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GSFC — GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

RADIOCOMMUNICATIONS FOR METEOROLOGICAL SATELLITE SYSTEMS

Barbara A. Walton

FOREWORD

In June 1973 the Meteorology Program Office was asked to provide assistance in updating and revising CCIR Papers on the Earth Exploration Satellite Service. The Consultative Committee on International Radio (CCIR) is the technical arm of the International Telecommunications Union (ITU). The ITU issues the Radio Regulations which is the basis for the frequency management policy of the United States.

I was named to represent the Meteorology Program Office in all matters relating to the CCIR. As a result, I prepared a Draft New Report to replace CCIR Report 395-1 (Rev. 72) of the same name. That report, now numbered Doc. USSG 2/60 (Rev. 1), as approved by the U.S. Study Group 2 of CCIR on September 27, 1973 was the basis for X-120-73-388. It was modified to include information on the Meteosat at the Interim Meeting of the CCIR Study Group 2 in Geneva and submitted to the XIIIth Plenary Assembly as Doc. 2/1024-E dated 9 April 1974 and became CCIR Report 395-2 (Rev. 74).

The revision, undertaken in 1975, was considered too long for submission to the international group with its translation, etc. expenses. Subsequently, the paper was reduced to a few pages by referencing this X-document, which gives U.S. civilian meteorological satellite characteristics.

Material from CCIR Report 395-2 (Rev. 74) on Meteosat was extracted for Appendix A of this X-document, while material furnished by the Japanese is the basis for Appendix B.

ACKNOWLEDGEMENTS

I wish to acknowledge the support of those people on Goddard Space Flight Center's project teams who provided information: Bill Gould on Nimbus, Tony Rossi on ITOS, Wayne Hembree on TIROS-N, and Robert Martel on SMS/GOES.

National Scientific Laboratory provided editorial support in the preparation of the CCIR report. Members of the U.S. Study Group 2 made appropriate modifications to the CCIR Report.

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RADIOCOMMUNICATIONS FOR METEOROLOGICAL SATELLITE SYSTEMS

1.0 INTRODUCTION

The ITU Radio Regulations define the Meteorological Satellite Services as an earth exploration satellite service for meteorological purposes. In the past, the United States has launched near-earth orbiting experimental and operational meteorological satellites, and more recently has expanded its meteorological satellite systems to include geostationary satellites.

Because of the results of the experimental meteorological satellite program, new operational sensing techniques have been developed and older methods have been refined. This document presents a general overview of the spectrum utilization and frequency requirements of present and planned United States Civilian Meteorological satellite programs.

Satellites in the meteorological service utilize portions of the radio-frequency spectrum for passive sensors (e.g., atmospheric sounders), for telemetering data from the satellites to Earth, as well as from small data collection platforms to the satellites, and for relaying of processed meteorological data.

The TIROS-1 (Television Infrared Observation Satellite) satellite (1960B) was orbited by the United States on 1 April 1960. It delivered a large quantity of pictures of the cloud cover of the Earth. Later TIROS satellites have telemetered data on the terrestrial and reflected solar radiation in both the visible and infrared portions of the spectrum. An automatic picture transmission (APT) system was test-flown on TIROS-8. The APT system represented a first step in using the satellite itself to convey weather information directly to data users. This slow-scan television system was designed to take, and immediately transmit, cloud pictures for reception by a relatively inexpensive earth station. The TIROS satellites served primarily research and development purposes, although the data were actually used in operations.

To implement the operational program at an early date, the TIROS satellite was modified into a wheel configuration and launched into a quasi-polar orbit to provide greater observational capability. These satellites were called TIROS Operational Satellite (TOS) during development, and known operationally as Environmental Survey Satellites (ESSA). The improved TIROS Operational Satellite (ITOS) became the basis for the operational program of National Oceanographic Atmospheric Administration (NOAA) satellites early in 1970. More recently, efforts have been focused on the prototype of the next series of operational environmental satellites, TIROS-N.

The Nimbus satellite is being used to provide research and development of advanced sensory systems, power supplies, stabilization systems, and to develop a more reliable, longer-life satellite with greater sensor carrying capacity to aid in development of operational satellites.

The Synchronous Meteorological Satellite (SMS) is the first in a series of spacecraft which will comprise the eventual Geostationary Operational Environmental Satellite (GOES) system, additional Geostationary Meteorological Satellites built in Europe (METEOSAT), Japan and U. S. S. R. are planned for use in the near future. All these satellites have visible and IR imaging, meteorological data collection and dissemination functions on an operational or pre-operational basis. Growing out of concepts proved in the SYNCOM and ATS programs, these satellites will yield new and improved data for weather prediction and timely warning of hazardous environmental conditions.

Nature uses the clouds to draw its own weather map; the satellites permit us to record and use this map in addition to providing other data. Thus, they provide global coverage, giving man a powerful tool to supplement conventional meteorological data by filling voids where they exist. Among such voids are vast oceanic areas and sparsely populated areas, where economic considerations prohibit an increase in the present conventional observational network.

Tables I and II summarize the first decade of U. S. civilian meteorological and related satellite flights, and indicate the sensors and functions provided and planned for the period 1970-1979.

Table I

Summary of Meteorological Satellite Flights, 1960-69

Satellite	Purpose	Launch Date	Operations Ceased Date
TIROS-1	Research	4/ 1/60	6/15/60
TIROS-2	Research	11/23/60	2/ 7/61
TIROS-3	Research	7/12/61	10/30/61
TIROS-4	Research	2/ 9/62	6/12/62
TIROS-5	Research	6/19/62	5/ 5/63
TIROS-6	Research	9/18/62	10/11/63
TIROS-7	Research	6/19/63	2/ 3/66
TIROS-8	Research	12/21/63	1/22/66
Nimbus-1	Research	8/28/64	9/23/64
TIROS-9	Research	1/22/65	2/15/67
TIROS-10	Research	7/ 1/65	7/31/66
ESSA-1	Operational	2/ 3/66	5/ 8/67
ESSA-2	Operational	2/28/66	10/16/70
Nimbus-2	Research	5/15/66	11/15/66
ESSA-3	Operational	10/ 2/66	10/19/68
ATS-1	Research	12/ 6/66	--
ESSA-4	Operational	1/26/67	6/19/67
ATS-2	Research	4/ 5/67	(1)
ESSA-5	Operational	4/20/67	2/20/70
ATS-3	Research	11/ 5/67	--
ESSA-6	Operational	11/10/67	11/ 4/69
ESSA-7	Operational	8/16/68	7/19/69
ESSA-8	Operational	12/15/68	--
ESSA-9	Operational	2/26/69	11/15/73
Nimbus-3	Research	4/14/69	9/25/70

(1) Unstable attitude; data not useful.

Table II

U.S. Civilian Meteorological and Related Satellite Flights and Functions, 1970-1979

SATELLITE	PURPOSE[1]	LAUNCH DATE	ORBIT	INSTRUMENTS AND FUNCTIONS[2]	REMARKS[3]
ITOS-1	R/O	1/23/70	Sun Synch. 1420 km	2 AVCS,2 APT,2SR, FPR, SPM	Ceased operations June 1971.
Nimbus-4	R	4/8/70	Sun Synch. 1100 km	IDCS,THIR,IRIS,SIRS,SCR,FWS, IRLS,BUV,MUSE.	BUV, MUSE still operating
NOAA-1	O	12/11/70	Sun Synch. 1420 km	2 AVCS,2 APT, 2 SR,FPR,SPM	Ceased operations August 1971.
ITOS-B	O	10/21/71	Sun Synch.	2 AVCS,2 APT, 2 SR,FPR,SPM	Failed to orbit.
ITOS-C[4]	O		Sun Synch. 1420 km	2 AVCS,2 APT,2 SR, FPR,SPM	Stored.
NOAA-2 (ITOS-D)	O	10/15/72	Sun Synch. 1450 km	2 SR, 2 VHRR, 2 VTPR, SPM	
Nimbus-5	R	12/12/72	Sun Synch. 1100 km	THIR,ESMR,ITPR,SCR,NEMS,SCMR.	SCMR not operable.
ITOS-E	O	7/16/73	Sun Synch.	2 SR,2 VHRR,2 VTPR, SPM	Failed to orbit.
NOAA-3 (ITOS-F)	O	11/6/73	Sun Synch. 1450 km	2 SR, 2 VHRR, 2 VTPR, SPM	Operational/Standby.
SMS-1	R/O	5/17/74	Geostationary 35,790 km	VISSR,DCDR,SEM	Located 75°W long.
ATS-6	R	5/30/74	Geostationary 34,790	GVHRR, Etc.	GVHRR failed 8/15/74.
NOAA-4 (ITOS-G)	O	11/15/74	Sun Synch. 1450 km	2 SR, 2 VHRR, 2 VTPR, SPM	Operational
SMS-2	R/O	2/4/75	Geostationary 35,790 km	VISSR, DCDR, SEM	Located 115°W long.
Nimbus-6	R	6/12/75	Sun Synch. 1100 km	THIR,ESMR,TWERLE,HIRS,SCAMS, LRIR,PMR,ERB,TDRE	
GOES-A (SMS-C)	O	10/ /75	Geostationary 35,790 km	VISSR, DCDR, SEM	
ITOS-E2	O	11/ /75	Sun Synch. 1450 km	2 SR, 2 VHRR, 2 VTPR, SPM	
GOES-B (SMS-D)	O	12/ /76	Geostationary 35,790 km	VISSR, DCDR,SEM	
GOES-C	O	5/ /77	Geostationary 35,790 km	VISSR, DCDR, SEM	
ITOS-H	O	10/ /76	Sun Synch. 1450 km	2 SR, 2 VHRR, 2 VTPR, SPM	
TIROS-N	R/O	/ /78	Sun Synch.	AVHRR, SEM, SSU, MSU, BSU,DCS	
ITOS-I	O	/ /78	Sun Synch.	2 SR, 2 VHRR, 2 VTPR, SPM	
Nimbus-G	R	/ /78	Sun Synch.	SMMR,SAMS,LIMS, SBUV/TOMS, ERB, THIR,CZCS, SAM II	
SEASAT	R	/ /78		SAR, ALT, MWS, SR	
TIROS-N OPERATIONAL FOLLOW-ON A	O	/ /78	Sun Synch.	AVHRR, SEM, SSU, MSU, BSU, DCS	
AEM-B	R	4/ /79		SAGE	
GOES-D	O	/ /79	Geostationary 35,790 km	VAS, DCDR, SEM	
TIROS-N OPERATIONAL FOLLOW ON B	O	/ /79	Sun Synch.	AVHRR, SEM, SSU, MSU, BSU, DCS	
GOES-E	O	/ /80	Geostationary 35,790 km	VAS, DCDR, SEM	

[1] R: Research
O: Operational
R/O: Operational prototype

[2] See acronyms
[3] As of 7/31/75
[4] ITOS-C became ITOS-E2 modified to ITOS-G configuration

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2.0 METEOROLOGICAL SATELLITE SENSORS

Weather data have very short-lived usefulness for operational purposes and delivery via communication links from satellite to earth station and on to the user, must be rapid. This can be achieved by multiple satellites, by frequent transmission of the essential information through the use of geostationary spacecraft, and by direct readout of data to the user.

Early meteorological systems used TV cameras to obtain images in the visible part of the spectrum which proved useful in the detection of fronts and large storm systems. Later, infrared (IR) images were also obtained, primarily with scanning radiometers, to permit night viewing and to provide surface and cloud top temperatures. Further improvements were made in resolution to less than 1 km in both visible and IR. These improvements increased communication bandwidth requirements. Now, there are plans for 4-channel imagery on TIROS-N. Another increase in bandwidth requirements arose from continuous viewing through the use of geostationary spacecraft.

The ability to determine the vertical profile of temperature, humidity, and atmospheric constituents has progressed in recent years to the point where operational spacecraft beginning with NOAA-2 now fly an instrument (VTPR) for making measurements from which temperature and humidity profiles can be inferred. The "sounding" concepts were advanced by experiments flown on R&D spacecraft. Recently, development has been focused on adding microwave channels which permit cloud penetration. Future advances in vertical and horizontal resolution, all weather capability, and in constituent measurement are expected. In addition, sounding from geostationary orbit is expected in 1979 with the launch of GOES-D. In general, data rates from "sounders" are comparatively low and direct readout to users have been provided beginning with the launch of ITOS-F (NOAA-3) in November 1973.

Radar is used extensively by aviation and weather forecasting services for the detection of three-dimensional precipitation patterns. The combination of precipitation information with cloud pictures is of inestimable value. Radar not only detects precipitation in itself, but also permits an estimate of intensity, volume, freezing level, extent of vertical convection, etc.

Thunderstorms and their frequently associated ancillaries, such as hail, turbulence, precipitation, strong winds, etc., represent severe weather hazards to life and property and are especially important in aircraft operations. At the present time, radar and ground-based sferics networks provide meteorologists with the location and movement of thunderstorms over only a small fraction of the surface of the earth. These observations have proved most valuable in weather analysis and forecasting. Potentially, satellites provide the means by which observations of thunderstorm activity can be obtained on a global basis. In addition, a sferic sensor aboard a meteorological satellite is probably the most economical method of extending the sferics network to a global basis. Supporting studies have been made to determine the feasibility of a satellite sferics sensor. Results from these studies are encouraging.

The collection of scientific, meteorological and other environmental data from fixed or mobile data sources by a satellite provides important inputs into the weather prediction and other environmental prediction and warning processes. Several systems have been developed or are under development and are addressed in Documents IV/55 and IV/69 (U.S.A.) 1966-1969.

2.1 Passive Microwave Sensors

The properties of the atmosphere in the microwave region have not yet been fully applied. Intensive research is being conducted to enable application of the microwave emissions and absorption lines to the measurement of atmospheric phenomena. However, it is necessary to know that no measurable interference exists at the absorption lines of interest so that the measurements are not distorted. Although several bands are allocated to space research (passive); namely, 52-54.25, 58.2-59, 64-65, 86-92, 101-102, 130-140, 182-185, and 230-240 GHz, experiments are being planned and conducted in other parts of the spectrum, such frequencies include: 4.99, 6.6, 10.69, 18, 19.35, 21.5, 22.2, 31.4, 37, many lines in the 50-70 GHz region, 118 GHz, and other lines above 100 GHz.

Nimbus-5 was the first meteorological satellite to fly microwave sensors which demonstrated the utility of such instruments to sound the atmosphere through clouds, determine rain rates, etc. Numerous other passive microwave sensors are being built or planned. Table III summarizes these for meteorological and related spacecraft. Sharing criteria for such sensors are given in Report USSG 2/305.

2.2 Active Microwave Sensors

Although ground radar has been used extensively in meteorology, no active microwave instrument has yet been flown for this purpose. SKYLAB was the first spacecraft to fly an active microwave sensor, it used a frequency of 13.9 GHz. A meteorological radar in the 10 GHz region is being studied for use on a shuttle sortie mission.

It should be noted that presently the only allocations for active microwave sensors are at 9,975-10,025 MHz and 34.4-34.5 GHz, where weather radar on meteorological satellites is permitted. It is necessary to determine where active bands are needed and to resolve possible conflicts between active and passive sensors. Table III summarizes active instrument efforts for meteorological and related spacecraft. Sharing criteria for such sensors are given in Report USSG 2/304.

Table III

Microwave Sensors For Meteorological and Related Spacecraft

Sensor	Program	Passive (GHz)	Active (GHz)
Nimbus-E Microwave Spectrometer (NEMS)	Nimbus-5	22.23/31.4/ 53.65/54.9/58.8	
Electronically Scanning Microwave Radiometer (ESMR)	Nimbus-5 Nimbus-6	19.35 37.0	
Scanning Microwave Spectrometer (SCAMS)	Nimbus-6	22.235/31.65/ 52.85/53.85/ 55.43	
Scanning Multichannel Spectrometer (SMMR)	Nimbus-G	6.6/10.69/18.0/ 21.5/37.0	
TIROS Operational Vertical Sounder (TOVS) — Microwave Sounding Unit (MSU)	TIROS-N	50.3/53.74/ 54.96/57.95	
Shuttle Imaging Microwave System (SIMS)	Shuttle	0.061/1.4/2.7/ 6.6/10.7/20.0/ 22.2/37.0/53.0/ 94.0/118.7	
Microwave Limb Sounder	AAFE	60/117/184*	
Radar Altimeter	SEASAT		13.9
Synthetic Aperture Radar	SEASAT		1.37
High Resolution Imaging Radar	Shuttle		1.4/9.8
Orbiting Met Radar	Shuttle		Somewhere Between 8-10
Act./Pas. Microwave Imaging System	AAFE	4.99/18.0/22.2/ 37.0	14.0/31
Coherent Imaging Radar	AAFE		1.5
Surface Profile Radar	AAFE		37.5
Radiometer/Scatterometer (RAD-SCAT)	AAFE	9.3/11.7/13.9	9.3/11.7/13.9

*Many frequency channels about these regions to be determined.

3.0 THE TIROS OPERATIONAL SYSTEM (TOS)

The TIROS Operation System was sponsored and operated by the United States. To meet the full operational objectives of the system, it was required that two TOS meteorological satellites be in orbit at all times: one carrying an Automatic Picture Transmission (APT) sub-system for direct local readout to APT stations throughout the world; and the other carrying the Advanced Vidicon Camera System (AVCS), which is capable of storing global video data for readout to associated ground stations that immediately relay the data to the National Environmental Satellite Service (NESS) Data Processing and Analysis Facility.

3.1 Orbit and Coverage

The spacecraft were placed in 1330 km altitude sun-synchronous polar orbit. Reception of telemetering and issuing of telecommands is performed from Command and Data Acquisition (CDA) stations located at Gilmore Creek, Alaska, and Wallops Island, Virginia. Onboard storage enables acquisition of data acquired by the satellite on all orbital passes.

3.2 Tracking and Telemetry

The TOS tracking system utilizes redundant 250 mW FM/FM beacon transmitters in the 136-137 MHz frequency range. The beacon transmits two channels of attitude information continuously and, on command, one channel of telemetry data. Provision has been made to turn the beacon off after 18 months of operation.

Telemetry sampling in the TOS is accomplished through a redundant 90-point commutator at a 10-point per second rate. The output signal frequency modulates one subcarrier of the 136 MHz frequency modulated beacon transmitter. Transmission of the telemetry information occurs on command from the CDA station.

The telemetry beacon antenna is circularly polarized and provides a nominal antenna gain of -5.0 dB.

3.3 Telecommand

Digital tone frequency shift-keyed commands are used to issue instructions to the spacecraft for activating or deactivating the various subsystems. An internal programming system permits the subsystems to be turned on and off at the proper time to give optimum coverage and is used to conserve the useful life of the television subsystems.

The telecommand antenna is a short monopole antenna with a nominal -5.0 dB gain.

3.4 Television Subsystem

The TIROS operational satellites are in two configurations, one using two 800-line advanced vidicon cameras (for redundancy) with 180° field-of-view. These provide pictures of about 3200 km on a side. The other configuration is a redundant APT camera system, using two 800-line storage vidicons with 108° field-of-view. These also provide pictures of about 3200 km on a side. Only one camera is in operation at a time.

3.4.1 AVCS (Advanced Vidicon Camera System)

The AVCS camera uses a 2.5 cm (1 in.) vidicon with a resolution of 800 television lines. After a 1.5 ms exposure time, the information is read out electronically and stored on a tape recorder for playback upon command from either CDA station. A maximum of 48 pictures may be stored on each tape recorder, which provides the ability to store up to three orbits. A second mode of operation permits direct read-out of pictures when the spacecraft is within range of a CDA station.

Each camera has a frequency-modulated local oscillator, which is recorded on its assigned track of the tape recorders. A circularly polarized set of antennae is used for transmission of the AVCS signal. The system can playback the AVCS information.

3.4.2 Automatic Picture Transmission (APT)

The APT camera in the TOS system is the same basic system as used in the TIROS-8 spacecraft and described in (Stampfl, 1963). In the TOS/ESSA/APT, a whip antenna is used with the APT video transmitter operating at 137.5 or 137.62 MHz at 5 watts. The beacon and command antenna are circularly polarized.

3.5 Infrared (IR) Subsystem

The TOS has provisions to accommodate a heat balance infrared subsystem. Data transmission is provided through the existing video or beacon transmitter on a time-sharing basis.

4.0 THE IMPROVED TIROS OPERATIONAL SATELLITE (ITOS)

The Improved TIROS Operational Satellite has replaced the original TIROS Operational Satellite (TOS) which provided daytime global viewing and direct read-out to local ground stations without interruption since February 1966. The ITOS system as shown in Figure 1, provides global data both day and night.

The prototype ITOS satellite was launched on January 23, 1970, as ITOS-1. NOAA-1, the first operational ITOS spacecraft, was launched on December 11, 1970.

ITOS-D, designated NOAA-2, successfully launched on October 15, 1972, is the first operational environmental satellite in the series to fly with no on-board cameras, relying entirely on scanning radiometers for imagery and to carry a sensor to obtain vertical temperature profile soundings on a near-global basis.

4.1 Spacecraft Configuration

The major features of the ITOS spacecraft are identified in Figure 2; they are the equipment module (main body), the deployable 3-panel solar array, and the momentum flywheel. The spacecraft is capable of supporting a total payload weight of 410 kg.

The solar array consists of three panels, each independently hinged to the main body of the spacecraft. The total area of the array is about 4.5 square meters.

The spacecraft are placed in a 1,460 km sun-synchronous polar orbit; (9:00 a.m.) descending node.

4.2 Communications and Data Handling Subsystems

The ITOS communications and data handling subsystems employ separate satellite/ground-station transmission links for handling communications between the satellite and the ground stations. These links are:

- command-receiving link for transmitting command messages from the CDA stations to the satellite;
- beacon/telemetry link for transmitting tracking signals, two analog FM channels, and a 512 bps data stream from the Digital Data Processor (DDP) operating on a frequency of 136.77 MHz at 0.25 watts;
- Band 8 video link for transmitting Scanning Radiometer (SR) data to worldwide local APT stations, operating on a frequency of 137.5 MHz or 137.62 MHz at 5 watts;

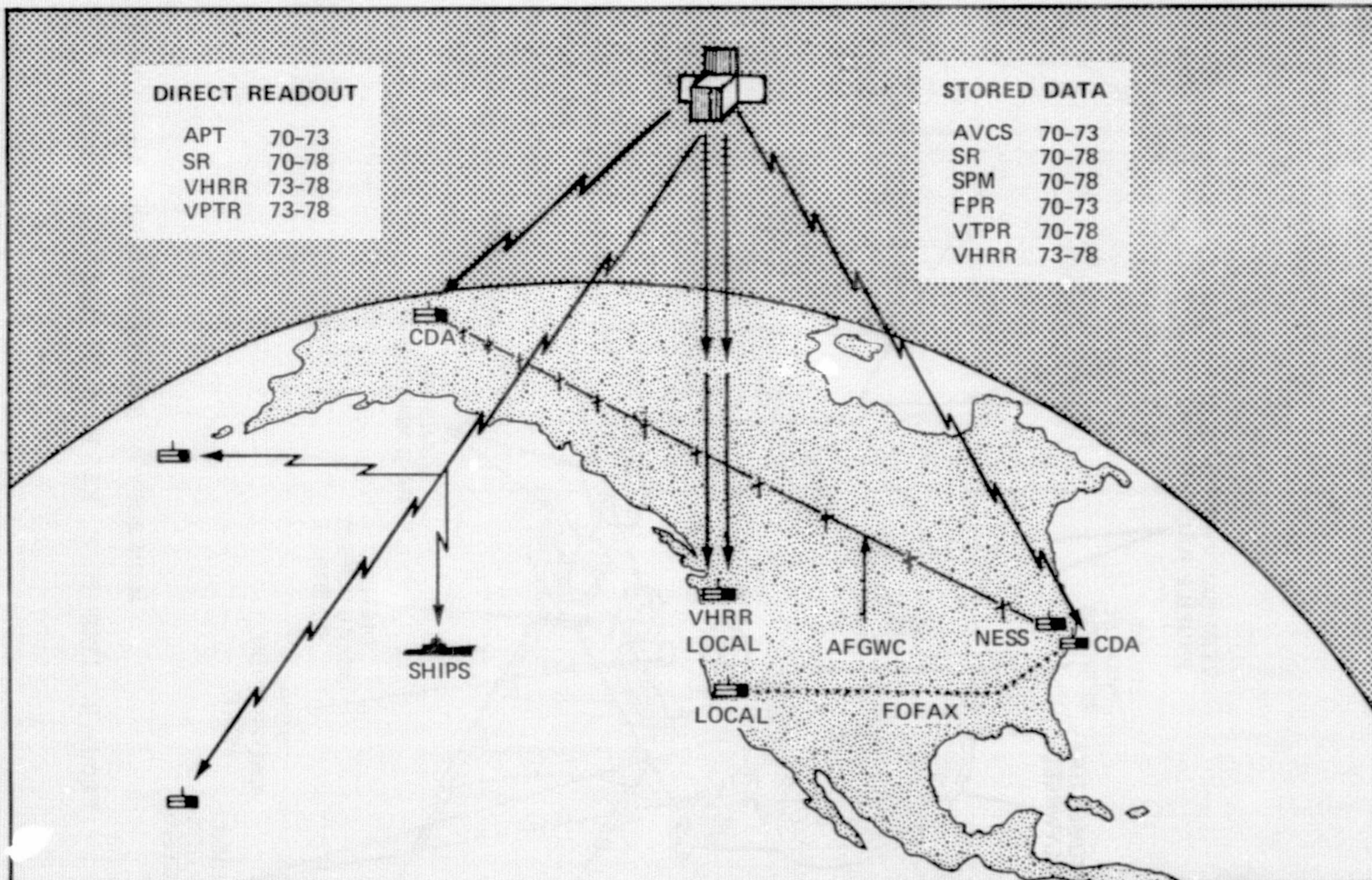

Figure 1. Schematic of ITOS System

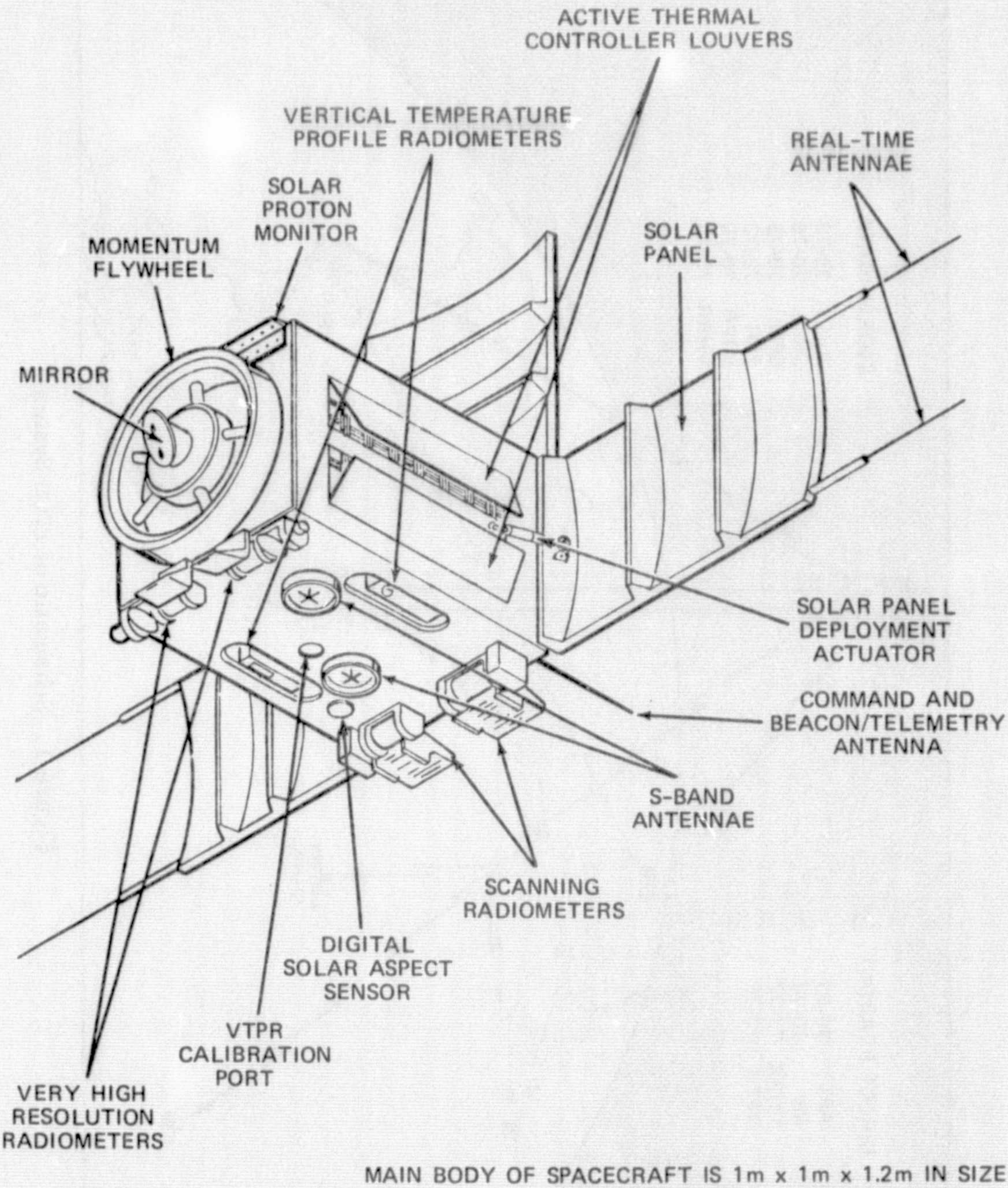

Figure 2. ITOS-D, E, E2, F, G, H, and I Spacecraft

- Band 9 real-time video link for transmitting Very High Resolution Radiometer (VHRR) data to worldwide local stations, operating on a frequency of 1697.5 MHz at 5 watts;

- Band 9 playback video link for transmitting recorded SR, VHRR and DDP data to the CDA station, operating on a frequency of 1697.5 MHz at 5 watts.

The satellite/ground station communications links are designed to operate concurrently and are compatible with the CDA and APT ground stations. The essential characteristics of the communications links are summarized in Table IV.

4.3 Operational Plan

The ITOS system will be maintained with launches as needed, projected at about 1-year intervals. Satellites of this series, beginning with NOAA-2, include a capability for obtaining vertical temperature and moisture profiles of the atmosphere. Addition of the Vertical Temperature Profile Radiometer (VTPR) system completes the first operational system for sounding the atmosphere twice daily on a global basis, a major objective of the national operational environmental satellite program. The VHRR system provides high-resolution imagery in both the visible and IR portions of the spectrum (1 km at subsatellite point). The VHRR operates mainly as a unique local readout subsystem to specially equipped locations, with limited high-resolution storage capacity for data from selected remote areas. The vidicon camera systems in use on the earlier ITOS have been discontinued; their day-time viewing is performed by the combined day and night viewing and temperature sensing Scanning Radiometer (SR). The primary sensor complement (SR, VHRR, and VTPR) is expected to continue on the polar-orbiting satellites into 1978. The APT service will continue with the signal provided by the SR; day and night service is available from the SR which observes in both the visible and infrared spectra. To receive SR data, a conventional APT ground station recorder must be modified, and the details of the modification vary with the manufacturer and type of recorder. A Solar Proton Monitor (SPM) is carried as a secondary sensor.

Table IV

ITOS Link Summary

Link	Carrier Frequency	Information Signal	Baseband Bandwidth	Modulation	Subcarrier Frequency	RF Spectrum Bandwidth*
1. Command	148.56 MHz	Enable Tone	CW	CW/AM	F_1	22.6 kHz
		Digital Commands	10 bits/sec	FSK/AM	F_2	
2. Beacon	136.77 MHz or 137.14 MHz	Maintenance Telemetry Command Verification DSAS and SPM Data	59 Hz	FM/PM	3.9 kHz	8.5 kHz
		Attitude Data Time Code and Analog VTPR Data	160 Hz	FM/PM	2.3 kHz	
3. Band 9 Real-Time	137.50 MHz**	Scanning Radiometer Video Data	900 Hz Visible 450 Hz IR	AM/FM	2.4 kHz	27.2 kHz
4a. Band 9 (Real-Time mode)	1697.5 MHz	Very High Resolution Radiometer Data (1 or 2 channels)	0.35 kHz	FM/FM	99 kHz and 249 kHz***	1.0 MHz
4b. Band 9 (Playback mode)	1697.5 MHz	VHRR Real Time Data	35 kHz	FM/FM	99 kHz	2.9 MHz
		Recorded VHRR or SR data	35 kHz (VHRR) 18.74 kHz VIS SR 9.38 kHz IR	FM/FM	272 kHz	
		Recorded SR Data	18.75 kHz, Visible 9.38 kHz, IR	FM/FM	448 kHz	
		Recorded Digital VTPR, SPM and Housekeeping Telemetry Data (2 channels)	10.67 kbits/sec	Quadrature DSBSC/FM	360 kHz	
		Flutter Correction (2 channels)	500 Hz	FM/FM	12.5 kHz and 25 kHz	
		Pilot Tone	CW	CW/FM	360 kHz	

*Information bandwidth only.
**Or 137.62 MHz alternate frequency.
***Backup mode only.

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5.0 TIROS-N SERIES

The ITOS series of operational environmental satellites will be replaced by a new series beginning in 1978. This development of the TIROS-N prototype spacecraft is necessary to provide a satellite platform for operation of the new and advanced instruments that have already been developed and demonstrated to be essential tools to improving long-range forecasting and storm warning advisories into the 1980 decade. Initially, these advanced instruments will provide measurements of cloud cover, cloud top and earth surface temperatures; mid-tropospheric circulation information; measurements of the vertical temperature and water vapor distribution throughout the atmosphere; collection of data from fixed or moving platforms (such as balloons and buoys) as well as measurements of their location; and measurements of the proton and electron fluxes surrounding the earth.

The existing operational meteorological satellite system is not adequate to meet the requirements for increased accuracy, improved spatial resolution, additional spectral intervals and improved data handling and communications that will be required for the 1978-1985 period. These requirements will necessitate the addition of large optical systems, an increased number of channels and on-board digital data handling to preserve the data accuracy. The TIROS-N spacecraft will have the capability to meet these requirements.

5.1 Sensing Systems

The TIROS-N Advanced Very High Resolution Radiometer (AVHRR) with its four spectral channels will increase the accuracy of sea surface temperature measurements and will allow improved observation of cloud cover and measurements of cloud heights. Cloud type identification and classification will be improved through the use of multispectral techniques permitting a better delineation of storm and jet stream structure. Flood areas, the extent and daily change in snow cover, and areas of recent precipitation will also be identified. This will lead to improved snow melt forecasting and better calculation of surface water boundaries.

The TIROS Operational Vertical Sounder (TOVS) will provide improved temperature sounding accuracy and an increase in altitude range from 30 km to 45 km. It will provide more accurate water vapor measurements through a greater depth of the atmosphere. It will also provide for contiguous global coverage whereas the current operational satellite sounder coverage is contiguous only above 50° latitude with a gap of 1,100 km at the equator. In addition, it will measure the ozone content of the atmosphere which is important in the assessment of the impact of aircraft such as the Supersonic Transport on the earth's atmosphere and climate.

The TOVS for TIROS-N will consist of three instruments. The first instrument, the Basic Sounding Unit (BSU) will have 14 channels and will measure one interval in the 3.7-μm window region, one interval in the 4.3-μm carbon dioxide band, one interval in the 9.7-μm ozone band, one interval in the 11.1-μm window region, seven intervals in the 15-μm carbon dioxide band, and three intervals in the 18-30-μm rotational water vapor bands. The second instrument, the Stratospheric Sounding Unit (SSU) will have 3 channels operating at 14.97-μm using selective absorption by passing the incoming radiation through three pressure modulated cells containing carbon dioxide. The third instrument, the Microwave Sounding Unit (MSU) will have 4 channels operating in the 50 to 60 GHz oxygen band to obtain temperature profiles which are free of cloud interference. The instruments will be cross-course scanning devices utilizing a step scan to provide a traverse scan while the orbital motion of the spacecraft provides scanning in the orthogonal direction.

The Space Environment Monitor (SEM) will provide continuous measurement of proton and electron flux activity near the earth. This instrument is an extension of the present solar proton monitor (SPM) now flying on ITOS spacecraft. The new monitor package additionally provides for measurement of alpha and electron flux, spectrum and total energy disposition into the earth's upper atmosphere.

The TIROS-N Data Collection (and location) Subsystem (DCS) will consist of:

- Free-floating balloon platforms;
- Free-floating buoy platforms;
- Fixed platforms located predominantly in polar regions;
- The satellite data collection subsystem;
- The ground station data retrieval subsystem;
- Centralized data reduction and processing.

Operation of the DCS is as follows. The TIROS-N spacecraft in a 830km orbit receives low-duty cycle transmissions, uncoordinated in time or frequency, from the platforms in a random access manner using a one-way RF link. The received transmission is processed on-board the satellite in order to recover the platform data message and, for the free-floating platforms, to measure the transmission received frequency so that additional ground processing can determine the platform location from the doppler induced frequency shift. The recovered data message and frequency measurements (along with time code) are stored on-board the spacecraft for ground station data retrieval at periodic intervals.

5.2 Spacecraft Configuration

The physical features of the TIROS-N spacecraft are shown in Figure 3. The total estimated weight at launch is 1409 kg, including the injection motor which remains attached to the spacecraft in orbit. The spacecraft is three-axis stabilized in a constant earth pointing attitude by an on-board computer controlled attitude system which will provide attitude control within ±0.2 degrees in each axis. A driven solar array will supply power.

5.3 Operational Plan

After the launch and in-flight checkout of TIROS-N, the prototype spacecraft, it is planned to maintain two spacecraft in flight at all times. One spacecraft will be in an 0800 hour local solar time descending node 830 km orbit and the second spacecraft will be in a 1600 hour local solar time ascending node 830 km orbit.

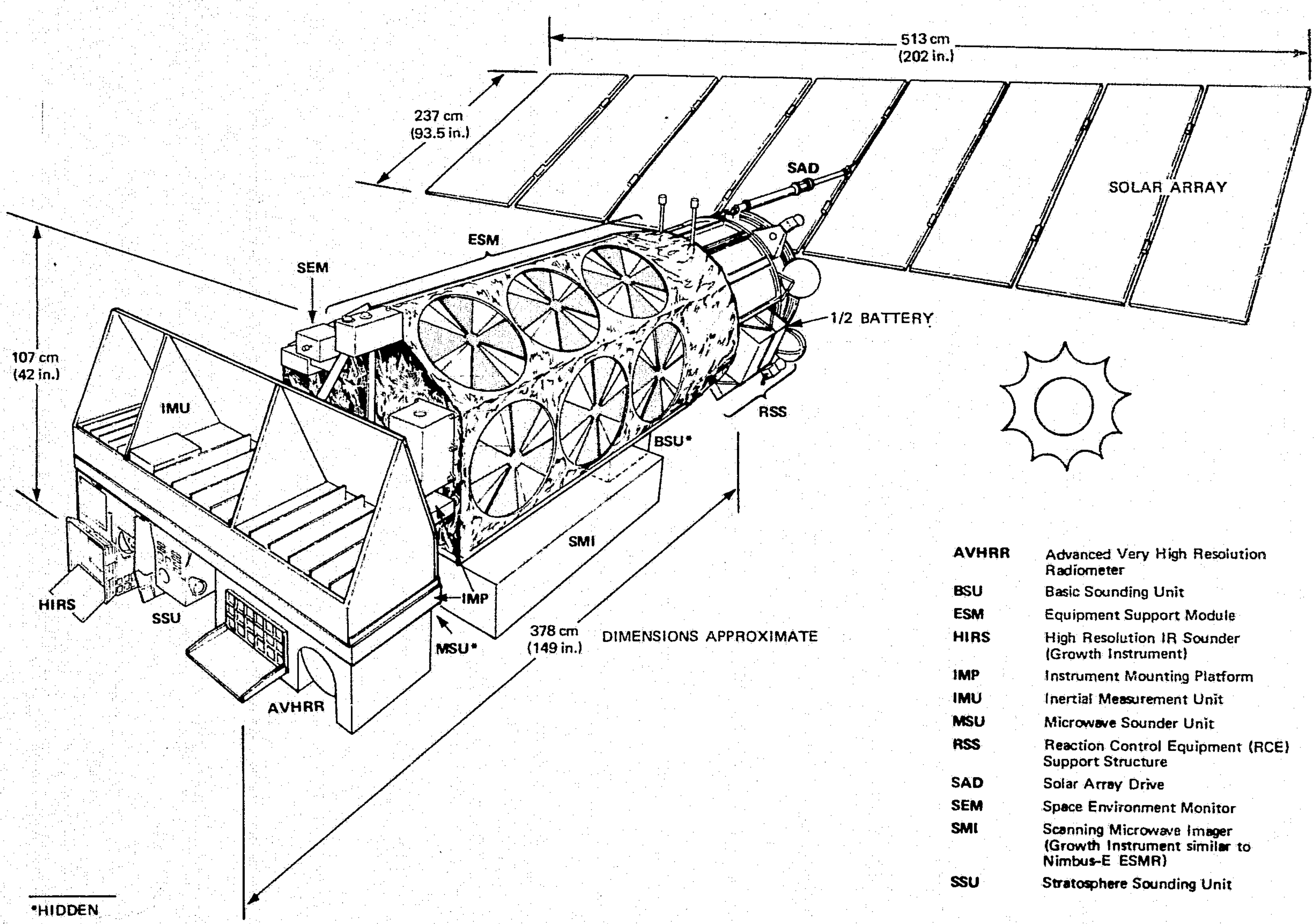
The TOVS, DCS, and SEM data will be transmitted continuously through the beacon at 137-138 MHz. The AVHRR data will be transmitted continuously in the 1695-1710 MHz range, and will include the beacon transmitted data time multiplexed with it. Two channels of the AVHRR data will be resolution reduced, corrected for earth curvature distortion and transmitted continuously in the 137 MHz range, in an APT compatible format.

All of the TOVS, DCS, and SEM data, together with a reduced resolution AVHRR data, will be collected globally and transmitted to NOAA CDA stations at Gilmore, Alaska and Wallops Island, Virginia, for transmission to Suitland, Maryland where the data will be processed in a large central computer. Data transmission from the CDA stations will be by commercial communications satellite as shown in Figure 4. In addition, a western European station will be used to relay TOVS data during the two to four orbits in which the CDA stations do not view the spacecraft.

5.4 Data Handling and Communication System

TIROS-N has two telemetry processors for data handling, TIROS Information Processor (TIP) and the Manipulated Information Rate Processor (MIRP). The TIP processes all lower rate data and the MIRP processes the high rate AVHRR data and time multiplexes the lower rate TIP data with it as shown in Figure 5.

The TIP provides serialized data from all the lower rate sources and provides it to one of two redundant VHF transmitters for continuous real-time transmission. In addition, the same data is presented to the MIRP for time multiplexing with the AVHRR data, as well as being provided to the tape recorder for special recording for blind orbit coverage and playback to a European station (not shown on Figure 5).



AVHRR	Advanced Very High Resolution Radiometer
BSU	Basic Sounding Unit
ESM	Equipment Support Module
HIRS	High Resolution IR Sounder (Growth Instrument)
IMP	Instrument Mounting Platform
IMU	Inertial Measurement Unit
MSU	Microwave Sounder Unit
RSS	Reaction Control Equipment (RCE) Support Structure
SAD	Solar Array Drive
SEM	Space Environment Monitor
SMI	Scanning Microwave Imager (Growth Instrument similar to Nimbus-E ESMR)
SSU	Stratosphere Sounding Unit

Figure 3. TIROS-N Configuration

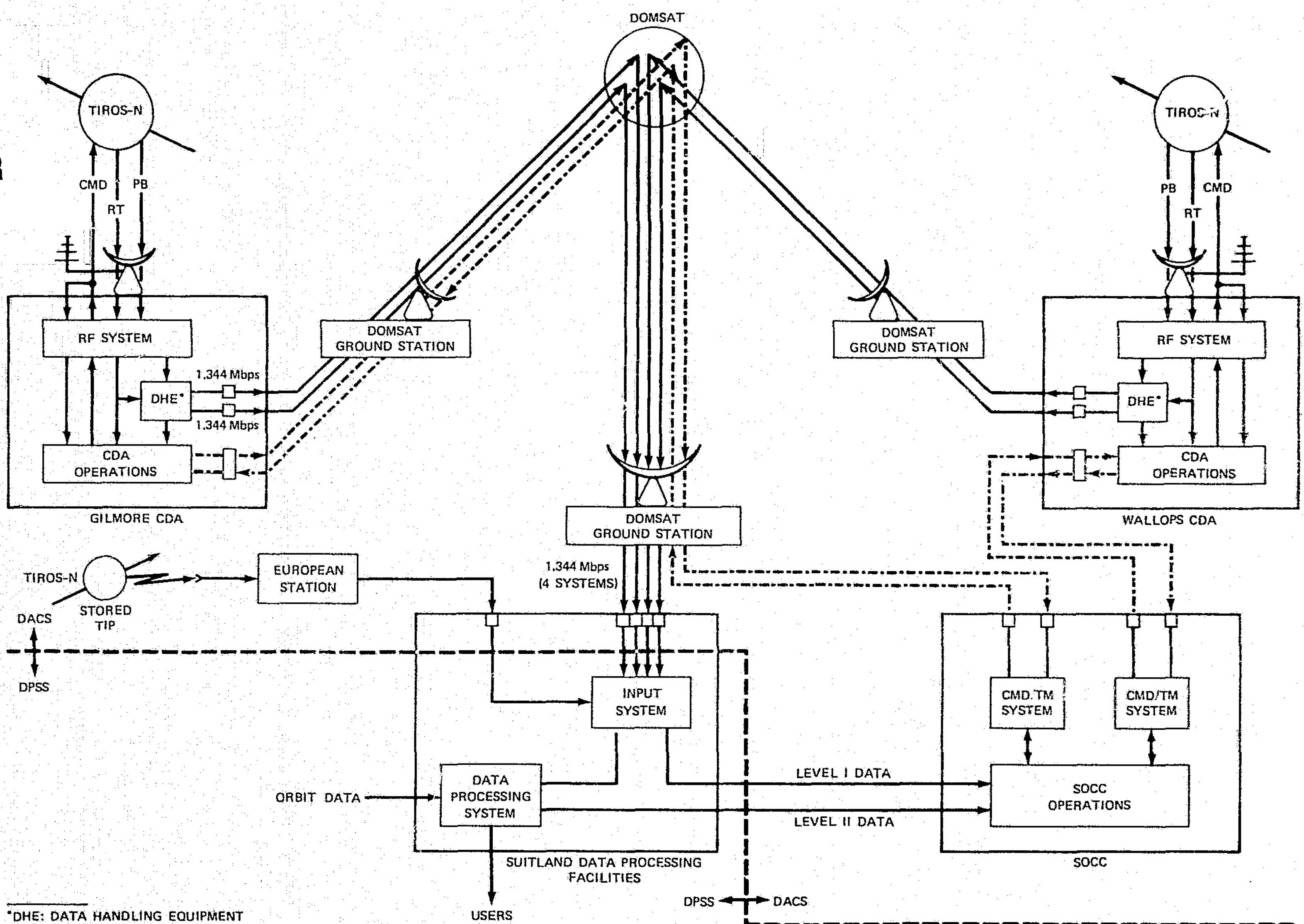


Figure 4. The Baseline Ground System Concept for TIROS-N

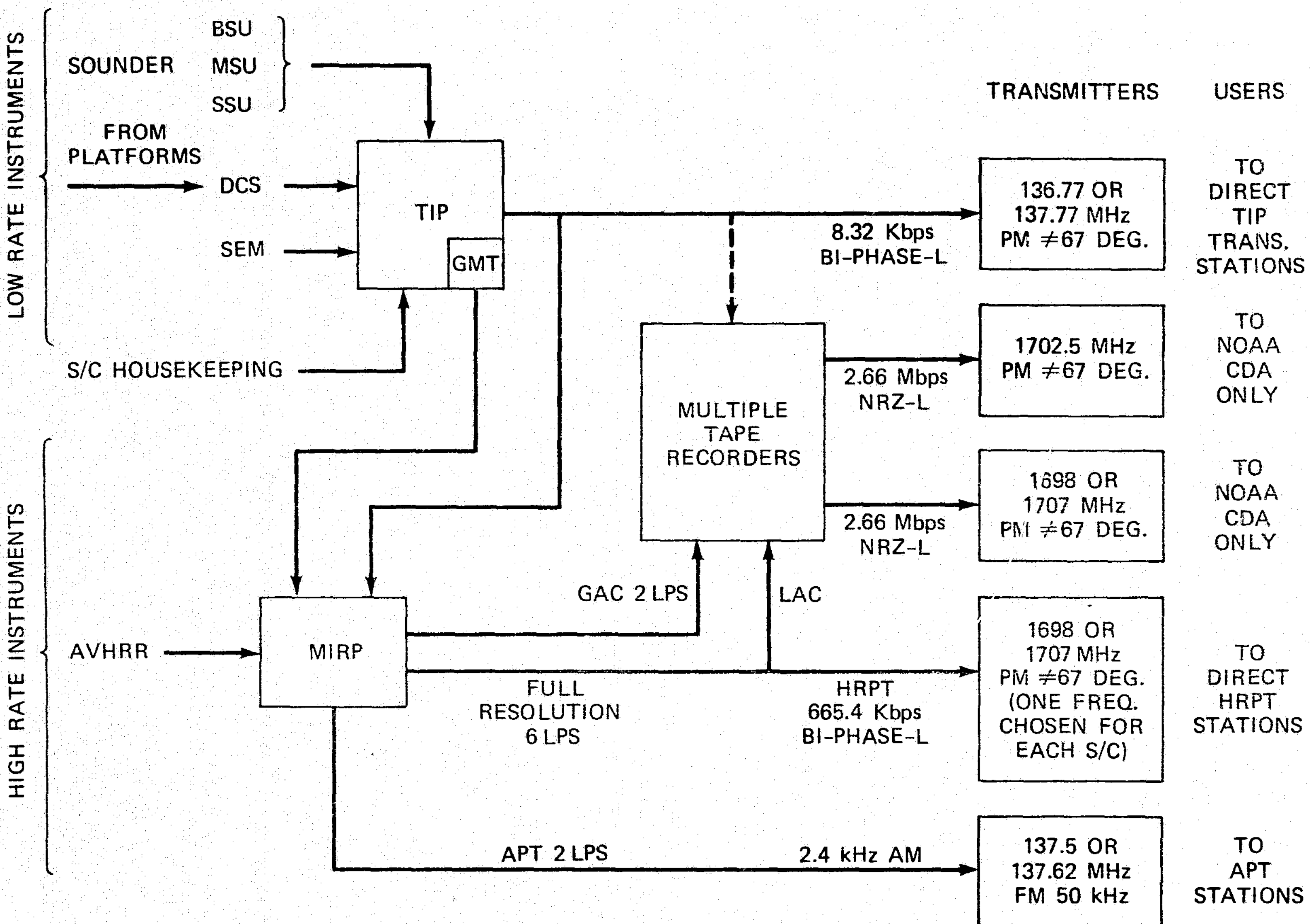


Figure 5. TIROS-N Data Block Diagram

The MIRP processes the AVHRR and TIP data and provides four outputs. High Resolution Picture Transmission (HRPT) output is forwarded to either of the two outer band transmitters (frequency fixed for any one spacecraft until a failure occurs) for continuous transmission. The HRPT data is also provided to the tape recorder to become Local Area Coverage data (LAC) by being recorded in selected segments for recovery at the CDA stations. In addition, the AVHRR data is processed to reduced resolution and provided to the tape recorders as Global Area Coverage (GAC) for recovery at the CDA stations. Finally, the MIRP processes the AVHRR data by reducing resolution and correcting geometric distortion, converts to an AM aignal and forwards this to one of two redundant VHF transmitters for continuous Automatic Picture Transmission (APT) data.

Figure 6 is a block diagram of the communications subsystems. The link analysis for these are shown in Tables V, VI, and VII. The characteristics of the DCS are given in Report AE/2.

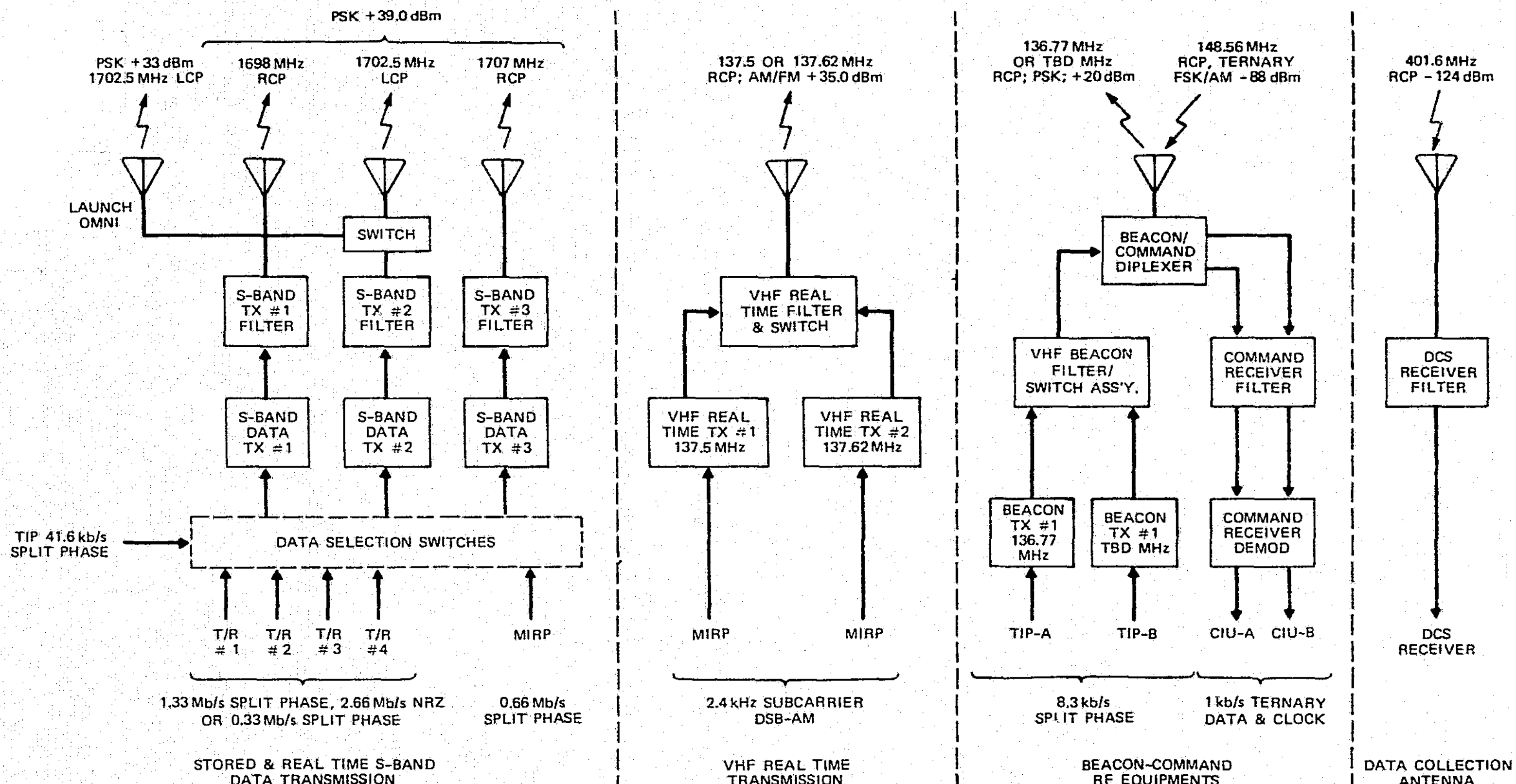


Figure 6. TIROS-N Communications Subsystems

Table V

TIROS-N S-Band Link Analysis

Parameter	Stored Data 2.66 Mb/s to CDA		Stored TIP to Europe 330 kb/s		AVHRR Real Time 660 kb/s	
	Worst Case	Nominal	Worst Case	Nominal	Worst Case	Nominal
Transmitter Power, dBm	37.2	37.8	37.2	37.8	37.2	37.8
Cable Loss, dB	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Antenna Gain, dBi	2.0	3.1	2.0	3.1	2.0	3.1
EIRP, dBm	38.7	40.4	38.7	40.4	38.7	40.4
Free Space Loss (5° Elev.), dB	-166.2	-166.2	-166.2	-166.2	-166.2	-166.2
Polarization Loss, dB	-0.5	-0.2	-0.5	-0.2	-0.5	-0.2
Fading and Rain, dB	-0.4	0	-0.4	0	-0.4	0
Ground Antenna Gain, dBi	46.8	46.8	31.0	31.0	31.0	31.0
Total Received Power, dBm	-81.6	-79.2	-97.4	-95.0	-97.4	-95.0
Modulation Loss, dB	-0.7	-0.6	-0.7	-0.6	-0.7	-0.6
Pre Mod. Filter Loss, dB	-1.2	-1.0	-0.2	-0.1	-0.4	-0.3
Effective Received Power, dBm	-83.5	-80.8	-98.3	-95.7	-98.5	-95.9
System Noise Temp., °K	324	324	280	280	280	280
Noise Spectral Density dBm/Hz	-173.5	-173.5	-174.2	-174.2	-174.2	-174.2
Adj. Chan. Inter. Degrad., dB	-7.2	-4.8	0	0	-1.2	0
Bit Rate Bandwidth dB-Hz	64.2	64.2	55.2	55.2	58.2	58.2
Total Noise, dBm	-102.1	-104.5	-119.0	-119.0	-114.8	-116.0
E_b/N_o, dB	18.6	23.7	20.7	23.3	16.3	20.1
Demod. Loss, dB	3.0	3.0	3.0	3.0	3.0	3.0
Required $E_b/N_o(10^{-6})$, dB	10.5	10.5	10.5	10.5	10.5	10.5
Margin, dB	5.1	10.2	7.2	9.8	2.8	6.6

Table VI

TIROS-N VHF Real Time APT Link

Parameter	Worst Case Value	Nominal Value	Remarks
Transmitter Power, dBm	37.0	37.5	5 watt min. EOL
Cable Loss, dB	-0.5	-0.4	
Antenna Gain, dBi	-0.3	+0.7	Unshaped Quadrifilar @ 63°
Filter/Switch Assembly, dB	-0.9	-0.6	
EIRP, dBm	+35.3	+37.2	
Free Space Loss, dB	-144.4	-144.4	137.5 MHz, 5° Elevation
Polarization Loss, dB	-0.5	-0.5	Ellipticity = 4 dB S/C, 3.5 dB Gnd.
Ground Antenna Pointing Error, dB	-0.3	0	
Ground Antenna Gain, dBi	10.0	10.0	
Total Received RF Power, dBm	-99.9	-97.7	
System Noise Temperature, °K	3460	3460	
Noise Spectral Density, dBm/Hz	-163.2	-163.2	
Receiver IF Bandwidth, dB-Hz	47	47	50 kHz IF
Total Noise Power, dBm	-116.2	-116.2	
C/N, dB	16.3	18.5	f_{LP} = 1.4 kHz, m = 0.9
AM-FM Gain, dB	18.8	18.8	Δ_f = 17 kHz
P-P/RMS Factor, dB	9.0	9.0	f_{SC} = 2.4 kHz
S/N (P-P/RMS), dB	44.1	46.3	

Table VII

TIROS-N Beacon/Command Link Analysis

Parameter	Beacon Link		Command Link		Local TIP Link
	Worst Case Value	Nominal Value	Worst Case Value	Nominal Value	Worst Case
Transmitter Power, dBm	27.0	28.0	60.0	60.0	27.0
S/C Cable Loss, dB	-1.0	-0.5	-1.0	-0.5	-1.0
S/C Antenna Gain, dBi	-4.5	-2.0	-4.5	-2.0	-4.5
S/C Filter/Switch Assembly, dB	-2.1	-1.5	-7.3	-6.0	-2.1
EIRP, dBm	19.4	24.0	69.0	69.0	19.4
Free Space Loss (5° El.), dB	-144.4	-144.4	-145.5	-145.5	-144.4
Polarization Loss, dB	-1.0	-0.5	-0.4	-0.2	-1.0
Ground Antenna Pointing Error, dB	-0.2	0	-0.1	0	-0.2
Ground Antenna Gain, dBi	27.6	27.6	9.0	9.0	16.0
Total Received RF Power, dBm	-98.6	-93.3	-89.8	-85.2	-110.2
System Noise Temp., °K	1922	1922	1483	1483	1922
Noise Spectral Density, dBm/Hz	-165.8	-165.8	-166.9	-166.9	-165.8
Receiver IF Bandwidth, dB-Hz	—	—	46.2	46.2	—
Total Noise Power, dBm	—	—	-120.7	-120.7	—
Modulation Loss, dB	-0.7	-0.6	-5.9	-5.7	-0.7
Bit Rate Bandwidth, dB-Hz	39.2	39.2	30.0	30.0	39.2
Received E_b/N_o, dB	27.3	32.7	41.2	46.0	15.7
Required $E_b/N_o (10^{-6})$, dB	13.5	13.5	20.0	20.0	13.5
Margin, dB	13.8	19.2	21.2	26.0	2.2

6.0 THE NIMBUS SATELLITES

Nimbus was conceived as a meteorological satellite concerned primarily with providing atmospheric data for improved weather forecasting. Its objectives are to serve as the R&D vehicle for the development and application of space technology to the problems of meteorology and weather forecasting. The Nimbus satellite carries a stabilization and attitude-control system which points the axis of symmetry of the vehicle towards the center of the Earth. The Nimbus spacecraft are placed in circular, sun-synchronous orbit at about 1,100 km.

The first Nimbus was successfully launched in August 1964. Among the significant contributions made by the Nimbus program to date are: Nimbus 1 and 2 provided nearly continuous day and night high resolution global cloud mapping and storm tracking data. Nimbus 3 and 4 provided techniques for making quantitative measurements of atmospheric structure through measurement of the three-dimensional distribution of atmospheric temperature and humidity. The success of this development and high utility of the data has led to incorporation of similar instrumentation on NOAA-2 to provide these measurements on an operational basis.

Nimbus-5 has been operating satisfactorily in orbit since 11 December, 1972 and has returned extremely useful data. It is providing data measured under conditions where previous infrared techniques were inadequate. These techniques include the use of microwave instruments for the first time from space to help overcome one of the limitations inherent in existing temperature measurement techniques and the mapping of surface features, i.e., the interference of clouds. Because of the importance of such measurements in a global meteorological system, Nimbus-5 and Nimbus-6 will improve our ability to observe the atmospheric mass and motion and surface features.

Nimbus-6, launched recently, contains improvements in microwave and infrared mapping over that received from Nimbus-5. A new experiment, the Tropical Wind, Energy Conversion and Reference Level Experiment (TWERLE), provides measurements, using balloon platforms, of lower stratospheric winds in the tropics and in situ measurements to verify the remote measurements in this data-sparse area. These data will improve the knowledge of energy conversion from the tropics to temperate zones. Another new experiment, the Earth Radiation Budget (ERB) experiment contributes to an assessment of the long-term effects of pollutants on the climate by determination of the earth's global and regional heat budget. For the first time, the angular dependence of the outgoing radiation as well as the total incoming radiational energy will be measured. Another new experiment is the Limb Radiance Inversion Radiometer (LRIR) which will extend vertical temperature profiles to altitudes previously sounded only by rockets. The Nimbus spacecraft's demonstrated capabilities in earth pointing from a stable platform will next be put to use in Oceanographic and Air Pollution observations by Nimbus-G.

6.1 Communications and Data Handling Subsystems (thru Nimbus-6)

6.1.1 Telecommand

Instructions must be issued to the spacecraft to activate or deactivate subsystems for data readout or to analyze the satellite problems, in case of malfunctions. A narrowband channel at 149.52 MHz is employed to give telecommands. To improve the protection against other transmitters, the code contains an address which is checked in the spacecraft and upon verification the "execute" telecommand is transmitted.

6.1.2 Tracking

Tracking systems used by the United States require a stable low-power beacon with low sideband interference close to the carrier. Nimbus uses a frequency in the 136 to 137 MHz band. This transmitter is employed also for VIP telemetry.

6.1.3 The Versatile Information Processor (VIP)

The VIP samples approximately 1000 outputs from spacecraft systems. The sensor data are digitized (where necessary), time-multiplexed, and formatted into a 4kbit/s serial bit stream. The serial bit stream can be recorded in biphase on the High Data Rate Storage System (HDRSS) tape recorder and simultaneously transmitted over the Pulse Code Modulation (PCM/AM) 136.5 MHz beacon transmission link.

Data transmitted in the VIP mode include spacecraft subsystem and experiment housekeeping telemetry such as temperature of components, calibration signals and voltages, plus the output of experiments. Switching is provided in the VIP so that, when commanded, the standard NASA time code format data (100 bits, pulse duration modulation) are substituted for the VIP data.

6.1.4 High Data Rate Storage System (HDRSS)

The HDRSS consists of a 5-channel tape recorder and the associated recording and playback electronics for collecting and storing data from sensors, VIP subsystems, and the time code. For purposes of redundancy and extending useful data capacity, there are two parallel and independent systems. The recorders can record in parallel or can be programmed to record sequentially for more complete coverage.

Included with this system is the band 9 transmitter to transmit the data to the ground. Each HDRSS operates into a 5-watt (nominal) solid-state transmitter. The transmitters operate at 1 702.5 MHz. Normal operation will use only one transmitter, with the capability of switching should one transmitter fail.

6.1.5 Data Collection and Location System

The Nimbus-6 Random Access Measurement System (RAMS) provides data collection, location and velocity determination for a large number of simple, inexpensive platforms. The platforms randomly transmit pulses of information to the satellite and the platform positions are derived from the relative motion between the platform and the satellite as determined by the measurement of frequency change of the signal received from the platform.

This system is being used to conduct TWERLE shown in Figure 7. The platforms transmit in the 401.2 MHz range. The sensor data produced by each platform are transmitted during a 1-second interval each minute. It is estimated that only 200 balloons (of a maximum of 400 in flight at any one time) will be overpassed in any twelve hour period and that 3-to-15 transmissions will be received from any one platform in an orbit. An average of 450 receptions per orbit are expected with a possible 900 receptions per orbit over the South Atlantic. These receptions consist of 64 bits of PCM data, 32 of which contain sensor data (temperature, pressure, altitude, etc.). Locating of platforms is performed by iterative analysis of the doppler signature detected from the sequence of platform receptions.

This information is demodulated by the RAMS, formatted by the VIP, and stored at 4 kbit/s on one of two HDRSS tape recorders aboard the satellite. The VIP/HDRSS data are played back and time reversed at 128 kbit/s to ground stations. The VIP data volume normally telemetered is 260 Mbit/s/orbit.

6.1.6 Nimbus-6 Tracking and Data Relay Experiment

This experiment is being conducted with ATS-6. Figure 8 shows the low altitude (1,100 km) Nimbus in relation to the ATS in equatorial synchronous orbit. Table VIII gives the communications characteristics.

6.2 Communications and Data Handling Subsystem for Nimbus-G

Figure 9 shows the Nimbus-G communications and data handling system described below.

6.2.1 S-Band Transponder Subsystem

The S-Band transponder subsystem consists of two S-Band transponders. Each transponder includes one S-Band receiver and one S-Band transmitter. Both

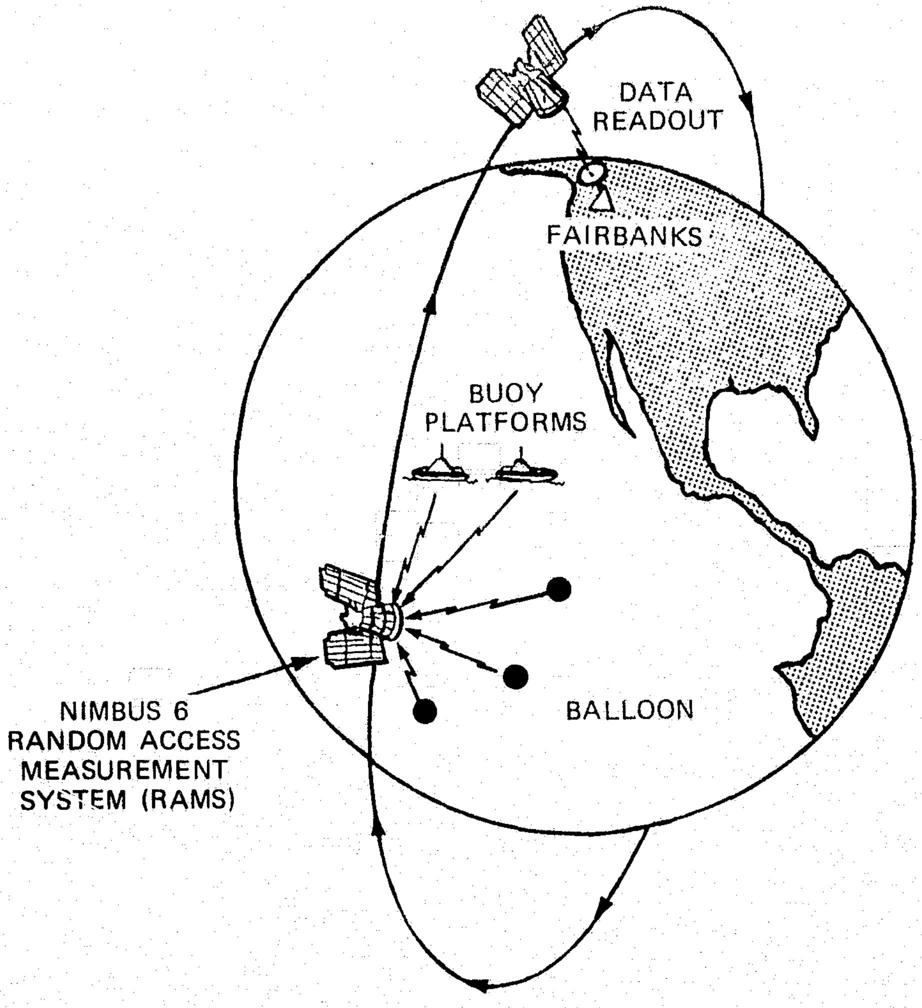


Figure 7. Tropical Wind, Energy Conversion and Reference Level Experiment (TWERLE)

S-Band receivers are energized; either of which can be used for two-way range rate and ranging and commands to the spacecraft. One of the two transmitters can be selected to provide the downlink. The downlink can be used for simultaneous transmission of 4 kbs real-time VIP telemetry and one of the following:

- STDN ranging signals, including the 500 kHz major tone, as defined in STDN 101.1 Rev. 2.
- 800 kbs Bi-phase PCM playback signal from a selected on-board tape recorder.
- 800 kbs Bi-phase PCM real-time CZCS sensor data.
- 25 kbs Bi-phase PCM real-time Digital Information Processor (DIP) sensor data.

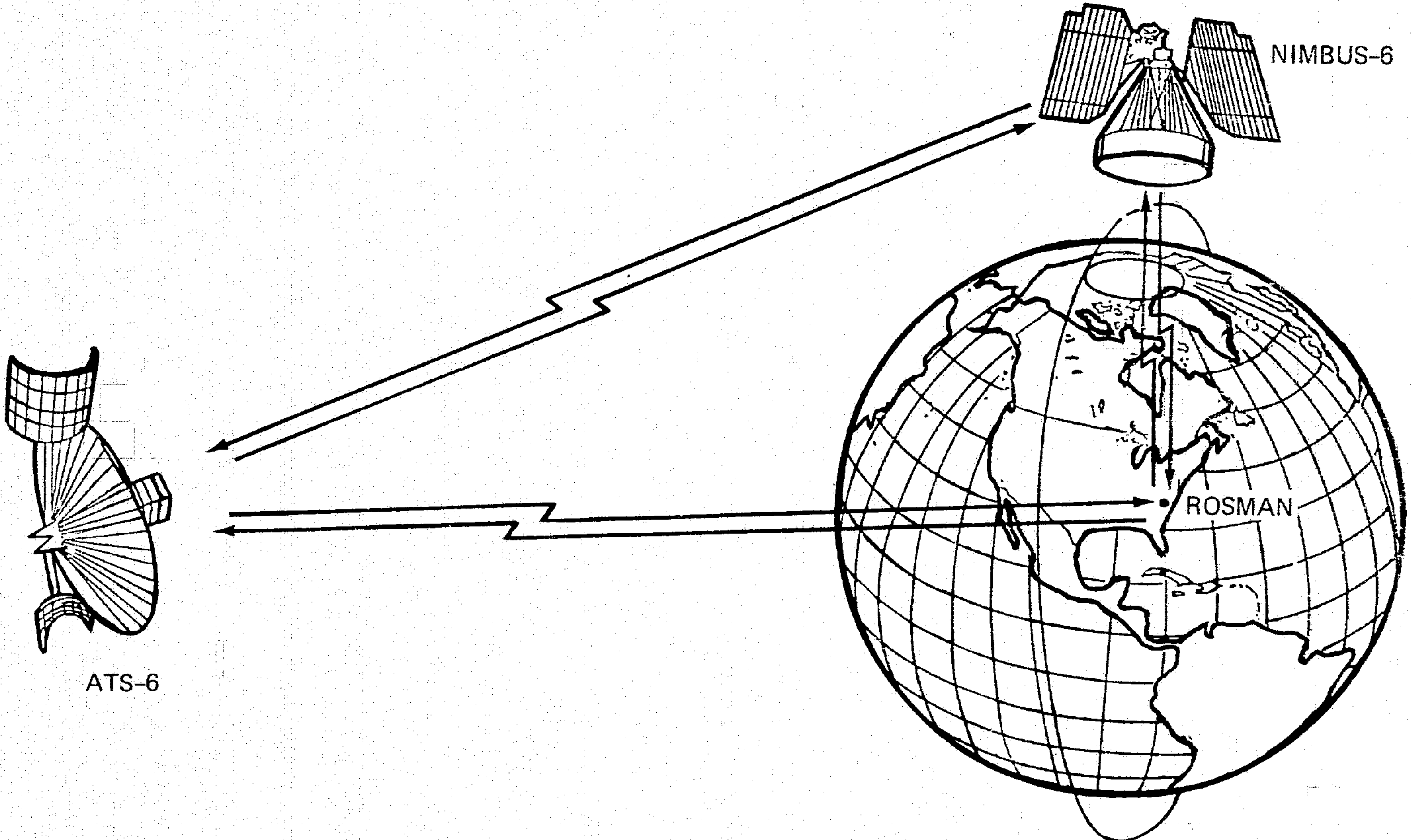


Figure 8. ATS-6 Nimbus T&DRE

Table VIII

Nimbus-6 T&DRE Performance Characteristics

Receive Frequency	2062.85 MHz
Transmit Frequency	2253 MHz
Antenna Gain	16 db
Antenna Beamwidth	12° - (1 db)
Gimbal Pointing Accuracy	±1.75° (static)
Gimbal Slew Velocity	30°/min.
Gimbal Operational Limits	±108.8°
Transponder Operating Range	(-60 dbm to -107 dbm)
Transmit Power	2, 4, 8 watts (nominal)
Time Delay Variation	±50 ns

Two-way range rate and ranging is not required when the downlink of one transponder is used with the receiver of the other transponder. The transponder receiving frequency is 2093.514583 MHz and the transmitting frequency is 2273.5 MHz. The transponder is capable of coherent operation (221:240 receive to transmit frequency ratio) or non-coherent operation, selectable by command.

6.2.2 Command and Data Interface Unit (CDIU)

The CDIU provides command interface between the transponder receivers and the command clock subsystem and transponder transmitters and the telemetry and data processing subsystems. In addition, the CDIU provides decoding of emergency commands and ancillary telemetry functions. The CDIU consists of redundant circuitry and power supplies and performs the following functions:

- Demodulates the command subcarriers from the transponder receivers and provides command data, clock, and enable signals to the command decoders.
- Decodes and executes emergency commands which are transmitted in real time from the command ground station.

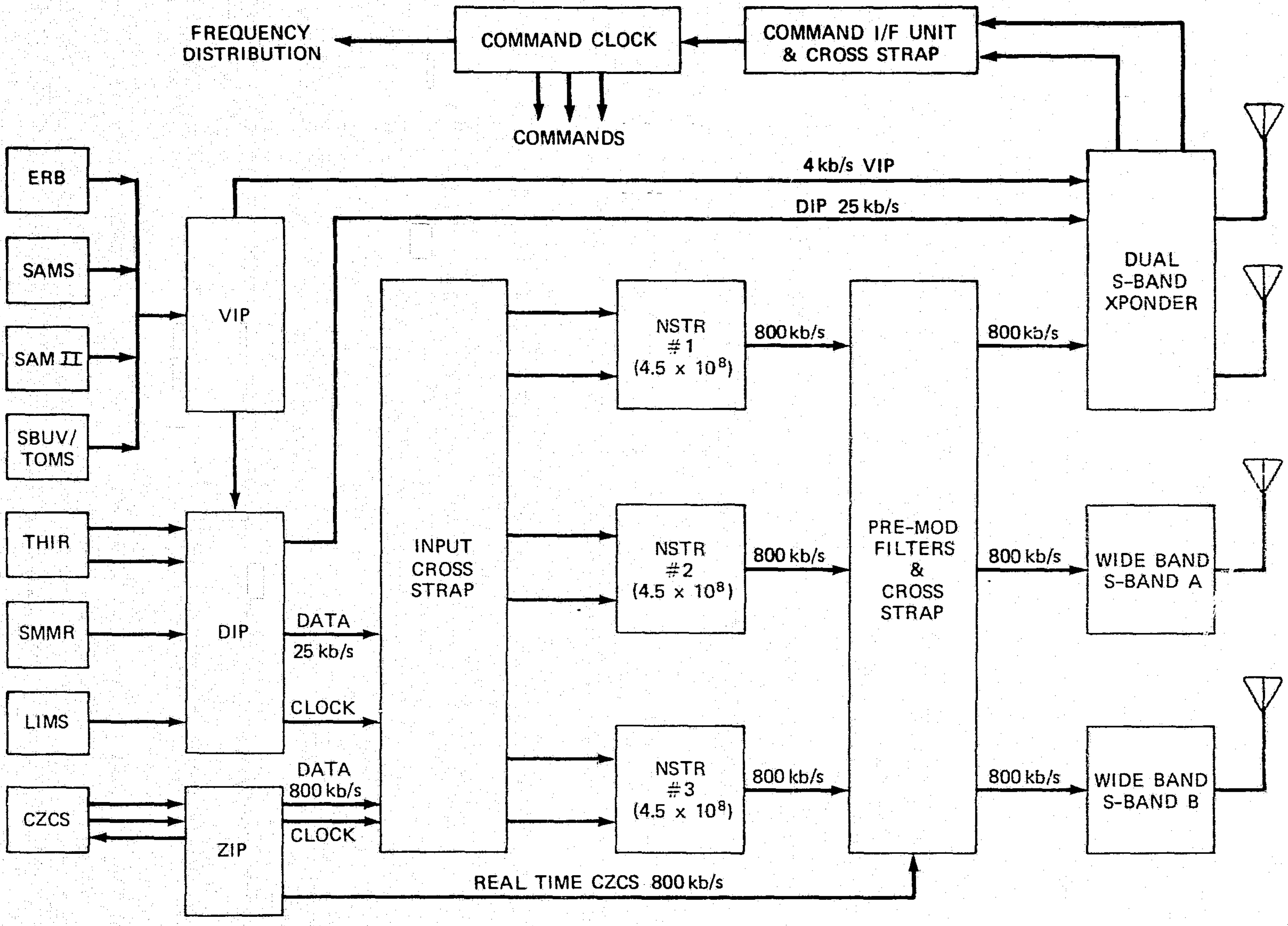


Figure 9. Nimbus-G Communication and Data Handling System

- Accepts 4kbs Bi-phase PCM real time VIP telemetry signals from the VIP subsystem and generates and provides 1560kHz PCM/PM subcarrier signals to the transponder transmitters.
- By monitoring the transponder coherent AGC voltage, provides automatic turn-on of the transponder transmission upon uplink lock and turn-off upon loss of lock. The automatic turn-on circuit is capable of being disabled by command.
- Turns off the Wideband S-Band Transmitters twenty minutes after their turn-on for spacecraft safety in case turn-off of these transmitters has been inadvertently deleted. The time is capable of being reset or disabled by command.

6.2.3 The Versatile Information Processor (VIP)

(See Section 6.1.3 for description.)

6.2.4 Digital Information Processor (DIP)

The DIP is a dual redundant PCM telemeter that accepts VIP, LIMS, and SMMR serial digital inputs and two THIR analog inputs from on-board experiments. The input data, together with time code, synchronization words and fill words, is formatted and outputted as a 25kb/sec PCM data stream. The DIP also contains an input router which routes data from the DIP and the ZIP to on-board tape recorders. The output router routes data from the tape recorders to the S-Band transmitters and transponders. The data is routed via logic commanded by relays under control of the spacecraft command decoder.

6.2.5 Coastal Zone Information Processor (ZIP)

The ZIP is a non-redundant rate buffer memory with 12K words x 8 bits of storage. The purpose of the ZIP is to accept 8 bit parallel data from the Coastal Zone Color Scanner (CZCS) experiment in high rate bursts and to provide a smoothed 800kb/sec output for transmission or recordings. The ZIP smooths the high rate burst CZCS data, formats this with S/C time code, synchronization words and fill words, and outputs the 800kb/sec PCM data stream. The memory technology employed is 4K N-channel silicon gate MOS.

6.2.6 Tape Recorder Subsystem

The Nimbus-G spacecraft uses three NASA Standard Tape Recorders (NSTR). Each tape recorder is identical and stores 4.5×10^8 bits of digital data. One recorder records Digital Information Processor (DIP) data at 25kbs, Bi-phase for periods up to 300 minutes. Another recorder records Coastal Zone Color Scanner Information Process (ZIP) data at 800 kbs, Bi-phase in bursts of 1 to 8 minutes duration each orbit until the recorder is full. The third recorder is a redundant unit that can be used for either the DIP or ZIP function should a recorder failure occur. The spacecraft Command and Data Handling Unit is designed to route either DIP or ZIP data to any one of the three recorders through use of the input router.

All data is reproduced in the reverse direction with data recorded last reproduced first at 800 kbs, Bi-phase. Each recorder responds to its own command set, which while the functions are identical for all three recorders, the specific commands are different. In the reproduce mode, the data is routed through a digital buffer which removes all tape recorder wow, flutter, jitter, and distortion. This reproduced data has a maximum assymetry of ±1% and with a frequency stability of the Nimbus 1.6 MHz crystal clock of typically ±0.01%. Each recorder also provides diagnostic telemetry.

The projected minimum lifetime of each tape recorder is 20,000 tape passes; or for the Nimbus-G mission with three tape recorders, used two at a time continuously for the DIP and ZIP modes previously described, provide about 4 years of tape recorder life.

7.0 SYNCHRONOUS METEOROLOGICAL SATELLITES (SMS)

The SMS is the first in a series of spacecraft which will comprise the eventual GOES system. Initially, SMS-1 was positioned in geostationary orbit over the eastern Atlantic to support the GARP Atlantic Tropical Experiment in the summer of 1974. It was later moved to its present position at 75°W longitude. This satellite, together with SMS-2 positioned at 115°W longitude provides coverage as shown in Figure 10. SMS has picture taking and communication functions on an operational basis that previously were available only experimentally. Growing out of concepts proven in the SYNCOM and ATS programs, SMS yields new and improved data for weather prediction, environmental sensing and timely warning of hazardous environmental conditions.

SMS was conceived as a multifunction spacecraft with a high resolution radiometer responsive in both the visible and infrared bands as its prime subsystem. In addition, it carries a high power transmitter for disseminating the radiometer video. A communications transponder is also onboard which allows the relay of facsimile charts and the received visual and IR video data to weather stations in remote areas, and serves as a repeater for signals transmitted from a large number of inexpensive, low power, known location, environmental data collection platforms (DCP). Some of these platforms report data on a synoptic basis while others report only in the event of emergencies, such as flood stage or earthquake. As usual with multifunctional satellites, SMS was required to have band 8 telemetry and command equipment (separate from and in addition to the communications transponder). In addition to transmitting spacecraft maintenance telemetry, the telemetry system is used to transmit the output of the Space Environment Monitor (SEM), an instrument package to measure radiation and magnetic fields in space. Finally, a method for determining the subsatellite point in real time is necessary in order to overlay a highly accurate latitude and longitude grid on the cloud cover pictures. The SMS/GOES frequency utilization is shown in Table IX.

7.1 Tracking and Telemetry

Once on station, the precise position and drift rate of the SMS is determined through a Trilateration Range and Range Rate system, which uses sidetone ranging. In the fine ranging mode, this system utilizes three 1 MHz bands in the 1 682.5 MHz region.

The SMS/GOES maintenance telemetry is transmitted on a center frequency of 1 694 MHz.

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SMS-1 & 2 USEFUL CAMERA COVERAGE AND COMMUNICATIONS

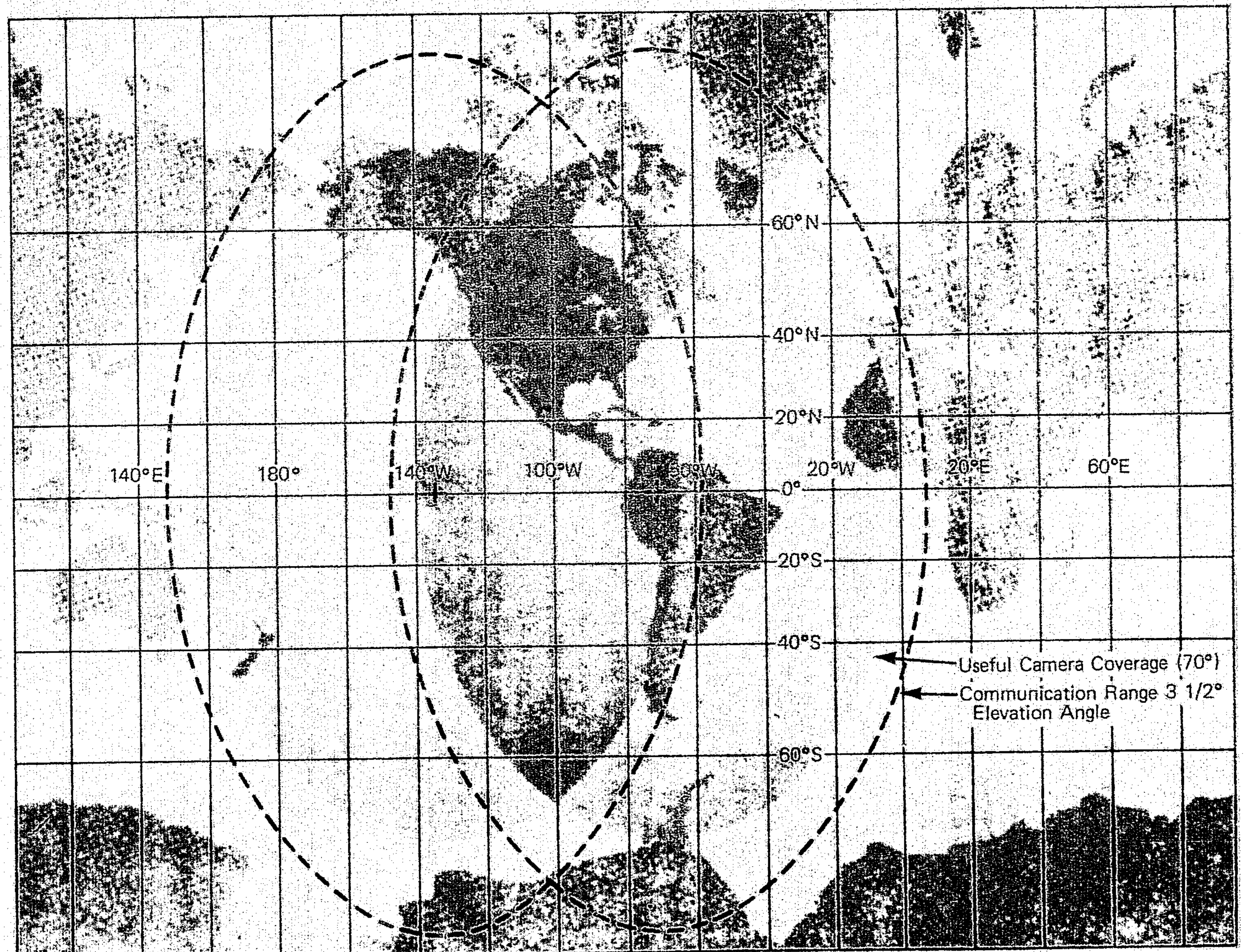

Figure 10. SMS-1 and 2 Useful Camera Coverage and Communications

Table IX

SMS/GOES Frequency Assignments

Uplink	Center Frequency	Transponder 3 db Bandwidth
DCP Reports	401.900 MHz	400 kHz
Stretched VISSR, WEFAX	2030.100 MHz }*	8.2 MHz
Ranging	2029.100 MHz	
DCP Interrogation	2034.925 MHz	200 kHz
S/C Command	2034.200 MHz	60 kHz
Downlink	**Center Frequency**	**Transponder 3 db Bandwidth**
DCP Interrogation	468.850 MHz	200 kHz
VISSR Data	1681.600 MHz	23.2 MHz
Stretched VISSR, WEFAX	1688.100 MHz } *	8.2 MHz
Ranging	1687.100 MHz	
DCP Reports	1694.500 MHz	400 kHz
Telemetry	1694.000 MHz	200 kHz

*Stretched VISSR, WEFAX and Ranging lie within the 8.2 MHz bandwidth.

7.2 Visible Infrared Spin-Scan Radiometer (VISSR)

The primary mission of SMS is to provide up-to-the-minute weather information through the use of high resolution spin-scan pictures. The high resolution of the VISSR, coupled with the ability to obtain a new full earth picture each 20 minutes, presents the meteorologist with a powerful instrument for making observations on the mesoscale.

The visible spectrum pictures permit meteorologists to view virtually in real time the evolution and motions of storms and other atmospheric phenomena.

Analysis of the reflection of the sun on the surface of the sea may lead to the ability to infer surface wind velocity and height of waves, providing important data for maritime interests. The infrared pictures extend storm tracking capability through the night. In addition, sensing in the infrared allows temperature measurements to be made of cloud tops and in cloud free portions of the terrain or ocean surface on a 24-hour basis. Such data provide additional inputs for mathematical modeling of the atmosphere with the hope of leading to improvements in the quantitative treatment of weather forecasting.

The VISSR selected for the SMS is equipped with eight identical visible and two infrared sensors. The instantaneous geometric field of view at the subsatellite point for each visible sensor is 0.025 x 0.021 milliradians (0.9 km earth resolution) and that of the infrared sensors 0.25 milliradians square (about 9 km earth resolution). The eight visible sensors are aligned so that they scan the same total area as a single infrared sensor during each earth-viewing period. The second infrared sensor is redundant and views the same area as the primary sensor. The spin-scan image is formed in the East-West plane by the spinning motion of the spacecraft while the North-South scan is performed by mechanically tilting the scan mirror. The North-South scan occurs in discrete steps while the VISSR is looking into space. Thus, the image is formed in very much the same way as a television picture. The total earth image will be composed of 1821 scans.

The VISSR data from the spacecraft are transmitted to the Command and Data Acquisition (CDA) station in 30 ms bursts every 600 ms spin period (assuming a spin rate of approximately 100 rpm).

7.3 Stretched VISSR Data

The wideband VISSR transmissions from the spacecraft are received at the CDA station, which is equipped with an 18 m diameter parabolic antenna and a cooled parametric RF preamplifier giving an overall system noise temperature of 100°K. By synchronizing its transmissions with the spacecraft spin, the CDA retransmits the VISSR data with a reduced bandwidth. This "stretched" VISSR data is relayed through the SMS/GOES transponder to the relatively inexpensive Data Utilization Stations. These transmissions are digital, utilizing bi-phase-shift keying (PSK) of the carrier. A band 9 transmitter, with a 3 db bandwidth of 8.2 MHz is used to transmit the "stretched" data to the National Environmental Satellite Center (NESC).

7.4 Data Collection System

The data collection system enables environmental data sensed at more than 10,000 known location data collection platforms to be relayed through the satellite to the CDA. Three methods of report initiation are used: Satellite interrogation, timed transmission and threshold initiation. The platforms utilizing threshold initiation form an emergency network to give warning of the occurrence of earthquakes, tidal waves, river levels and other potentially hazardous natural phenomena.

The interrogation signal transmitted from the CDA station is so situated in band 9 that it falls within a satellite channel which translates the interrogate signal to the band 9 (468.850 MHz) down-link frequency. This down-link signal is normally transmitted at 10 watts although 40 watts is available. The decoding circuit in each DCP continuously compares the incoming addresses with its own. When the platform address decodes properly, the DCP turns on its band 9 PSK transmitter and sends its stored data to the satellite at 100 bits until the message is completed.

The DCP reports are received by the satellite band 9 (401 MHz) receiver which is cross-strapped to the band 9 transmitter. The CDA station receives the reports on the band 9 down-link and coherently demodulates each frequency channel. The data is then sent to the NESC by land line where it is routed to the various data customers throughout the U.S.A. At present, the method for the distribution of DCP data from NESC is by teletype land lines although it could be relayed in bulk form from the CDA through the satellite if the data customers were equipped with the necessary receiving equipment.

7.5 SMS Transponder

The two band 9 transmitters are solid state hard limited amplifiers. Some of the important parameters of the SMS transponder are given in Table X.

7.6 Geostationary Operational Environmental Satellite (GOES)

After SMS-1 and 2 were launched and checked out they became the first of a new operational series of geostationary meteorological satellites. These satellites greatly expand the available United States operational meteorological satellite service.

GOES A, B, and C are identical to SMS 1 and 2. GOES D, E, and F, however, have two principal changes:

- An improved sensor, the VISSR Atmospheric Sounder (VAS)
- Band 8 tracking, telemetry, and command equipment will be replaced with band 9 equipment

Table X

Salient Characteristics of the SMS/GOES Transponders

	Upper Band 9	Lower Band 9
Transmitter Power (Watts)	20	10/40
Transmit Antenna Gain (db) (with losses, on beam center)	15.7	7.4
Receive Antenna Gain (db) (with losses, on beam center)	9.2	4.4
Receiver Noise Temperature (° K)	1630 (mixer)	385 (transistor)
Antenna Design	Switched Phased Array	Switched Dipoles
Antenna Polarization	Linear	Right-Hand Circular
Receive Frequency (MHz)	2 030 ± 5	401.9 ± 0.2
Transmit Frequency (MHz)	1681.6*	468.825 ± 0.75

*14 Mbs sin X/X

The VAS is an extension of the original VISSR imaging capability and includes additional thermal bands for the determination of atmospheric temperature at various altitude layers by spectral selection in the CO_2 absorption bands. Water content is also determined at several altitudes in the H_2O absorption bands. In addition, the cloud and earth surface temperature is measured in a second band for improved temperature values. The VAS preserves the two spectral bands and data format of the early VISSR when operated in the VISSR mode. The additional spectral bands provide new meteorological sounding data from which atmospheric temperature and moisture profiles can be developed when the VAS is operated in the dwell sounding mode. These bands are listed in Table XI. Geometrically precise time sequences of multispectral images showing cloud and water motions and temperatures of selected layers of the atmosphere are provided when the VAS is operated in the multispectral imaging mode. These added capabilities of the VAS provide the additional atmospheric measurements which

Table XI

VAS Infrared Spectral Bands

Spectral Band	ν (cm^{-1})	λ (μm)	$\Delta\nu$ (cm^{-1})	Single Sample S/N at 320°K Scene Temperature		Remarks
				0.192 mr IGFOV (db)	0.384 mr IGFOV (db)	
1	680	14.71	10	22.4	28.4	CO_2
2	692	14.45	16	30.3	36.3	CO_2
3	703	14.22	16	31.0	37.0	CO_2
4	715	13.99	20	33.3	39.3	CO_2
5	745	13.42	20	32.3	38.3	CO_2
6	760	13.16	20	32.4	38.4	CO_2
7	790	12.66	20	32.6	38.6	H_2O
8	895	11.17	140	52.9*	56.6	Window
9	1380	7.25	40	24.7	30.7	H_2O
10	1490	6.71	150	34.3	40.3	H_2O
11	2335	4.28	50	N.A.	38.5	CO_2-InSb Detector
12	2680	3.73	440	N.A.	47.0	Window-InSb Detector

*For 340°K Scene Temperature

enable extensive research in atmospheric science from a geostationary vantage point. Parameter flexibility including spectral band selection, spatial resolution, signal-to-noise (S/N) ratio and geographic location are incorporated into the sounding or multispectral imaging modes to provide measurements which best meet the needs of the research scientist. These three distinct operational modes, which accomplish both the operational and research mission of the VAS, are available. The instantaneous geometric field of view for the infrared sensors has been reduced to 0.192 milliradians to give about 6.9 km earth resolution.

The band 8 equipment being deleted was used primarily during transfer orbit and as a backup to the main system. This is no longer considered necessary.

Figure 11 summarizes the GOES D, E, and F communication systems.

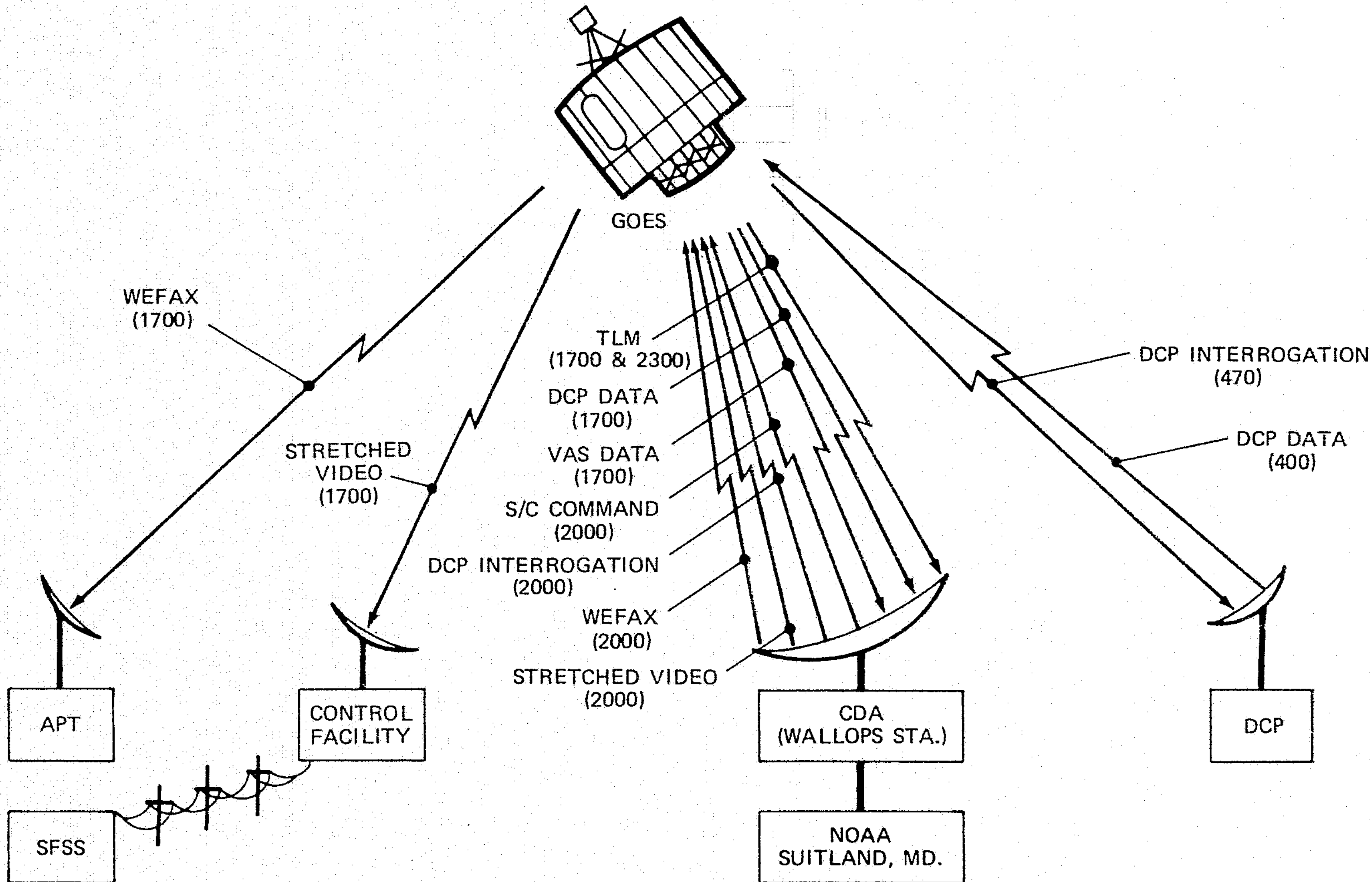

Figure 11. GOES D, E, and F Communication Systems

8.0 STORMSAT

Stormsat, a planned mission under study, will be a 3-axis stabilized geostationary spacecraft whose prime instrument is the Advanced Atmospheric Sounding and Imaging Radiometer (AASIR). The AASIR is a modified VISSR designed to take advantage of the improved S/N ratio available in a 3-axis-stabilized instrument. Many of the spectral bands being sensed are the same as in the VAS (see Section 7.6). The spacecraft (see Figure 12) for this mission will be the Multimission Modular Spacecraft (MMS) also being planned for Landsat-D (reference document 2/300) and is expected to have similar communication systems. Data rates of about 7 Mbps are planned to support sounding resolution of 13.5 km, thermal imaging resolution of 4.5 km, and visible/near IR imaging resolution of 0.75 km. Coverage will vary from $(750\,\text{km})^2$ up to full earth disk. Launch for this research mission is planned for the early 1980's.

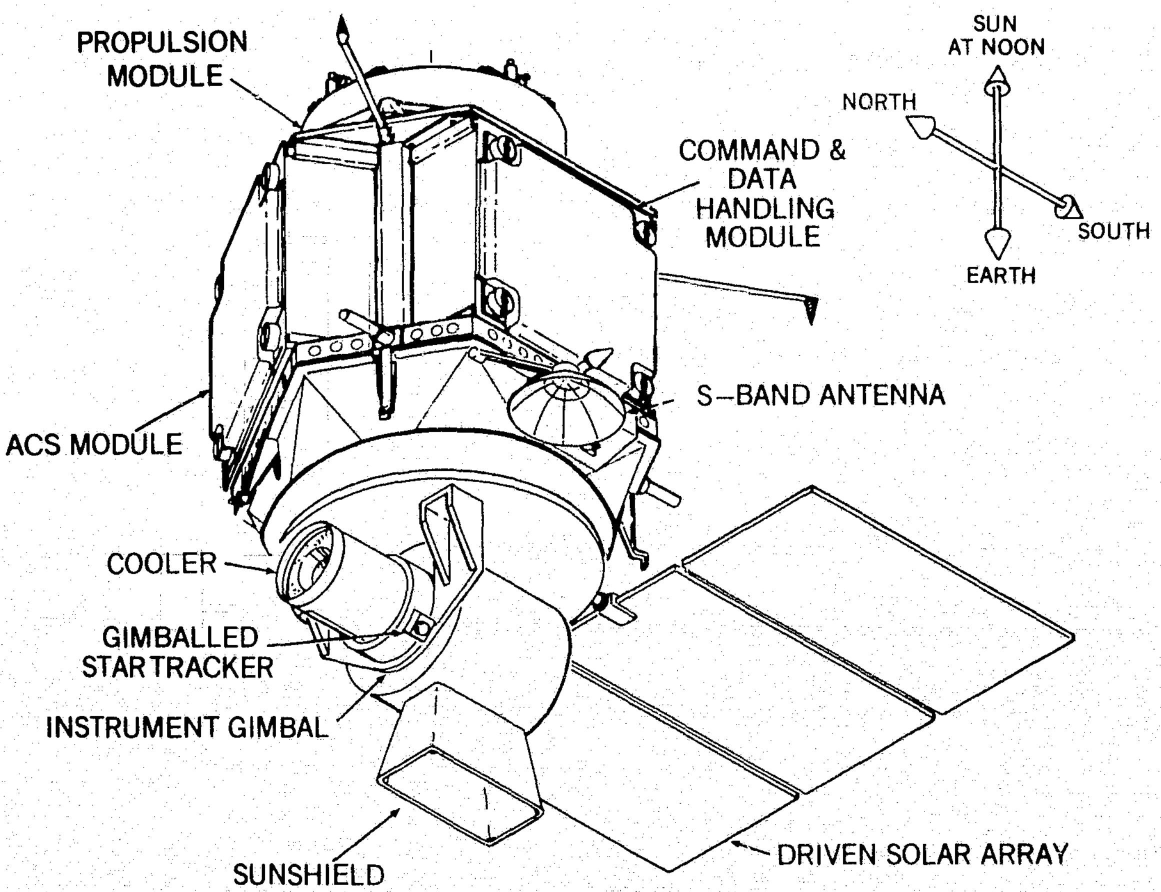

Figure 12. Stormsat Concept Using Multimission Modular Spacecraft

9.0 OTHER CARRIERS OF METEOROLOGICAL PAYLOADS

The United States plans through the mid-1980's include a number of multidisciplinary efforts which will include meteorological instruments and also payloads for other disciplines such as air pollution, oceanography, and earth resources whose data will be of value to meteorology. These efforts are summarized below with some estimate of data rates. However, it must be recognized that these plans are preliminary and that not all radiocommunication requirements are firm at this point.

9.1 SEASAT

The Seasat spacecraft are dedicated to ocean-dynamics applications in the late 1970's and early 1980's. Ocean circulation plays a major role in the control of global climate and weather. A number of active microwave sensors are part of the payload. Reference Document 2/302 for further details.

9.2 Synchronous Earth Observatory Satellite (SEOS)

The objective of SEOS will be to observe and study hazardous transient environmental phenomena so that their effects can be ameliorated, and adequate notice can be given to the public. Such meteorological phenomena include floods, frost, hurricanes, and other severe weather, in addition to thunderstorms and tornadoes. To attack these problems, nearly continuous observations having good spatial resolution are required. It is believed these requirements can be met by combining observations made with a 1.5 m diameter infrared/visible telescope and an infrared vertical atmospheric sounder 3-axis stabilized in geostationary orbit, with appropriate ground-based observations.

A real-time data rate of up to 40 Mbps is anticipated for this spacecraft. For further detail see Document 2/300.

9.3 Applications Explorer Missions (AEM)

These small spacecraft are a continuing series meant to serve all the applications disciplines. The second mission, for example will be an air pollution mission carrying the Stratospheric Aerosol and Gas Experiment. A succeeding mission is being planned for an earth energy budget experiment. All communications for the second and following missions are planned for band 9.

9.4 Spacelab

Studies are directed toward developing mission requirements and conceptual design of an earth observation sensor development laboratory for Spacelab missions. The duration of these missions makes it feasible in many cases to return data recorded on tape and/or film to earth along with the instrument. However, in some cases it will be desirable to telemeter the data immediately. Data rates up to 200 Mbit/s are being considered. A meteorological radar and Atmospheric Cloud Physics Laboratory are under study as part of this effort.

10.0 SUMMARY

10.1 Present Systems

The Improved TIROS Operational System (ITOS) and the present Nimbus experimental spacecraft, generally make use of the lower frequency meteorological satellite service allocations. The ITOS satellites use the upper portion of band 8 (near 137 MHz) for command, tracking, and narrowband telemetry functions, and band 9 (1697 MHz) for the transmission of wideband telemetry.

The Nimbus spacecraft use these allocations for tracking and narrowband telemetry functions, but use the 149 MHz and 1700 MHz space research allocations for telecommand and wideband telemetry, respectively. The Nimbus system also operates with a data collection system, interrogating the data collection platforms at 466 MHz (Nimbus 4) and receiving the platform information at 401 MHz.

The Geosynchronous Operational Environmental Satellite (GOES) operational system has been initiated recently with the launch of two of its prototype satellites, the Synchronous Meteorological Satellite (SMS) by the United States. These spacecraft use band 8 telemetry, tracking and command during the transfer orbit and band 9 (near 401 and 469 MHz for data collection platform receive and interrogation, near 2030 MHz for other uplinks and near 1690 MHz for other downlinks) during normal operations.

10.2 Near-Future Systems

Within the next few years, several new meteorological satellites will be launched:

- Geostationary meteorological satellites: will be placed in geostationary satellite orbit all around the equator, in order to achieve an almost complete earth coverage. They will gather meteorological information from both on-board sensors (earth imaging) and a large number of ground based Data Collection Platforms (DCP). In addition they will relay meteorological information to small earth user's stations (dissemination mission).

  - The Meteosat Satellite: pre-operational system is being developed as a responsibility of ESA and should be launched at the end of 1976.

  - The Geostationary Meteorological Satellite (GMS) is under development by Japan and will be launched in the middle of 1977.

  - The U.S.S.R. Geostationary Meteorological Satellite.

- The TIROS-N Satellite: the prototype of a new series of near earth meteorological satellites will be launched in 1978. Because of the necessarily higher data rates involved with these meteorological systems, available frequency allocations in band 9 (near 1700 MHz) will be used for most communication functions, with the exception of the data collection system which will continue to operate in the vicinity of 400 MHz and the low-data-rate beacon system which will operate in band 8 (near 137 MHz).

In addition, some departures from present frequencies will be made in the Nimbus-G and the GOES-D and following spacecraft due to the deletion of the band 8 ranging, telemetry and command functions at the NASA ground stations. These functions will utilize the upper part of band 9 (near 2090 MHz and 2270 MHz).

10.3 Advanced Meteorological Systems

The advanced meteorological satellites include both operational systems (based upon the TIROS-N satellites) and experimental multidisciplinary spacecraft.

The multidisciplinary spacecraft are discussed in Reports USSG 2/300 and 2/302. Many of these systems will use communication systems with very high data rates and correspondingly large bandwidth requirements (i.e., on the order of 300 MHz per spacecraft). The spacecraft with very high data rate requirements will operate in band 10 for wideband telemetry transmission. The upper portion of band 9 will be used for certain spacecraft with lower data rate requirements and for maintenance telemetry, command and tracking data transmission.

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ACRONYMS

AAFE	—	Advanced Applications Flight Experiment
AEM	—	Applications Explorer Mission
ALT	—	Radar Altimeter
APT	—	Automatic Picture Transmission
ATS	—	Applications Technology Satellite
AVCS	—	Advanced Vidicon Camera System
AVHRR	—	Advanced Very High Resolution Radiometer
BSU	—	Basic Sounding Unit
BUV	—	Backscatter Ultraviolet Spectrometer
CDA	—	Command and Data Acquisition
CZCS	—	Coastal Zone Color Scanner
DATTS	—	Data Acquisition Telecommand and Tracking Station
DCDR	—	Data Collection and Data Relay
DCP	—	Data Collection Platform
DCS	—	Data Collection System
DDP	—	Digital Data Processor
DUS	—	Data User Stations
EOS	—	Earth Observatory Satellite
ERB	—	Earth Radiation Budget
ESMR	—	Electrically Scanning Microwave Radiometer
ESA	—	European Space Agency
ESSA	—	Environmental Sciences Service Administration
FPR	—	Flat Plate Radiometer
FWS	—	Filter Wedge Spectrometer
GARP	—	Global Atmospheric Research Program
GAC	—	Global Area Coverage
GMS	—	Geostationary Meteorological Satellite
GMT	—	Greenwich Mean Time

GOES	—	Geosynchronous Operational Environmental Satellite
GVHRR	—	Geosynchronous Very High Resolution Radiometer
HDRSS	—	High Data Rate Storage System
HIRS	—	High Resolution Infrared Sounder
HRPT	—	High Resolution Picture Transmission
IDCS	—	Image Dissector Camera System
IR	—	Infrared
IRLS	—	Interrogation, Recording and Location System
ITOS	—	Improved TIROS Operational System
ITPR	—	Infrared Temperature Profile Radiometer
LAC	—	Local Area Coverage
LIMS	—	Limb Infrared Measurements in the Stratosphere
LRIR	—	Limb Radiance Inversion Radiometer
MAPS	—	Measurement of Air Pollution from Satellites
MIRP	—	Manipulated Information Rate Processor
MSU	—	Microwave Sounding Unit
MUSE	—	Monitor of Ultraviolet Solar Energy
MWS	—	Microwave Scatterometer
NEMS	—	Microwave Spectrometer
NESC	—	National Environmental Satellite Center
NESS	—	National Environmental Satellite Service
NOAA	—	National Oceanic Atmospheric Administration
PCM	—	Pulse Code Modulation
PMR	—	Pressure Modulated Radiometer
RAMS	—	Random Access Measurement System
SAGE	—	Stratospheric Aerosol and Gas Experiment
SAM II	—	Stratospheric Aerosol Measurement
SAMS	—	Stratospheric and Mesospheric Sounder
SAR	—	Synthetic Aperture Radar

SBUV/ TOMS	—	Solar Backscatter Ultraviolet/Total Ozone Mapper System
S/C	—	Spacecraft
SCAMS	—	Scanning Microwave Spectrometer
SCR	—	Selective Chopper Radiometer
SEM	—	Space Environment Monitor
SIRS	—	Satellite Infrared Spectrometer
SMMR	—	Scanning Multichannel Microwave Radiometer
SMS	—	Synchronous Meteorological Satellite
SPM	—	Solar Proton Monitor
SR	—	Scanning Radiometer
SSU	—	Stratospheric Sounding Unit
STDN	—	Spaceflight Tracking and Data Network
SYNCOM	—	Synchronous Communication Satellite
TDRE	—	Tracking and Data Relay Experiment
THIR	—	Temperature-Humidity Infrared Radiometer
TIP	—	TIROS Information Processor
TIROS	—	Television Infrared Observational Satellite
TOS	—	TIROS Operational Satellite
TOVS	—	TIROS Operational Vertical Sounder
TWERLE	—	Tropical Wind, Energy Conversion, Reference Level Experiment
VAS	—	VISSR Atmospheric Sounder
VHRR	—	Very High Resolution Radiometer
VIP	—	Versatile Information Processor
VISSR	—	Visual Infrared Spin-Scan Radiometer
VTPR	—	Vertical Temperature Profile Radiometer
WEFAX	—	Weather Facsimile
WMO	—	World Meteorological Organization
WWW	—	World Weather Watch

APPENDIX A**

METEOSAT — ESA

6. METEOSAT satellite

The METEOSAT satellite is a geostationary satellite under development by ESRO * for launch in 1976. METEOSAT will be positioned over the equator at about 0° longitude, giving coverage of Europe, Africa and large portions of the Atlantic and Indian Oceans. The main functions of METEOSAT are Earth imaging in both the visible and the infra-red spectra, dissemination of cloud pictures or any meteorological data towards user data receiving stations, and collection of environmental data from remote *in-situ* data collection platforms. METEOSAT will be a spin-stabilized satellite, the spin rate being about 100 rev/min, and the spin axis being parallel to the north-south direction.

6.1 *Imaging mission*

This is the first main mission of METEOSAT. Pictures of cloud coverage, in both the visible and the infra-red spectra, are produced by a radiometer including a telescope and a set of detectors functioning in the visible and infra-red spectra. At each revolution of the satellite around its spin axis, *one* infra-red line and *two* adjacent visible lines are generated simultaneously, and stored in real-time during the $\frac{1}{20}$ revolution in which the radiometer views the Earth, in an *on-board* memory and after sampling and digitization. The on-board memory is read out and the digital picture data are transmitted towards the ground, during the rest of the revolution; in the case of on-board memory failure, it is possible, as a back-up mode, to transmit the picture data in real-time, and at a bit rate roughly 20 times greater.

A complete picture contains 2500 lines $\times$ 2500 samples in the infra-red, and 5000 lines $\times$ 5000 samples in the visible spectrum. The instantaneous field of view (IFOV) at the subsatellite point is about 4·5 km for the infra-red picture, and about 2·25 km for the visible picture. A set of pictures, one in the infra-red plus one in the visible spectrum, is completed in 25 min and the recurrence time is 30 min.

6.2 *Dissemination mission*

This is the second main mission of METEOSAT. Data to be disseminated can be either *high-resolution digital picture*, extracted from those generated by the imaging mission, to be transmitted to data users through stations of an advanced type, designated primary data users stations (P.DUS) or *analogue pictures* of APT type or Weather Facsimile (WEFAX) to be transmitted to data users through stations of a simpler type, designated secondary data users stations (S.DUS). For the purpose of dissemination, the METEOSAT transponder provides for two independent and interchangeable channels. The word 'interchangeable' is to be understood as meaning that each of them can be used to disseminate either the digital pictures or the analogue data (APT or WEFAX).

6.3 *Data collection mission*

This is the third mission of METEOSAT, which has a lower priority than the two preceding ones. The purpose of this mission is to gather environmental data from remote *in-situ* data-collection

*Now the European Space Agency.

**Material extracted from CCIR Report 395-2 (Rev. 74).

platforms in a central facility (designated as data acquisition telecommand and tracking station — DATTS) by using METEOSAT as a telecommunication relay. The METEOSAT data collection system will be able to operate three kinds of data collection platforms:

— either self-timed DCP's, which have an internal clock and which automatically transmit their messages, within preset time/frequency slots;

— or interrogated DCP's, which transmit this message only upon interrogation from DATTS, via the METEOSAT transponder;

— or alert DCP's which transmit data whenever a certain measured environmental parameter exceeds a preset threshold, with the object of giving warning of the occurrence of any abnormal phenomenon.

6.4 *Housekeeping telemetering, telecommand and ranging*

These functions are normally integrated within the mission performance telecommunication and will be performed in the 1670 to 1700 and 2096 to 2120 MHz frequency ranges. Accurate ranging, using trilateration techniques, will be performed by using both dissemination channels in time sharing with the dissemination mission. The VHF frequency range will be used also, in the transfer orbit and as a back-up in the geostationary satellite orbit.

6.5 *METEOSAT telecommunication assembly*

Omnidirectional toroidal mode antennae are used for reception in the 2096 to 2120 MHz frequency range, and for emission and reception in the 400 to 470 MHz frequency range.

Transmissions in the 1670 to 1700 MHz frequency range are made through an electrically despun antenna, using variable power dividers steering technique.

Signals in the 2096 to 2120 MHz frequency band are received through the same front end and are separated in the intermediate frequency amplifier by filtering (HK telecommand or DCP interrogation and two disseminated signals).

Two band-limited chains with high power amplifiers allow transmission of signals within the 1670 to 1700 MHz frequency band:

— one chain is operated in a multicarrier mode, for real-picture transmission, HK telemetry, DCP reports and one dissemination channel;

— the other chain is dedicated to the second dissemination channel.

The section of equipment for the lower part of the UHF band, which operates within the 400 to 470 MHz frequency range is used for reception of DCP's reports and transmission of interrogation signals.

6.6 *Data acquisition telecommand and tracking station (DATTS)*

This station will centralize the links with METEOSAT within the frequency bands 2096 to 2120 MHz for up-links and 1670 to 1700 MHz for down-links. Except for disseminated data of APT or WEFAX types, all the links are digital. The station will be equipped with a 15-m diameter antenna and an uncooled parametric amplifier. The receiving noise temperature is expected to be about 115 K.

6.7 *Links characteristics*

Some characteristics which are not necessarily specifications are given in Tables VII and VIII.

Table VII

METEOSAT

Frequency assignments

Up-links	Centre frequency	Transponder 3 dB bandwidth
HK telecommand and ranging (Transfer orbit + back-up synch. orbit)	149·34 MHz	
DCP reports	402·1 MHz	200 kHz
DCP interrogation — international (1) or domestic (1)	2112 MHz	100 kHz
HK telecommand (synch. orbit) (1)	2112 MHz	60 kHz
Picture dissemination or ranging (2)	2115·5 MHz	1000 kHz
(Two interchangeable channels)	2119 MHz	1000 kHz

Down-links	Centre frequency	Transponder 3 dB bandwidth
HK telemetry and ranging (Transfer orbit + back-up synch. orbit)	137·08 MHz	
DCP interrogation — international (1) or domestic (1)	468·900 MHz	100 kHz
DCP reports	1675·281 MHz	200 kHz
HK telemetry (synch. orbit)	1675·929 MHz	30 kHz
Raw-picture data: (normal) stretched mode	1686·833 MHz	660 kHz
real-time (back-up)	1686·833 MHz	5400 kHz
Picture dissemination or ranging (2)	1691 MHz	1000 kHz
(Two interchangeable channels)	1694·5 MHz	1000 kHz

(1) The same channel is used in time sharing for the purpose of HK telecommand, or interrogation of the international or domestic DCP's.

(2) Two identical channels, both used in time sharing for the purposes of WEFAX dissemination, or high resolution picture dissemination, or ranging.

TABLE VIII

Salient characteristics of the METEOSAT transponder

	Band 9	
	Upper	Lower
Transmitter power (Watts)	14×2 (two channels)	20
Transmit antenna gain (dB) (including losses, coverage's edge)	7·5	0
Receive antenna gain (dB) (including losses, coverage's edge)	3	0
Receiver noise temperature (K)	600 (transistor)	600 (transistor)
Antenna design	Electronically de-spun variable power dividers	Omnidirectional dipole array
Antenna polarization	Linear	Right-hand circular
Receive frequencies (MHz)	2112 and 2112 ± 0·025 2115·5 2119	402·1 ± 0·1
Transmit frequencies (MHz)	1675·281 1675·929 1686·833 1691 1694·5	468·875 468·925

APPENDIX B*

GEOSTATIONARY METEOROLOGICAL SATELLITE (GMS) — JAPAN

7. Geostationary Meteorological Satellite (GMS)

The GMS is a geostationary meteorological satellite under development by Japan to participate in the World Weather Watch (WWW) plan, and in particular in the First GARP Global Experiment (FGGE) which will take place during September 1977 through August 1979. It will be launched in the middle of 1977 and be placed over the equator at 140°E longitude giving coverage of East and Southeast Asia, Oceania and western-half of Pacific Ocean.

The GMS has four missions which are similar to SMS/GOES of U.S.A., i.e., observation of the earth with a visible and infrared spin scan radiometer (VISSR) in both visible and infrared spectra, dissemination of cloud pictures and other meteorological information, collection of meteorological and oceanographic data from remote observation platforms (data collection platform — DCP) and monitoring of solar protons, alpha-particles and electrons. The GMS frequency assignments are shown in Table IX.

7.1 Tracking and Telemetry

The precise position of GMS will be determined through a trilateration ranging system. This system utilizes S-band as is indicated in Table IX. The GMS telemetry and command will be performed in S-band during normal operation and in VHF for backup purpose.

7.2 Visible and Infrared Spin Scan Radiometer (VISSR)

The VISSR of GMS is very similar to the one used in SMS/GOES except minor modifications.

The VISSR consists of 2 sets of detector combinations, one of which is a redundancy. Each set consists of one infrared and four identical visible sensors. The instantaneous geometric field of view of the IR sensor and the visible sensor are 0.14 milli-radians (about 5 km earth resolution at the sub-satellite point), and 0.034 x 0.031 milli-radians (about 1.25 km earth resolution) respectively. The four visible sensors are aligned so that they scan the same total area as a single IR sensor does during an earth scan period. The scan mechanism is

*From material submitted by Japanese as a revision to CCIR Report 395-2 (Rev. 74).

similar to that of SMS/GOES. A scan mirror is tilted step-wise by 70 microradians per spin, and 2500 steps complete a normal North-South scanning of the total earth disk during a period of 25 minutes at the nominal spin rate of 100 rpm. Since 2.5 minutes are needed to return the scan mirror to the initial position and an additional few minutes are needed to stabilize the satellite nutation caused by the quick stepping back motion, observation of a full image of the earth will be made at 30 minute intervals. If necessary, more frequent observations of a limited portion of the earth are possible by specifying the upper and lower limits of the VISSR scan-line-number. Such partial scan mode will be useful to observe rapidly changing weather phenomena. The VISSR data is transmitted in S-band to the command and data acquisition (CDA) station in real time by use of 32.8 ms bursts in every 600 ms spin period.

7.3 Data Collection System

The data collection system will relay environmental data sensed at manned as well as unmanned observation platforms such as robot stations, buoys and ships through GMS to the CDA station. In this system, both the interrogation type and the self-timed transmission type DCP's will be used. The observation data will be transmitted to the satellite at the rate of 100 bps.

7.4 Dissemination Mission

The cloud pictures produced from the VISSR data will be disseminated to user stations within the GMS service area. The full disc picture of the earth observed from the satellite will be transmitted by a high resolution facsimile, and partial pictures will be sent by a low resolution facsimile.

7.5 Space Environment Monitoring

Using the space environment monitor, the incoming number of solar protons will be counted in 7 levels for the range of 1-500 MeV. Alpha particles and electrons are also monitored.

7.6 GMS Telecommunication System

The frequency assignments and the transponder characteristics in the GMS are shown in Tables IX and X respectively.

Table IX

GMS

Frequency Assignments

Up-link	Center Frequency	Transponder 3-db Bandwidth
DCP report	402.2 MHz	400 kHz
WEFAX		8.2 MHz
High resolution	2029.1 MHz	
Low resolution	2033.0 MHz	
Ranging	2026.0 MHz	
	2030.2 MHz	
	2032.2 MHz	
DCP interrogation	2034.9 MHz	200 kHz 6 kHz/Ch
S-band command	2034.2 MHz	60 kHz
VHF command	149.1 MHz	30 kHz
Down-link	**Center Frequency**	**Transponder 3-db Bandwidth**
DCP interrogation	468.8 MHz	200 kHz
VISSR data	1681.6 MHz	20 MHz
WEFAX		8.2 MHz
High resolution	1687.1 MHz	
Low resolution	1691.0 MHz	
Ranging	1684.0 MHz	
	1688.2 MHz	
	1690.2 MHz	
DCP report	1694.5 MHz	400 kHz
S-band telemetry	1694.0 MHz	200 kHz
VHF telemetry	136.89 MHz	85 kHz

Table X

Characteristics of the GMS Transponder

Items	Frequency Bands		
	S-Band	UHF Band	VHF Band
Receiver			
Antenna gain	14.8 db (±7°)	8.5 db (±9°.2)	>-11.0 db (±50° elevation, 0°-360° azimuth.)
Noise temperature	33.3 dbK	31.1 dbK	34.4 dbK
Transmitter			
Antenna gain	16.0 db (±7°) 14.0 db (±9°.2)	10.0 db (±9°.2)	>-11.0 db (±50° elevation, 0°-360° azimuth.)
Power	20 w and 5 w	6 w	8 w
Antenna			
Type	Mechanical despun	Mechanical despun	Omni directional
Polarization	Vertical linear	Right hand circular	Right hand circular