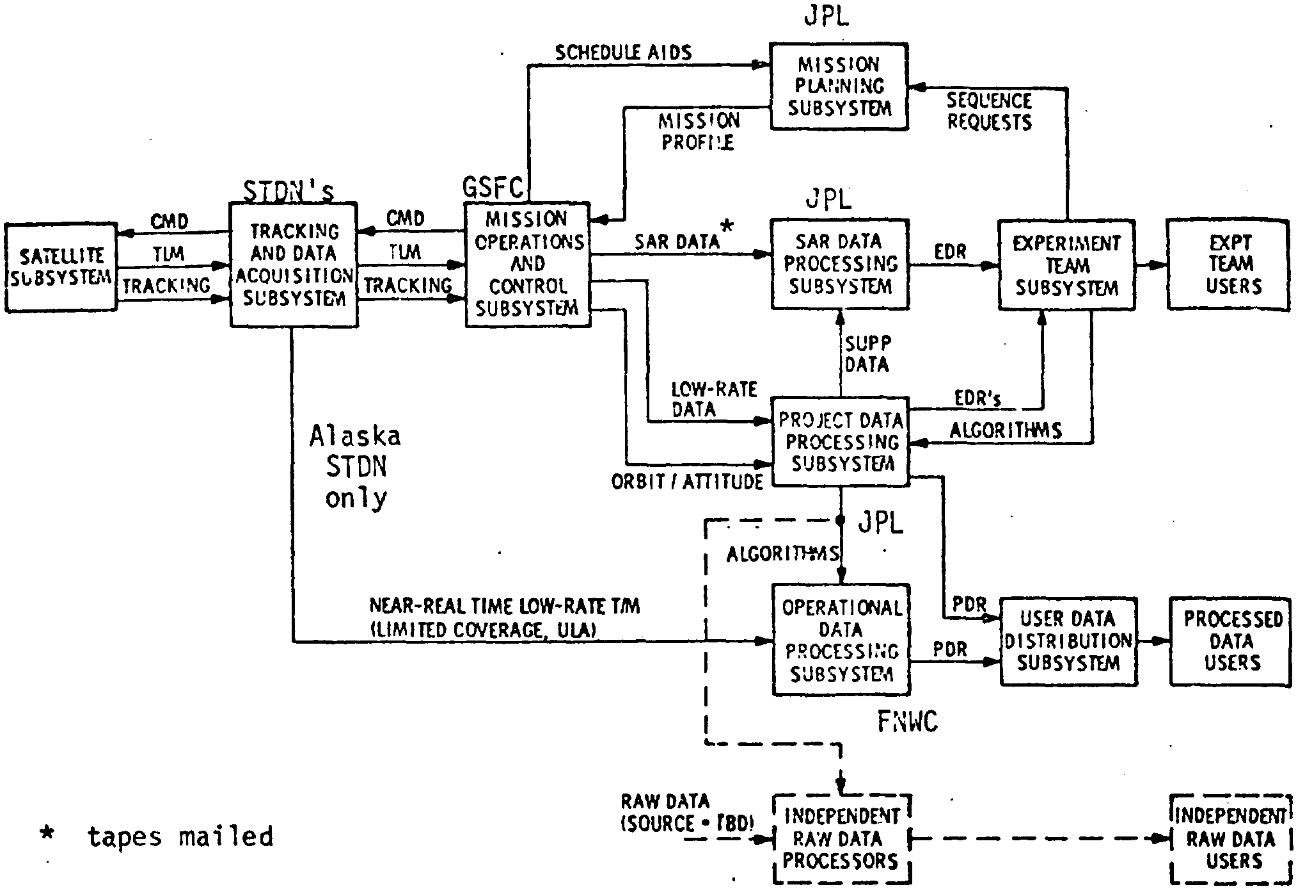
Ascension Island	(ACN)
Santiago, Chile	(AGO)
Quito, Peru	(QUI)
Guam	(GWN)
Hawaii	(HAW)
Bermuda	(BDA)
Canary Islands	(CYI)

The overall Seasat-A data flow is shown in the general block diagram of Figure 3-5. The satellite command, data telemetry and tracking are performed by the NASA Tracking and Data Acquisition Subsystem (TDAS). This consists of the five STDN stations presently committed to supporting Seasat-A and the NASA Communication (NASCOM) lines which link these STDN sites to the Mission Operations and Control Subsystem (MOCS) at GSFC. The 56 kb/s NASCOM lines will be used for all but the SAR data, i.e., the low data rate ALT, SASS, SMMR and VIRR data will be transmitted to GSFC in real to near-real time. The raw SAR data will be mailed to JPL in the form of digital tapes from those STDN sites especially equipped to receive, digitize and record the SAR data. A special high data link will provide the Operational Data Processing Subsystem of the Navy's Fleet Numerical Weather Central (FNWC) with low rate (non-SAR) data from the Fairbanks, Alaska STDN site. These data are then processed in near real time by the FNWC and made available to NOAA and other outside users.

All of the low rate (non-SAR) sensor data are processed at JPL by the Project Data Processing Subsystem (PDPS) and the SAR data are processed by the SAR Data Processing Subsystem (SDPS). The PDPS outputs include both experiment data records (EDR's) for use by experiment teams and processed data records (PDR's) of geophysical data for the users. As indicated in Figure 3-5 the exeriment teams will use the EDR data to develop algorithms which will in turn be used by the PDPS to generate the PDR's. The SDPS consists of specialized equipment for processing the SAR data into EDR's in the form of imagery and tapes.

3.1.3.2 Data Products

Data products have not been completely formalized at this time and are still under review.



* tapes mailed

Figure 3-5. - Overall Seasat-A Data System

Reference

3.1.3-1. Chism, S. B.: Seasat-A Land Applications Data Processing Plan, LEC-9978, January 1977

3.1.4 AEM-A

3.1.4.1 Data Transmission

The Applications Explorer Mission (AEM-A) will be a small, versatile, relatively low-cost spacecraft containing a single experiment, the Heat Capacity Mapping Radiometer (HCMR), which will be launched in 1978. The spacecraft will not have on-board recording and so will be limited in recording times by line of sight coverage of available NASA Spaceflight Tracking and Data Network (STDN) stations and by line of site coverage of approved domestic and foreign stations which desire and have the necessary equipment to receive AEM-A data. The NASA STDN stations are located at Fairbanks, Alaska; Goldstone, California; Rosman, North Carolina; Madrid, Spain; and Orrora., Australia. Their coverage is illustrated in Figure 3-6. Stations other than NASA may recieve the data and either process the data themselves or contract with Goddard Space Flight Center for processing if their received data and formats are compatible to those at Goddard. Details on suggested receiving equipment are contained in reference 3.1.4-1.

Raw data available from the HCMR will consist of a digital telemetry channel and two dc to 50 KHz bandwidth analog signals containing visual and thermal channel data.

3.1.4.2 Data Products

Data Products available to approved users and processed by the Information Processing Division (IPD) at Goddard Space Flight Center, Greenbelt, Maryland are as follows:

- Calibrated and geometrically corrected visible channel images in the form of positive and negative transparencies and positive and negative prints.
- Calibrated and geometrically corrected infrared channel images in the form of positive and negative transparencies and positive and negative prints. The convention used will be increase of whiteness with temperature.
- Calibrated and geometrically corrected day/night temperature difference images in the form of positive and negative transparencies and positive and negative prints.

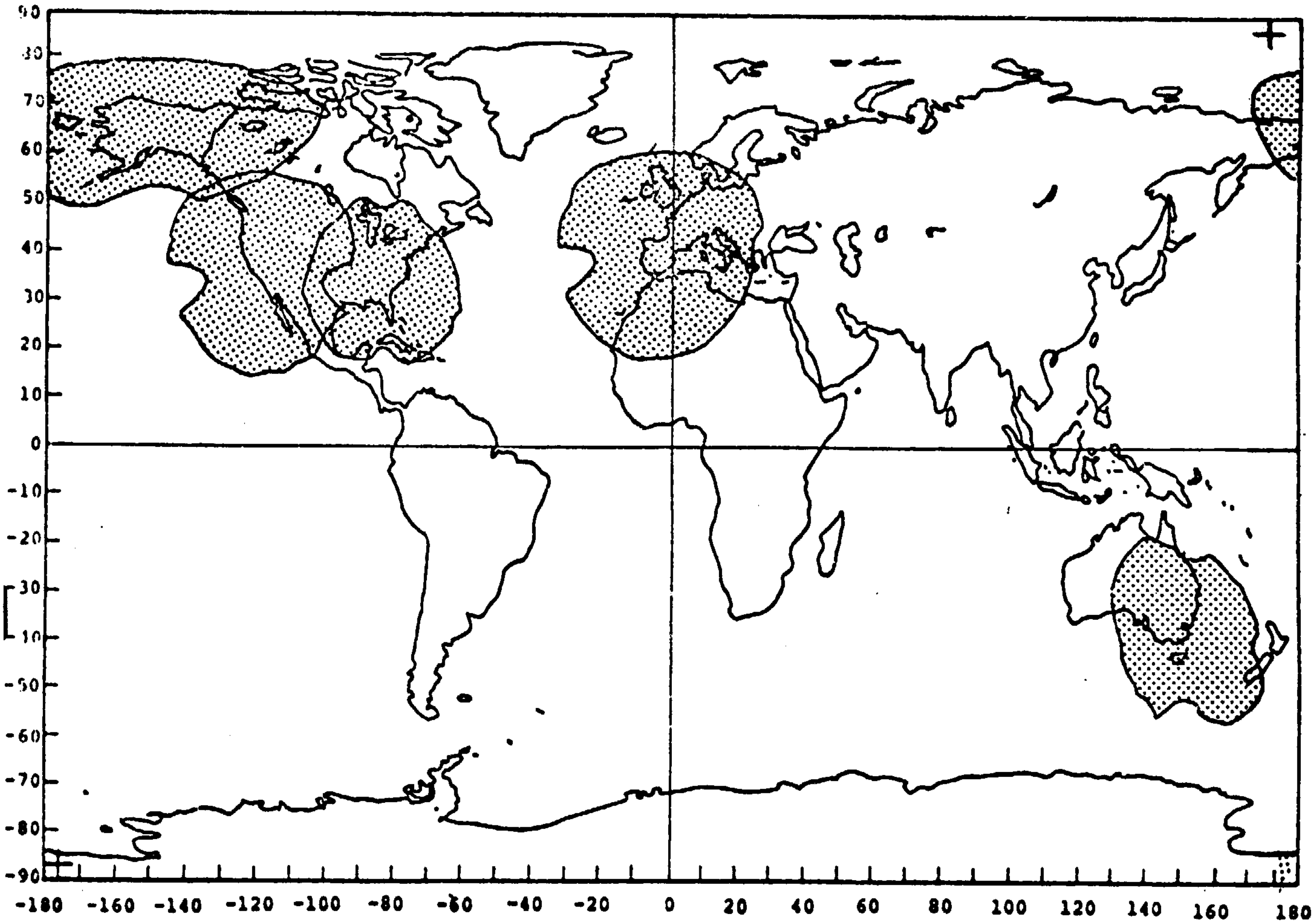


Figure 3-6. - Coverage by NASA STDN Stations Assuming Line-of-Sight Reception as Low as 10^{o}

- Calibrated and geometrically corrected thermal inertia images in the form of positive and negative transparencies and positive and negative prints.
- Computer compatible 1600 BPI tapes containing the above products.

Formats of the computer tapes are to be determined.

If additional interest is shown in the HCMM, then further information can be obtained by directing inqurіes as follows:

National Aeronautics and Space Administration
Applications Directorate, Missions Utilization Office
Code 902
Goddard Space Flight Center
Greenbelt, Maryland 20771

Attention: Mr. Locke M. Stuart, Jr.

References

3.1.4-1 User's Guide for Direct Readout Application; Applications Explorer Mission-A, Heat Capacity Mapping Mission (HCMM). Goddard Space Flight Center, Greenbelt, Maryland, September 1976.

3.1.5 GEOS-3

3.1.5.1 Data Transmission

The GEOS-3 is a highly specialized experiment conducted primarily by NASA and the Department of Defense, with participation by several universities and international organizations, for (1) improvements in the science of satellite geodesy through precision orbit determination and, (2) for accurate measurements of the ocean geoid and sea state. The ocean geoid and sea states are primarily measured by the radar altimeter while a number of other instruments are utilized in satellite positional determination. The ultimate accuracy of the geoid is determined by the known accuracy of the satellite position. GEOS-3 instruments are as follows:

1. Radar altimeter
2. Coherent C-band transponder
3. S-Band instrumentation for satellite-to-satellite experiments (ATS-6)
4. Laser retroreflectors
5. Doppler transmitters
6. Non-coherent C-band transponder
7. S-band instrumentation for earth tracking experiments

The laser retroreflectors will be used in a triangulation calibration of spacecraft position and the C-band transponders will be used for range, range rate, and angle measurements. An illustration of the calibration range is shown in Figure 3-7. The doppler system provides the basis for altimeter pulse repetition rate, telemetry rate, and spacecraft timing. The S-band system is utilized as the carrier for the telemetry. There are two telemetry rates, 1.56 kbps and 15.6 kbps and each can be transmitted on a S-band carrier or a 136.32 MHz VHF carrier. A number of VHF telemetry sites presented in table 7, ref. 3.1.5-1 can receive GEOS-3 data. These sites are operated by NASA, DOD, and foreign agencies. Table 8 of the same reference contains several NASA STDN S-band stations which can also receive telemetry. In addition, the Applications Technology Satellite (ATS) can receive telemetry and doppler information from the GEOS-3 on the lower data rate channel only and relay this data to its receiver sites at Rosman, North Carolina and Madrid, Spain.

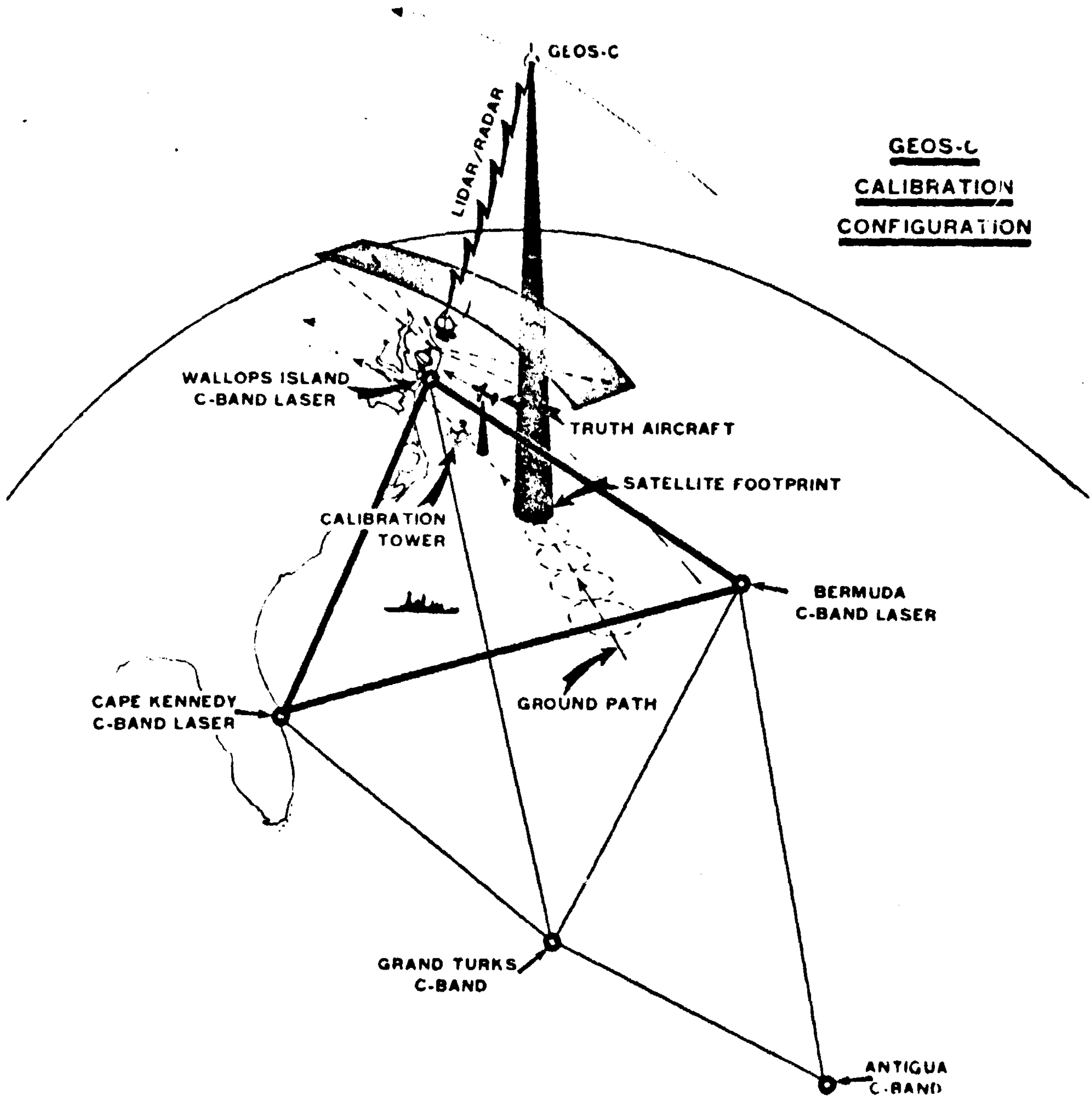


Figure 3-7. - GEOS-3 Calibration Range

3.1.5.2 Data Products

The primary information available to the author on data products from GEOS-3 are from a Proposal Briefing on 13 December 1972 (ref. 3.1.5-2). All instruments utilized in the calibration experiment had processing plans as outlined in this reference. In addition, a later document on the GEOS-3 altimeter pre-processing report (ref. 3.1.5-1) developed very detailed pre-processing techniques for the altimeter data. A revision to this report was made on March 3, 1976.

Further information can be obtained from this experiment by directing inquiries to Mr. R. Stanley at Wallops Island, Virginia.

References

3.1.5-1. Leitao, C. D.; Purdy, C. L.; Brooke, R. L.: Wallops GEOS-C Altimeter Pre-processing Report. NASA TM X-69357, May 1975.

3.1.5-2. GEOS-C Mission Proposal Briefing Information. Wallops Island, Virginia, December 13, 1972.

3.1.6 LAGEOS

3.1.6.1 Data Acquisition

There exist three mobile laser stations for ranging on the satellite which will be increased to eight by May 1978. There are fixed stations operated by the NASA Spaceflight Tracking and Data Network (STDN) at Goddard and Patrick Air Force Base and stations operated by the Smithsonian Astrophysical Observatory (SAO) network at Cambridge, Massachusetts and foreign countries. In addition, several foreign governments have planned or are building stations.

The goal is to achieve 2 cm accuracy within several years. The present performance is ahead of schedule with 20 cm accuracy achieved and 7 cm internal consistancy in the equipment, with 2 cm internal consistancy sometimes obtained.

A catalog of "Quick Look" information is issued by SAO. All NASA and Smithsonian data is archived. The data is pre-processed and put into the GEOS-3 format for archiving. There is no formal documentation on this format. The data must be computer processed before becoming useful and considerable processing is necessary.

3.1.6.2 Data Products

Data is distributed only to approved users. However, if a need can be shown there is no difficulty in obtaining the approval. For information, contact:

Chris Stephanides, Code 943
Goddard Space Flight Center
Greenbelt, Maryland 20771

3.1.7 NIMBUS

3.1.7.1 Data Transmission

Data transmission from NIMBUS-5 is normally made to two Spaceflight Tracking and Data Network (STDN) stations located near Fairbanks, Alaska and Rosman, North Carolina. All data is processed by the Meteorological Data Handling Station (MDHS) at GSFC. It is received either by wide band data link or by microwave link from the tracking sites. Where noise becomes a factor which degrades data recovery, then tapes are made at the tracking sites and mailed directly to GSFC. PCM data may also be acquired at any of the STDN sites including the previously mentioned ones and Goldstone, California; Honeysuckle Creek, Australia; and Madrid, Spain. This data is relayed directly by data link to GSFC.

NIMBUS-6 utilizes much the same data transmission link as NIMBUS-5 except that the S-band data can also be received by a STDN station at Orroral, Australia for elimination of a gap in global coverage that exists when using only Rosman and Alaska data. In addition, NIMBUS-6 also has a Tracking and Data Relay Experiment (T & DRE) which uses the ATS-6 as a data relay.

NIMBUS-G will have similar data transmission links as NIMBUS-5 except that a Coastal Zone Color Scanner (CZCS) will be a primary instrument and will have a high data rate which can only be processed and stored for approximately 10 minutes. Several STDN tracking and receiving stations will be required to obtain substantial ground coverage from the instrument.

3.1.7.2 Data Products

The data products from each of the many sensors on NIMBUS-5 and NIMBUS-6 are best described in the User's Guides. There are referenced in the bibliography.

Bibliography

1. The Nimbus-5 User's Guide, Goddard Space Flight Center, Greenbelt, Maryland, November 1972.
2. The Nimbus-6 User's Guide, Goddard Space Flight Center, Greenbelt, Maryland, February 1975.
3. Streaker, Davis M.: The Nimbus-G Sensor Systems: A Preliminary Description, Goddard Space Flight Center, Greenbelt, Maryland, September 1975.

4. Heath, D. N.; et. al. The Solar Backscatter and Total Ozone Mapping Spectrometer (SBUV/TOMS) for NIMBUS-G, Optical Engineering, Volume 14, July/August 1975. No. 4, pp. 323-331.

3.2 NOAA CONTROLLED SATELLITES

3.2.1 ITOS/NOAA

The many modes of data transmission from the satellite to earth, processing of the data and transmission to the user are divided into two general categories, central operations and direct broadcast. Direct broadcast is the real time line-of-sight transmission to a user owned station. It is described in the next section. Transmission via central operations is reception via a large government owned station, data processing in a central facility and reception of the data by the user via transmission lines or mail. This method will be described in this section.

3.2.1.1 Central Services

For central processing the data is usually recorded aboard the satellite and transmitted to Command and Data Acquisition Stations (CDA). A multiplicity of modes of operations exist, expecially to provide redundancy to ensure against failure, but also for optimization, and generalities are difficult to make. The description here is brief. For details see Reference 3.2.1-1. The CDA stations are at Wallops Island, Virginia and Gilmore Creek, near Fairbanks, Alaska. In addition, the San Francisco VHRR Satellite Field Service Station (SFSS) and Honolulu receive data which can not be received at the other stations because of line-of-sight limitations. The data is relayed to the Satellite Operations Control Center (SOCC) at Suitland, Maryland via a satellite communications network (SATCOM), then transmitted to the central data processing facility (DAPAF) in Suitland. Goddard and Offut Air Force Base can also receive data simultaneously from Wallops or Gilmore. Wallops is the only station which can receive multi-orbit data, although Gilmore can accept data stored for one orbit. Only Wallops and Gilmore can receive the S-band which contains the stored data.

In addition, HRPT (VHF beacon real time transmitted) stations at Wallops, Gilmore and San Francisco will send displays directly to local users by 4 kHz C-5 transmission lines.

DAPAF is a part of NESS (National Environmental Satellite Services) central operations. There the data is recorded, digitized and reformatted by the Digital Data Handling System (DDHS) and put on magnetic tape. This process is called ingestion. The data is then ready for processing.

The CDC processes the SR tapes, applies calibrations, removes some atmospheric absorption effects from the IR data and removes the effects of uneven solar illumination on the VIS data. Distortions are removed and grids placed on the maps. Several types of SR maps are produced:

- Global Polar Mosaics are a 2048 x 4096 array with 7.4 km mesh size at the equator. The mesh size is doubled at the poles due to the curvature of the earth. Both hemispheres are included. The mosaics are used for Global Weather Prediction Applications.
- Mercator mapping is used for tropic and subtropic areas.
- Polar and Mercator mosaics are made every 48 hours. Also, individual maps are made for each pass. These are received by facsimile.
- Sometimes maps are produced of small areas with higher resolution. IR maps are made for the polar sectors with 7.4 km resolution at the poles. A similar map is made of the 48 states.
- Also, unmapped imagery is produced.
- Sea Surface Temperature (SST) maps are produced using corrections from the VTRR for the atmosphere.

The VHRR data has low priority. Several modes may be used. It may be recorded on 10 inch film or the data sent on out on C-5 lines. The data, as processed, is similar to that for the HRPT stations.

VTPR data is separated from the other data and put on magnetic tapes during ingestion.

In determining profiles the steps are performed in the following order:

1. The geographical location is determined, the conversion to radiance is made and the calibrations are applied.
2. The clear radiance areas are located. This means that areas containing clouds are eliminated.
3. The first-guess temperature and water vapor profiles are made.
4. The transmittances are calculated.
5. The surface temperature is calculated.
6. Temperature profile is calculated.
7. Water vapor profile is calculated.
8. The iteration may be repeated if more accuracy is desired.

The output is called the Satellite Infrared Sounding (SIRS). It includes locations, heights, temperature and dewpoint temperature regressions at specified pressure levels up to 400 mb and temperatures at significant levels. Initially, only temperatures over the ocean are released to users. Data is archived, teletyped to users and sent to the National Meteorological Center (NMC).

North of 21°N, all heights are referenced to NMC 850 mb forecast height, south of 18° all heights are thicknesses between 850 mb and the given level, and between 18° and 21° either method may be used for the sounding.

Archival types of VTPR data (raw radiances, "clear radiances" and retrieved profiles) are available in different forms at three major points in the data processing. Tape is transmitted to Goddard in real time for space studies and a copy is sent to the National Climatic Center.

3.2.1.2 Data Products

The data products are divided into three types:

1. Photographic imagery products include photographic prints, positive film transparencies and 16mm movie film.

2. Facsimile products include standard 120 line/minute imagery as transmitted over FOFAX and NAFAX circuits, 240 line/minute APT formatted imagery (includes WEFAX) and any other scanned hard copy material formatted for transmission over the facsimile distribution system.

3. Alphanumeric products include teletype transmissions, punched cards, punched paper and magnetic tape.

Real time products may be ordered and sent by mail or user's communication links by contacting:

National Environmental Satellite Service (NESS)
Director of Operations, FOB-4
Washington, D.C. 20233

Retrospective (archived) data products may be obtained from:

National Climatic Center (NCC)
National Oceanic and Atmospheric Administration
Federal Building
Asheville, North Carolina 28801

The data products change as requirements change, thus any listing is quickly outdated. For more detailed descriptions of these products see Hoppe and Ruiz, reference 3.2.1-2.

A tentative listing of data products, subdivided according to the type of processing follows:

A. Manual and Basic Products

1. Facsimile

<u>Great Lakes Ice Chart</u> (VHRR, VIS and IR). Areas are image sliced into three areas according to the reflectance.

<u>Satellite Input to Numerical Analysis and Prediction (SINAP)</u> (SR, VIS and IR). The 300 mb height field is shown over the North Pacifice Ocean. Troughs and ridges are plotted. At the present time the basic chart is made available only to NMC analysts.

Northern Hemisphere Snow and Ice Chart (SR, VIS and IR; VHRR, VIS and IR). An 8½" x 11" chart showing snow fields and boundaries is updated weekly.

2. Alphanumeric

<u>Satellite Weather Bulletins and Tropical Disturbance Summary</u> (SR, VIS). Coded messages describe the location, time, movement, present and forecast intensity, and general cloud characteristics of tropical cylcones.

<u>Two-Layer Moisture Analysis</u> (SR, VIS and IR). Cloudiness in two layers (surface to 700 mb and 700 - 500 mb) is determined twice daily in the Pacific, Western Atlantic and Gulf of Mexico.

<u>Plume Winds</u> (satellite experimental upper winds, tropical) (SR, VIS). Estimated wind speed and direction as shown by cloud tops are plotted daily from 150°W to 30°E between 20°N and 40°S.

B. <u>Quantitative Computer Derived Products</u>

1. Alphanumeric

<u>Vertical Temperature Profile Radiometer (VTPR) Soundings</u>. Temperature and Humidity Profiles are shown on a global basis at 0000 GMT and 1200 GMT for open ocean areas only.

<u>Experimental Global Operational Sea Surface Temperature Observations GOSSTCOMP)</u> (SR, IR). Global sea surface temperature is calculated

for 5000 to 6000 points daily.

C. Computer Derived Image Products

1. Photographic Imagery

Gridded Unmapped Pass-By-Pass SR Images (SR, VIS and IR). Almost pole-to-pole coverage is achieved by mosaicing, for quick look.

SR Hemispheric Polar Mosaics (SR, VIS and IR). Maps for each hemisphere are prepared for night and daylight data.

SR Mercator Mosaics (SR, VIS and IR). Mosaics are displayed in two sections for east and west longitude for latitudes 40°S to 40°N, both for VIS and IR.

SR North American Polar Mosaic Sectors (SR, VIS, IR day and IR night). Daily 10" x 10" films are produced extending from 90°W to near 170°W from the equator to 90°N.

Very High Resolution Radiometer Basic Images (VHRR, VIS and IR). Selected 2400 x 2400 km areas are available on 10" x 10" film, 2 or 3 pictures per pass.

Five-Day Minimum Composite Brightness (SR). Cloudless pictures are shown for each hemisphere for areas where at least one cloudless picture could be obtained during the time interval. These pictures are especially useful for showing large scale ice fields, although also useful for other purposes.

Augmented Resolution Map Sectors (SR). Several limited area map sectors, polar or mercator, having a resolution of 4 km at the equator and 8 km at the poles, are issued for specific objectives.

2. Facsimile Products

Visual and Infrared Scanning Radiometer Products for Transmission On NWS Facsimile Networks (SR, VIS and IR). A number of polar sector and mercator mosaics are available and supplied to a large percentage of the users. The data is formatted for transmission over standard facsimile circuits at 120 lines/minute. There are 16 shades of gray. Schedules are available from:

NOAA, NWS 154
8060 13th Street
Gramax Building
Silver Spring, MD 20910

Visual Scanning Radiometer Products for Transmission Via Weefax (SR, VIS and IR). Several polar and mercator products are available to users with APT stations.

D. Archival Products

Magentic tapes, called Scanning Radiometer Data Tapes, Sea Surface Temperature Data Tapes and Vertical Temperature Profile Radiometer Data Tapes are available in engineering units. Photographic images are available in 35 mm reel for SR and, started early in 1974, VHRR images in 10" x 10" format.

E. Miscellaneous Products

TWXX 1-10, Cloud Motion Vector Field Messages. Messages under the headings TWXX1 KWBC and TWXX2 KWBC contain low-level winds over the central and eastern Atlantic Ocean.

3.2.1.3 Direct Broadcast Transmission

The available options for user stations are quite limited in comparison with those which involve Suitland. Data from each of the three instruments may be broadcast directly to users who have their own stations. The station requirements are different for the three instruments.

The SR data is transmitted via VHF beacon transmitter to local ground stations via the Automatic Picture Transmission (APT) system. A modification of the APT station is necessary to receive the 48-lines/minute SR data. Frequencies are 137.5 MHz or 137.62 MHz. The two frequencies eliminate interference between broadcasts of two satellites at the same ground station.

The usual display at 48 rpm is 10" wide. The IR and VIS each are 1/3 the width, with alphanumeric data on the other third. By suppressing the alternate IR or VIS signals and going to 96 rpm the display may be doubled in size and improved, but only the IR or VIS display is shown. The problem with the dual display is the different gain required for each display. At least six passes a day can be recorded. A broader bandwidth is required for the display than for APT data prior to ITOS D, namely 1200 Hz for the VIS and 600 Hz for the IR.

The VHRR data may be received by local stations in real time on the High Resolution Picture Transmission (HRPT) system, but a much more sophisticated station is required than for the APT. It is transmitted on a sub-band of a 1.7 GHz S-band. Also stored data may be transmitted. The data is received at the station, digitized to eight bits, and recorded. After the pass it is displayed. The IR and visible are handled separately. There is 10" of data displayed for each six minutes of IR data and the same in the visible. The images are 2,580 km on a side with 2,400 scan lines. A maximum gap of 320 km occurs at the equator on successive orbits.

The VTPR data is broadcast directly via the beacon transmitter at 136.77 or 137.14 Mhz (two frequencies are used to eliminate interference between satellites). The data can be processed to yield temperature profiles.

References

3.2.1-1 Fortuna, Joseph, J.; and Hambrick, Larry N. (1974); The Operation of the NOAA Polar Satellite System, NOAA Technical Memorandum NESS 60, Office of System Integration, National Environmental Satellite Service, NOAA.

3.2.1-2 Hoppe, Eugene, R.; and Ruiz, Abraham (1974): Catalog of Operational Satellite Products, NOAA Technical Memorandum NESS 53, National Environmental Satellite Service, NOAA.

3.2.1-3 McMillin, L. M.; et. al., (1973); Satellite Infrared Soundings from NOAA Spacecraft; National Environmental Satellite Service, NOAA, Government Printing Office.

3.2.1-4 Brower, R. L. et. al. (1976); Satellite Derived Sea Surface Temperatures from NOAA Spacecraft, National Environmental Satellite Service, NOAA, Technical Memorandum NESS 78, June 1976.

3.2.2 SMS/GOES

3.2.2.1 Data Transmission

Normal data transmission and distribution from SMS/GOES is accomplished according to Figure 3-8. Unprocessed Visible/Infrared Spin Scan Radiometer (VISSR) data are collected and transmitted from the satellite to the Command and Data Acquisition (CDA) station at Wallops Island, Virginia. The visible data, which has a higher data rate, and the IR data are stretched* at the CDA station and re-transmitted back to the SMS/GOES. (This stretching process is possible because the spinning spacecraft only views the earth during 18° of its rotation leaving 342° of re-transmission time.) The stretched data is then received from the Satellite Operations Control Center (SOCC) located at National Environmental Satellite Service (NESS). The stretched data is transmitted by microwave link to the Central Data Distribution System (CDDS) at Marlow Heights, Maryland. The IR data because of its lower data rate has a back-up system of land line transmission from the CDA to SOCC and then to CDDS. At the CDDS the stretched data are "sectorized", i.e., sections are then extracted from the full earth disc data of specific geographic areas with specific resolution. This data is then transmitted along with full disc IR data over dedicated C-5 land lines to 6 Satellite Field Services Stations (SFSS's) and co-located National Weather Service (NWS) units. Presently operational SFSS and NWS units are shown below:

SFSS	Co-located NWS Units
Washington, D.C.	Washington, D.C. WSFO
Miami, Florida	National Hurricane Center (NHC), Miami
Kansas City, Missouri	Nat'l. Severe Storms Forecast Center (NSSFC) Kansas City, Missouri
San Francisco, California	San Francisco WSFO and Eastern Pacific Hurricane Center (EPHC)
Honolulu, Hawaii	Honolulu WSFO and Central Pacific Hurricane Center (CPHC)
Anchorage, Alaska	Anchorage WSFO, Alaska

*The reason for stretching the data is so that transmission bandwidth will be compatible with the land lines.

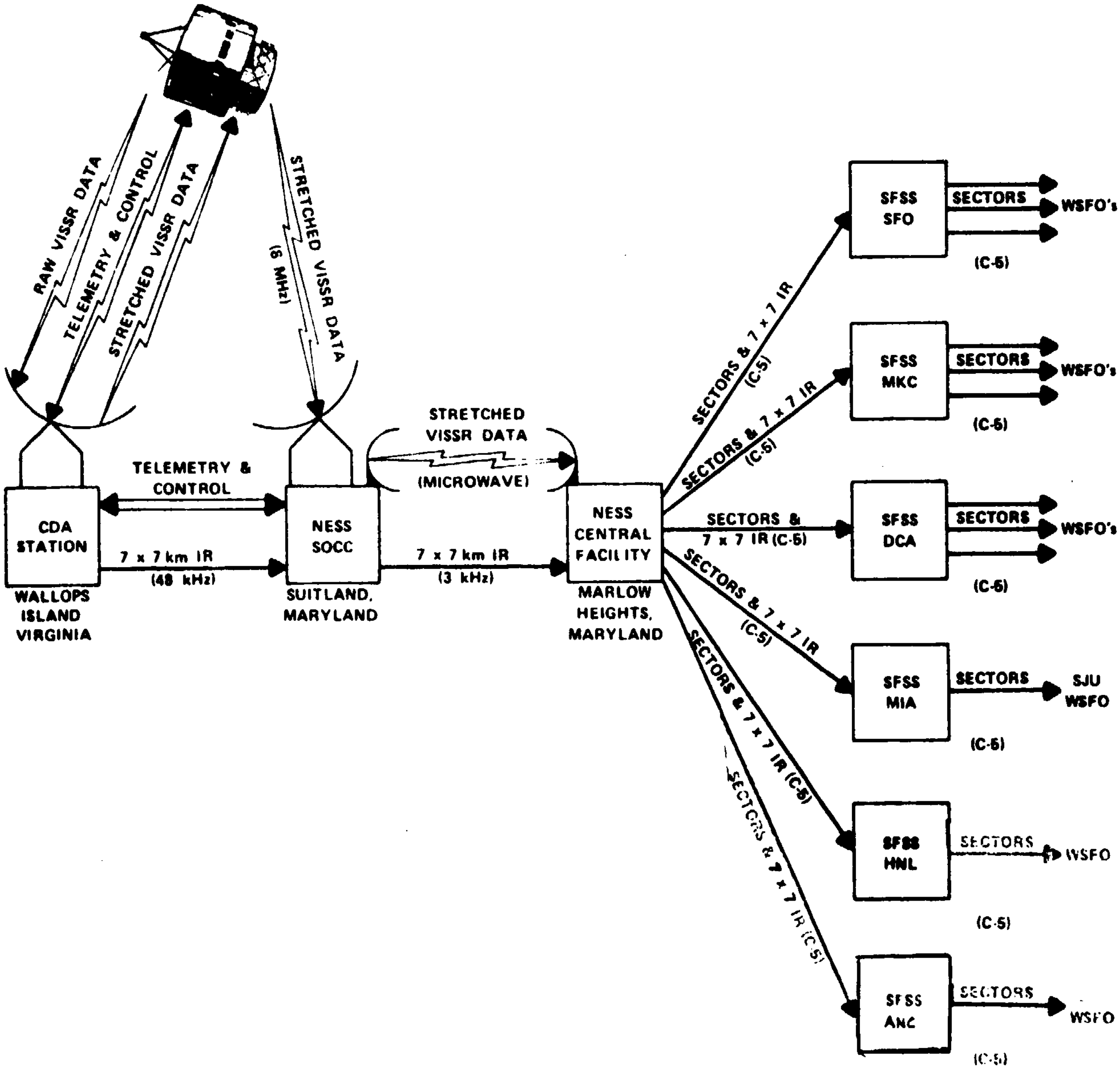


Figure 3-8. - SMS/GOES Central Data Distribution System (CDDS)

In addition to the SFSS's and the National Weather Service Forecast Offices (WSFO's), the NESS Analysis and Evaluation Branch are the primary users of SMS/GOES data.

For secondary users of GOES imagery such as universities, government agencies, state institutions, TV stations, news media, and the general public, a program has been developed which supplies their needs. It is called "GOES-TAP" and entails the reception by land line of information available to the SFSS's. The user must provide appropriate telephone communication from the SFSS closest to his location, purchase or lease his terminal or display equipment, consummate an agreement with the government and pay both an initial connection fee and an annual recurring service fee to cover costs involved. Further details of the "GOES-TAP" distribution systems are contained in Section V and Appendix III of reference 3.2.2-1.

There are two secondary data transmission and distribution techniques which can be employed by the SMS/GOES. These are the Data Collection System (DCS) and Weather Facsimile (WEFAX) system.

The DCS consists of the SMS/GOES, radio equipped environmental Data Collection Platforms, (DCS), the CDA station at Wallops Island, VA, and the control and data dissemination center located in the CDDF at the World Weather Building. The DCS can perform these functions:

- Collect and distribute environmental data measured on remotely located, attended and unattended data collection platforms (DCP's) located on land, at sea, or in the atmosphere.
- Collect all data on scheduled or on a request basis.
- Collect data from a minimum of 10,000 DCP's.
- Provides a capability for collecting data in a routine or emergency manner.

One of the unique uses which has been made of this DCS relay system is for the establishment of an operational all-weather Great Lakes Ice information system. This is described in ref. 3.2.2-2 and consists of U. S. Coast Guard C130B aircraft flying a Motorola X-band SLAR and S-band down looking radar during the winter over the Great Lakes area. The data collected is digitized and is then transmitted via SMS/GOES to the U. S. Coast Guard Center in Cleveland, Ohio. After ice cover interpretation, an ice chart map is sent out in near-real time via facsimile to vessels plying the Great Lakes for reduction of hazards and delays associated with winter navigation.

Further information about the DCS system can be obtained from ref. 3.2.2-1, page 16.

The Weather Facsimile (WEFAX) is both a communication subsystem and a service provided by the SMS/GOES to users in remote locations without access to normal satellite data outlets. The service consists of acquisition and processing of SMS/GOES data on the ground and re-transmission of these data via the spacecraft to relatively low-cost receiving units within viewing range of SMS/GOES spacecraft. This practice had been started during the Applications Technology Satellite (ATS) operation and utilized Automatic Picture Transmission (APT) ground stations. The APT stations require modification in order to receive the SMS/GOES S-band WEFAX broadcasts.

WEFAX transmission must be scheduled because VISSR data acquisition and WEFAX transmissions cannot occur simultaneously. At present, WEFAX transmissions are made only from GOES-1 eight times per day. Transmission were scheduled to begin in late 1976 from SMS-2.

New products are presently under study for transmission by SMS/GOES WEFAX and are awaiting user reviews. An "SMS/GOES WEFAX users guide" is also in preparation by NOAA. Further information about the WEFAX system can be obtained by writing:

Coordinator, Direct Readout Services
U. S. Department of Commerce
National Bureau and Atmospheric Administration
National Environmental Satellite Service
Suitland, Maryland 20023

3.2.2.2 Data Products

As of September 1, 1976 (according to ref. 3.2.2-1, pages 40 - 41) the following standard imagery products are available to the SFSS's and their users:

SFSS	Primary Sector	Reserve Sector
a. Miami	Full Disc IR (E GOES)	Full Disc IR (W GOES)
	Floater M1 (E GOES)	Floater M1 (W GOES)
	Floater M2 (E GOES)	Floater M2 (W GOES)
b. Washington	Full Disc IR (E GOES)	Full Disc IR (W GOES)
	DB-5 VIS & EQUIV IR	DB-10 VIS & EQUIV IR
	KB-8 VIS & EQUIV IR	KB-3 VIS & EQUIV IR
	KA-5 VIS Only	KA-5R VIS Only
	DA-1 VIS Only	DA-6 VIS Only
	DA-2 VIS Only	DA-7 VIS Only
	Floater D1 (E GOES)	Floater D1 (W GOES)
	Floater D2 (E GOES)	Floater D2 (W GOES)
c. Kansas City	Full Disc IR (E GOES)	Full Disc IR (W GOES)
	KB-8 VIS & EQUIV IR	KB-3 VIS & EQUIV IR
	KB-4 VIS & EQUIV IR	KB-9 VIS & EQUIV IR
	SB-6 VIS & EQUIV IR	SB-1 VIS & EQUIV IR
	KA-3 VIS Only	KA-3R VIS Only
	KA-4 VIS Only	KA-4R VIS Only
	KA-5 VIS Only	KA-5R VIS Only
	SA-1 VIS Only	SA-6 VIS Only
	SA-2 VIS Only	SA-7 VIS Only
	UC-2 VIS & EQUIV IR	
	Floater K1 (W GOES)	Floater K1 (E GOES)
	Floater K2 (E GOES)	Floater K2 (W GOES)
d. San Francisco	Full Disc IR (W GOES)	Full Disc IR (E GOES)
	SB-6 VIS & EQUIV IR	SB-1 VIS & EQUIV IR
	SA-1 VIS Only	SA-6 VIS Only
	SA-2 VIS Only	SA-7 VIS Only
	UC-2 VIS & EQUIV IR	
	Floater S1 (W GOES)	Floater S1 (E GOES)
	Floater S2 (W GOES)	Floater S2 (E GOES)
	VHRR (Polar Orbiter)	
e. Honolulu	Floater H1 (W GOES)	VHRR (Polar Orbiter)
	Floater H2 (W GOES)	VHRR (Polar Orbiter)
	VHRR (Polar Orbiter)	
f. Anchorage	VHRR (Polar Orbiter)	
	(UC-2, FD IR/W GOES	
g. Central (CDDF)	PR-1 E GOES	
	(Scheduled, 1/2 mi.,	Floater M1 (E GOES)
	1 mi. or 2 mi. sectors)	Floater M2 (E GOES)
h. Central CDDF	WB-1 (E GOES)	WB-2 (W GOES)
(Available	WB-2 (W GOES)	WB-1 (E GOES)
locally only)	Full Disc VIS (E GOES)	Full Disc VIS (W GOES)
	(WC-1)	(WC-2)
	Full Disc VIS (W GOES)	Full Disc VIS (E GOES)
	(WC-2)	(WC-1)

Where the sectors are defined in figures 3-9, 3-10, 3-11, 3-12, and 3-13, (Ref. 3.2.2-1, pages 35-39).

In addition to these normal products, enhancement can be performed on the infrared VISSR imagery in order to accent certain features. This is necessary in some cases because the range of count values for desired features may be small when compared to overall gain and hence the feature may not show up in normal processing. Enhancement is performed by modification of count values in the sectorizers (before conversion to analog) at the CDDF, and step linear, multiple linear, and step functions are some of the operational enhancement curves available to users. These include meteorological and hydrological enhancements. With approval of NESS Imagery Enhancement Review Group (IERG), new enhancement routines may be utilized.

An automatic dissemination of enhanced imagery may be established for given sectors at the WSFO's.

References

3.2.2-1 Corbell, R. P.; Callahan, C. J.; Kotsch, W. J.: The GOES/SMS User's Guide. (No date) (Written approximately in September 1976.)

3.2.2-2 Gedney, R. T.: An Operational All-Weather Great Lakes Ice Information System: Presented at 3rd Canadian Symposium on Remote Sensing, Edmonton, Alberta, 22-24 September 1975, pp. 73-82.

FIELD SERVICES DIVISION NESS

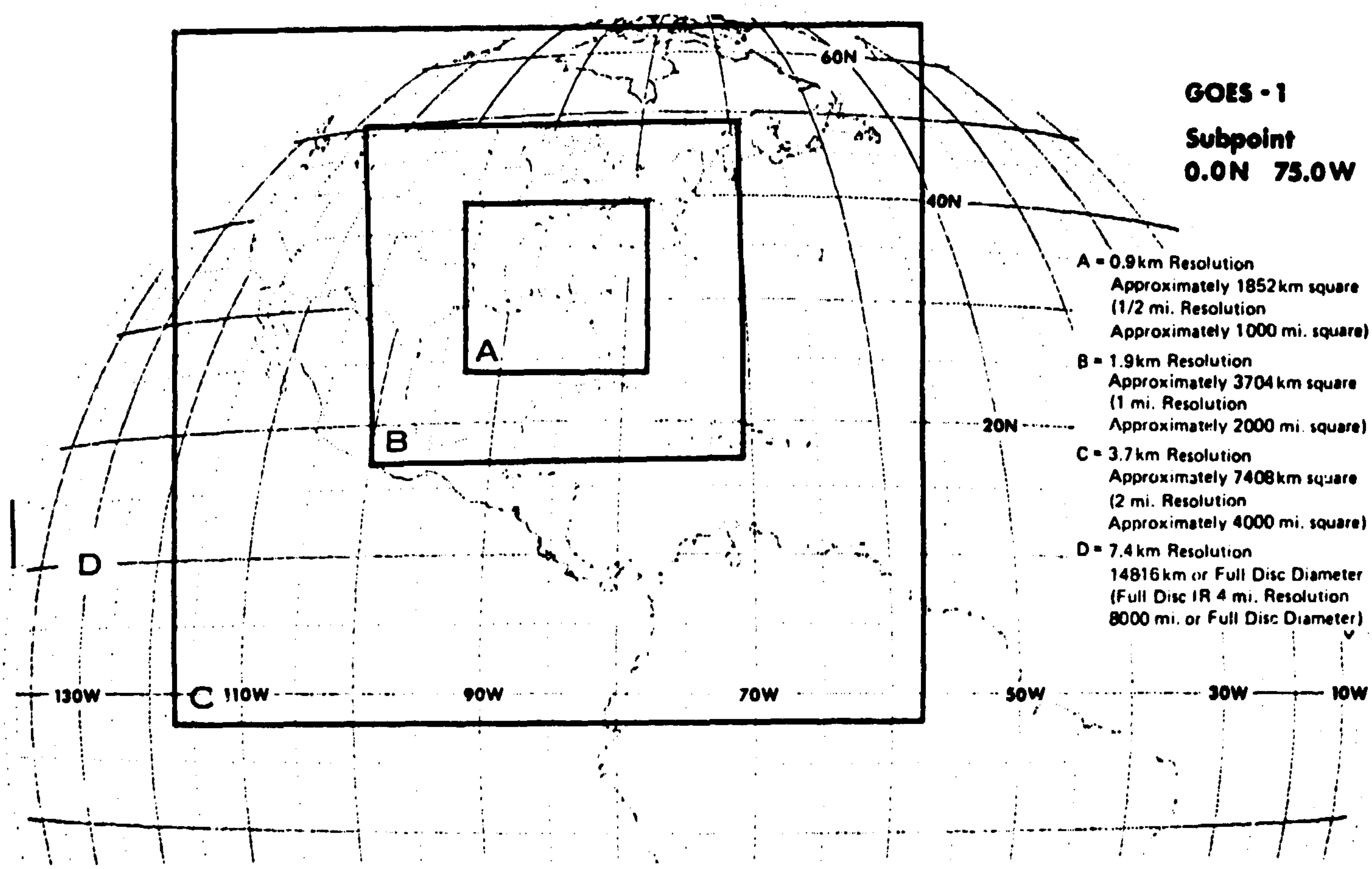
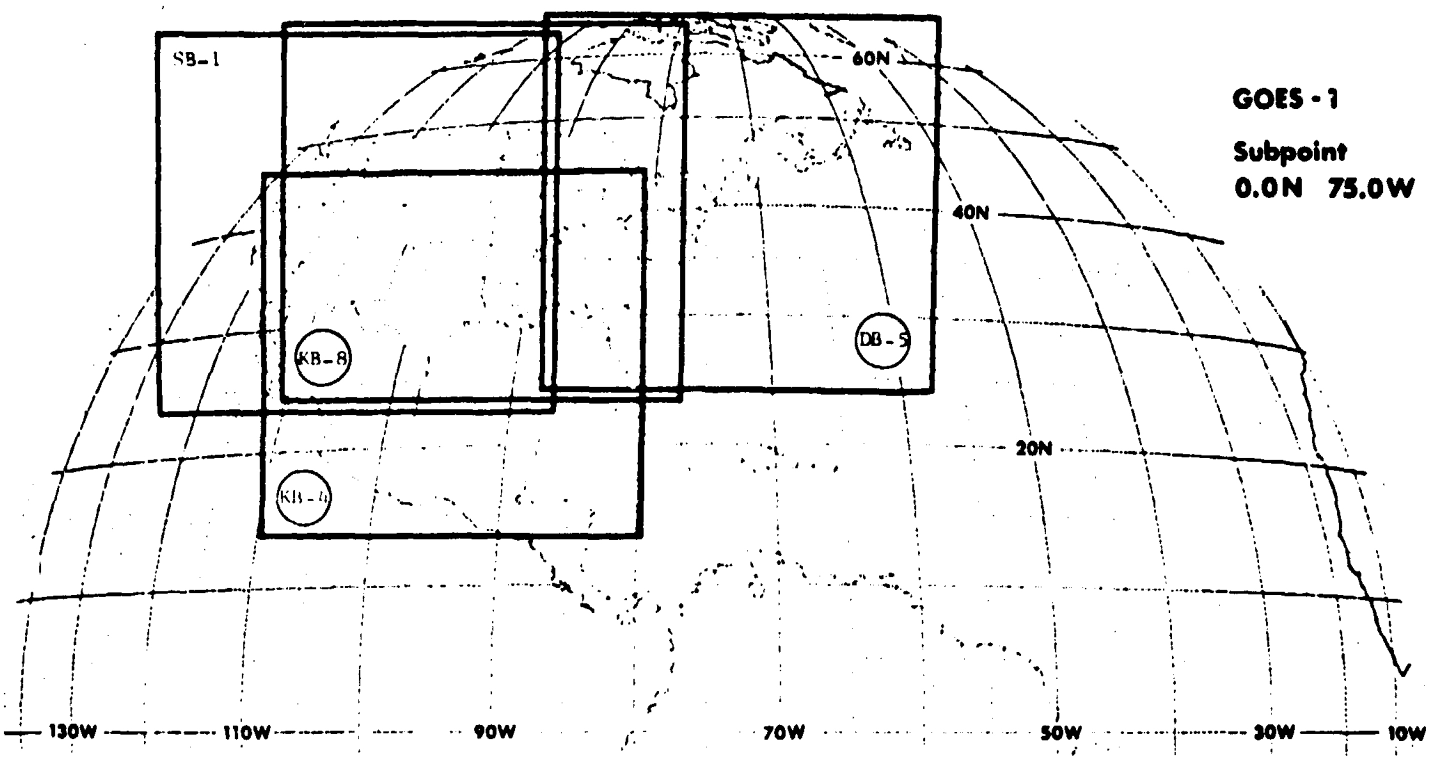


Figure 3-9. - Resolutions and Geographical Coverage (GOES-1)

FIELD SERVICES DIVISION NESS



GOES - 1 (EAST GOES) 1 MILE RESOLUTION SECTORS

(SECTOR LOCATIONS EFFECTIVE JULY 27, 1976)

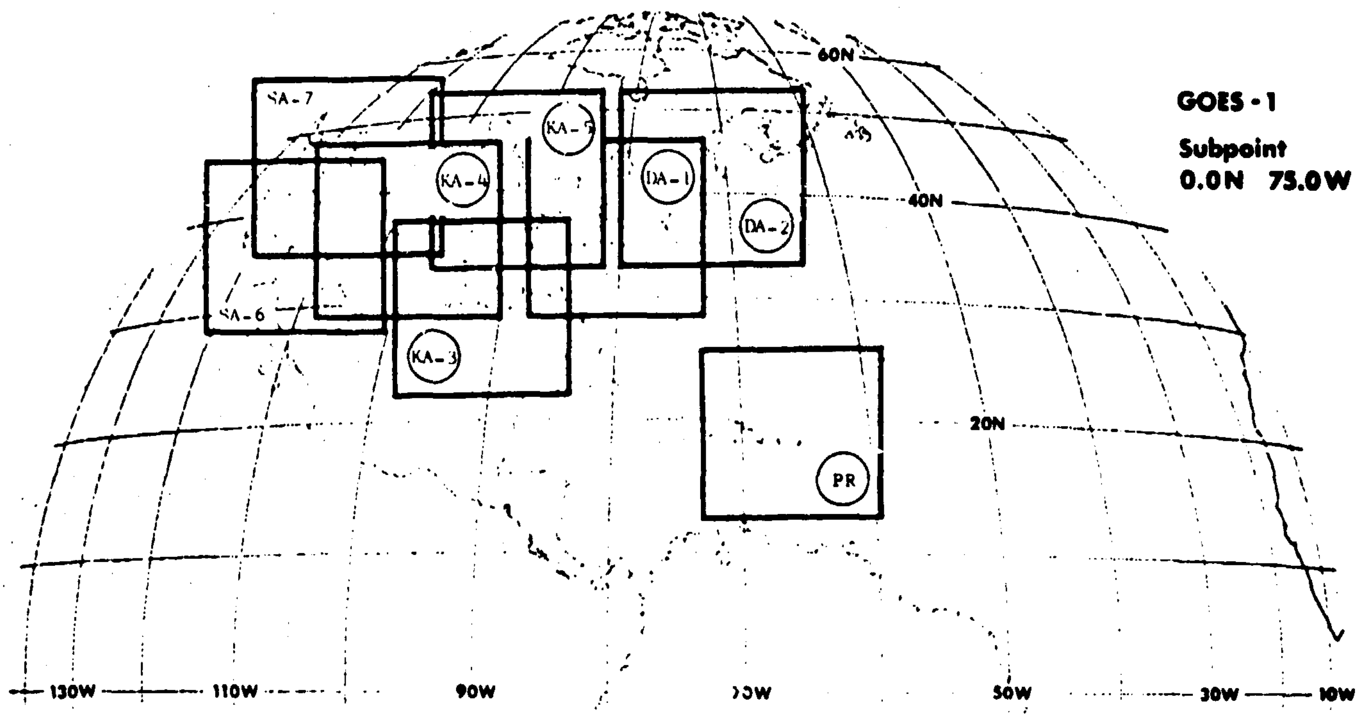
VIS & Equiv. IR Sectors

Sector	Center Point Lat/Long
SB-1	40.0/109.0
KB-8	40.0/ 97.0
KB-4	27.0/ 95.0
DB-5	38.0/ 79.0

NOTE: Sector numbers that are circled are routinely available. Those not circled are reserve sectors to be utilized in case of WEST GOES failure. UC-1 utilized for enhancement tables only.

Figure 3-10. - One Mile Resolution Sectors (GOES-1)

FIELD SERVICES DIVISION NESS



GOES-1 (EAST GOES) HALF MILE SECTORS (VIS ONLY)

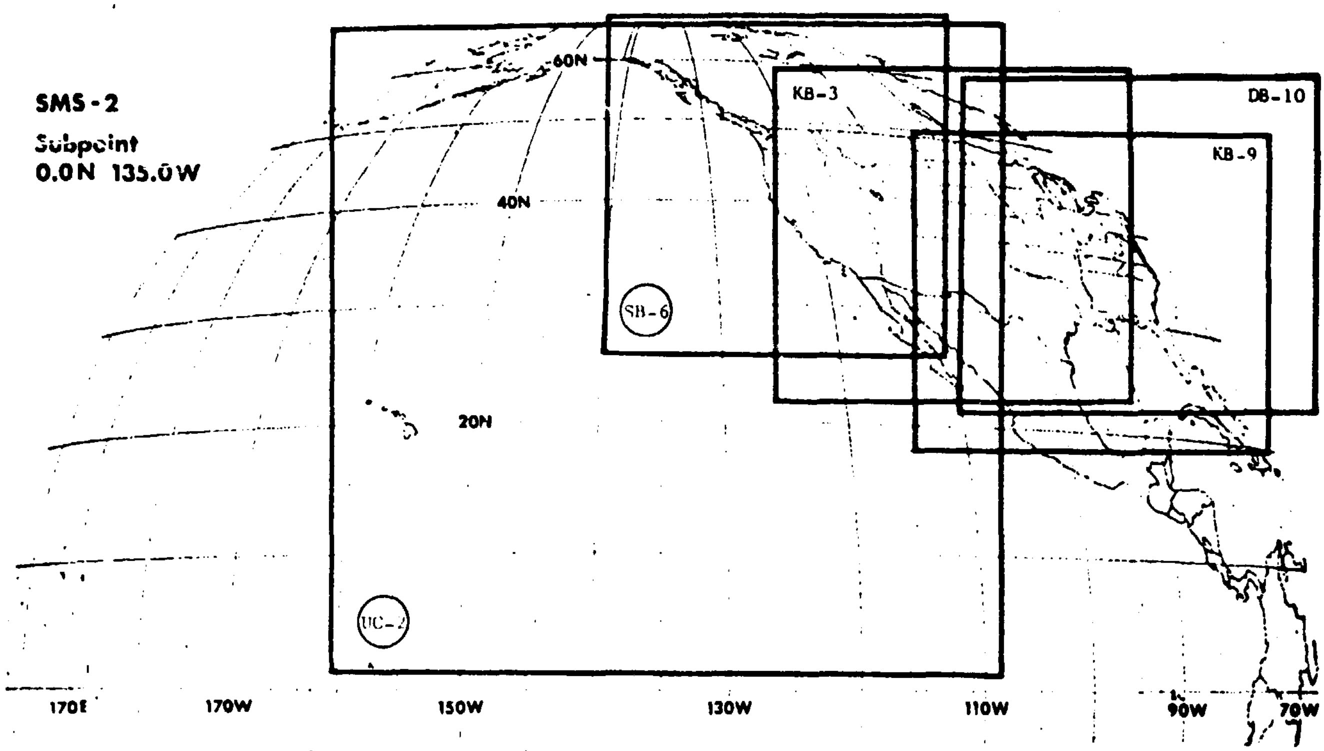
(SECTOR LOCATIONS EFFECTIVE JULY 27, 1976)

Sector	Center Point Lat/Long
DA-1	37.0/ 82.0
DA-2	42.0/ 72.0
KA-3	30.0/ 92.0
KA-4	37.0/102.0
KA-5	42.0/ 91.5
SA-6	36.0/115.0
SA-7	45.0/116.0
PR	18.0/ 66.0

NOTE: Sector numbers that are circled are routinely available. Those not circled are reserve sectors to be utilized in case of WEST GOES failure.
Puerto Rico has routinely six scheduled sectors utilizing ½, 1 and 2 mile resolution.

Figure 3-11. - Half-Mile Sectors (VIS Only) (GOES-1)

FIELD SERVICES DIVISION NESS



SMS-2 (WEST GOES) 1 & 2 MILE RESOLUTION SECTORS

(SECTOR LOCATIONS EFFECTIVE JULY 27, 1976)

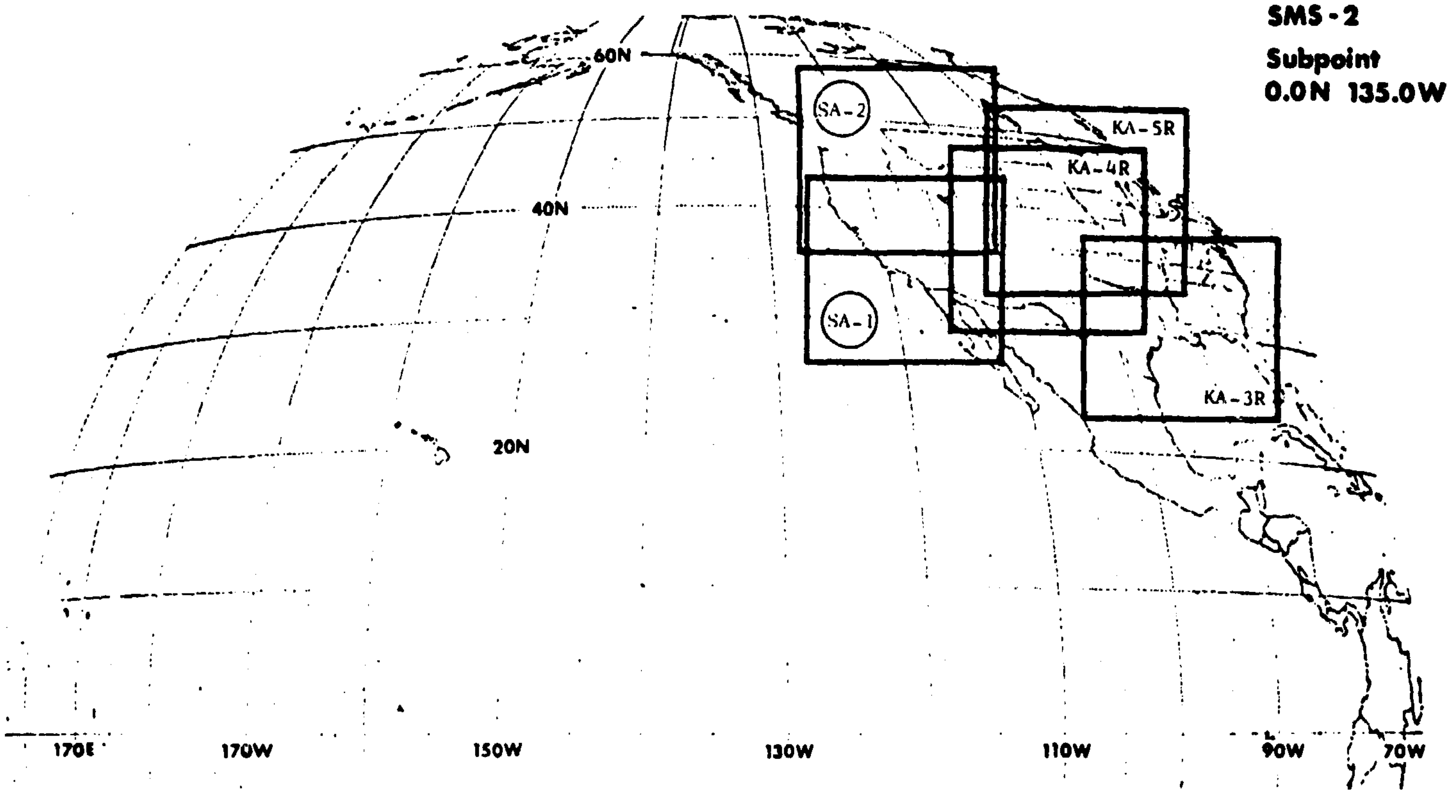
VIS & Equiv. IR Sectors

Sector	Center Point Lat/Long
SB-6	42.0/124.0
KB-3	37.0/107.0
KB-9	33.0/ 91.0
DB-10	35.0/ 80.0
UC-2	28.0/135.0

NOTE: Sector numbers that are circled are routinely available. Those not circled are reserve sectors to be utilized in case of EAST GOES failure.

Figure 3-12. - One and Two Mile Resolution Sectors (SMS-2)

FIELD SERVICES DIVISION NESS



SMS-2 (WEST GOES) HALF MILE SECTORS (VIS ONLY)
(SECTOR LOCATIONS EFFECTIVE JULY 27, 1976)

Sector	Center Point Lat/Long
SA-1	36.0/118.0
SA-2	45.0/116.0
KA-3R	30.0/ 94.0
KA-4R	37.0/102.0
KA-5R	42.0/ 92.0

NOTE: Sector numbers that are circled are routinely available. Those not circled are reserve sectors to be utilized in case of EAST GOES failure.

Figure 3-13. - Half-Mile Sectors (VIS Only) (SMS-2)

3.3 USAF CONTROLLED SATELLITES

3.3.1 DMSP

3.3.1.1 Block B/C, Transmission of Data to Sites

There are two types of sites for receiving and processing the data. First, the Air Force Global Weather Control (AFGWC) at Offutt Air Force Base, Nebraska, and associated receiving stations; and secondly, the tactical sites.

Up to 210 minutes of HR and IR data and 20 minutes of VHR and WHR data are recorded in the spacecraft and dumped. Tracking and receiving sites located at Fairchild Air Force Base, Washington, and Loring Air Force Base, Maine, receive the data. No processing is done at the tracking stations. Most of the data from the satellite "dump" is relayed over special wideband communication lines in real time to AFGWC, although some is relayed later from tape recordings. AFGWC is the prime DMSP site for processing data. Global coverage of the world's weather is received and processed by AFGWC twice daily for each spacecraft.

There are four "blind" orbits per day, that is, four orbits on which the satellite is not accessible for playback of its recorded data. The other ten orbits are within readout range of one of the two United States stations.

Tactical sites receive digital, encrypted DMSP data in real time. They are

a. Vandenberg Air Force Base, California
b. Keesler Air Force Base, Mississippi
c. McClellan Air Force Base, California
d. Hickman Air Force Base, Hawaii
e. Elmendorf Air Force Base, Alaska
f. Patrick Air Force Base, Florida
g. Fuchu Air Base, Japan
h. Ramstein Air Base, Germany
i. Howard Air Force Base, Canal Zone
j. Kadena Air Base, Okinawa
k. Nimitz Hill, Guam
l. Constellation (aircraft carrier)

The tactical sites have diverse missions because they are tailored to support the decision makers of the commands they serve. These sites are mobile and not permanent in location.

Although the data from Global Weather Central are worldwide, the data from the tactical sites are restricted to 27^{o} around each site.

3.3.1.2 Block 5D - Data Transmission

The processor for the OLS also performs other computer functions and receives data from the special meteorological sensors. All data is processed, stored, and transmitted in digital format.

There are three tape recorders, each with a storage capacity of 1.67 by 10^{9} bits. Each recorder can record at any one of three data rates and playback at 1.33 or 2.66 mbs. Tape recorder and transmission constraints limit the amount of LF and TF data which can be provided in the SDF (stored data fine) mode to a total of 40 minutes per ground readout. For LS and TF data, 400 minutes can be transmitted in a single ground station readout.

There are three S-band transmitters and three earth oriented antennas for data transmission. Two of the S-band systems may be operated simultaneously to transmit stored data.

In the RTD (Real Time Data Transmission) mode, one type of high resolution data and the complimentary smoothed resolution data (either LF and TS, or TF and LS) may be transmitted at the data rate of 1.024 mbs. The third S-band is dedicated to direct data transmission to tactical sites around the world.

Either encrypted or clear RTD data can be output simultaneously with two channels of stored data. Also, two channels of RTD data with either channel encrypted or clear can be transmitted.

Telemetry is provided by a duplicate S-band transmitter and antenna and also an S-band system with an antenna for spherical coverage to allow all-attitude communication. The telemetry transmitters can also be used in a back-up mode to transmit OLS data.

3.3.1.3 Data Processing and Formats

The processing system is the Data Display Segment (DDS). The processing is similar at AFGWC and the tactical sites, but there are a number of distinct differences. At AFGWC, the data is analog whereas at the tactical sites, it is digital. The tactical sites can receive only data covering one-sixth orbit at most, whereas AFGWC has the capability of handling several hundred minutes of data which is suddenly received. The geometrical corrections are applied at the tactical site assuming a constant altitude whereas at AFGWC a sinusoidal function is assumed.

Corrections are made for the earth's rotation and the vehicle velocity, altitude, and orientation.

The objective is to produce pictures which can be inspected for meteorological and other information. In order to aid photointerpretation, the following options are available:

a. Choice of VHR or WHR
b. Inversion or normal
c. Enhancement
d. Thresholding
e. Image slicing
f. Temperature scale expansion
g. Geometric expansion

Only certain options are useful for certain channels, even if others are possible. All but the choice of VHR or WHR are made in processing. The choice of VHR or WHR must be made by command to the satellite before data acquisition. Band width limitations cause this constraint. The lower data rate channels, HR and IR are always acquired.

When a strong signal is displayed as light and a weak signal as dark, the brilliance is defined as "normal." The image is often called a positive. This type is customary for displaying the visib .. However, in the infrared, clouds, because of their cooler temperature, w ıld be displayed dark. In order to make an infrared display psychologically acceptable, the count is usually reversed in the computer. The resulting display is a negative, causing clouds to be light. Such a display is, by definition, "inverted." Whether the scene is normal or inverted is stated on the annotation of the picture.

There are 64 levels in the digital signals recorded by the tactical sites. However, only 16 levels can be displayed. The situation is similar for the analog data. In order for the eye to perceive details at different parts of the dynamic range, the radiometric scale for low counts or high counts or both may be expanded. In the case of both, the contrast in the middle of the dynamic range is partly suppressed in order to expand the ends. The four options are "off" (linear display), "low", "high", and "low/high." This option is usually not used for the infrared channels.

Thresholding is the specifying of a particular level beyond which only black is displayed and the remaining portion of the dynamic range is expanded to match the capability of the display. For example, for an infrared display of normal data, all parts of the scene with apparent black body temperatures below the specified temperature appear black. A more common option is the thresholding of an infrared scene and then inverting it. Thresholding not only aids the eye in sensing a radiometric contour line at a particular value, but also permits quantitative evaluation of the imagery. The threshold temperature is called the "base temperature." Also, the visible channels may be thresholded, but the threshold temperature associated with it is only a parameter rather than a physical entity.

In addition to a simple threshold, there is image slicing called the Threshold or Thresh mode. The scene may be divided into as many as four parts according to the radiance. For example, in the invert mode with temperatures Y_1, Y_2, and Y_3 specified, all areas warmer than Y_1 are black, all areas cooler than Y_3 are white, areas between Y_1 and Y_2 are dark gray, and all areas between Y_2 and Y_3 are light gray.

Another option is the (range) "expand" option, but only for IR data. In the XI range, all 64 input levels are divided linearly to temperatures between 210°K, or another base temperature if one is specified, and 100° above the base temperature. In the X2 range, the next 50 degrees above the base temperatures are spread over 32 levels and the full dynamic output of the CRT is utilized. In the X4 range, the next 25 degrees above the base temperature are spread over 16 shades of gray. Only the normal (no enhancement) mode is used for the X2 and X4 options.

All DSMP imagery is displayed in one of two scales, the normal scale of 1:15 million at 150 km per cm or the expand scale of 1:7.5 million at 75 km per cm. When the expand scale is selected, usually only VHR or WHR data is processed. The expansions are produced by spreading one-half of the data signal over the full width of the CRT, and at the same time advancing the film twice as fast over the capstan drive assembly. Three portions of the signal can be expanded: center half (EXP C), left half (EXP L), or right half (EXP R). Left and right are defined with respect to the spacecraft direction. For example, for a northward moving path, left is west.

Data from the IR channel is made linear with respect to temperature, not radiance, in the detector output.

3.3.1.4 Data Products

Archiving of DMSP data began March 1973. Imagery is available from:

DMSP Satellite Data Library
Space Science and Engineering Center
The University of Wisconsin
1225 W. Dayton Street
Madison, Wisconsin 53706
Telephone: (608) 262-5335

Bonnie Lynne Robinson is the DMSP data project coordinator. Data is available from the following vehicles:

P - Vehicle 6530, dawn-dusk. Archived 24 February 1973 to 21 June 1973 with data value diminished in June 1973.

Q - Vehicle 5528, noon-midnight. Archived 24 February 1973 to 23 February 1974 with good data throughout. V data archived from 1 January to 31 December 1973.

R - Vehicle 7529, dawn-dusk. Archived 24 August 1973 to 9 December 1976. Good data throughout with a failure of the 1/3 nm resolution sensor in March 1974. Coverage of 30 May 1975 to 1 November 1975 is very sporadic.

S - Vehicle 8531, noon-midnight. Archived 19 March 1974 to 31 October 1975 with a temporary failure of the I channel 7 August 1974 to 1 October 1974. Intermittent failure of all channels from 2 August 1975 to 31 October 1975. Sporadic coverage beginning 1 December 1975 to 14 May 1976.

T - Vehicle 9532, dawn-dusk. Archived 8 August 1974 to 27 November 1974 with H and V data of questionable value.

Y - Vehicle 10533, dawn-dusk. Archived 24 May 1975 to present. H channel is of questionable value. W channel only archived through 13 December 1976.

The pass direction is ascending (A) during local day and descending (D) during local night.

The tactical or transportable terminals (transterms) have data equal to or better in quality than that of the data received from the two fixed United States stations. In general, they make more use of options. These options are labeled on the film. The following data and data aids are available:

1. Ephemeris or two-min computer listing predictive of satellite subtrack. Xerox copy available.
2. Normal mode (9.5 inch) universal grid overlay.
3. Expand mode (16 inch) universal grid overlay.
4. DMSP Users Manual. Available on three week loan basis only.
5. Photocopies are available in the following formats:
    a. 8 by 10 glossy prints from a 35 mm negative.
    b. 8 by 10 glossy prints from a 4 by 5 negative. Loss of detail of a print from a 4 by 5 negative is minimal.
    c. 8 by 10 contact prints from an 8 by 10 negative.
    d. 8 by 10 print from USAF negative.
6. The original 9-1/2 positives may be borrowed for three weeks.

Only photographs are available with options which have been determined at the processing sites.

Only primary sensor data, not special sensor data, is available.

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APPENDIX A*

REMOTE SENSING SYSTEMS
RECENT, CURRENT AND FUTURE

*Taken from "Advanced Sensors and Applications Study (ASAS)", November 1976, JSC-10975, LEC-7790, with minor additions and changes.

SYSTEM	LANDSAT 1 & 2				
Agency	NASA				
Launch Date	Landsat-1, July 1972; Landsat-2, January 1975				
Altitude/ Orbit	907 km; near polar, sun-synchronous orbit				
SENSOR SUBSYSTEMS	Multispectral Scanner (MSS)	Return Beam Vidicon (RBV)			
Type	objective mirror scanner	3 RBV camera			
Manufacturer	Hughes	RCA			
Ground Coverage	swath = 185 km	185 x 185 km			
Repeat Coverage	every 18 days	every 18 days			
IFOV	86 µrad				
Resolution	79 m	80 m			
Scan Efficiency	45%				
f/Number	3.6				
Bands	0.5-0.6 µm 0.6-0.7 0.7-0.8 0.8-1.1	0.49-0.58 µm 0.59-0.66 0.68-0.73			

SYSTEM	LANDSAT-C				
Agency	NASA				
Launch Date	1977				
Altitude/ Orbit	911.8 km; circular, near polar, sun-synchronous orbit				
SENSOR SUBSYSTEMS	Multispectral Scanner (MSS)	Return Beam Vidicon (RBV)			
Type	objective mirror scanner	2 RBV camera (side-by-side coverage)			
Manufacturer	Hughes	RCA			
Ground Coverage	swath = 185 km	93 x 93 km			
Repeat Coverage	every 18 days	every 18 days			
IFOV	86 μrad				
Resolution	visible/NIR 57m	40 m			
	Th.IR 171 m				
		4500 TV lines			
		90 lines/mm			
Bands	0.5-0.6 μm 0.6-0.7 0.7-0.8 0.8-1.1 10.4-12.6 μm 1-3 bands PMT 4th Si Photo-diode 5th HgCdTe	0.50-0.75 μm (both RBV's)			

SYSTEM	Landsat-D				
Agency	NASA				
Launch Date	1980				
Altitude/ Orbit	702.4 km; circular, near polar, sun-synchronous orbit				
SENSOR SUBSYSTEMS	Thematic Mapper (TM)				
Type	6-band MSS (type-TBD)				
Manufacturer	TBD				
Ground Coverage	swath - 185 km				
Repeat Coverage	every 8 days *				
IFOV	43 and 250 µrad				
Resolution	30 m visible/near IR, 120 m thermal				
Scan Efficiency	~80%				
Bands	0.45-0.52 µm** 0.52-0.60 0.63-0.69 0.76-0.90 1.55-1.75 10.4-12.5				

*with 2 satellite system

**According to O Weinstein, NASA Technical Officer, GSFC, 19 October 1976.

SYSTEM	AEM-A (Applications Explorer Mission)				
Agency	NASA/GSFC				
Launch Date	1978, second quarter				
Altitude/ Orbit	600 km, polar orbiting, sun synchronous				
SENSOR SUBSYSTEMS	Heat Capacity Mapping Radiometer (HCMR)				
Type	Visible/in- frared imager				
Manufacturer	ITT				
Ground Coverage	693 km				
Repeat Coverage	every 12 hrs 2:30 am, 1:30 pm local time (mid latitudes)				
IFOV	.83 mrad				
Resolution	0.5 km				
Scan Efficiency					
Bands	.55-1.1 μm 10.5-12.5 μm				

SYSTEM	ITOS - Improved TIROS Operational Satellite			
Agency	NOAA			
Launch Date	NOAA-2, Oct. 1972; NOAA-3, Nov. 6, 1973; NOAA-4, Nov. 15, 1974 NOAA-5, July 29, 1976.			
Altitude/ Orbit	1464 ± 46 km; polar, sun-synchronous orbit			
SENSOR SUBSYSTEMS	Scanning Radiometer (SR)	Very High Resolution Radiometr (VHRR)	Vertical Temp. Profile Radomtr (VTPR)	Solar Proton Monitor (SPM)
Type	line-scanning visible-IR radiometer	line scanning radiometer	visible - IR spectroradiometer	
Manufacturer	Santa Barbara Research Center	RCA	Barnes Engineering	
Ground Coverage	Global*	±75°	± 31.45°	
Repeat Coverage (Imagers only)	every 12 hrs, 0900/2100 local time		N/A	N/A
IFOV	5.3 mrad	0.6 mrad	38 mrad	
Resolution	7.5 km at nadir	0.9 km at nadir	55.6 km	
Scan Efficiency				
Bands	0.5-0.7 μm 10.5-12.5 μm Si Photo-voltaic for visible Thermistor bolometer for IR	0.6-0.7 μm 10.5-12.5 μm Si Photodiode for visible HgCdTe for IR	6 channels in CO_2 band (~15 μm) 1 channel in H_2O band (18.7 μm) 1 channel in 'window' (8-12 μm)	Protons: 10^+, 30^+, 60^+ MeV Electrons: 100-750 KeV

*horizon to horizon

SYSTEM	Nimbus 5			(page 1 of 2)	
Agency	NASA/GSFC				
Launch Date	December 11, 1972				
Altitude/Orbit	600 n. mi.; circular sun-synchronous orbit				
SENSOR SUBSYSTEMS	Electrically Scanning Microwave Radiometer (ESMR)	Temperature Humidity Infrared Radiometer (THIR)	Surface Composition Mapping Radiometer (SCMR)	Infrared Temperature Profile Radiometer (ITPR)	Selective Chopper Radiometer (SCR)
Type	imaging microwave system	thermal mapper	thermal and near infrared mapper	atmospheric sounder	atmospheric sounder
Manufacturer					
Ground Coverage	swath = 3200 km	Global	swath = 800 km	swath = 1050 km	nadir only
Repeat Coverage (Imagers only)	every 12 hours-local noon/midnight			N/A	N/A
IFOV					
Resolution (Nadir)	25x25 km	22 km (6.5-7.0 μm) 8 km (10.5-12.5 μm)	660x660 m	31.8 km	42 km (15 μm) 29 km (all others)
Bands	19.225-19.475 GHz	6.5-7.0 μm 10.5-12.5 μm	0.8-1.1 μm 8.3-9.3 μm 10.2-11.2 μm	3.8 μm 11.0 μm 13-15.0 μm (4 bands) 19.8 μm	2-100 μm (16 bands)

SYSTEM	Nimbus 5 (page 2 of 2)				
Agency	NASA/GSFC				
Launch Date	December 11, 1972				
Altitude/Orbit	600 n. mi.; circular sun-synchronous orbit				
SENSOR SUBSYSTEMS	Nimbus-E Microwave Spectrometer (NEMS)				
Type	atmospheric sounder				
Manufacturer					
Ground Coverage	continuously along nadir				
Repeat Coverage	N/A				
IFOV					
Resolution	100 n. mi.				
Bands	27.23 GHz 31.40 53.65 54.90 58.80				

SYSTEM	Nimbus-6 (page 1 of 2)				
Agency	NASA/GSFC				
Launch Date	June 12, 1975				
Altitude/Orbit	1100 km; polar sun-synchronous orbit				
SENSOR SUBSYSTEMS	Temperature Humidity Infrared Radiometer (THIR)	High Resolution Infrared Radiation Sounder (HIRS)	Scanning Microwave Spec-trometer (SCAMS)	Electrically Scanning Microwave Radiometer (ESMR)	Earth Radiation Budget (ERB)
Type	thermal imager	atmospheric sounder	atmospheric sounder	atmospheric sounder (conical scan)	spec-trometer
Manufacturer					
Ground Coverage	swath = 3000 km	swath = 1650 km	2060 km	1200 km	500x500 km
Repeat Coverage (Imagers only)	every 12 hrs. local noon/ midnight	N/A	12 hrs. local noon/midnight	12 hrs. local/noon midnight	N/A
IFOV					
Resolution (Nadir)	22.5 km (6.5-7.1 μm) 8.2 km (10.3-12.5)	25 km	145 km	18-22 km cross track 35-54 km down track	
Bands	6.5-7.1 μm 10.3-12.5 μm	.69 μm 3.71 μm 4.24-4.57 μm (5 bands) 6.7 μm 8.2 μm 11.0 μm 13.4-15 μm (7 bands)	22.235 GHz 31.650 52.850 53.850 55.450	37.0 GHz	.2-50 μm (22 chan-nels)

SYSTEM	Nimbus-6				(page 2 of 2)
Agency	NASA/GSFC				
Launch Date	June 12, 1975				
Altitude/Orbit	1100 km; polar sun-synchronous orbit				
SENSOR SUBSYSTEMS	Limb Radiance Inversion Radiometer (LRIR)	Pressure Modulator Radiometer (PMR)			
Type	IR MS scanning radiometer	atmospheric sounder			
Manufacturer					
Ground Coverage	N/A scans earth limb	Steerable to ± 15° FWD & AFT			
Repeat Coverage	N/A	N/A			
IFOV					
Resolution at Tangent Height (in order of bands)	2x11.7 km	77 km along track			
	2x20.7 km	383 km across track			
	2x20.7 km 2.5x25.4 km				
Bands	14.9-15.5 µm (Narrow CO_2 band) 14.4-16.9 (Broad CO_2 band) 8.6-10.2 (O_3) 23.0-27.0 (H_2O)	CO_2 pressure comparison in several bands around 15 µm			

SYSTEM	Nimbus-G			(page 1 of 3)
Agency Launch Date Altitude/Orbit	NASA/GSFC 1978 955 km; polar sun-synchronous orbit			
SENSOR SUBSYSTEMS	Stratospheric and Mesospheric Sounder (SAMS)	Temperature Humidity Infrared Radiometer (THIR)	Coastal Zone Color Scanner (CZCS)	Solar Backscatter Ultraviolet Spectrometer and Total Ozone Mapping (SBUV/TOM)
Type	atmospheric sounder	2-channel scanning radiometer	scanning radiometer	
Manufacturer				
Ground Coverage			± 0.7 rad scan ± 0.35 rad view angle	
Repeat Coverage (Imagers only)	N/A	every 12 hrs.	every 12 hrs.	Unknown
IFOV	28x2.8 mrad	21 mrad (6.5-7.0 μm) 7 mrad (12.5 μm)	.865 mrad sq.	.052 rad sq.
Resolution				
Bands	15 μm (CO_2) 4.1-5.4 μm (CO_2, CO, NO) 2.7, 2.5-100 μm (H_2O) 7.6-7.8 μm (N_2O, CH_4) Detectors: 4 TGS 1 InSb 1 PbS	6.5-7.0 μm 12.5 μm	0.433-0.453 μm 0.510-0.530 0.540-0.560 0.660-0.680 0.700-0.800 10.5-12.5 Detectors: Th. IR = HgCdTe Others = SiPD	160-400 μm continuous scan (PMT)

SYSTEM	Nimbus-G			(page 2 of 3)
Agency Launch Date Altitude/Orbit	NASA/GSFC 1978 955 km; polar sun-synchronous orbit			
SENSOR SUBSYSTEMS	Limb Infrared Monitoring of Stratosphere (LIMS)	Earth Radiation Budget	Stratospheric Aerosol Measurement II	Scanning Multichannel Microwave Radiometer (SMMR)
Type	infrared radiometer -modified Nimbus-6 LRIR	22 channel radiometer		5 wavelength dual polarized
Manufacturer				
Ground Coverage			altitude range 10 km to space	
Repeat Coverage	N/A	N/A	N/A	12 hrs.
IFOV	0.5 mrad sq. (1x8 mrad- H_2O, NO_2)	4.4x89.4 mrad (scan) 2.32 rad cone (earth) 0.46 rad (solar)	0.145 mrad	
Bands	6.08-6.39 μm (NO_2) 6.41-7.25 (N_2O) 8.64-10.64 (O_3) 10.87-11.76 (HNO_3) 13.16-17.24 (CO_2(wb)) 14.71-15.75 (CO_2(nb)) Detectors: HgCdTe	'Solar' channels: 0.2-4.0 μm (2ch.) 0.4-0.5 0.35-0.45 0.2-0.5 0.53-3.0 0.7-3.0 0.3-0.4 0.28-0.35 0.25-0.30 (this column cont. on next page)	0.06 μm band at 1.0 μm	37 GHz (0.8 cm) 21 GHz (1.4 cm) 18 GHz (1.7 cm) 10.7 GHz (2.8 cm) 6.6 GHz (4.0 cm)

SYSTEM	Nimbus-G			(page 3 of 3)
SENSOR SUBSYSTEMS		Earth Radiation Budget		
Bands (cont. from previous page)		'Earth' channels: 0.2-0.5 μm (2 ch.) 0.2-4.0 0.7-3.0 'Scanning' channels: 0.2-5.0 μm (4 ch.) 4.5-5.0 (4 ch.)		

SYSTEM	Seasat-A		(page 1 of 2)		
Agency	NASA/JPL				
Launch Date	May 1978				
Altitude/Orbit	790 km; circular, non sun-synchronous, near polar orbit				
SENSOR SUBSYSTEMS	Synthetic Aperture Radar (SAR)	Radar Scatter-ometer	Scanning Multi-frequency Microwave Radiometer (SMMR)	Radar Altimeter	Visible-Infrared Radiometer (VIRR)
Type	imaging system, single po-larization	fan beam	bidirec-tional scan	precision pulse	scanning 2-band
Manufacturer	Hughes/JPL	GE	JPL	APL, Johns Hopkins	Santa Barbara Research Center
Ground Coverage	100 km on one side from 17°-23°	750 km ea. side ± 25°-55° around nadir ± 70 km	638 ± 70 km	12 km circle*	2127 km
Repeat Coverage	within receiving station range, real time only	N/A	36 hours	N/A	36 hours
IFOV					visible: 2.8 mrad IR: 5.3 mrad
Resolution	25 m	50 km ± 5%	(see following page)	1.6 km*	visible: 2.2 km IR: 4.2 km
Polarization	H	sequenced HH, VV	dual linear		
Bands - (see following page)					

*due to integration

SYSTEM	Seasat-A				(page 2 of 2)
Agency	NASA/JPL				
Launch Date	May 1978				
Altitude/Orbit	790 km; circular, non sun-synchronous, near polar orbit				
SENSOR SUBSYSTEMS	Synthetic Aperture Radar (SAR)	Radar Scatter-ometer	Scanning Multi-frequency Microwave Radiometer (SMMR)	Radar Altimeter	Visible-Infrared Radiometer (VIRR)
Bands	1.275 GHz	14.6 GHz	6.6 GHz 10.69 GHz 18.0 Ghz 21.0 GHz 37.0 GHz *footprint sizes in order: 121x79 km 74x49 km 44x29 km 38x25 km 21x14 km	13.5 GHz	0.47-0.94 μm 10.5-12.5 μm

SYSTEM	SMS/GOES (Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite)				
Agency	SMS*, NASA/GFSC; GOES*, NOAA				
Launch Date	SMS-1, May 1974; SMS-2, Feb. 1975; GOES-1, Oct. 1975; GOES-B, May 1977; GOES-C, January 1978				
Altitude/ Orbit	34,781 km, earth synchronous				
SENSOR SUBSYSTEMS	Visible/Infrared Spin Scan Radiometer (VISSR)				
Type	Visible/Infrared Imager				
Manufacturer	Hughes Aircraft				
Ground Coverage	Earth Disc				
Repeat Coverage	Earth Disc every 20 min.				
IFOV	.026 mrad (visible) at nadir 0.20 mrad (infrared) at nadir				
Resolution	.9 km (visible) 7 km (infrared)				
Scan Efficiency					
Bands	.55 to .75 µm 10.5-12.5 µm (advanced versions with VAS (VISSR atmospheric sounder proposed on GOES-E) also include bands centered at 3.94, 4.44, 4.52, and 13.3 µm)				

*SMS-Developed and experimentally flown by NASA; GOES-operationally flown by NOAA.

SYSTEM	SEOS-A			(page 1 of 2)
Agency	NASA/GSFC			
Launch Date	1981			
Altitude/Orbit	~35,700 km; geosynchronous, equatorial orbit			
SENSOR SUBSYSTEMS	Large Earth Survey Telescope (LEST)	Advanced Atmospheric* Sounder and Imaging Radiometer (AASIR)	Microwave Sounder*	Framing Camera*
Type	multispectral scanner with pushbroom scan	imaging radiometer		television
Manufacturer	TBD	Santa Barbara Research Center		
Ground Coverage	Pointable to ± 1 km			1000x1000 km & 200x200 km
Repeat Coverage	nearly continuous on earth disc	N/A	N/A	frame every 15 sec. of earth disc
IFOV	imaging: vis. 2.8 μrad IR 22.4 μrad			
Resolution	imaging: vis. 100m IR 800m IR sounding: 18-30 km		200 km at 50 GHz 50 km at 220 GHz	216 m for 1000 km 45 m for 200 km
FOV	0.6x1.2°			
Bands - (see following following page)				

*potential candidates; L.S.Walter, EASCON 1974, pp. 631-636.

SYSTEM	SEOS-A			(page 2 of 2)
SENSOR SUBSYSTEMS	Large Earth Survey Telescope (LEST)	Advanced Atmospheric* Sounder and Imaging Radiometer (AASIR)	Microwave Sounder*	Framing Camera
Bands	series of bands in the following spectral regions: .45-1.1 μm** 2.3 3.5 4.3 6.5-7.0 10.5-12.5** 14-15 23-24	.55 - 1.1 μm** 3.7 μm 4.24-4.57 μm (5 chs.) 6.71 μm 7.25 μm 11.11 μm** 12.66-15 μm (7 chs.)	5 bands in the 50-220 GHz region	0.4-0.9 μm

*potential candidates; L.S. Walter, EASCON 1974, pp. 631-636.
**imaging bands

SYSTEM	SKYLAB Earth Resources Experiment Package (EREP) (page 1 of 3)				
Agency Launch Date Altitude/Orbit	NASA Operated: May 1973 - February 1974 435 km				
SENSOR SUBSYSTEMS	S-190A	S-190B	S-191	S-192	S-193
Type	6 multiband cameras	earth terrain camera	pointable filter wheel spectrometer	13 band conical scanner	Ku band, 3 modes: 1) radiometer 2) scatterometer 3) altimeter
Manufacturer	Itek	Actron	Block Engineering/ Martin	Honeywell	General Electric
Ground Covering	163 x 163	109 x 109	non-imaging	swath = 68.5 km	total scan of 22.7°
Repeat Coverage	N/A	N/A	N/A	N/A	N/A
IFOV	(FOV = 21.23° sq)	(FOV = 14.24° sq)	1 mrad	0.182 mrad sq.	1.6° half power beam width
Resolution	78-223 ft.**	35-99 ft*	0.435 km dia.	79.2 m	11.0 km dia. circle at nadir
Format (cameras)	5.7x5.7 cm	11.5x11.5 cm			
Focal Length	152 mm	457 mm			
f/Number	2.8	4			
Forward Motion Compensation	0-30 mrad/sec	0-25 mrad/sec			

*35 ft for SO-242 aerial color film, 99 ft. for EK 3443 color IR film
**78 ft for SO-356 color film, 223 ft. for EK 2424 B&W IR film

SYSTEM	SKYLAB Earth Resources Experiment Package (EREP) (page 2 of 3)				
SENSOR SUBSYSTEMS	S-190A	S-190B	S-191	S-192	S-193
Bands	6 bands 0.4-0.9 μm bands selected with filters .7-.8 μm BW IR .8-.9 BW IR .5-.88 Color IR .4-.7 μm Color .6-.7 BW Red .5-.6 BW Green	0.40-0.90 μm film selected from following: aerial color .4-.7 μm aerial B&W .5-.7 μm color IR .5-.88 μm	continuous 0.39-2.5 μm (Si and PbS) 5.82-15.99 μm (HgCdTe)	0.41-0.46 μm 0.46-0.51 0.52-0.56 0.56-0.61 0.62-0.67 0.68-0.76 0.78-0.88 0.98-1.08 1.09-1.19 1.20-1.30 1.55-1.75 2.10-2.35 10.2-12.5	13.9 GHz
Remarks	Grid reseau 0-30 frames/min.	varying overlap between frames 0-25 frames/min.			

SYSTEM	SKYLAB Earth Resources Experiment Package (EREP) (page 3 of 3)			
Agency Launch Date Altitude/Orbit	NASA Operated: May 1973 - February 1974 435 km			
SENSOR SUBSYSTEMS	S-194			
Type	Non-imaging L-band radiometer			
Manufacturer	AIL			
Ground Coverage				
Repeat Coverage	N/A			
IFOV				
Resolution	half power pts: 124 km dia.			
Bands	1.414 GHz			

SYSTEM	Shuttle OFT-2
Agency Launch Date Altitude	NASA July 1979 166-275 km, 32°-40°
SENSOR SUBSYSTEMS	Synthetic Aperture* Radar (SAR)
Type	Imaging system Single Polarization
Manufacturer	Hughes/JPL
Ground Coverage	25 km on one side from 17°-23°
Repeat Coverage	NA
IFOV	
Resolution	25 meters
Polarization	H
Bands	1.275 GHz (L band)

*Proposed

SYSTEM	Operational Shuttle Earth Resources Sensors*			
Agency Launch Date Altitude/Orbit	NASA 1980's - - -			
SENSOR SUBSYSTEMS	Shuttle Imaging Radar (SIR)*	Mark II Interfer-ometer*	Spaceborne Meteorolog-ical Radar*	Shuttle Imaging Microwave System * (SIMS)
Type	synthetic aperture radar	non-imaging	synthetic aperture radar; afocal	passive scanning, imaging radar
Manufacturer	JPL/Hughes**	JPL	Hughes **	JPL
Ground Coverage				FOV = 106°
Repeat Coverage	Unknown	N/A	N/A	Unknown
IFOV	1-17 mrad	fixed nadir FOV		26 mrad
Resolution				
Launch Date	1982			
Bands	1.4 GHz 9.8 GHz	1-9 μm	~10 GHz	0.61 GHz 1.4 2.7 6.6 10.7 20 22.2 37 53 94 118.7 GHz

*definition stage
**under study

SYSTEM	TIROS-N*			(page 1 of 2)	
Agency Launch Date Altitude/Orbit	NASA/NOAA 1978 833 ± 90 km polar orbit				
SENSOR SUBSYSTEMS	Basic Sounding Unit (BSU)	Stratospheric Sounding Unit (SSU)	Microwave Sounding Unit (MSU)	Advanced Very High Resolution Radiometer (AVHRR)	Space Environment Monitor (SEM)
Type	rotating mirror, cross track scan	selective absorption pressure cells	4-channel Dicke radiometer	4-channel visible-IR radiometer	four detector arrays
Manufacturer	Ball Brothers Research Corp.	Provided by United Kingdom	JPL	ITT	NOAA/ERL Boulder, Colo.
Ground Coverage	± 1127 km (± 49.5°)	± 737 km (± 40°)	± 47.35°		
Repeat Coverage	N/A	N/A	N/A	12 hrs.	N/A
IFOV					
Resolution	21.8 km dia. -nadir 75.2x37.3 km -scan end	147 km dia. -nadir 244x186 km -scan end	7.5°	1.1 & 4 km	
No. Steps/ Angle per step	56/1.8°	8/10°	11/9.47°		
Bands (see following page)					

*2nd generation of ITOS/NOAA

SYSTEM	TIROS-N*			(page 2 of 2)	
SENSOR SUBSYSTEMS	Basic Sounding Unit (BSU)	Stratospheric Sounding Unit (SSU)	Microwave Sounding Unit (MSU)	Advanced Very High Resolution Radiometer (AVHRR)	Space Environment Monitor (SEM)
Bands	3.70 μm 4.26 9.71 11.12 13.33 13.61 13.99 14.29 14.49 14.75 14.95 18.80 23.15 29.41	3 channels each at $668 cm^{-1}$ central wave number cell pressures: 100 mb 35 10	50.3 GHz 53.74GHz 54.96GHz 57.95GHz	0.55-0.9 μm 0.725-1.0+ 3.55-3.93 10.5-11.5 (11.5-12-5)**	Detector arrays: 1) High Energy Proton-Alpha Telescope (HEPAT) protons = 100,400,600 MeV alpha = 2400, 4000, MeV 2) Low Energy Proton-Alpha Telescope (LEPAT) protons = 150 KeV - 40 MeV alpha = 0.6-100 MeV 3) Proton Omni-directional detector (POD) protons = .75,10,30, 60 MeV alpha = 75, 40,120,140 MeV 4) Total Energy Detector (TED)

*2nd generation of ITOS/NOAA
**not on first, but considered on later TIROS-N/NOAA satellites as AVHRR-II

SYSTEM	Defense Meteorological Satellite Program (DMSP 1 & 2; Block B/C) (page 1 of 2)			
Agency	Air Force			
Launch Date	Unknown; now in orbit			
Altitude/ Orbit	830 km (450 n.mi.) polar, sun-synchronous orbit at 98.747°			
SENSOR SUBSYSTEMS	Scanning Radiometer* (SR)	Special Meteorological Sensor (SSE)	Precipitating Electron Spectrometer	
Type	Visible/ infrared imager	atmospheric sounder	unknown	
Manufacturer			unknown	
Ground Coverage	swath = 3000 km	swath = 185 km	unknown	
Repeat Coverage (imagers only)	DMSP-1 sunset, sunrise DMSP-2 midnight, noon	N/A	N/A	
IFOV		37 km	unknown	
Resolution	Visible: VHR-0.63 km HR-3.7 km Infrared: WHR-0.66 km IR-4.4 km		unknown unknown	
Bands: (see following page)				

*includes Very High Resolution (VHR) and High Resolution (HR) for visible
Very High Resolution (WHR) and High Resolution (IR) for infrared

SYSTEM	Defense Meteorological Satellite Program (MDSP 1 & 2; Block B/C)			(page 2 of 2)
SENSOR SUBSYSTEMS	SR*	SSE		
Bands	0.4-1.1 µm 8-13 µm Detectors: • Visible: VHR-back biased Si diode HR-photo-conductive mode-Si diode • Infrared: WHR-HgCdTe IR-thermister bolometer	• 5 CO_2 bands around 15 µm • atmospheric window at 12 µm • 1 H_2O band at 20 µm		

*includes Very High Resolution (VHR) and High Resolution (HR) for visible
Very High Resolution (WHR) and High Resolution (IR) for infrared

SYSTEM	Defense Meteorological Satellite Program (DMSP - Block D)		
Agency	Air Force		
Launch Date	to be launched		
Altitude/ Orbit	830 km (450 n.mi.), polar, sun-synchronous orbit		
SENSOR SUBSYSTEMS	Operational Linescan System (OLS)	Special Meteorological Sensor H (SSH)	
Type	imager	atmospheric sounder	
Manufacturer	Westinghouse	Barnes Engineering	
Ground Coverage	3000 km	± 551.1 n. mi. 25 steps across track	
Repeat Coverage (IMAGERS only)	every 12 hrs.	N/A	
IFOV		2.7°	
Resolution	0.55 km 2.8 km		
FOV		± 48°	
Bands	0.41-1.1 μm 8-13 μm Detectors: PMT Si photo-diode HgCdTe	9.8 μm - O_3 12.0 - window 13.4 CO_2 13.8 14.1 14.4 14.8 15.0 18.7 H_2O 22.7 23.9 24.5 25.2 26.7 28.2 28.3	

SYSTEM	STORMSAT	
Agency Launch Date Altitude/ Orbit	NOAA 1983 Geosynchronous	
SENSOR SUBSYSTEMS	Advanced Atmospheric Sounding and Imaging Radiometer (AASIR)	Microwave Atmospheric Sounding Radiometer (MASR)
Type	Imaging and sounding	Imaging
Manufacturer	TRW or Hughes	
Ground Coverage	Earth's disc	Earth's disc
Repeat Coverage	≤ 20 minutes	
IFOV	Vis/NIR 0.021 mrad Thermal IR 0.13 mrad	
Resolution	Vis/NIR 0.75 km Thermal IR 4.5 km	30-40 km
Bands	Imaging 0.55-1.1 μm 11.1 μm Sounding 12.66-14.96 μm ($668.5-760\ cm^{-1}$) 7.25 μm ($1380\ cm^{-1}$) 6.71 μm ($1490\ cm^{-1}$) 4.24-4.57 μm ($2190-2360\ cm^{-1}$) 3.70 μm ($2700\ cm^{-1}$)	118 and 183 GHz

SYSTEM	GEOS-3
Agency Launch Date Altitude/ Orbit	NASA 9 April 1975 Circular 843 km, 115°
SENSOR SUBSYSTEMS	Radar altimeter
Type	
Manufacturer	
Ground Coverage	
Repeat Coverage	
IFOV	
Resolution	±5m absolute altitude 1-2m relative altitude
Bands	13.9 GHz

APPENDIX B

NOAA TECHNICAL MEMORANDUMS
NATIONAL ENVIRONMENTAL SATELLITE SERVICE SERIES

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NOAA TECHNICAL MEMORANDUMS
NATIONAL ENVIRONMENTAL SATELLITE SERVICE SERIES

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