IRS-P4 mission

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IRS-P4 in the series of Indian Remote Sensing Satellites (IRS) is designed to serve the applications in the area of oceanography and atmospherics. Ocean Colour Monitor (OCM) and Multi-frequency Scanning Microwave Radiometer (MSMR) are the two payloads. The OCM operates in the visible and near infra-red bands and MSMR in microwave bands. These instruments will sense such important geophysical parameters as, chlorophyll content, yellow substance and suspended sediments in ocean waters; sea surface temperature, sea surface winds, water vapour in an atmospheric column and water content in clouds. The orbit is selected such that a systematic coverage of the whole globe is achieved once in two days. The satellite mainframe derives its heritage from the earlier IRS mission. IRS-P4 along with the two co-passengers was successfully launched on 26 May 1999 by PSLV-C2 from Sriharikota. Subsequently, it has been operationalized after on-orbit checkout. The data from both the payloads is regularly received and processed by National Remote Sensing Agency (NRSA) at Hyderabad. In this paper various aspects of IRS-P4 mission including satellite mainframe, payloads and ground segment have been described.

IRS-P4 satellite was the main passenger for PSLV-C2 flight. It was launched on 26 May 1999 in 720 km altitude and 98.28° inclination sunsynchronous orbit with an equatorial crossing time of 12 noon for descending pass. This orbit provides a systematic coverage of earth's surface once in two days.

The satellite has two payloads namely, Ocean Colour Monitor (OCM) and Multi-frequency Scanning Microwave Radiometer (MSMR). Both the payloads are configured to serve the application areas related to oceanography. Accordingly, the satellite is called OCEANSAT-1. The data gathered from these two payloads will be useful in deriving direct economic benefits in areas such as, identifying the potential fishing zones, coastal zone management, ship routing, operations of offshore oil rigs, etc. Apart from these applications, the data will provide important inputs for weather predictions, and for scientific studies like carbon cycle in nature.

Satellite mainframe

The satellite has a configuration which is appropriately suited to support the two payloads. The satellite mainframe is derived from the robust design of Indian Remote Sensing Satellite (IRS) bus which has been flown seven times before IRS-P4. However, many subsystems have incorporated improvements for better efficiencies of their performance parameters. Salient characteristics of the satellite bus are given in Table 1.

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The mechanical configuration of the satellite in solar-panel-deployed condition is shown in Figure 1. The main structure is a parallelopiped with a central load bearing cylinder. Four vertical equipment panels are connected to the cylinder with the shear webs. The equipment panels, top deck and bottom deck are used to mount various subsystem packages. Both payloads are mounted on the top deck and the bottom deck has an interface with the launch vehicle. Four tanks containing hydrazine fuel for reaction control system (RCS) are mounted inside the cylinder. Sixteen 1N RCS thrusters are suitably mounted on the eight corners of the satellite. One 11N thruster is mounted along the negative roll axis. Required thermal control of the subsystems is achieved by passive and semi-active elements. There are mechanisms for OCM and solar panel deployments after launch.

The electrical configuration of the satellite comprises subsystems including power, telemetry, tracking and command (TTC), attitude and orbit control system (AOCS) and payload data handling. A simplified block diagram of electrical configuration of the satellite is shown in Figure 2. Two sun tracking solar panel arrays on both sides are the primary source of power. Two rechargeable Ni-Cd batteries are secondary source of power to meet requirements of eclipse period in each orbit and peak loads during payload operation. The heart of TTC subsystem is an S-band transponder. It receives the command signals from ground and after getting decoded by a command decoder, they are routed to the designated subsystems. Telemetry encoder receives the data on the health of various subsystems,

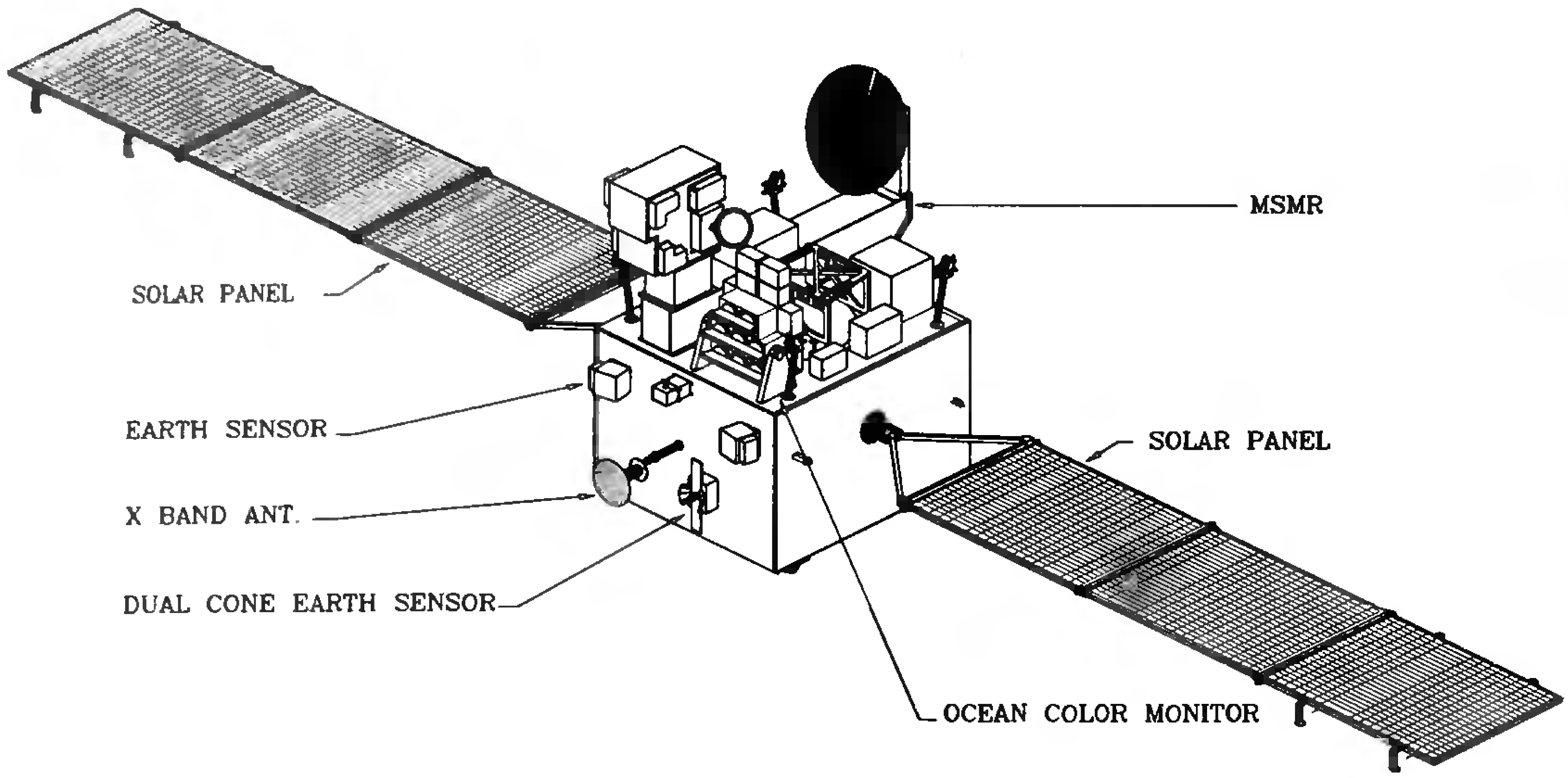

Figure 1. Deployed view of Oceansat-1.

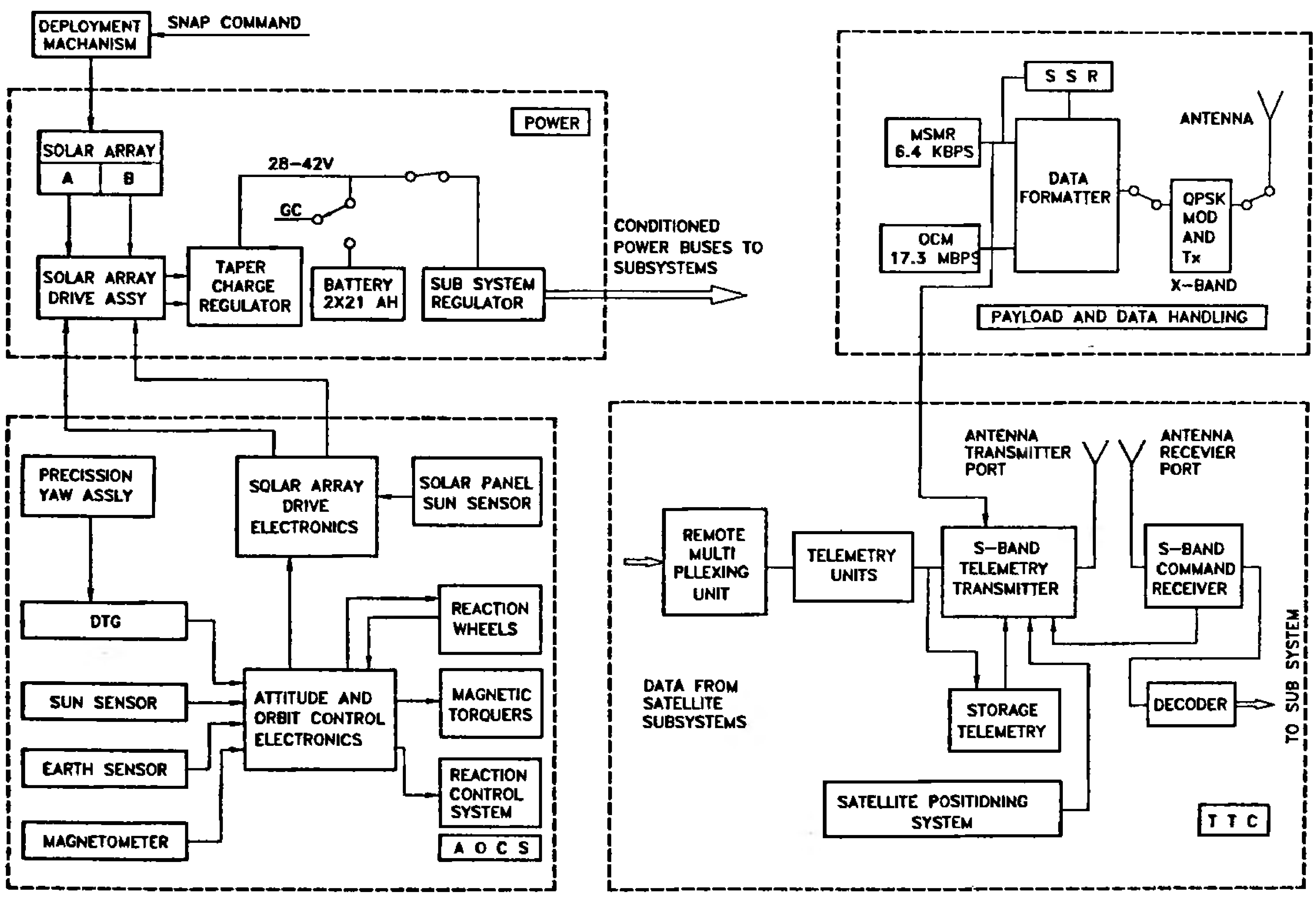

Figure 2. Simplified block diagram of IRS-P4 spacecraft.

encodes them before the transponder transmits the same to the ground station. Additionally, a newly developed satellite positioning system, working on differential ground positioning system principle forms part of the TTC. The transponder also helps in getting range and range rate of the satellite with respect to a ground station. The AOCS subsystem maintains the orbit and the attitude of the satellite in three axis stabilized mode. It

Table 1. IRS-P4 spacecraft characteristics

Mechanical system		
Structure	Aluminium/aluminium honeycomb with CFRP element for MSMR payload structure	
Thermal system	Passive/semi-active thermal control with paints, MLI blankets, OSRs and closed-loop temperature controllers	
Thermal control	Payloads	15 ± 2°C for OCM 20 ± 10°C for MSMR
	Battery	5 ± 5°C
	Electronics	0 to 40°C
Mechanisms	Solar panel deployment OCM hold and release OCM tilt	
Power system		
Solar panels	9.636 sq m rigid sun tracking type, generating 800 W at EOL	
Chemical battery	2 × 21 AH Ni-Cd batteries	
Power electronics	Power conditioning and distribution to all sub-systems	
TTC system		
Telecommand	PCM/FSK/FM/PM modulation Time tag command facility	
Telemetry	PCM/PSK/PM modulation storage capacity of 4 orbit data	
Transponder	Unlink and down link in S-band	
Satellite positioning system	Working in DGPs mode	
AOCS		
Sensors	Earth sensors, sun sensors, magnetometers and gyros	
Actuators	Reaction wheels, magnetic torquers, hydrazine thrusters (1N and 11N)	
AOCE	Microprocessor-based system	
Pointing accuracy	0.15° (pitch and roll) 0.20° (yaw)	
Drift rate	$<3.0 \times 10^{-4}$ deg/s	
Data handling system		
Baseband data rate	20.8 Mbps	
Modulation	QPSK	
Transmission	X-band	
Data recorder capacity	320 Mbits separate for OCM & MSMR	
Satellite mass	1036 kg	

Table 2. Relationship of spectral bands and their sensitivity to the ocean scene attributes

Band	Band centre (nm)	Band width (nm)	Applications
B1	412	20	Yellow substance and turbidity
B2	443	20	Chlorophyll absorption
B3	490	20	Chlorophyll and other pigments
B4	510	20	Turbidity, suspended sediment
B5	555	20	Chlorophyll, suspended sediment
B6	670	20	Chlorophyll absorption
B7	765	40	O_2 absorption
B8	865	40	Aerosol optical thickness, vegetation, water vapour reference over the ocean

Table 3. Major characteristics of the OCM payload

Parameter	Specification
Swath	1420 km
Ground resolution	240 m across track 360 m along track
Signal to noise ratio	> 512
Signal digitization	12 bits
Tilting provision	± 20°

receives the attitude errors from the sensors such as 4π sun sensor, analog yaw sensor, earth sensors and dynamically tuned gyros (DTGs). In normal mode operation, DTGs provide the attitude errors for pitch, roll and yaw axis. DTGs are updated by earth sensors for pitch and roll directions and the yaw direction update is provided by a precision yaw sensor at the north pole and a digital sun sensor at the south pole. The actuators to correct the attitude and orbit are reaction wheels and RCS thrusters respectively. Also, RCS thrusters and two magnetic torquers are used for momentum dumping of reaction wheels to keep their speeds within preset limits. Data handling subsystem receives data from OCM and MSMR. The data is formatted, randomized and differentially encoded before QPSK modulation by the X-band transmitter. The transmitter has a travelling wave tube amplifier of 12 watts RF output.

OCM payload

OCM operates in eight spectral bands. The imaging principle of OCM is based on push-broom technique which is the same as for the Linear Imaging Self Scanner (LISS) cameras used in earlier missions. There is a separate refractive optics for each band. Each band has a linear Charge Coupled Devices (CCD) array in the focal plane of the optics as the detector. The detector outputs are processed by the payload electronics which provide serial digital data stream for each band to the data handling system. Block schematic of OCM is given in Figure 3.

Monitoring the colour of the ocean water leads to the information on the phytoplankton concentration, suspended sediments and yellow substance. OCM characteristics like observation bands and their bandwidths, spatial resolution, etc. are dictated by these water constituents. Table 2 gives the relationship of spectral bands and their sensitivity to the ocean scene attributes. Additionally, the applications of OCM data for land-based applications, where frequent information is required on regional scale, are also kept in view while choosing the OCM parameters. The OCM is characterized

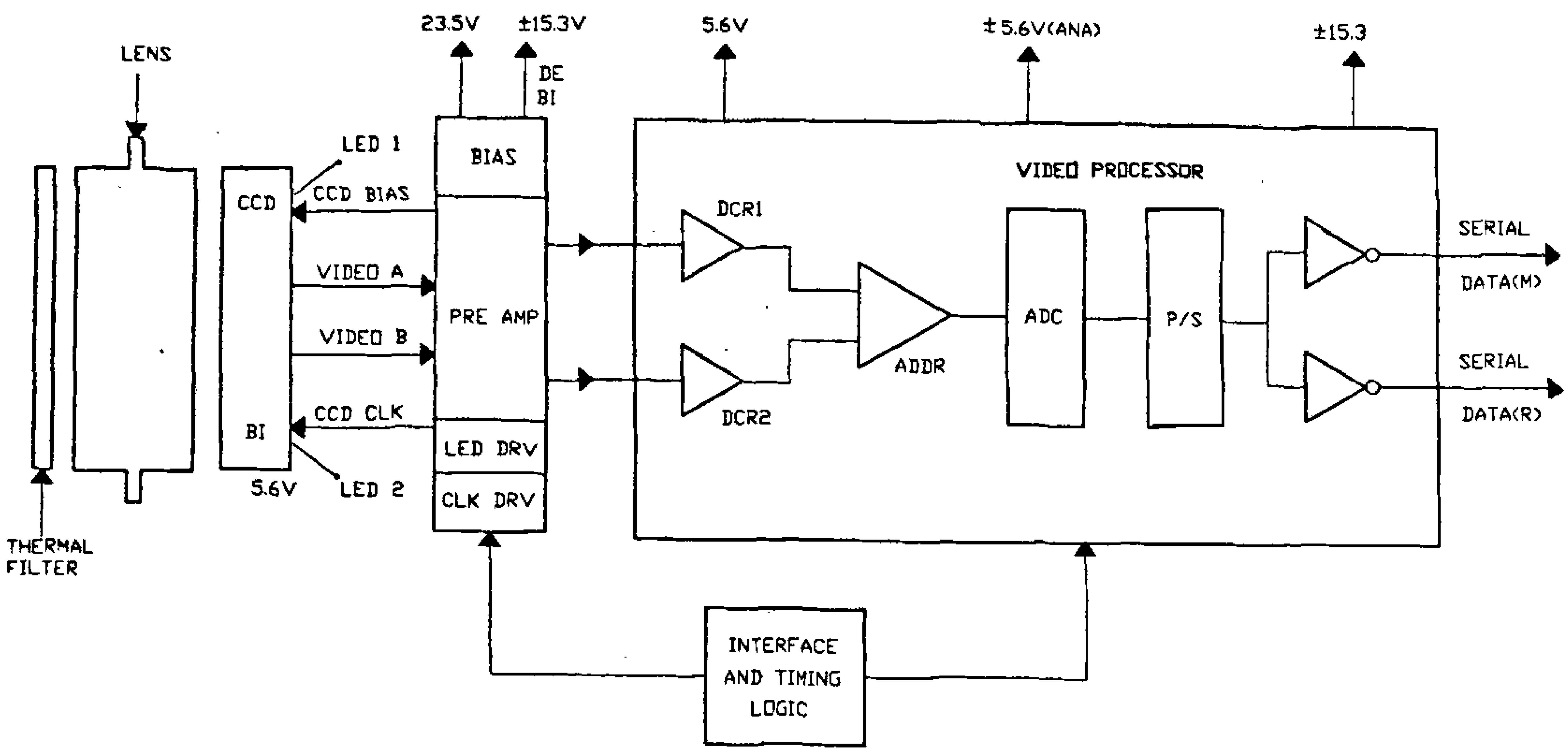

Figure 3. Block schematic of Ocean Colour Monitor.

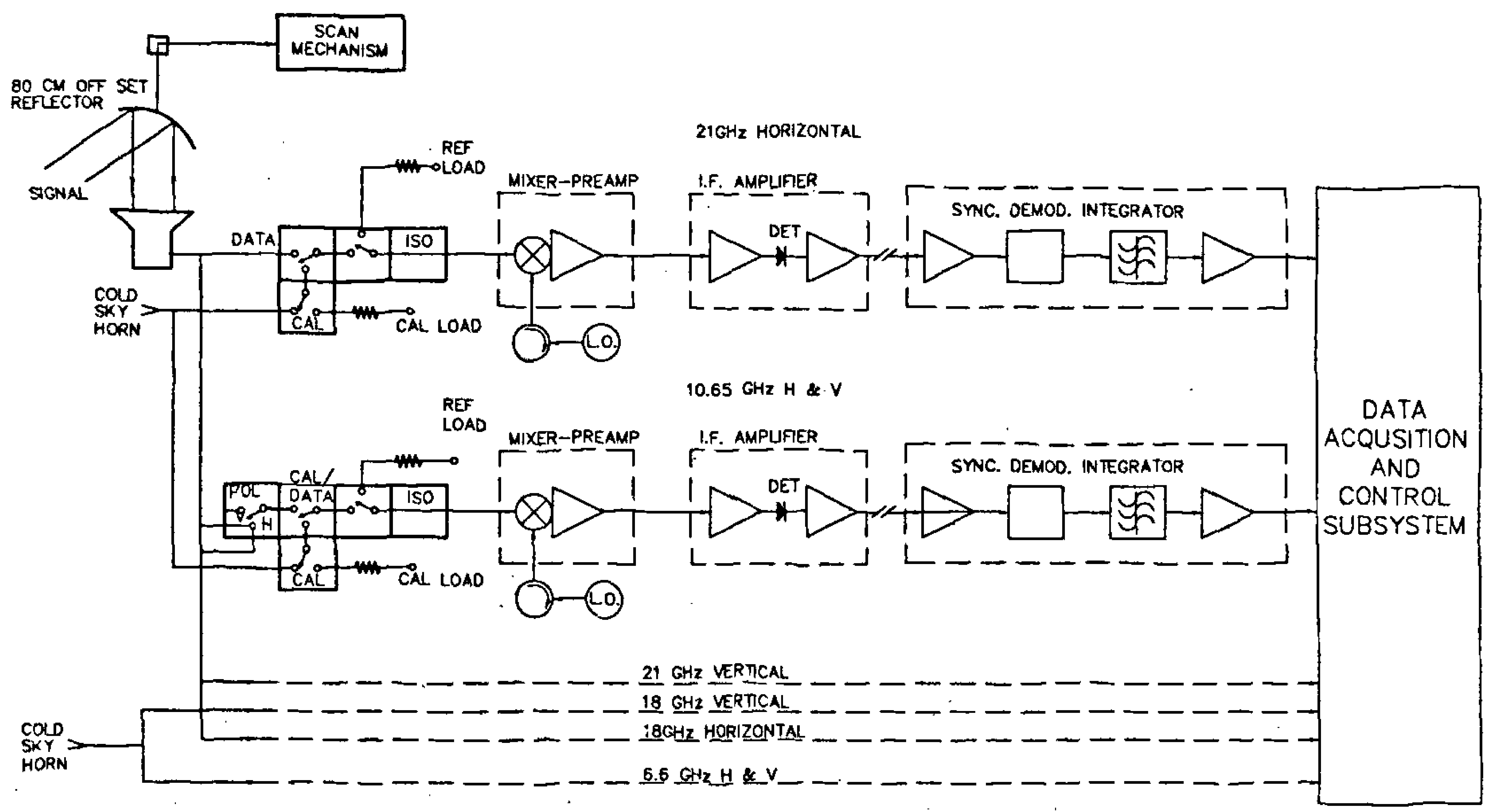

Figure 4. Multifrequency Scanning Microwave Radiometer.

:oarse spatial resolution, eight narrow spectral bands, ı radiometric resolution, large field of view (± 43° viding a swath of 1420 km). Designing OCM for low an surface radiance and wide FOV were some of the llenges in its realization.

/hile only about 20% of the signal received by the M optics in the orbit comprises ocean radiance, 80% he contribution from intervening atmosphere. Thus, xtract information on ocean colour, the contribution from atmosphere needs to be eliminated, and, theref accordingly correction is carried out by using data f band 7 and 8. Ocean radiance being low, 12 noon been chosen as the time of equatorial crossing for scending pass to maximize the signal. This has an a: ciated phenomenon of sun glint entering into the fiel view of OCM, time of which is a function of season latitude. To get over the problem of sun glint, a pr sion to tilt the OCM payload by ± 20° has been ı vided. Its position can be fixed according to the latitude of observation and season. Tilt mechanism ensures a glint-free observation anywhere on the globe. Major characteristics of the OCM payload are given in Table 3.

Multi-frequency scanning microwave radiometer

It is a day-night-all weather sensor, designed to measure sea surface temperature, sea surface wind speed, atmospheric water vapour and liquid water content in the clouds. Four microwave frequencies, in both horizontal and vertical polarizations, have been chosen which are sensitive to these geophysical parameters. Basic design parameters of MSMR are given in Table 4.

MSMR has a 860 × 800 mm off-axis parabola as the antenna reflector, and a corrugated feed to receive the emitted radiation from earth and its atmosphere. The antenna reflector is rotated at 11.16 rpm to get a circular scan of 1360 km width at the earth's surface, and 49.7° constant incidence angle at the beam centre. The feed meets the requirements of multifrequency and multipolarization operation. It is characterized by high-polarization purity, high-beam efficiency and low-ohmic losses. The receiver following the feed is a Dicke receiver which switches its inputs between incoming signal, reference load and cold-sky calibration horns. Block schematic of MSMR is given in Figure 4.

MSMR was fully calibrated on ground for various return losses and receiver parameters. Various challenges in MSMR design included the stringent alignment stability requirement of 0.01° during launch and over a wide temperature range, antenna steering mechanism, and feed and a sensitive receiver.

Table 4. Basic design parameters of MSMR

Frequency (GHz)	6.6	10.65	18	21
Polarization	V&H	V&H	V&H	V&H
Resolution (km)	120	75	45	40
Swath (km)	1360	1360	1360	1360
Dynamic range (K)	–	2.7–330	–	–

Ground support systems

Soon after the composite launch, along with the co-passengers (KITSAT of South Korea and TUBSAT of Germany), the control of IRS-P4 was taken over by the Spacecraft Control Centre at ISTRAC, Bangalore. The payload data is regularly being received by a ground station of National Remote Sensing Agency (NRSA), Hyderabad. Unlike the other remote sensing missions, OCEANSAT-I payloads need appropriate algorithms to convert the received data into geophysical parameters. These algorithms were worked out before the launch. Their coefficients need fine tuning by carrying out simultaneous *in situ* observations with satellite data collection, during validation phase which will last for six months to one year covering all seasons.

The MSMR data is continuously being collected and stored in an onboard memory which is played back during ground station visibility, once in 12 h. Thus MSMR covers the entire globe in 24 h. In case of OCM, the data rate is high and the required size of memory is large beyond realization for continuous operation. Thus, OCM is switched on over a ground station and the data is collected in real time. However, it can be switched on anywhere on the globe, wherever ground station exists. The OCEANSAT-I mission being truely global in nature, data dissemination policy is accordingly being worked out by ISRO.

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