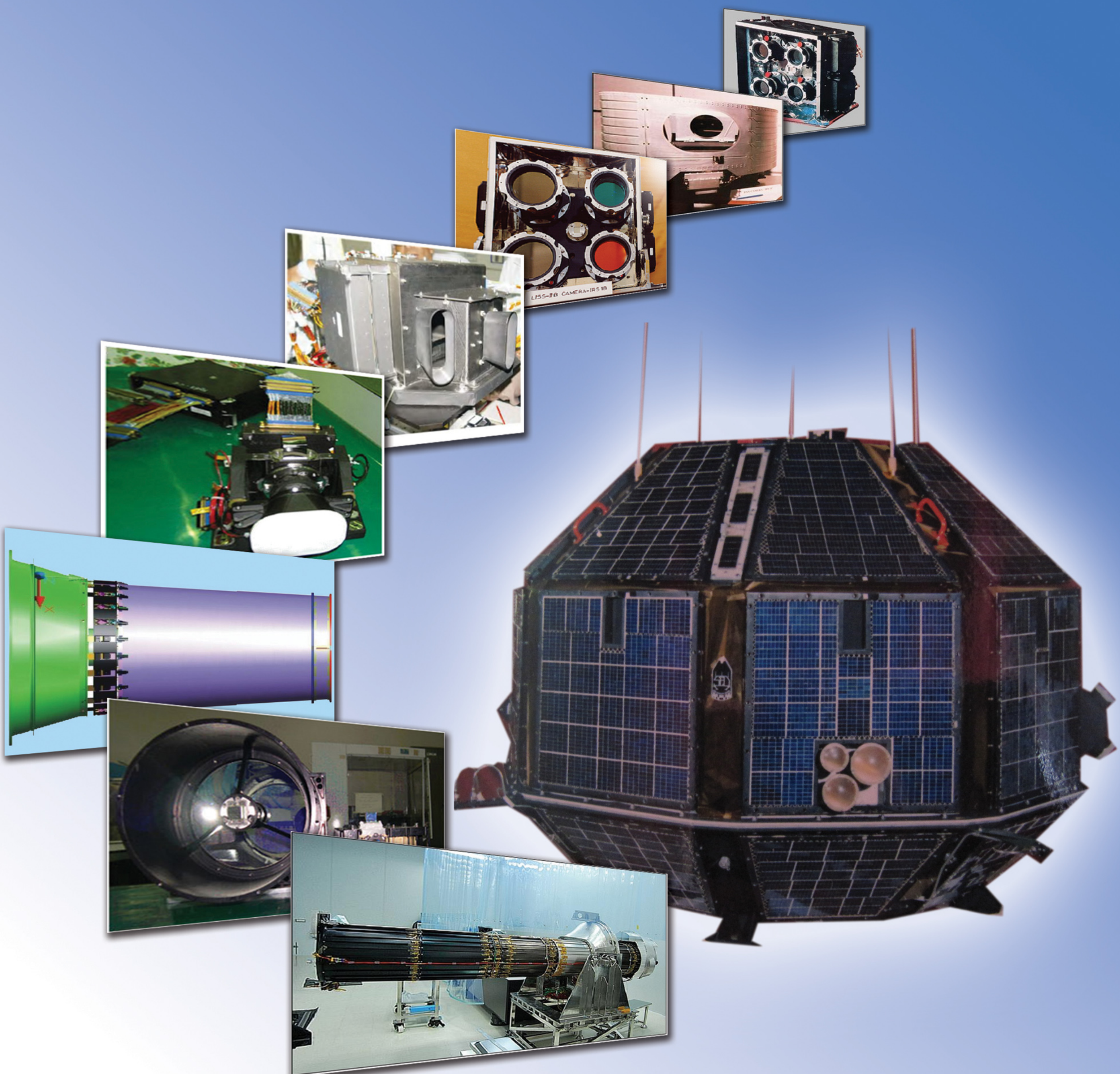
Indian Remote Sensing Missions and Payloads- a Glance



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ACKNOWLEDGEMENT

*This book, "**Indian Remote Sensing Missions and Payloads - A Glance**" is an attempt to provide in one place the information about all Indian Remote Sensing and scientific missions from Aryabhata to RISAT-1 including some of the satellites that are in the realization phase.*

This document is compiled by IRS Program Management Engineers from the data available at various sources viz., configuration data books, and other archives.

These missions are culmination of the efforts put by all scientists, Engineers, and supporting staff across various centres of ISRO. All their works are duly acknowledged

INDIAN REMOTE SENSING MISSIONS & PAYLOADS
A GLANCE

IRS Programme Management Office

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INTRODUCTION

The Indian Space Research Organisation (ISRO) planned a long term Satellite Remote Sensing programme in seventies, and started related activities like conducting field & aerial surveys, design of various types of sensors for aircraft surveys and development of number of application/utilization approaches. These were followed by planning, designing, fabrication of experimental remote sensing missions viz., Aryabhata, Bhaskara 1 & II etc. These missions gave experience in developing futuristic remote sensing satellites, setting up of ground-based data reception and processing systems, experience in over-all mission management etc.

The launch of IRS-1A satellite on 17th March, 1988 into the orbit is the start of operational remote sensing era of IRS programme. The IRS Satellites are providing imagery data for many projects of national importance and applications. Some of the remote sensing applications being catered are provided below

Agriculture and soils

- Phase level information of soils
- Improved multiple crop discrimination
- Crop monitoring &condition assessment
- Crop canopy water stress
- Crop yield estimates
- Crop management
- Cropping system analysis
- Damage assessment
- Surveillance of pests and diseases

Forestry

- Inventory and updating
- Forest landscape analysis
- Forest infra-structure mapping
- Forest encroachment
- State of forests
- Wildlife habitat analysis
- Bio-diversity
- Fire damage
- Implementation of forest policies

Environment

- Hydrologic units
- Land unit maps
- Soil contamination maps
- Quarries and waste identification
- Desertification analysis
- Oil spills
- Point and non-point sources of pollution
- Environmental impact assessment

Geology and Exploration

- Rock type mapping
- Tectonic geo- structure mapping
- Mining pollution analysis
- Off/on shore seeps analysis
- Coal fire analysis
- Mining subsidence analysis
- Landslide vulnerability / risk
- Geo-energy
- Water cycle study

Ocean application

- Phytoplankton observation
- Chlorophyll content,
- Yellow substance
- Suspended sediments
- Sea surface winds,
- Sea roughness monitoring
- Sea surface temperature
- Identifying the potential fishing zones,
- Coastal zone management,
- Ship routing,
- Operations of offshore oil rigs

Meteorology

Water vapour in an atmospheric column,

Cloud formation

Low pressure zone identification

Cyclone movement speed & direction

Weather predictions,

Infrastructure and Utilities

Road networks

3D-city models

Infrastructure maps

Siting of hydro-power locations

Site suitability

Rural and urban infrastructure

Structural and hydrological inventory

Municipal GIS

Utility corridor mapping

Transportation network

Rural road connectivity

Tracking changes in road

Telecom facilities

Recreation Facilities

Tourism

Violations

Damage assessment

Cartography

Updating topo-maps

Augmenting Databases

Image maps as base maps

Watershed management

Terrain evaluation

City models

Road and infrastructure maps

Site suitability assessment

Cadastral map generation

Defence

Strategic target monitoring

Mission planning

Training

Treaty verification

Demining

Lunar & Stellar Observation

Understand the way planets created

Stellar movement,

Celestial body feature study

Studying radiations coming from stars

Different elements available on stellar objects

Above said applications can be categorized in the following way as part of National Natural Resources planning as well as in other areas.

- Multiple crop production estimates,
    - Area estimate, crop health estimate
- Land and Water Resources optimization,
- Urban planning and management,
    - Infrastructural plan
- Coastal zone studies and regulation
    - Fishing, chlorophyll, phytoplankton etc.
- Mapping and inventory of forests, wastelands, land use,
- Lunar & stellar observation missions

The aim of this document is to collect the Indian Remote Sensing payload details available at various sources and consolidate to bring them in a single document. This document provides brief, condensed information of various IRS

Missions and payloads. This document will serve the new entrant engineers to understand the evolution of Remote sensing Programme in India. Information provided in this document is collected from various sources like configuration data books, internet sources, Journals and books. The list of references is provided in annexure-1.

IRS missions can be classified based on their applications as follows.

- Land and Water Resource Observation Series
- Ocean and Atmospheric Observation Series
- Cartographic Satellite Series
- Microwave Remote Sensing Series
- Environmental monitoring series
- Space Science Series
- Micro and Nano Satellite Series

Land and Water Resource Observation Series

These satellites cater to the requirements of following applications:

Agriculture, forestry, land use, land cover, soil, geology, terrain, water resources, disaster management like flood, forest fire, drought, land slide, etc.

Satellites launched for these applications are IRS-1A, IRS-1B, IRS-1C, IRS-1D, IRS-P6 (Resourcesat-1), Resourcesat-2, and IMS-1A. Resourcesat-2 satellite with improved performance having three payloads namely, LISS-IV with 5.8m Resolution and 70 km swath in 3 bands, LISS-III with 23.5m Resolution and 140 km swath and AWIFS with 56m Resolution and 740 km swath was launched on 20thApril 2011 and successfully operationalized and is providing data for above said applications.

Presently the following IRS Satellites are operational and providing data for above applications

- IMS-1A
- Resoucesat-2

Ocean and Atmospheric Observation Series

Under Ocean and Atmospheric Observation Series, satellites were launched to meet the needs of potential fishing zone (PFZ) forecasting, sea state forecasting, coastal zone studies and to provide inputs for weather forecasting and for climatic studies:

Satellites launched for this application are Oceansat-1, Oceansat-II, and Megha Tropiques

Oceansat-2: satellite with Ocean Colour Monitor (OCM) payload with 360m spatial resolution and 1420 km swath and Ku-Band pencil beam scatterometer and

Radio Occultation for Sounding of Atmospheric (ROSA) was launched on 23rd September 2009 was successfully operationalized for providing data for the above applications.

Megha-Tropiques: Under Ocean and Atmospheric Observation series to study the convective systems that influence the tropical weather and climate. The Megha-Tropiques mission was launched on 12th October 2011. The Megha-Tropiques spacecraft carries 4 payloads namely:

- MADRAS (A Microwave Imager to study the precipitation and cloud properties).
- SAPHIR (A Microwave Sounder for the retrieval of water vapour vertical profiles).
- SCARAB (A Radiometer for the measurement of outgoing radiative fluxes at the top of the atmosphere) and
- ROSA (Radio Occultation for Sounding of Atmosphere) to provide vertical profiling of temperature.

The Megha-Tropiques mission will provide sampling of water and energy budget of the Tropical Convective Systems in the inter-tropical band.

Cartographic Satellite Series

In order to meet the large scale and thematic maps for urban & rural infrastructure development & management and to provide National Digital Elevation Model (DEM) for cadastral overlay these satellites were launched. They cater cartographic applications, coastal features mapping, coral reef mapping and for mineral studies also

The features of these satellites are : TES with <1 m resolution PAN, Cartosat-1 with 2.5m Resolution PAN and 30km swath with along track stereo imaging capability, Cartosat-2,2A,2B with 0.8m Resolution PAN with 9.6 km swath

In order to meet the increased demand for large scale mapping and other cartographic applications for cadastral level and for urban and rural infrastructure development & management Cartosat-2A and Cartosat-2B with 0.8m Resolution PAN with 9.6 km swath were launched for above applications.

- Technology Experimental satellite (TES)
- Cartosat-1 (since May 2005)
- Cartosat-2 (since January 2007)
- Cartosat-2A (April 2008)
- Cartosat-2B (since July 2010)

Microwave Remote Sensing Satellite Series

In order to provide data during the cloud cover seasons (Kharif) over the tropical regions for many applications like agriculture and damage assessment during flood and for mitigation effects Microwave Remote Sensing Satellites are planned.

The **RISAT-1** with C-Band synthetic Aperture Radar (SAR) launched on 26th April 2012

The spacecraft can operate in different modes of operation and provides various resolution imageries like:

- High Resolution Spotlight Mode (HRS) provides 1 - 2m resolution with 10 km x 10 km spot scenes.
- Fine Resolution Strip Mode (FRS-I) provides 3 - 9m resolution with 30 km x 30 km scenes.
- Fine Resolution strip mode (FRS-2) provides 6 - 9m resolution with 30 km swath.
- Medium Resolution Scan SAR Mode (MRS) with 25m resolution with a swath of 120 km.

The RISAT-1 is expected to provide all weather day and night imageries for applications in the areas of Agriculture for identifications, detection and classification for acreage estimation, forest type plantations and accurate bio-mass estimation, flood mapping to provide accurate flood inundation zones for early relief measures, soil moisture and Hydrology including snow cover and snow wetness, etc.

Space Science and Planetary Series

The study of Lunar and stellar sources provide better understanding about the universe and planet creation etc. Following satellites are in this series.

IRS-P3: This satellite carried X ray monitor

CHANDRAYAAN-1: The launch of Chandrayaan-1 has demonstrated the technological capabilities of reaching the outer planets and has confirmed the scientific findings of the previous International Missions, like the presence of water molecules and other precious elements on the surface of the moon.

The significant scientific finding have provided impetus to further space research activities in the country and has created special awareness and enthusiasm among the younger generation.

Micro, Nano and Pico Satellite Series

IMS-1: With the advances in miniaturization and the advances in high performance devices and techniques, it has become feasible to realize the functions of bigger satellites into Micro & Nano satellites. The ISRO's first Mini Satellite (IMS-1) with 36m Resolution Mx with 141 km swath and 505 m resolution Hyper-spectral

Imager (HySI) with 64 bands has been realized within 85 kgs and was launched successfully during April 2008.

Youthsat: This satellite is second in IMS-1 series, carrying three payloads namely SOLRAD, LiVHiSI and RaBIT. It was launched into space on 20th April 2011 by PSLV-16 along with Resourcesat-2. The SOLRAD payload monitors the Solar activities through hard X-rays gamma rays and particle mostly electrons and protons. The effect of the solar activities on atmosphere is studied by the RaBIT. The effect on the thermosphere, which co-exists with the ionosphere, is monitored by LiVHySI.

The interest and the enthusiasm created by the launch of many Nano satellites in a single launch by the PSLV induced many students community from Colleges, Universities, and Indian Institute of Technologies to involve in the development of many Micro and Nano satellites for various applications.

The STUDSAT, the first pico satellite conceived and designed by seven Engineering Colleges of Karnataka and Andhra Pradesh was successfully launched during July 2010.

JUGNU from IIT-Kanpur and SRMSAT were successfully launched on 12th October 2011.

PRATHAM from lIT-Bombay and Sathyabhama-sat from Sathyabhama Universities are under advanced stages of realization for many EO and environmental monitoring applications.

Some more premier educational institutions of India are ready to get an opportunity for making satellites.

Environment Monitoring Series

In order to provide data for various studies in the atmospheric domain pertaining to climate modeling and prediction, series of satellites are planned. The increase in quantity of some gases causes global warming. The detection and monitoring these trace gases is important to control them. For this purpose suitable payload parameter were studied and finalised. Satellite proposal is also prepared.

Metrological applications payload series

ISRO provides continuous service to the meteorological observation through its multi-utilization platforms (INSAT & GEOSAT satellite). Some satellites are launched for dedicated meteorological applications. This chapter provides the configuration of Very High Resolution Radiometer (VHRR) used for this application and its evolution in last two decades.

Satellites launched for this application are INSAT-2A, 2B, 2E, Kalpana-1, and INSAT-3A. INSAT-3D is under development with advanced features.

List of Satellites and Payloads

Sl.No	Satellite Name	Payload	Abbreviation
1	Aryabhata	X-ray Aeronomy Solar Neutrons & Gamma	X-Ray Aeronomy experiment Solar Neutrons & Gamma detection
2	Bhaskara 1 , 2	SAMIR, TV Camera	Satellite Microwave Radiometer Two Band TV Camera
3	Rohini Satellites	Astronomy/ stellar	X-ray , Gamma ray Detection
4	IRS 1A & 1B	LISS-I, LISS-II	Linear Imaging Self Scanner -I Linear Imaging Self Scanner -II
5	IRS-1E	LISS-I MEOSS	Linear Imaging Self Scanner -1 Monocular Electro-Optical Stereo Scanner
6	IRS-P2	LISS-II	Linear Imaging Self Scanner -II
7	IRS-P3	WiFS MOS IXAP	Wide Field Sensor Multispectral Opto-Electronic Scanner Indian X-Ray Astronomy Payload (IXAP)
8	IRS 1C & 1D	PAN, LISS-III, WIFS	Panchromatic Linear Imaging Self Scanner –III Wide Field Sensor
9	IRS-P4	OCM, MSMR	Ocean Colour Monitor Multi-frequency Scanning Microwave Radiometer
10	TES	PAN	Panchromatic

Sl.No	Satellite Name	Payload	Abbreviation
11	IRS-P6	LISS-IV, LISS-III*, AWiFS	Linear Imaging Self Scanner –IV Linear Imaging Self Scanner –III* Advanced Wide Field Sensor
12	Cartosat-1	PAN-AFT, PAN- FORE	Pan camera - Looking Forward Pan camera - Looking Forward
13	Cartosat 2,2A,2B	PAN	Panchromatic
14	IMS-1	Mx, HYSI	Multispectral Camera Hyper Spectral Camera
15	Chandrayaan-1	TMC	Terrain Mapping Camera
		HySI	Hyper Spectral Imager (0.2u to 0.9u)
		LLRI	Lunar Laser Ranging Instrument (LLRI)
		HEX	High Energy X-ray payload (HEX)
		MIP	Moon Impact Probe(MIP)
		LEX	Low Energy X-ray (LEX) Payload (CIXS).
		MINISAR	Mini SAR from Applied Physics Laboratory (APL, USA
		SIR-2	SIR-2 from Max Plank Institute / ESA
		RaDoM	Radiation Dose monitor from Bulgarian Academy of sciences.
		SARA	Sub-KeV Atom Reflecting Analyser (SARA) Experimental developed jointly by IRE Sweden, SPL-VSCC India, ISAS/JAXA Japan and VBE Switzerland
		MMM	Moon Mineralogy Mapper (M3) from HJPL, USA

Sl.No	Satellite Name	Payload	Abbreviation
16	Oceansat-2	OCM, Scatterometer, ROSA	Ocean Colour Monitor Ku Band Scatterometer Radio Occultation Sounder for Atmosphere
17	Resourcesat-2	LISS-IV, LISS-III*, AWiFS HIP	Linear Imaging Self Scanner –IV Linear Imaging Self Scanner –III* Advanced Wide Field Sensor Hosted Indian Payload
18	Youthsat	SOLRAD, LiHySI, RaBIT	Solar Radiation Monitor Limb-View Hyper spectral Imager Radio Beacon for Ionospheric tomogram
19	Megha Tropiques	MADRAS SAPHIR ScaRaB, ROSA	Microwave Analysis and Detection of Rain and Atmospheric Structures Soundeur Atmospherique du Profile d'Humidite Interopicale par Radiometrie Scanner for Radiation Budget Radio Occultation Sounder for Atmosphere
20	RISAT-1	C-Band SAR	Synthetic Aperture Radar

Sl.No	Satellite Name	Payload	Abbreviation
21	SARAL	ARGOS, ALTIKA SCBT	Advanced Research and Global Observation Satellite Altimeter Ka-band Solid state C – Band Transponder
22	Astrosat	LAXPC CZT SXT SSM UVIT CPM	Large area xenon-filled proportional counter Cadmium Zink Telluride Soft X-Ray imaging Telescope Scanning Sky Monitor Ultra Violet imaging telescope Charge Particle Monitor
23	Chandrayaan-2	ChACE-2 CLASS XSM SAR IIRS TMC-2 APIXS Rover Imager LIBS	Chandrayaan-2 Altitudinal Composition Explorer Chandrayaan-2 Large Area Soft x-ray spectrometer Solar X-ray Monitor L and S band Synthetic Aperture Radar Imaging IR Spectrometer Terrain Mapping Camera Alpha Particle Induced X-ray Spectroscope Rover Imager Laser Induced Break Down Spectroscope
24	INSAT missions	VHRR	Very High Resolution Radiometer
25	Aditya		Solar Coronagraph
26	Mars Orbitr Mission	MCC, MSM, TIRIS, LAP and MENCA	

Experimental Satellites

Satellites	Payloads	Altitude km	Inclination deg	Mass kg	Power W	Launch Vehicle	Launch Date
Aryabhata	X-ray Gamma ray Aeronomy	619 x 562	50.7	358	46	Intercosmos	19-04-75
Bhaskara-1	TV Camera Micrometer	519 x 541	50.6	442	47	C1-Intercosmos	07-06-79
RTP	LV Monitor instruments	**Not achieved**		35	3	SLV-3	10-08-79
RS-1	LV Monitor instruments	305 x 919	44.7	35	16	SLV-3	18-07-80
RS-D1	Landmark tracker	186 x 418	46	38	16	SLV-3	31-05-81
Bhaskara-2	TV Camera micrometer	541 x 557	50.7	444	47	C1-Intercosmos	20-11-81
RS-D2	Smart sensor	371 x 861	46	41.5	16	SLV-3	17-04-83
SROSS-1		**Not Achieved**		150	90	ASLV	24-03-87
SROSS-2	MEOSS			150	90	ASLV	13-07-88
SROSS C	GRB, RPA	267 x 391	45	106.1	45	ASLV	20-05-92
SROSS-C2	GRB, RPA	430 x 600	45	115	45	ASLV	04-05-94

Lunar and Stellar Observation Satellites

Satellites	Payloads	Mass (Kg)	Power (W)	Launch Vehicle	Launch Date
Chandrayaan-1	TMC,Hysi,LLRI, HEX,MIP,CIXS,SIR-2, SARA,MINISAR, M3,RADOM	1380	700	PSLV-XL	22-10-08

Operational Earth Observation Satellites

Satellites	Payloads	Altitude (km)	Inclination (deg)	Local Time (hr.mm)	Mass (kg)	Power (EOL) (W)	Launch Vehicle	Launch Date
IRS-1A	Liss-I, Liss-II	904	99.08	10.30	975	709	Vostak	17-03-88
IRS-1B	Liss-I, Liss-II	904	99.08	10.30	975	709	Vostak	29-08-91
IRS-1E	LISS-I, MEOSS	**Not achieved**			846	415	PSLV-D1	04-05-94
IRS-P2	LISS-II	817	98.68	10.30	804	510	PSLV-D2	15-10-94
IRS-1C	Liss-3 Panchromatic WiFS	817	98.68	10.30	1250	809	Molniya	28-12-95
IRS-P3	WiFS, MOS IXAE	817	98.68	10.30	920	817	PSLV-D3	21-03-96
IRS-1D	Liss-3 Panchromatic WiFS	740 x 817	98.73	10.30	1250	809	PSLV-C1	27-09-97
IRS-P4 (Oceansat-1)	MSMR, OCM	720	98.28	12.00	1050	750	PSLV-C2	26-05-99
TES	Panchromatic	560	97.65	9.30	1108	800	PSLV-C3	22-10-01
IRS-P6 Resourcesat-1	Liss-3, Liss-4 AWiFS	817	98.68	10.30	1360	1250	PSLV-C5	17-10-03
IRS-P5 (Cartosat-1)	PAN(Fore) PAN(Aft)	618	97.87	10.30	1560	1020	PSLV-C6	05-05-05
CartoSat-2	Panchromatic	635	97.91	9.30	650	1200	PSLV-C7	10-01-07
Cartosat-2A	Panchromatic	635	97.91	9.30	690	1200	PSLV-C9	28-04-08
IMS-1 (TWSAT)	Mx, HySI	636.2	97.91	9.30	83.2	229	PSLV-C9	28-04-08
Oceansat-2	OCM, Scatterometer ROSA	720	98.28	12.00	960	1360	PSLV-C14	23-09-09
Cartosat-2B	Panchromatic	630	97.71	9.30	694	1200	PSLV-C15	12-07-10
Resourcesat-2	Liss-3 , Liss-4 AWiFS, HIP	822	98.73	10.30	1206	1250	PSLV-C16	20-04-11

Youthsat	SOLRAD RaBiT, LivHySI	822	98.73	10.30	90	229	PSLV-C16	20-04-11
Megha Tropiques	MADRAS SHAPHIR SCARAB ROSA	867	20.00	---	998	1180	PSLV-C18	12-10-11
RISAT	C-Band SAR	536.4	97.554	6.00	1858	1514 (min)	PSLV-C19	26-04-12
SARAL	ARGOS, ALTIKA SCBT	789 x 773	98.53	18.00	412	800	PSLV-C20	25-02-2013
Astrosat	LAXPC, CZT SXT, SSM UVIT, CPM							
Chandrayaan-2	ChACE-2, CLASS, XSM, SAR, IIRS, TMC-2, APIXS, Rover Imager, LIBS							
Aditya	Solar Coronagraph							

1 ARYABHATA

1.1 Introduction

The Indian Space research activities started with initiating sounding rocket progamme in 1963 at Thumba for conducting scientific experiments for the study of upper atmosphere and ionosphere. In addition to this ISRO started a systematic programme for setting up a full-fledged indigenous base for the design, fabrication, and qualification and in orbit operation of satellites for variety of scientific applications. ISRO signed an agreement with the USSR Academy of Sciences in 1972 for launching Indian satellite from a Soviet Cosmodrome, using Intercosmos rocket carrier. The ISRO Satellite System Project (ISSP) was established at Peenya, at the outskirts of Bangalore. The successful launch of Aryabhata, the first satellite designed and fabricated by India on 19th April 1975, was the major milestone of space research of India.

1.2 Mission objectives

The primary objectives of Aryabhata mission were:

- *Indigenous design and fabrication of a space worthy system and evaluation of its performance in orbit;*
- *Evolving the methodology of conducting a series of complex operations on the satellite in its orbital phase;*
- *Setting up the necessary ground-based receiving, transmitting and tracking systems; and*
- *Establishing the relevant infrastructure for the fabrication, testing and qualification of spacecraft systems*

1.3 Orbit Details

Table 1.1 Orbit details of Aryabhata satellite

Sl.No	Parameter	Aryabhata
1	Mass	358 Kg
2	Power	25 W (Generated 46W)
3	Altitude	619 x 562 Km
4	Orbit	Near circular
5	Inclination deg.	50.7
6	Stabilization	Spin Stabilization
7	Spin rate	10 to 90 rev/min

7	Launch Date	19th April 1975
8	Orbital Time	95.2 min.
9	Launched by	Soviet Intercosmos rocket

1.4 Salient features of Aryabhata Systems

Table 1.2 Features of Aryabhata Systems

Sl.No.	Parameter	Values
1	Structure	Quasispherical shape with 26 flat faces, 1.59 m equivalent dia. and 1.19 m height. Quasispherical shape was selected to get more surface area get illuminated by Sun
2	Thermal	Passive thermal control system employing paints of required emissivity and absorptivity. Temp Range 0 - 40 Deg.C
3	Power	Body mounted silicon solar cells (36,800 cm^2) Ni-Cd Chemical batteries 10 A-H Avg. raw power generated 46 W Four buses +14,+9,-14 and -9V
4.	Telecommand system TTC Uplink	 PCM/AM/AM at 1 KW transmitter (Total 35 Commands) 148.25 MHz
	TTC Downlink	PCM/FM/PM, 91 Parameters monitored, 256 bits/sec, 4 min data transmission, 137.44 MHz
5	AOCS	Triaxial magnetometers and digital sun sensors. Measurement accuracy < 1 Deg. Coning angle < 0.1 deg. Controlled by Gas bottles
6	Payloads (ISAC)	• X-ray astronomy payload (2.5-150 KeV),ISAC • Solar neutron and gamma rays experiment,TIFR • Aeronomy experiment,PRL
7	Ground stations	Receiving and commanding from SHAR
8.	Mass	358 Kg

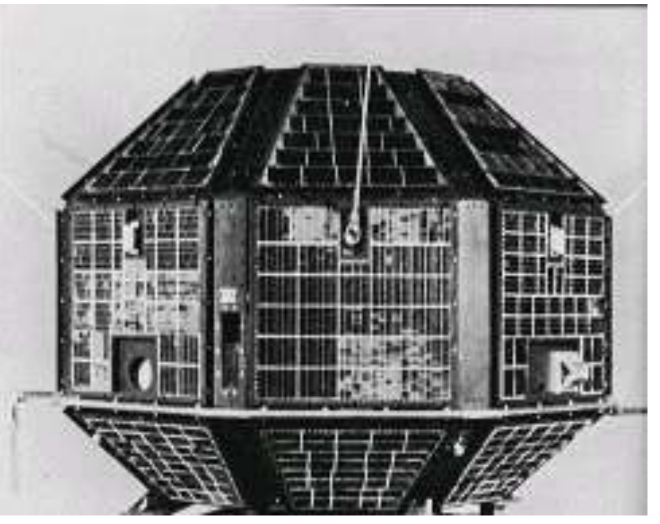


Figure 1.1 View of Aryabhata Satellite

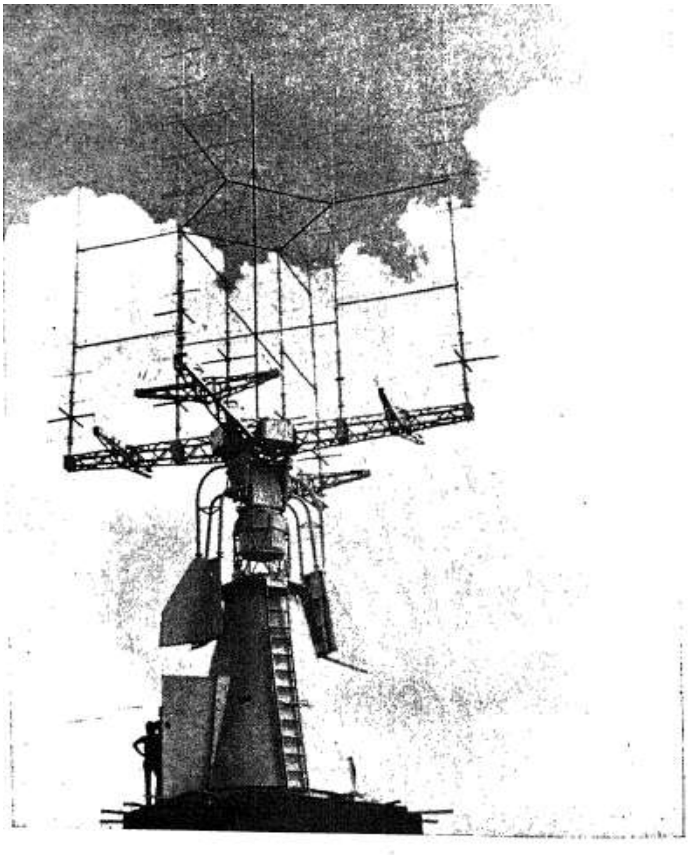


Figure 1.2 View of Ground antenna at SHAR

1.5 Payloads

The payload system of aryabhata consists of three sensors. Thay are for

- X-ray astronomy Experiment
  - To investigate celestial x-ray sources primarily in relation to their time variation effect in energy range of 2.5-150 Kev.
- Solar neutrons and gamma rays detection and monitoring
  - To detect high energy neutrons and gamma rays from the sun both during quiet times and flares.
- Aeronomy experiment
  - To detect super thermal electrons up to 100ev and to measure the intensities of Lyman alpha and oxygen line at F-region altitudes of the earth's ionosphere

1.5.1X-Ray astronomy Experiment

The main objectives of the x-ray astronomy experiment onboard Aryabhata were

1. The determination of flux and energy spectra of X-ray sources in the energy range 2.5 keV to 155 keV;
2. The exploration of new / transient x-ray sources with a sensitivity of 0.1 photon cm^{-2} s^{-1} in the 2.5 – 18.75 keV and 10^{-2} photons cm-^{2} s^{-1} in the 15.5 – 155 keV range;
3. Study of the time variation in the intensity of strong x-ray sources with time scales of the order of a minute or more.

1.5.1.1 X ray telescopes

The X ray with energy range of 2.5 – 18.75 keV was investigated using a gas proportional counter telescope. The proportional counter was filled with a mixture of organ and carbon dioxide in the ratio of 9: 1 to a pressure of one atmosphere. The entrance window was 50 micron thick beryllium.

The sensitivity depth was 3 cm. Charge particle induced events were eliminated by an additional gas depth of 1.5 cm with an independent anode wire and setting the top anode events in anticoincidence with the bottom anode events. Addition to this the pulse shape discrimination (PSD) technique was employed for minimizing contamination due to non-x-ray events such as those due to gamma rays. The detector was imparted directionality by the use of a set of cylindrical collimators made out of an aluminum block.

The X-ray telescope for the higher energy range (15.5 keV to 155 keV) consisted basically of a NaI (TI) crystal of 3.8 cm diameter and 4 mm thickness placed in a cylindrical plastic scintillator NE102A anticoincidence wall. The cylindrical graded shield of lead, tin and copper used as the internal lining or the plastic scintillator imparted directionality to the telescope. The entire assembly was viewed from the bottom by a Dumont K – 2227 photomultiplier of 5 cm cathode diameter. The charged particle – induced events were eliminated by the pulse shape discrimination technique, which separated the events having 10 ns rise time from those in NaI(TI) that had 250 ns risetime. The physical configuration of scientillation counter telescope is shown in figure 1.4.

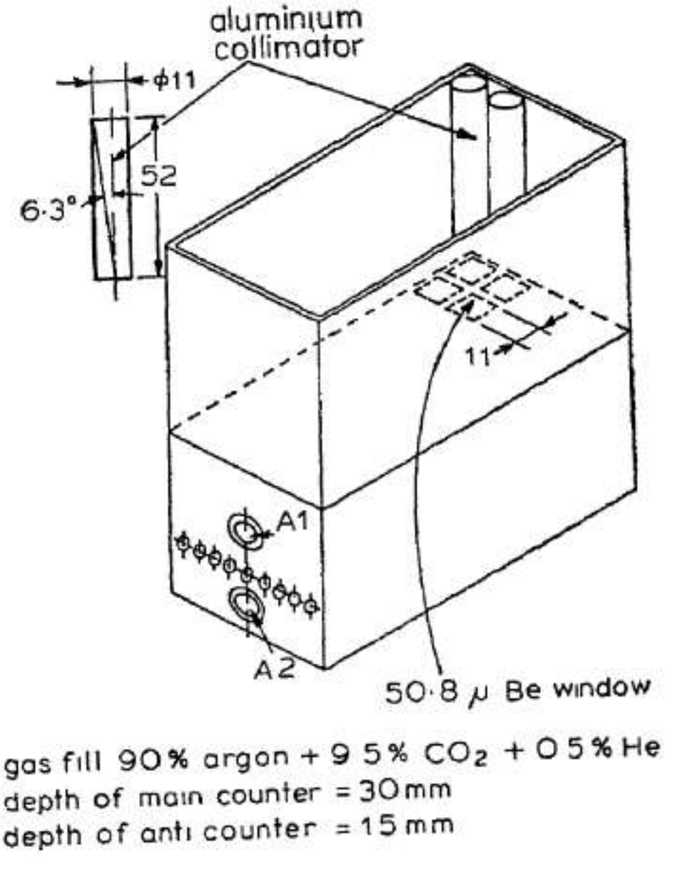


Figure 1.3 Physical configuration of proportional counter telescope

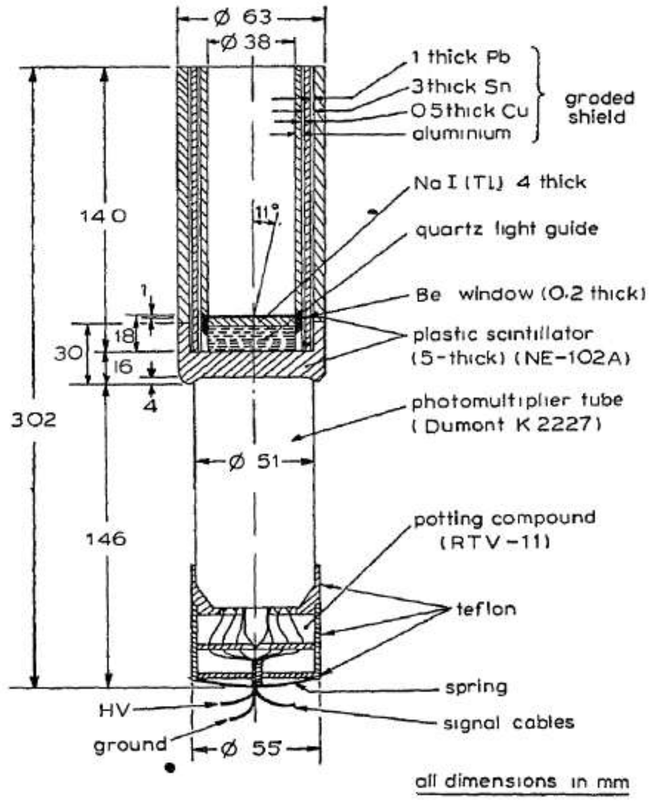


Figure 1.4 scintillation counter telescope

Table 1.3 Specifications of the telescopes

Nature of telescope	Effective area	Nature of window	Viewing condition	Collimater	Angular response (in deg. FWHM)	Telescopic geometrical factor	Energy range (keV)
Proportional counter telescope	15.2 cm^2	50 um Be with 1/e cut off energy of 2.5 keV	Along the spin axis	Aluminum block with a number of cylindrical holes.	12.5°	0-58 cm^2 streradian	2.5-18.75
Scientillation counter telescope	11.3 cm^2	0.285 mm Be	Across the belly band perpendicular to the spin axis	Graded shield of 0.1 cm lead, 0.3 cm tin and 0.05 cm copper	14.5°	11 cm^2	15.5 – 155.0

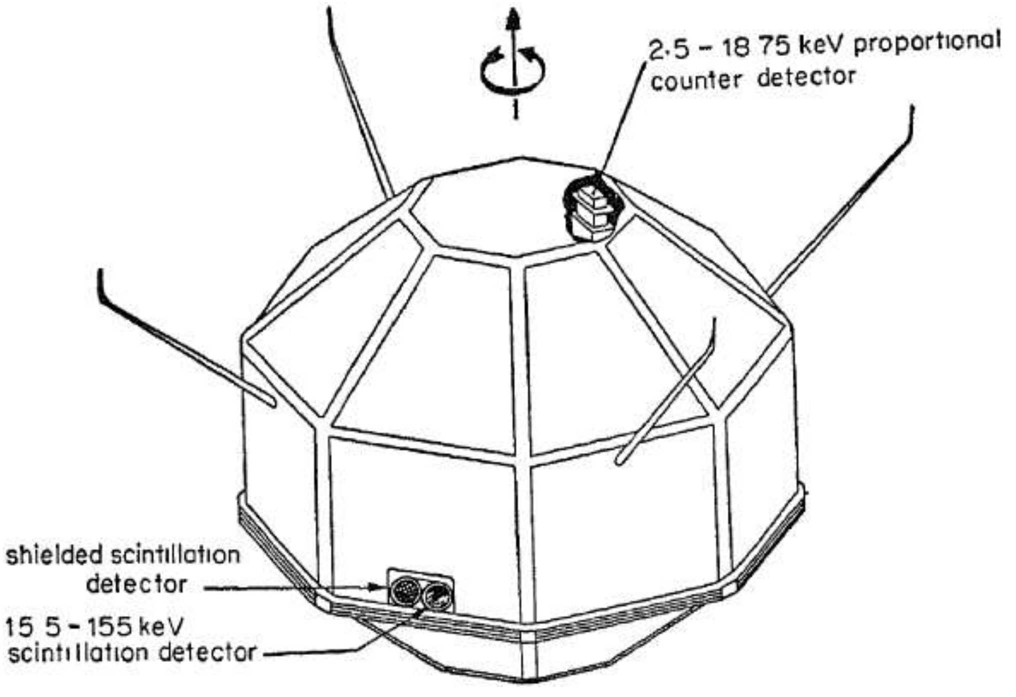


Figure 1.5 Location of X- ray telescopes on satellite

1.5.2Solar neutron and gamma ray telescope

The second payload for the detection and measurement of high energy neutron and gamma rays from the sun was developed at Tata Institute of Fundamental Research.

The objective of this payload was

1. To detect simultaneously the possible impulsive emission of energetic neutron(10-500 MeV) and gamma rays (0.2-20 MeV at times of intense solar activity. The possibility of observing the delayed signal from neutrons with respect to the gamma rays is an important capability of the experiment.
2. To detect any steady or quasi-steady solar emission of energetic neutrons and gamma rays.
3. To measure the splash albedo flux of neutron and gamma rays as a function of latitude.
4. To detect gamma ray bursts of the type first discovered by Vela satellites and any other type so far not discovered.

1.5.2.1 Configuration of the payload

The method of the detection and separation of the neutrons and gamma rays is based on the fact that in an inorganic crystal scintillator like CsI(TI), the high rate of ionization due to the low energy protons and helium nuclei caused by neutrons, gives rise to a pulse shape different from the low rate of ionization due to the fast electrons originating from gamma ray interactions in the crystal.

The experimental payload consisted of two boxes, referred as Ex-21 and Ex-22. They were placed one above the other, with Ex-21 near the deck plate as shown in fig. 1.6 The main detector crystal housed in Ex-21 was viewed by a 12.5 diameter photo multiplier tube and completely surrounded by a 1 cm thick NE-102 plastic scientillator viewed by four 3.81 cm diameter photomultipler tubes; the latter served as the charged particle anticoincidence shield for the main detector. The amplifiers for the CsI(TI) and plastic scientillator logic electronics and high voltage supply for photomultipliers were housed at Ex-21.

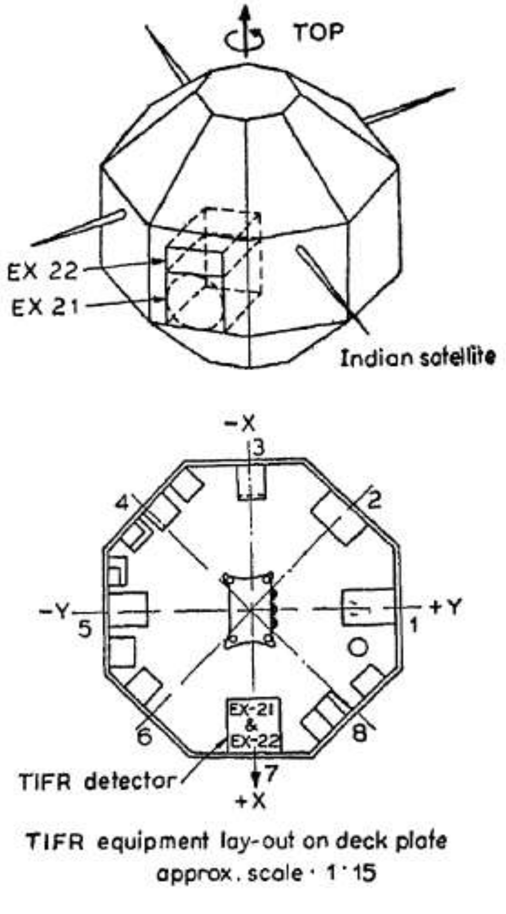


Figure 1.6 Schematic diagram showing the position of the experiment in the satellite.

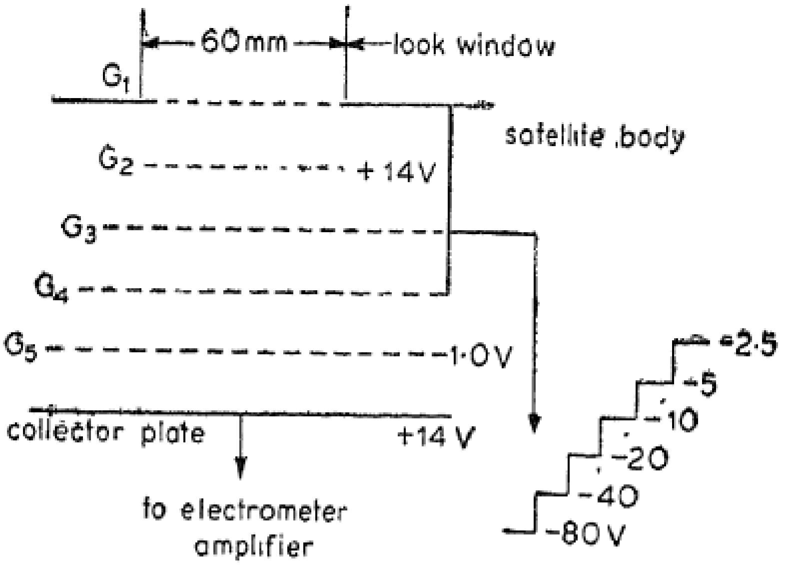
1.5.3The aeronomy experiment

This experiment was mainly designed to study the global distribution of suprathermal electron, ionosphere-magnetosphere coupling, the F-region anomaly and the hydrogen geo-corona. This experiment consisted of a retarding potential analyser and two ultraviolet ion chambers. The first one was designed to measure the flux of suprathermal electrons in the earth's atmosphere and the second one was designed to measure the intensity of the resonantly scattered hydrogen Lymen alpha (1216 A) and photo-electronically excited OI (1304 A) emissions.

1.5.3.1 Retarding Potential Analyser (RPA)

This detector was designed to measure the flux of electrons in the energy range between 2.5 eV and 80 eV. The RPA consisted of a system of five tungsten grids G1 to G5 and a collector plate. Grids G1 and G4 were connected to the satellite body while G2 was connected to +14 V and G3 to the retarding potential varying from -2.5 to -80 V. The grid G5 was connected to -1.0 V and the collector plate was biased at + 14 V. A small annular metallic ring concentrically mounted on RPA detector and electrically insulated from it, was used for measuring floating potential with respect to the spacecraft potential. This measurement was required to determine the effective retarding potential as applied to grid G3 of the RPA.

The aeronomy experiment



The RPA grid voltage diagram.

1.5.3.2 UV Detectors

Two UV chambers similar to each other but with different spectral pass bands were used for the experiment. The first chambers was fitted with a magnesium fluoride window and filled with NO gas at a pressure of about 10 to 20 mm of Hg. The spectral pass band of this chamber was from 1120 to 1340 A. The second chamber with calcium fluoride window and filled with NO had a pass band from 1250 to 1340 A. Both chambers were operated in the unity gain mode with a bias voltage of +45 V and were mounted at the satellite equatorial plane. The 2.5 cm dia. look windows of each detector provided a field of view of about ± 22.5 deg.

The two experiments the RPA and UV detectors were programmed to operate in a pre- arranged time-sequence. Each experiment was switched on 12 seconds before data were collected from it for stabilization of its electronics.

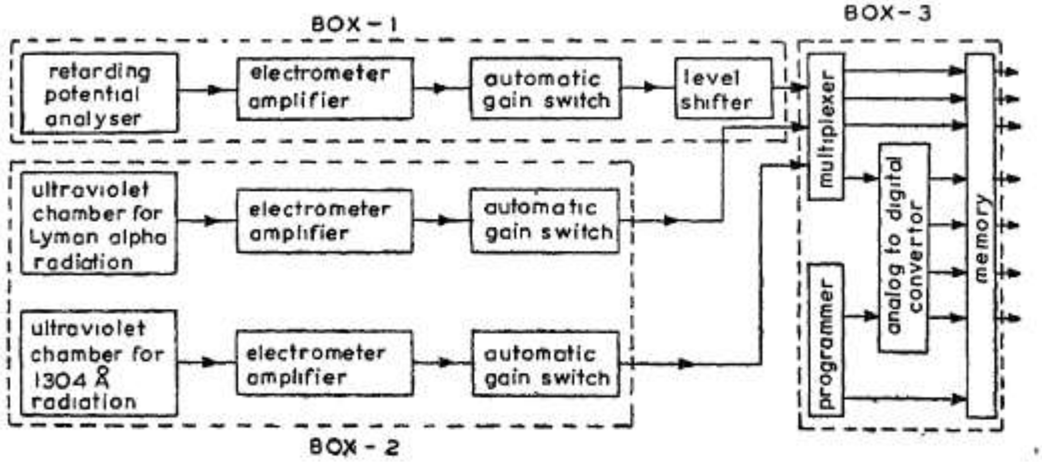


Figure 1.7 Block diagram for the payload electronics of the RPA and UV experiments.

2 BHASKARA-1 & 2

2.1 Introduction

The dream of making Earth Observation Satellite by India came to true through the BHASKARA-I mission. It is the first experimental Terrain remote sensing satellite built by India and launched in 7th June 1979. This was followed by a follow-on mission BHASKARA-II with some modification on and was launched on 20th November 1981. The technologies developed for ARYABHATA were used in BHASKARA with some improvements such as spin rate and spin axis control, using Infrared Horizon sensor for earth reference and high bit rate telemetry for payload data transmission. These missions provided a system experience on End-to-End basis, configure, design, develop, and assemble a satellite for remote sensing to reception and processing of remotely sensed data and generation of data products as per user requirement.

2.2 Mission objectives

The primary objectives of Bhaskara-I mission were:

- *To conduct earth observation experiments that would yield useful data in the areas of metrology, hydrology and forestry using a two band TV camera system operating in the 0.54 to 0.66 microns visible band and 0.75 to 0.85 micron near Infrared band (The earth imagery obtained from an altitude of 525 Km provides a spatial resolution of 1 Km X 1 Km in a picture frame of 341 x 341 Km)*
- *To conduct ocean surface studies using a three chain radiometer operating at microwave frequencies.*
- *To evolve the methodology of reception, processing and dissemination of data and thus establish visibility of management of earth resources through remote sensing satellites.*

The secondary objectives are

- *To develop the technology for relaying data collected from the unattended platforms to a central receiving station to obtain useful meteorological data on an experimental scale, from presently inaccessible regions at short turn-around times and thus develop the expertise and infrastructure for large scale applications of automatic data collection platforms.*
- *To study the performance of indigenously developed solar cells, thermal paints and heat pipe under prolonged exposure to space environments.*
- *To study the time variations of celestial X-ray sources and detect transient sources.*

The Basic Objective of the Bhaskara – II was to provide continuity to the Bhaskara-I experiment.

2.3 Orbit Details

Bhaskara I & II comparison

Table 2.1: Orbit details of Bhaskara satellites

Sl.No	Parameter	Bhaskara-I	Bhaskara-II
1	Mass	444 Kg	444 kg
2	Power	47 W	47 W
3	Altitude	534 Km	548.269 Vs 514.304 Km
4	Eccentricity deg.	0.0023	0.002459
5	Orbit	Near circular	Near circular
6	Inclination deg.	50	50.635
7	Stabilization	Spin Stabilization	Spin Stabilisation
8	Launch Date	June 7, 1979	Nov. 20 1981
9	Orbital Time	95.2 min.	95.2 min.

2.4 Salient features of Bhaskara-I and Bhaskara-II Systems

The Bhaskara-I project, originally known as the Satellite for Earth Observation (SEO) was conceived as one of the key intermediate steps towards going for a full-fledged operational remote sensing satellite system for India.

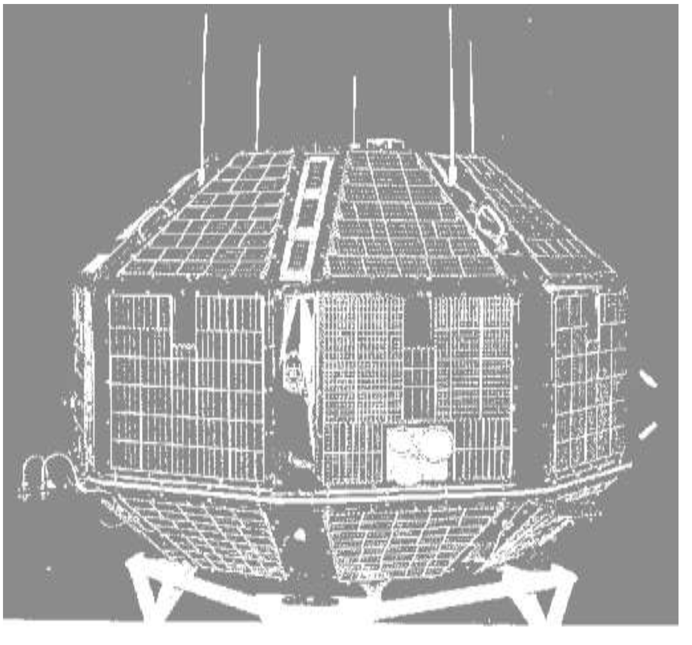


Figure 2.1 View of Bhaskara satellite

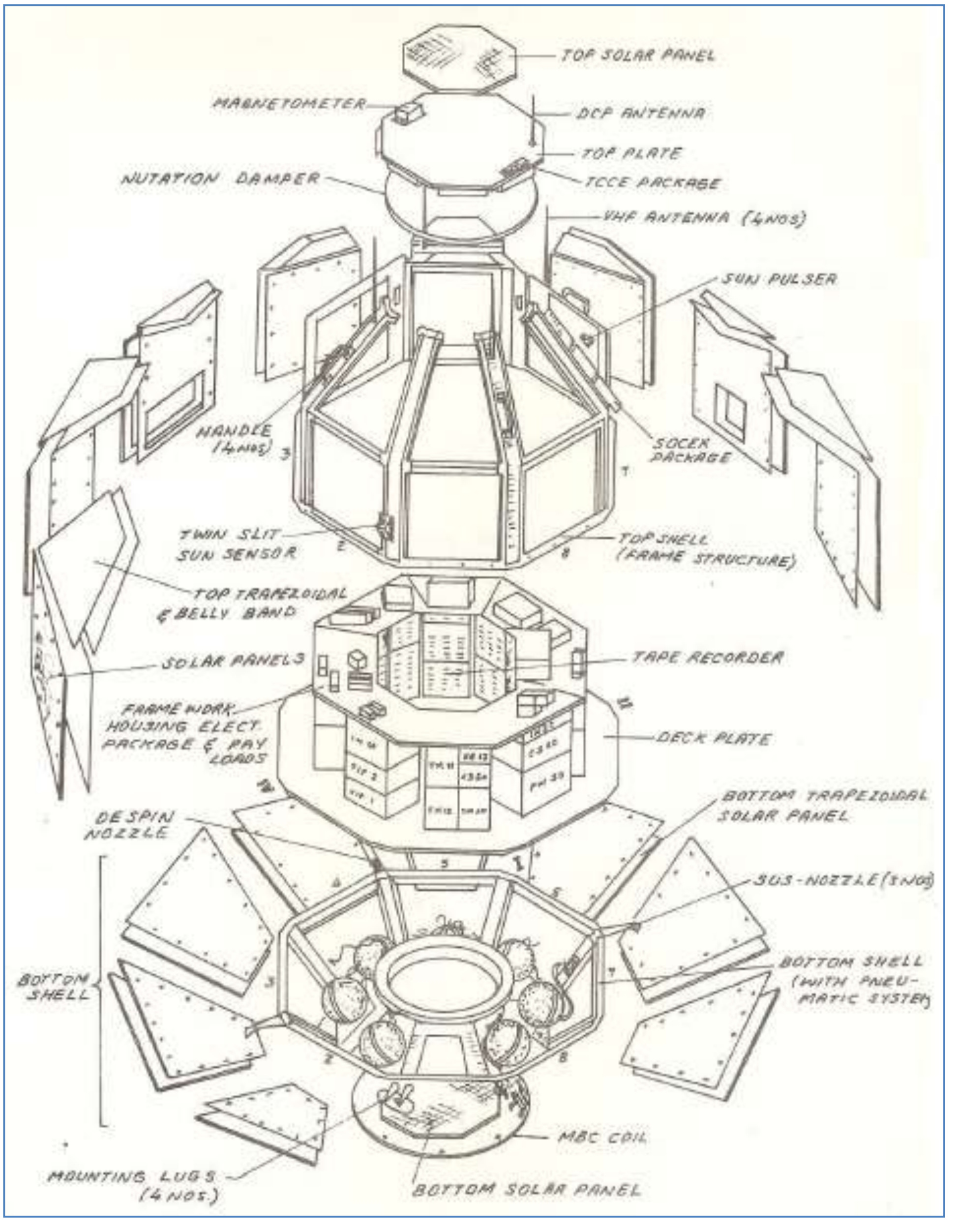


Figure 2.2 Exploded view of Bhaskara satellite

Table 2.2 salient Features of Bhaskara satellite

Sl.No.	Parameter	Values
1	Structure	Similar to Aryabhata Overall height inclusive of antenna 1559 mm Distance between axes of nozzles 1900
2	Thermal	Passive systems Temperature limit 0 to 40 deg. C.
3	Power system	Body mounted solar panels backed by 10 AH NiCd Battery
4.	TTC Uplink TTC Downlink LBT (224 Bits/Sec) TTC downlink HBT (91 Kbs) Tracking System	PCM/FM/AM at 148.25 MHz. PCM/FM/AM at 137.20 MHz. PCM/BSK at 137.20 MHz 148.61 MHz uplink 137.1 Mhz downlink with tones 32 Hz top 20 MHz
5	AOCS Type of stabilization Spin Rate range Spin axis orientation Attitude determination	 Cold gas jet –spin stabilization 6 to 11 RPM Within 3 deg of orbit normal Within 1 deg.
6	Payloads (SAC)	TV slow scan videcon cameras operating in the visible Band 0.54 – 0.66 microns and IR Band 0.75 to 0.85 microns Microwave Radiometers operating at 19 and 22 GHz (in Bhaskara II, 32 GHz chain included)
7	Mass	444 Kg(436 for Bhaskara- II)

2.5 Payload

In an ideal case an earth observation satellite system should be three axes stabilized so that the sensors can point towards the earth continuously. However to gain time, the satellite configuration of the first Indian satellite ARYABHATA was adopted and images were acquired while spacecraft was spinning. 'BHASKARA-I' was launched on June 7, 1979 from a Soviet Cosmodrome in a near circular orbit of mean altitude 534 kms and inclination 50.deg. The 444 Kg satellite carried two major remote sensing payloads namely a two band TV camera system and a three frequency microwave radiometer. The satellite was spin stabilised with its spin axis maintained at right angles to the orbital plane. Such configuration enables both the payloads to 'look' along the local vertical once during every spin. 'Bhaskara-II' was launched on November 20, 1981. It is an improved version of 'Bhaskara-I' having **a three**

frequency radiometer to enable differentiation between water vapour and liquid water in the atmosphere.

2.5.1Multispectral TV Camera

Bhaskara TV payload system consists of two TV cameras, one operating in the 0.54 to 0.66 micron band and the other in the 0.75 to 0.85 micron band. Each picture frame covers an area of 340 km x 340 km with a ground resolution of about one km and a typical over lap of 10% between successive picture frames. The built in marks and in flight radiometric calibration help in producing geometrically and radio-metrically corrected picture on the ground. The camera is mounted on the spacecraft with its optical axis at the right angles to the spin axis. The cameras are exposed at the instant when the optical axis of the camera points to the local vertical. Read out takes place at a slower rate commensurate with the telemetry capability of the spacecraft. The basic sensor of the TV camera payload is a Super Vidicon Camera Tube consisting of an image intensifier with a gating facility coupled to a storage type vidicon tube. A specially designed multi-element lens is used for each camera. The focal length of the lens and the active face plate area together decide the field of view of the camera. A summary of the camera specifications is given below.

Table 2-2: TV Camera paylaod specifications

Sensor Type	Slow scan vidicon coupled to an image intensifier
Imaging lens	F/no.1.9, Focal length 18.46 mm, FOV 49.37°
Spectral channels	Camera-1 0.54 – 0.66 microns Camera-2 0.75 – 0.85 microns
Picture Frame	340 x 340 Km^2 for a 525 Km altitude
Ground Resolution	About 1Km
Exposure control	1, 1.5, 2 ms selectable by gorund command
Power	22.5 W average

The system can be put in 'calibration mode’ by ground command. The mechanical shutters do not operate during the calibration mode and the tube face plate is illuminated by flashing an LED source. In one calibration cycle, the cameras are exposed to four different intensity levels, one of which is zero illumination and other three are spread out, over the dynamic range. This calibration cycle then repeats itself during the calibration mode. The exposure duration can be changed by ground command to get additional calibration levels.

The initial 'switch ON' of BHASKARA-I TV camera payload was not successful. Extensive ground simulation studies indicated that the anomalous behavior during the switch on of the TV camera was due to a corona discharge in the high voltage section of the payload. Poor adhesion of the potting compound with the high voltage standoff, coupled with trapped air, caused the corona. With time, the trapped air leaked out and camera-l was switched on successfully on May 16, 1980.

BHASKARA-II payload was suitably modified to take care of the problems observed in BHASKARA-I and the camera performance was satisfactory in BHASKARA-II. The imagery received from both bands was comparable in quality to any other imagery of similar resolution. Multiband imagery from the TV payload has been received over the complete Indian subcontinent. The multiband imagery received from BHASKARA-II has been used to demonstrate various applications in the field of geology, hydrology, and forestry.

2.5.2Satellite Microwave Radiometer (SAMIR)

The SAMIR system of BHASKARA-I consisted of three independent channels operating at 19.1, 19.6, and 22.235 GHz frequency bands. Each channel contains a scalar horn antenna, dicke switch, mixer/preamplifier, square law detector, suitable D.C. amplifiers, and telemetry interface circuits. In the case of BHASKARA-II one of 19 GHz channels has been replaced by a channel at 31.4 GHz.

In BHASKARA-I the spatial resolution of the 19 GHz radiometer was 150 km and the spatial resolution of the 22 GHz radiometer was 230 km respectively. In BHASKARA-II all the three radiometers had same spatial resolution of 125 km. Broad specifications of the radiometers are given in Table 2-3.

Table 2-3: Specificatios of SAMIR

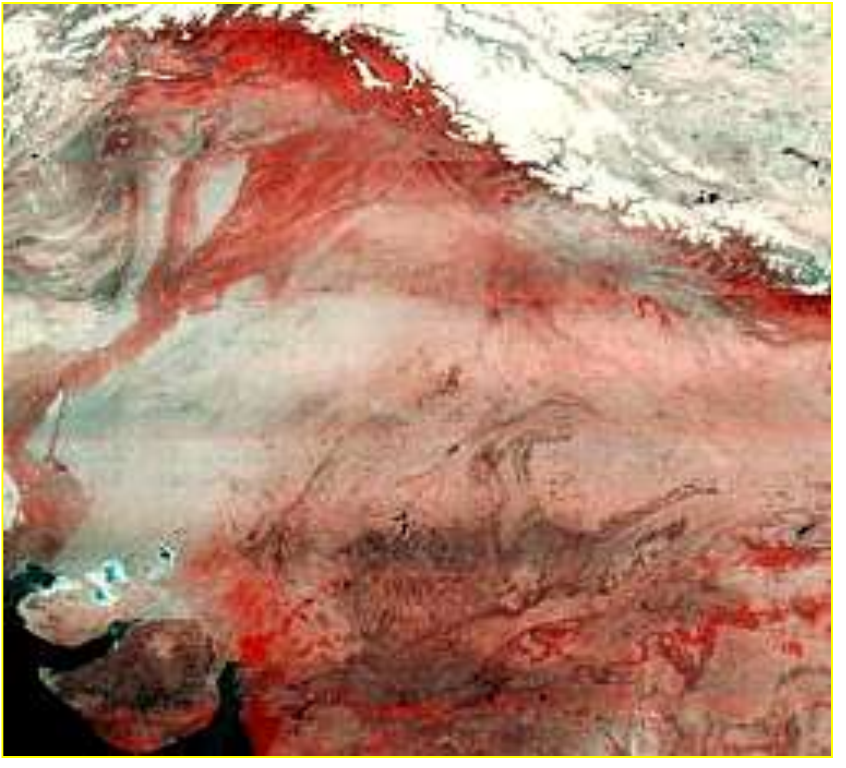
System Parameter	Bhaskara – I			Bhaskara - II		
	R-1	R-2	R-3	R-1	R-2	R-3
Frequency (GHz)	19.1	19.6	22.235	31.4	19.35	22.235
Bandwidth(MHz)	250	250	250	250	250	250
Integration Time(ms	350	350	470	300	300	300
Temp Sensitivity	1	1	1	1	1	1
System Noise Fig. (dB)	6.5	6.5	7.5	8.5	6.5	7.5
Spatial Resolution	150	150	230	125	125	125

The SAMIR system can be operated in two possible modes, depending upon the spin-axis orientation. In the 'Normal Mode' the spin axis of the satellite is normal to the orbital plane and hence the antenna would scan along the satellite track. In the ‘Alternate Mode' the spin axis of the satellite would lie in the orbital plane, tangential to the orbit at a certain latitude, thus converting the radiometers effectively into a scanning system. In the 'Alternate Mode' data will be sampled at fourteen different angular positions and the effective coverage during each orbit will be around 1000 km with a 125 km ground resolution at nadir.

Analog data from all the channels is sampled at various angular positions around nadir, depending upon the mode of operation. As the data acquisition and telemetry transfer rate are not synchronous, data is held in various sample and hold circuits, till it is transferred to the satellite data stream.

Various tests conducted during the initial phase operations and operational phase have confirmed the consistent performance of SAMIR Radiometers onboard BHASKARA-I & **II.** SAMIR data was used for a number of meteorological applications. These include estimation of water vapor and liquid water content, rain fall estimation over ocean area, estimation of wind speed over ocean, study of floods etc.

After realizing the mission objectives the Bhaskara-II mission was terminated in March 1981.



Bhaskara-1

3 ROHINI (RS) AND STRETCHED ROHINI SATELLITE SERIES (SROSS)

3.1 Introduction

The Rohini satellites were launched with various remote sensing payloads for X-ray observations and as payloads for the SLV launch vehicles which were under development.

Rohini Satellite Series had four satellites of 35 kg class namely

- RTP (Rohini Test Project), RS, RS-D1, RS- D2

Stretched Rohini Satellite series had four satellites of 150 kg class namely

- SROSS-1, SROSS-2, SROSS-C1, SROSS-C2

3.2 RTP - Rohini Test Project

RTP carried Launch vehicle monitor equipments. The mass of the satellite was 35 Kgs. It was launched on 10-08-79. Launce failed

RTP Rohini Test Project

Mission	Experimental
Weight	35 kg
onboard power	3 Watts
Communication	VHF band
Stabilization	Spin stabilized (spin axis controlled)
Payload	Launch vehicle monitoring instruments
Launch date	August 10,1979
Launch site	SHAR Centre, Sriharikota, India
Launch vehicle	SLV-3
Orbit	Not achieved

3.3 RS-1

Mission Objectives: To monitor the launch vehicle performance.

RS-1

Mission	Experimental
Weight	35 kg
Onboard power	16 Watts
Communication	VHF band
Stabilization	Spin stabilized
Payload	Launch vehicle monitoring instruments
Launch date	July 18,1980
Launch site	SHAR Centre, Sriharikota, India
Launch vehicle	SLV-3
Orbit	305 x 919 km
Inclination	44.7 deg.
Mission life	1-2 years
Orbital life	20 months

3.4 RS-D1

Mission Objectives:

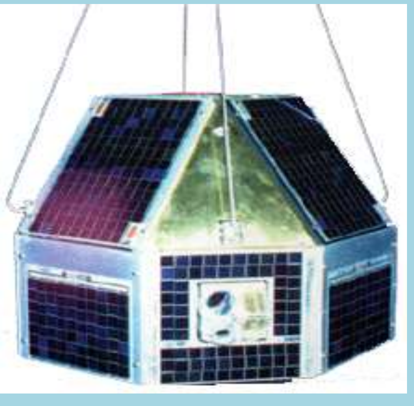
Carried a Land Mark sensor payload whose solid state camera performed to specifications. The satellite re-entered the earth's atmosphere nine days after launch on account of the launch vehicle's injecting the satellite into a lower than expected altitude.

RS_D1

Mission	Experimental
Weight	38 kg
onboard power	16 Watts
Communication	VHF band
Stabilization	Spin stabilized
Payload	Landmark Tracker (remote sensing payload)
Launch date	May 31,1981
Launch site	SHAR Centre, Sriharikota, India
Launch vehicle	SLV-3
Orbit	186 x 418 km (achieved)
Inclination	46 deg
Orbital life	Nine days

3.5 RS-D2

Mission Objective: The Smart Sensor Camera was the primary payload on board the satellite. It was operated for over five months and sent more than 2500 pictures frames in both visible and infrared bands for identification of landmarks and altitude and orbit refinement. The camera had on-board processing capability to use the data for classifying ground features like water, vegetation, bare land, clouds and snow. After completing all its mission goals, RS-D2 was closed down on Sept. 24, 1984.

RS-D2		
	Mission	Experimental
	Weight	41.5 kg
	Onboard power	16 Watts
	Communication	VHF band
	Stabilization	Spin stabilized
	Payload	Smart sensor (remote sensing payload), L-band beacon
	Launch date	April 17, 1983
	Launch site	SHAR Centre, Sriharikota, India
	Launch vehicle	SLV-3
	Orbit	371 x 861 km
	Inclination	46°
	Mission life	17 months
	Orbital life	Seven years (Re-entered on April 19, 1990)

3.5.1 Payload Smart Sensor Onboard ROHINI Satellite

Rohini series of satellites are launched by the Indian launch vehicle SLV-3. A two band solid state camera was designed for Rohini Satellite. A 256 element photo diode array is used as the basic detector. The satellite is spin stabilised with spin axis normal to the orbital plane. During each spin the camera scans the earth approximately ±4.5° to the local vertical producing 80 scan lines thereby generating a picture frame of 250 km x 80 km. The image resolution is about 1 km from 500 km orbit.

One of the unique features of the camera is that it is capable of carrying out limited feature identification onboard. This is realized by taking the ratio of the 2 band output and having a decision circuitry to discriminate between the different classes based on rationing. The feature identification code and video information from anyone of the cameras is transmitted. The camera specifications are given in Table 3-4.

Table 3-4: Rohini Smart Sensor Specifications

Resolution	**1Km(Nominal)**
Spectral bands	
Channel-1	0.65±0.05 microns
Channel-2	0.85±0.05 microns
Swath	25Km
Overlap	30%
Optics size	Focal length 25mm, f/1.4 system
Memory	140 kbits
Power	4 watts
Weight	3Kg

The Rohini satellite (RS-D2) carrying this payload was launched on April 17, 1983 from the Indian launch station at Sriharikota. The camera functioned normally as planned and it was possible to establish the possibility of limited feature identification on board. Water bodies, biomass, bare land and clouds can be easily identified with onboard processing.

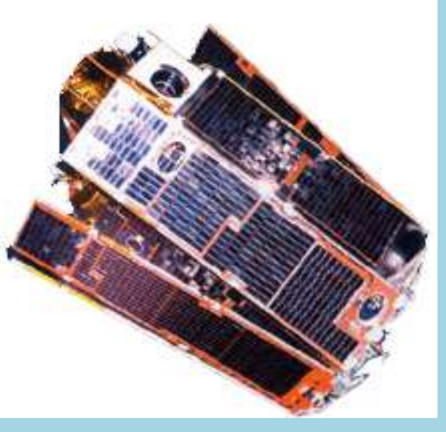
3.6 SROSS-1(Stretched Rohini Satellite Series)

The satellite was launched onboard the first developmental a flight of ASLV. It did not reach the orbit.

SROSS-1		
	Mission	Experimental
	Weight	150 kg
	Onboard power	90 Watts
	Communication	S-band and VHF
	Stabilization	Three axis body stabilized (biased momentum) with a Momentum Wheel and Magnetic Torquer
	Propulsion system	Monopropellant (Hydrazine based) Reaction control system
	Payload	Launch Vehicle Monitoring Platform(LVMP), Gamma Ray Burst (GRB) payload and Corner Cube Retro Reflector (CCRR) for

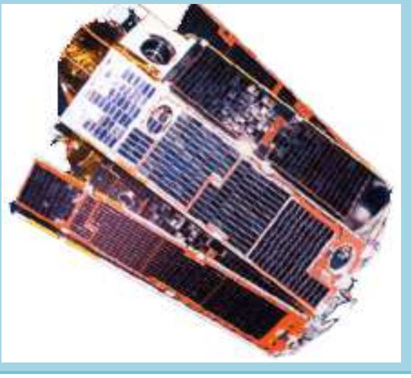
		laser tracking
	Launch date	March 24, 1987
	Launch site	SHAR Centre, Sriharikota, India
	Launch vehicle	Augmented Satellite Launch Vehicle (ASLV)
	Orbital life	Not realised
	Mission	Experimental
	Weight	150 kg

3.7 SROSS-2

SROSS-2		
	Mission	Experimental
	Weight	150 kg
	Onboard power	90 Watts
	Communication	S-band and VHF
	Stabilization	Three axis body stabilized (biased momentum) with a Momentum Wheel and Magnetic Torquer
	Propulsion system	Monopropellant (Hydrazine based) Reaction Control System
	Payload	Gamma Ray Burst (GRB) payload and Mono-ocular Electro-Optic Stereo Scanner (MEOSS) built by DLR, Germany
	Launch date	July 13, 1988
	Launch site	SHAR Centre, Sriharikota, India
	Launch vehicle	Augmented Satellite Launch Vehicle (ASLV)
	Orbit	Not realised

3.8 SROSS-C

SROSS-C		
	Mission	Experimental
	Weight	106.1 kg
	Onboard power	45 Watts



Communication	S-band and VHF
Stabilization	Spin stabilized with a Magnetic Torquer and Magnetic Bias Control
Payload	Gamma Ray Burst (GRB) experiment & Retarding Potential Analyser (RPA) experiment
Launch date	May 20,1992
Launch site	SHAR Centre, Sriharikota, India
Launch vehicle	Augmented Satellite Launch Vehicle (ASLV)
Orbit	267 x 391 km
Mission life	Two months (Re-entered on July15,1992)

3.9 SROSS-C2

SROSS_C2

Mission	Experimental
Weight	115 kg
Onboard power	45 Watts
Communication	S-band and VHF
RCS	Monopropellant Hydrazine based with six 1 Newton thrusters
Payload	Gamma Ray Burst (GRB) & Retarding Potential Analyser (RPA)
Launch date	May 04,1994
Launch site	SHAR Centre, Sriharikota, India
Launch vehicle	Augmented Satellite Launch Vehicle (ASLV)
Orbit	430 x 600 km.
Inclination	45 deg.

3.9.1Mission Objectives

To monitor celestial gamma ray bursts in the energy range 20-3000 KeV

To measure temporal variations of gamma ray burst with high time resolution(2 ms, 16ms and 2556 ms) to search for periodicities in the emitted radiation.

To measure temporal evolution of burst energy spectra to search for cyclotron lines and features in the energy range 20-100 KeV and possible red-shifted annihilation radiation in the energy range 400-500 KeV.

To study the characteristic features of the thermal structure of the equatorial and low latitude ionosphere

To study the effect of magnetic storms and Spread-F on thermal structure

To Study the behavior of electron density anomaly in the low latitude region

3.9.2Salient features of SROSS-C

Sub system		Features
Structure		**Aluminum frames and honeycomb decks**
Thermal		**Using passive elements and 2W heaters. Temp. limit is 0 to 40 deg.**
Power	**Solar Panel**	**Four units of body mounted panels (each unit with two panels bonded at 135 deg. Along the vertical edge.**
	Battery	**18 AH Ni-Cd cells connected in series.**
	Electronics	**DC/DC converter, Under/Over volt detector circuits, E/N logic Battery Voltage control Logic**
TTC	**Telemetry**	**Format-1 mode and Dwell mode with reentrancy. PROM based main system and microprocessor based (RCA 1802) Redt. system** **256 BPS, PCM/PSK/PM, 2245.68 MHz**
	Telecommand	**Microprocessor (RCA 1802) Based Main Decoder and Hardware redt. Decoder Unit.100 bps, S-Band PCM/FSK/FM/PM,** **2067.897 MHz**
AOCS	**Sensors**	**Magnetometer, Twinslit Sun sensor**
	Stabilisation	**Spin stabilisation**
Mass		**106.1 Kg**

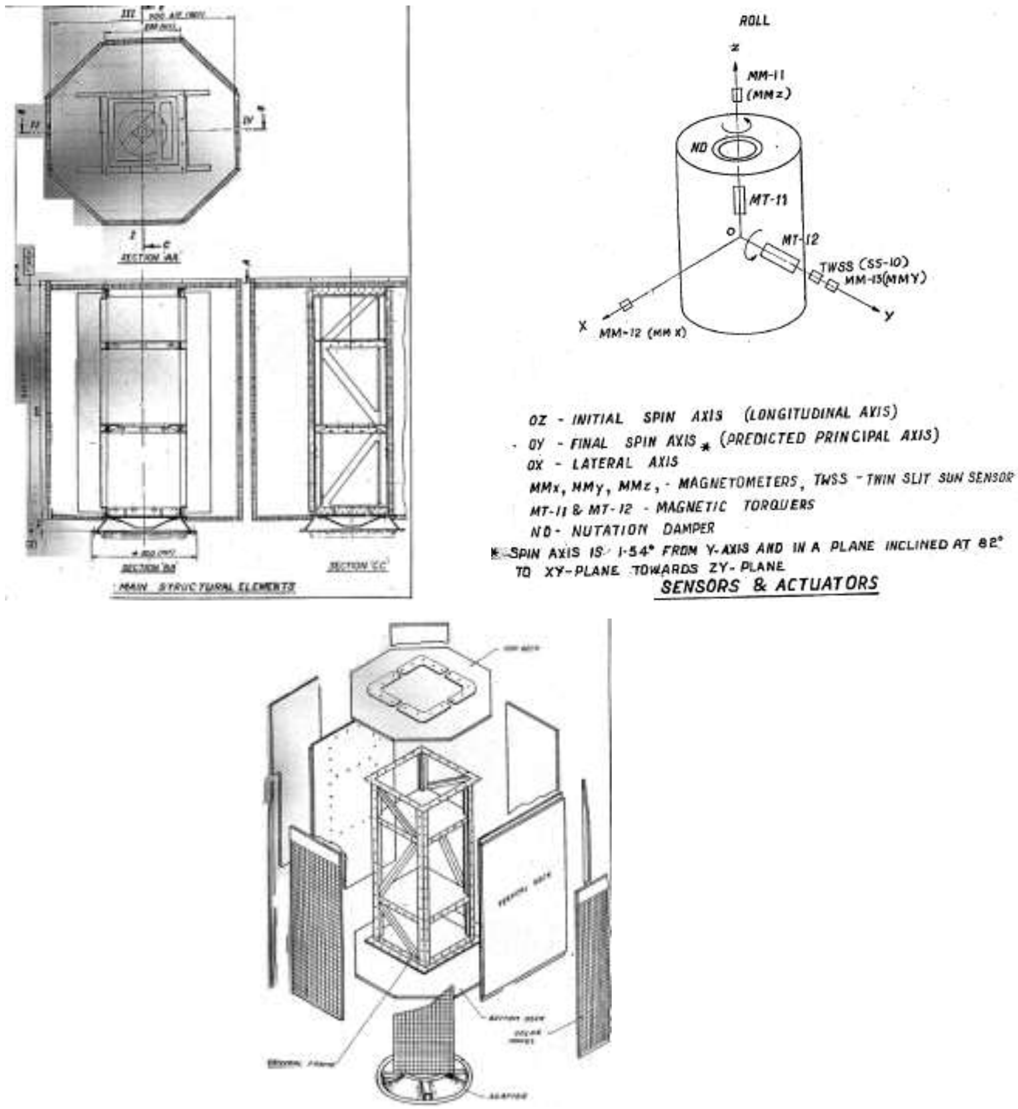


Figure 3.1Exploded view of SROSS-C1

3.9.3Salient features of Payloads

Payload consists of two sensors namely

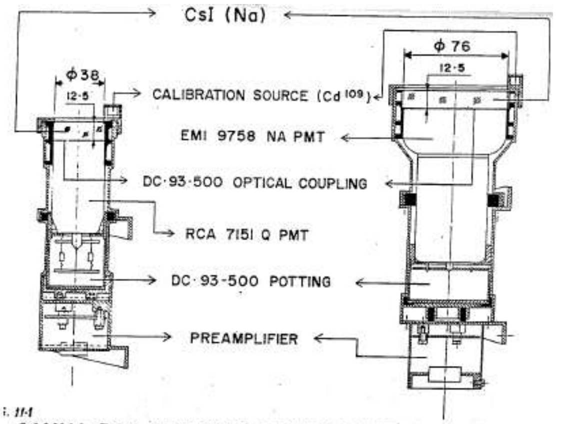
Gamma Ray Burst Detection (GRB) Experiment

Retarding Potential Analyser (RPA) Payload

3.9.3.1 Gamma Ray Burst detector

The gamma ray burst payload consists of a main and a redundant scintillation detector viewed by separate photomultiplier tubes and powered by independent high voltage supplier. A common microprocessor based (RCA

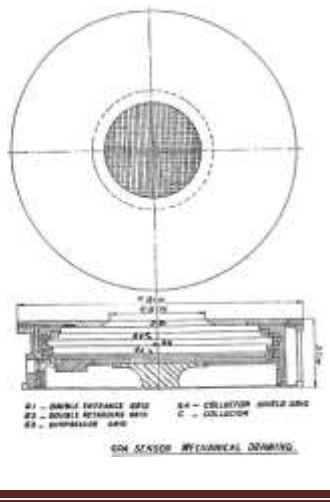
CDP1802) electronics system process the signals from either of the detectors. The main detector consists of a 76 mm diameter and 12,5mm thick CsI(Na) scintillator optically coupled to an EMI 9758 NA PMT. The redt. detector is also CsI(Na) crystal and has a diameter of 38mm and a thickness of 12.5 mm. It is viewed by RCA 7151Q tube. The scintillator is coupled to the PMT. By means of DC-93-500 potting compound.



GAMMA RAY BURST DETECTORS (SROSS-C)

3.9.3.2 Retarding Potential Analyser (RPA)

The RPA experiment is proposed to investigate the characteristics and energies of the equatorial and low latitude ionosphere and thermosphere which is an important element in understanding the sun-earth relationship and the effects of dynamics, turbulence and storms on the thermal behavior. It indents to study characteristics variation of electron density over the equator and around it ($\pm$ 15 deg latitude). This involves measuring plasma parameters like density & temp. to characterize the ionosphere. It also indented to identify understand and estimate various energy deposition and loss process to derive thermospheric temp.



4 IRS-1A & 1B

4.1 Introduction

The successful launch and operation of Bhaskara-I and II satellites provided experience in setting up of ground-based data reception and processing systems, gaining experience in over-all mission management, receiving data from other satellites like LANDSAT and activities related to data analysis, interpretation & utilization.

The experience gained in conceptualisation and implementing a space segment with necessary ground based data reception, processing and interpretation system, and integrating the satellite based remote-sensed data with conventional data systems for resource management, provided a way for a programme for operationalising the remote-sensing system for the country. The evolution of National Natural Resources Management System (NNRMS) is the outcome of all the above efforts and IRS-1A mission is the first step in such an operational resources management system for the country.

IRS-1A, the first of the series of indigenous state-of-art operating remote sensing satellites, was successfully launched into a polar sun-synchronous orbit on March 17, 1988 from the Soviet Cosmodrome at Baikonur. *IRS*-1A carried two cameras, LISS-I and LISS-II with resolutions of 73 metres and 36.25 metres respectively with a swath of about 140 km during each pass over the country. Mission completed during July 1996 after serving for 8 years and 4 months.

IRS-1B, with some improved features compared to its predecessor like gyro referencing for better orientation sensing, time tagged commanding facility for more flexibility in camera operation and line count information for better data product generation, was launched on 29.08.1991. Mission completed on December 20, 2003 after serving for 12 years and 4 months.

4.2 Mission Objectives

The main objectives of IRS-1A mission are

- *To design, develop, and deploy a three axis stabilised polar sun-syncronise satellite carrying near state-of-art-multiple solid state pushbroom cameras operating in visible and near infrared bands for aquiring imageries for each resources applications on an operational basis.*
- *To establish and routinely operate ground based systems for spacecraft data reception, recording, processing, generation of data products, analysis, and archival as well as mission control facilities.*

- *To use the data from IRS in conjunction with supplementary/ complementary information from other sources for survey and management of resources in imporatnt areas such as agriculture, geology and hydrology in association with the user agencies, that will additionally enable characterisation of a future operational system for the country at the optimum level.*

4.3 Orbit Details

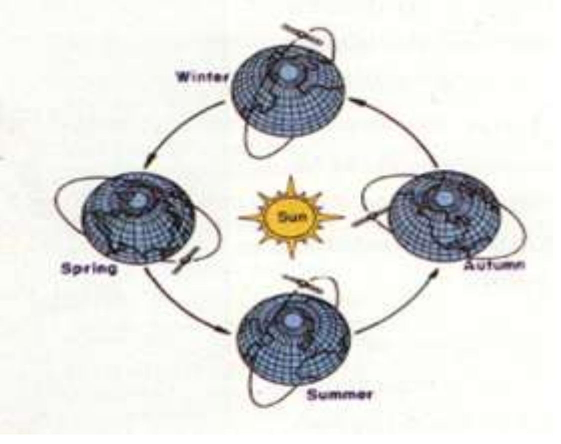


Figure 4.1 Sun Synchronous orbit

IRS-1A was launched into a polar sun synchronous orbit at an altitude of 904 Kms. In the sun-syncronous orbit, the orbit plane rotates at the same rate as the mean rotation rate of the earth around the sun (0.9856 deg/day). Thus the satellite passes over particular latitude approximately at the same local time. It enables the ground illumination conditions at sub-satellite regions to be constatnt throughout the mission. The equatorial crossing time of the descending node for IRS-1A is around 10.25 AM.

As the orbital period of IRS-1A is nearly 103 minues, with the satellite completing 14 orbits/day, each successive orbit is shifted westward over earth's surface by 25.798 degree of longitude, corresponding to 2872 kms at equator. The satellite's path is shifted by 1.17 ~1.1 deg longitude to the west every day corresponding to 130.84 km at the equator. The satellite completes one coverage cycle of the Indian subcontinent in 22 days(307 orbits)

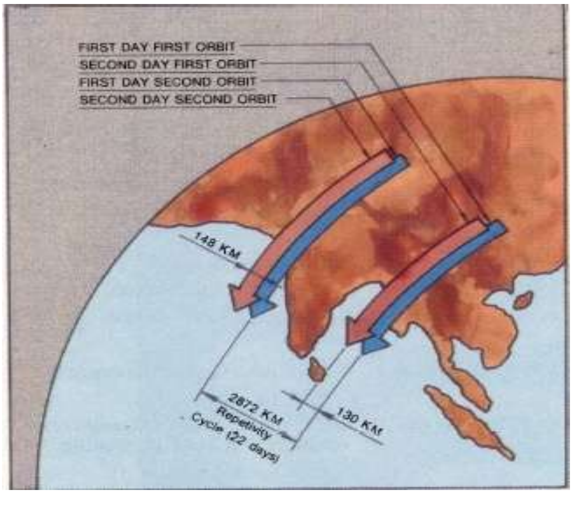


Figure 4.2 Swath coverage

Table 4.1: Orbit details

Parameters	IRS-1A	IRS-1B
Altitude	904 Km	904 Km
Inclination	99.028 deg	99.028 deg
Eccentricity	0.008	0.008
Equatorial Crossing Time	10.30 A.M	10.30 AM
Orbital period	103.192 min.	103.192 min.
Recurrence	14 orbits/day	14 orbits/day
Repetition cycle	22 days (307 orbits)	22 days (307 orbits)
Daily shift at equator	130.54 Km westward (1.17 deg)	130.54 Km westward (1.17 deg)
Node	Descending	Descending

4.4 Salient Features of Spacecrafts

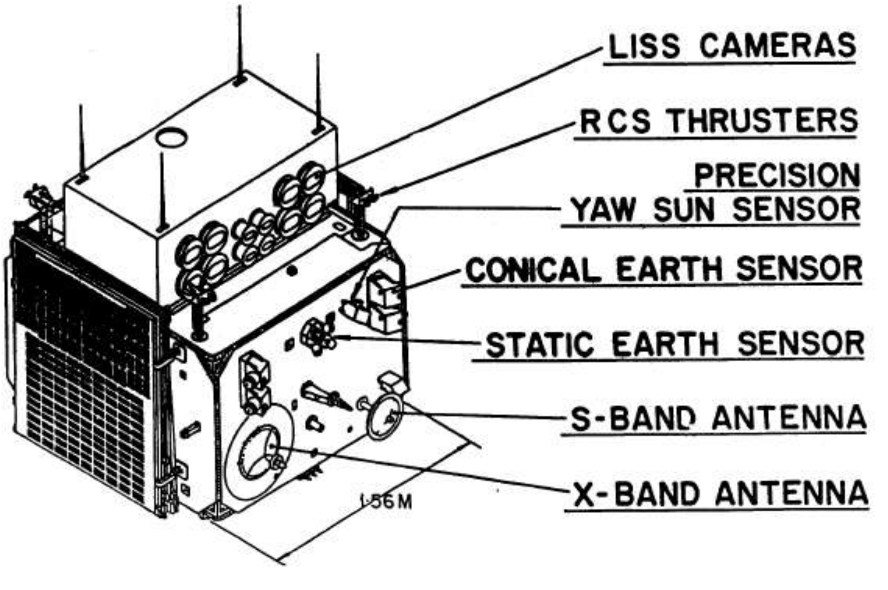


Figure 4.3 Stowed mode view of IRS-1A

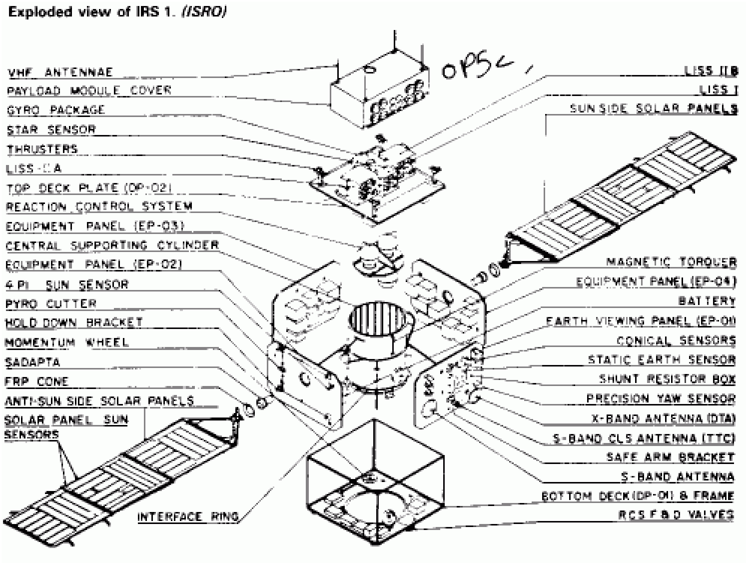


Figure 4.4 Exploded view of IRS-1A

Table 4.2: Salient features of IRS-1A & 1B

Parameter		IRS-1A	IRS-1B
Mission		Launched as experimental satellite later declared as Operational.	
Structure		Aluminium and Aluminium honeycomb structure Central load bearing cylinder and 6 honeycomb panels.	
Thermal	Components	Passive control using tapes , OSR, MLI Blankets and semi-active/active control using proportionate temperature controller and heaters	
	Temp. Range	20±5 deg.C range for imaging sensors electro-optics 5±5 deg. C for Chemical Batteries 0 to 40 deg.C for electronic packages	
Mechanism	SADA	Solar Panel Deployment and Drive Mechanism	
Power	Solar Array	8.5 m^2 area, deployable and sun tracking panel, Power generation at EOL is 620 Watts (Totally 6 panels)	
	Battery	Two Ni-Cd batteries of 40 AH capacity each	
Communication	Telemetry	House Keeping(HK) information in S-Band; PCM/PSK Real Time rate 256 bps and play back rate 4 Kbps; Onboard storage capacity of 98 minutes of HK data	

	Telecommand	S-Band : PCM/PSK/FM/PM, and VHF : PCM/FSK/AM	
	Tracking	Facility for ON/OFF and Data commands S-Band tone ranging and two way Doppler	
Attitude and Orbit Control (AOCS)	Attitude sensors	IR Horizon sensors(Conical and Static), Star sensor, sun sensors, Dynamically Tuned Gyros (DTG)	
	Attitude control	Reaction Wheel(three 5NMS and one 10 NMS), Magnetic torquers, Hydrazine thrusters(16 one Newton)	
	Orbit Control	Monopropellant hydrazine thrusters	
	Orbit-Determination accuracy	1 Km	
	Attitude Determination Accuracy	0.1 deg.	
Payload	LISS-1 LISS-2A and LISS-2B	(72.5 meter resolution), (36.25 meter resolution)	
Mass		975 kg	
Launch date		March 17, 1988	August 29, 1991
Launch site		Baikanur Cosmodrome ,Kazakhstan	
Launch vehicle		Vostok-II	

4.5 Payloads

IRS missions envisage primarily meeting the specific Indian application needs in the areas of agriculture, hydrology, and geology. Hence the basic mission characteristics like spectral bands and resolutions, spatial and radiometric resolutions; repetivity and choice of local time have been arrived keeping these applications in view.

It is well known that to increase the accuracy of interpretation, the information has to be collected in more than one spectral band. A number of studies and experiments with Landsat data showed that four spectral bands covering visible and near infrared wavelength regions are adequate for most of the applications. Thus payloads should have multi spectral imaging capability, with four spectral bands in the visible and near infrared regions of the electro-magnetic spectrum.

Table 4.3: Spatial resolution and repetivity considerations

Application	Spatial resolution	Temporal resolution
Agriculture	40-70 meters resolution	Weekly / monthly repetivity Soil classification needs seasonal considerations also
Hydrology	40-100 meters resolution	Weekly observation for soil moisture study for penetration beyond surface prefers microwave
Geology	100-150 meters resolutions	Repetivity can be monthly and more
Coastal studies	100-150 meters resolution; sea food study needs 70-100 meters resolutions	Weekly / monthly repetivity, for coastline delineation, yearly repetivity sufficient
Land use planning	80 meters resolution	Yearly repetivity

Table 4.4: Spectral resolution consideration

Spectral Bands microns	Characteristics of bands
0.45-0.52	Strong relationship between spectral reflectance in this region and plant pigment and has comparatively higher penetration in water. This band is useful for mapping suspended sediments/water quality and various studies related to coastal region.
0.52-0.59	Centered on the first local maxima of the vegetation reflectance, useful for vegetation discrimination and the study of senescence rate of leaves. Also sensitive to ferric iron oxides.
0.62-0.68	Centered around the chlorophyll absorption band of vegetation and, useful for identification of plant species. Greater soil contrast is found in this region. The upper end is limited to 0.68 to avoid the atmospheric absorption at 0.69 microns
0.77-0.86	Shows high reflectance for healthy vegetation and useful for green biomass estimation and crop vigor studies. Water absorption in this region clearly demarcates land water boundary. The upper end is limited to 0.86 microns to avoid the broad water vapor absorption band centered around 0.92 micron. In addition, this also helps to improve the Modulation Transfer Function (MTF) of this band since CCD MTF falls fast as wavelength increases in the near infrared region

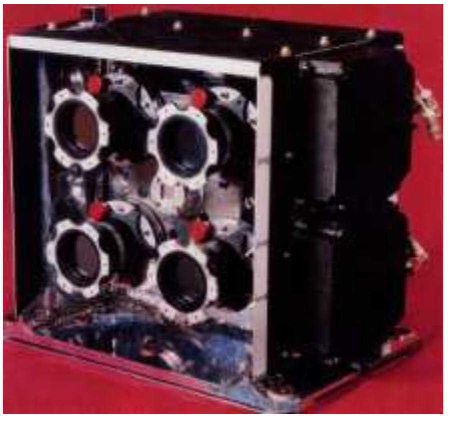


Figure 4.5 LISS-I

Figure 4.6 LISS-II

The IRS-1A cameras operated in four spectral bands which are mentioned in the table 4.4. Each Band has separate optical system, spectral filters, thermal filters and detector.

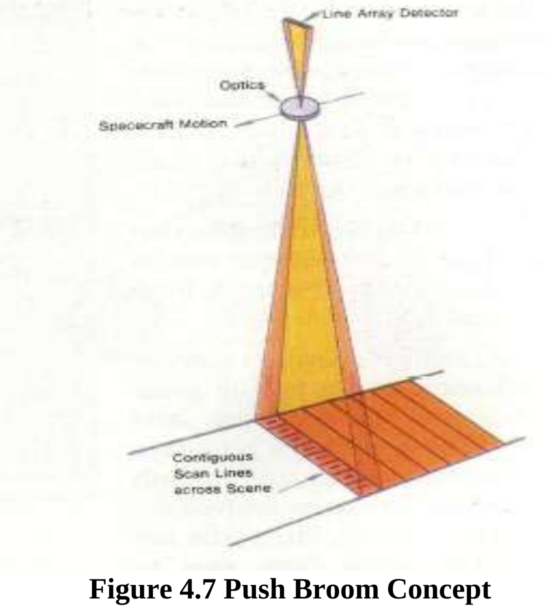
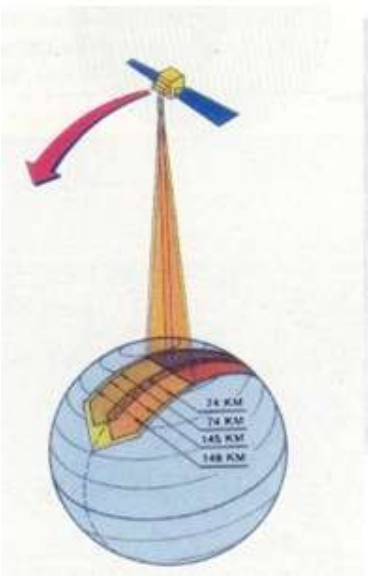
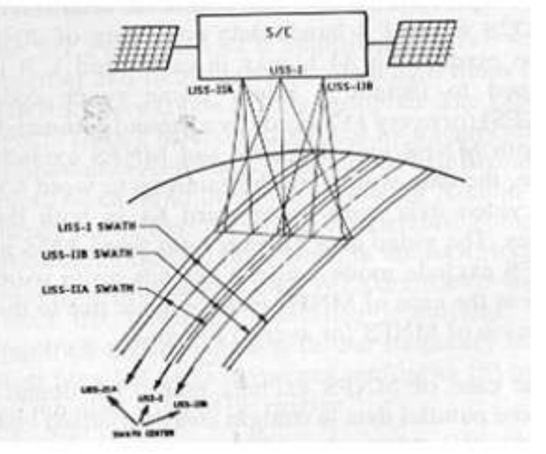


Figure 4.7 Push Broom Concept

The payload system of IRS-1A is a Linear Imaging Self-Scanning Sensor (LISS) working on the 'push-broom scanning' concept. In this mode of operation, each line of the image is electronically scanned by a linear array of detectors (Charge Coupled Devices (CCD)) and successive lines of the image are produced as a result of satellite's forward motion.

The payload system consists of two solid state cameras operating in four spectral bands in the visible and near- IR range using Charge Coupled Devices (CCD) linear arrays as sensors. There are two cameras, one is called LISS-1, and the other one is called LISS-II (It has two modules, IRS-IIA and IRS-IIB). LISS-I provide geometrical Instantaneous Field of View (IGFOV) of 73 meters and cover a swath of 148 Kms on ground, while LISS-II provides an IGFOV of 36.5 meters and individual swath of 74 Kms each. The combined swath of both LISS-II cameras is 145 kms with a 3 km side lap between them.





The data handling system, consisting of baseband and RF modules, receives digital data from payload, formats it and after modulation transmits the data to ground station as a PCM stream LISS-I data is transmitted through a BPSK modulator in S-band at 5.2 MBPS and the data from both LISS-II cameras is transmitted through a QPSK systems in X-band at 10.4 MBPS.

Table 4.5: Payload specification

Payload specification		
Optics	Refractive , F/4.5	**Refractive , F/4.5**
Equivalent Focal Length (EFL)(mm)	162.2	**324.4**
Spectral Bands(um)		
Band-1	0.45 – 0.52	**0.45 – 0.52**
Band-2	0.52 - 0.59	**0.52 - 0.59**
Band-3	0.62 – 0.68	**0.62 – 0.68**
Band-4	0.77 – 0.86	**0.77 – 0.86**
Field of View	9.4 deg.	**4.7 Deg (each)**
Detector		
CCD	Linear array	**Linear array**
No. of pixels	2048	**2048**
Pixel size (um)	13 x 13	**13 x 13**
System		

Geometrical IGFOV (meters)	73	36.5
Angular IFOV (microradians)	80	40
Swath (Km)	148	74 each (145 combined)
Integration time (m sec)	11.2	5.6
No. of radiometric levels	128	128
Data rate (Mbps)	5.2	10.4 x 2
Noise equivalent reflectance (NEdP)	<1 %	<1%
Signal – To – Noise Ratio(SNR)	>127 for all bands at saturation level exposure	
Square wave response (SWR) at 40 Lines per millimeter (lpmm)		
Band -1	>40	>40
Band -2	>40	>40
Band –3	>30	>30
Band - 4	>20	>20
Band to Band registration (Pixel)	+/- 0.25	+/- 0.25
Operating temperature range		
EO module	20±5 deg. C	20±5 deg. C
Electronics (PLE)	0 to 40 deg. C	0 to 40 deg C
Power(W)		
Imaging mode	34.2	34.2 x 2
Cal. Mode	37.9	37.9 x 2
Mass(Kg)		
EO Module	27.50	70.00 x 2
Electronics	4.48	4.41 x 2
Power supply	6.44	6.44 x 2

4.6 Ground Segment

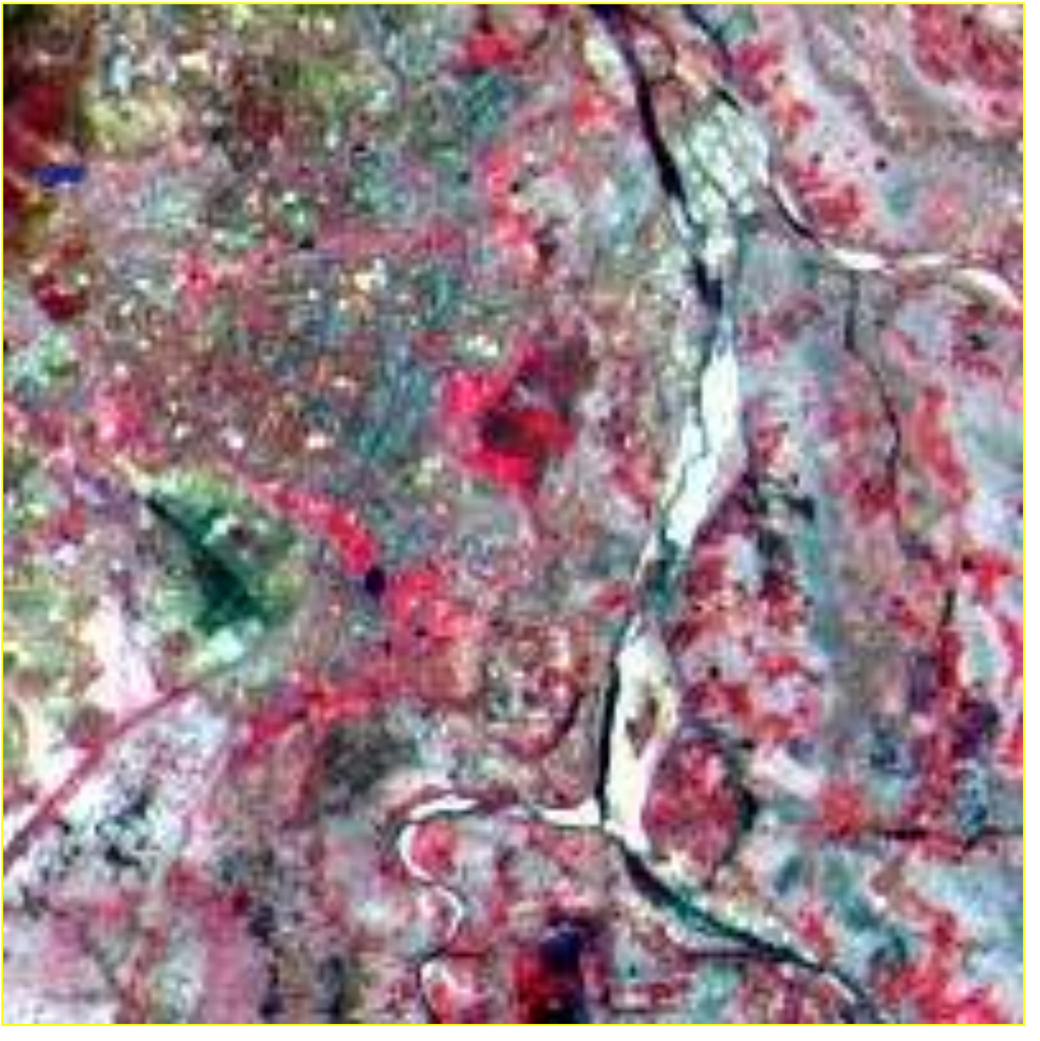
The IRS-1A Ground segment controlled and monitored the satellite throughout the mission and performed the image data reception, processing, generation/dissemination and archival of data products.

The major elements of IRA-1A ground segment were

- Telemetry, Tracking and Command (TTC) network
- Spacecraft Control Centre (SCC)
- Data Reception System
- Data Products System

Ground segments location and functionality

Element	Location	Functions
Telemetry, Tracking & Command(TTC)	ISTRAC stations at Bangalore and Lucknow (Selective Support from External stations)	• Satellite Health data reception and recording • Spacecraft commanding and tracking
Spacecraft Control Centre (SCC)	ISTRAC, Peenya Bangalore, India.	• Network coordination and control • Spacecraft Operations • Spacecraft health analysis and control • Orbit and attitude determination • Communication links
Data Acquisition	National Remote Sensing Agency(NRSA), Shadnagar, Hyderabad, India.(Now it is National Remote Sensing Centre(NRSC).	• Reception and recording of Image data • Quick-look imagery and display. • Ancillary data generation for further processing of data.
Data Processing, Dissemination and Archival	NRSA, Balanagar, Hyderabad, India Space Application Centre (SAC) Ahmedabad, India.	• Generation and distribution of Browse and Standard products. • Generation of precision and special products. • Data quality evaluation.



IRS-1A Image

5 IRS-1E

5.1 Introduction

IRS-1E satellite, derived from the engineering model of IRS-1A incorporating a Monocular Electro-Optical Stereo Scanner developed by DLR, Germany, and a LISS-I camera similar to that on IRS-1A, could not be placed into orbit by the PSLV-D1 launched in September 1993.

The mission was not realised due to problems faced by Launch Vehicle. It was the first development flight of PSLV.

5.2 Mission Objectives

- *The spacecraft was realized as a payload for the First developmental flight of PSLV to carry 846 kg payload of IRS class in 817 km polar sun synchronous orbit.*
- *Combine stereo capability of MEOSS data along with multi spectral LISS-I data and evolve stereo products on experimental basis*
- *To support IRS-IA/IB LISS-1 Users.*

5.3 Orbital Details

Orbit	Not Realised
Power	415
Mass	846
Launch Date	September 20, 1993
Launch Vehicle	PSLV-D1

5.4 Salient features of Spacecraft

Parameter		IRS-1E
Mission		The spacecraft was realized as a payload for the First developmental flight of PSLV to carry 860 kg payload of IRS class in 817 km polar sun synchronous orbit.
Structure		Aluminium and aluminium honeycomb structure (IRS-1A's EM)
Thermal	Components	Passive control using tapes , OSR, MLI Blankets and semi-active/active control using proportionate temperature controller and heaters
	Temp. Range	20±5 deg.C range for imaging sensors electro-optics

		5±5 deg. C for Chemical Batteries 0 to 40 deg.C for electronic packages
Mechanism	Solar Panel	Solar Panel hold down and Deployment Mechanism
Power	Solar Array	5.72 m^2 area, deployable and sun tracking panel, Power generation at EOL is 415Watts (Totally 4 panels)
	Battery	Two Ni-Cd batteries of 40 AH capacity each
Communication	Telemetry	House Keeping(HK) information in S-Band; PCM/PSK Real Time rate 256 bps and play back rate 4 Kbps; Onboard storage capacity of 102 minutes of HK data
	Telecommand	S-Band VHF
	Tracking	Facility for ON/OFF and Data commands S-Band tone ranging and two way Doppler
Attitude and Orbit Control (AOCS)	Attitude sensors	IR Horizon sensors(Conical and Static), sun sensors, Dynamically Tuned Gyros (DTG)
	Attitude control	Reaction Wheel(three 5NMS and one 10 NMS), Magnetic torquers, Hydrazine thrusters(16 - one Newton) 80kg fuel , dry mass 34 kg
	Orbit Control	Monopropellant hydrazine thrusters
	Orbit-Determination accuracy	1 Km
	Attitude Determination Accuracy	0.4 deg.
Payload	LISS-1 MEOSS	65.5 meter resolution 143 meter IGFOV, 50.3m along track
Data handling		Datarate: 5.2 + 2 x 10.4
Mass		860kg
Launch site		SHAR
Launch vehicle		PSLV-D1

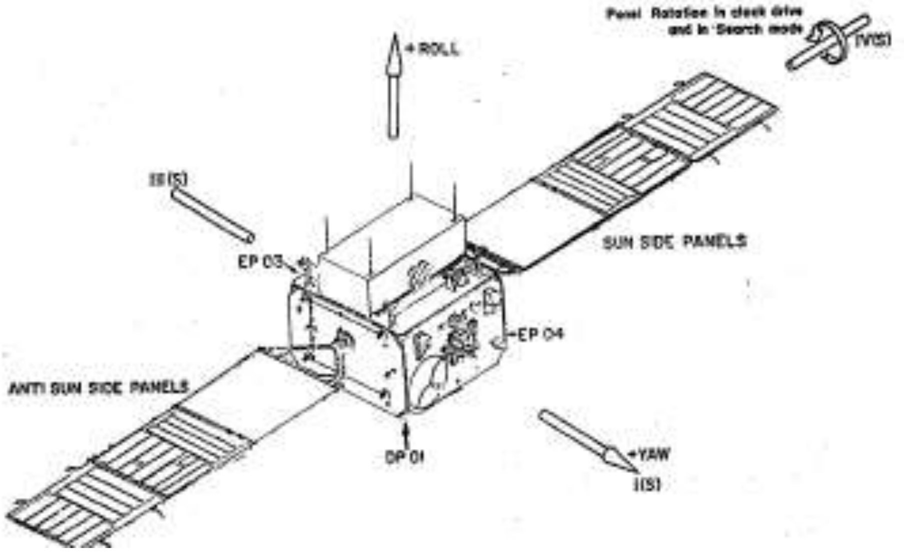


Figure 5.1 Deployed view of IRS-1E

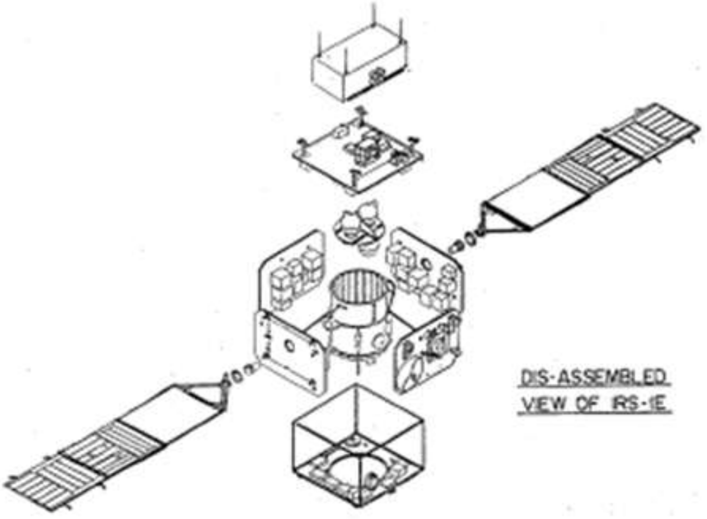


Figure 5.2 Exploded view of IRS-1E

5.5 Payloads

5.5.1LISS-1 (Linear Imaging Self scanning Sensor)

The payload system consists of solid state cameras operating in four spectral bands in the visible and near- IR range using Charge Coupled Devices (CCD) linear arrays as sensors. LISS-I provide an IGFOV of 65.5m and cover a swath of 134km. The along track sampling corresponding to the integration time of 11.2ms is 74m.

Payload specification	
Optics	**Refractive , F/4.5**
Equivalent Focal Length (EFL)(mm)	**162.2**
Spectral Bands(um)	
Band-1	**0.45 – 0.52**
Band-2	**0.52 - 0.59**
Band-3	**0.62 – 0.68**
Band-4	**0.77 – 0.86**
Field of View	**± 4.7 deg.**
Detector	
CCD	**Linear array**
No. of pixels	**2048**
Pixel size (um)	**13 x 13**
System	
Geometrical IGFOV (meters)	**65.5**
Angular IFOV (microradians)	**80**
Swath (Km)	**134**
Integration time (m sec)	**11.2**
No. of radiometric levels	**128**
Data rate (Mbps)	**5.2**
Noise equivalent reflectance (NEdP)	**<1 %**
Signal – To - Ratio(SNR)	**>127 for all bands at saturation level exposure**
Square wave response (SWR) at 40 Lines per millimeter (lpmm) %	
Band -1	**>40**
Band -2	**>40**
Band –3	**>30**
Band - 4	**>20**
Band to Band registration (Pixel)	**+/- 0.25**
Operating temperature range	
EO module	**20±5 deg. C**

Electronics (PLE)	**0 to 40 deg. C**
Power(W) **Imaging mode** **Cal. Mode**	 **34.2** **37.9**
Mass(Kg) **EO Module** **Electronics** **Power supply**	 **27.50** **4.48** **6.44**

5.5.2MEOSS (Monocular Electro Optical Stereo Scanner)

The MEOSS payload developed by DLR, Germany is the second payload of IRS-IE mission. MEOSS is a solid state push broom scanner operating in a single spectral band of 0.57-0.70 microns.

Three 3456 element ccd are placed in the focal plane of imaging optics to image the small ground scene with an oblique view of +/- 23 deg in the along track direction thus providing a stereoscopic viewing capabilities.

The major specification of MEOSS given below:

Payload specification	
Optics	**Refractive , F/7.2**
Equivalent Focal Length (EFL)(mm)	**61.1**
Spectral Band(um)	**0.57-0.7**
Detector	
CCD	**Linear array**
No. of pixels	**3456**
Pixel size (um)	**10.7 x 10.7**
System	
Geometrical IGFOV (meters)	**143**
Along track sampling(meters)	**50.8**
Swath (Km)	**463**
No. of radiometric levels	**256**
Data rate (Mbps)	**10.4**
Noise equivalent reflectance (NEdP)	**<1 %**
MTF	**25**
Position of CCDs	
Roll direction	**Distance between CCDs 26.7mm**
Pitch direction	**CCD1,CCD3 w.r.t CCD2 is +/-25micron**

Yaw direction	Deviation from focal plane +/- 25microns
Parallism of CCDs	5microns

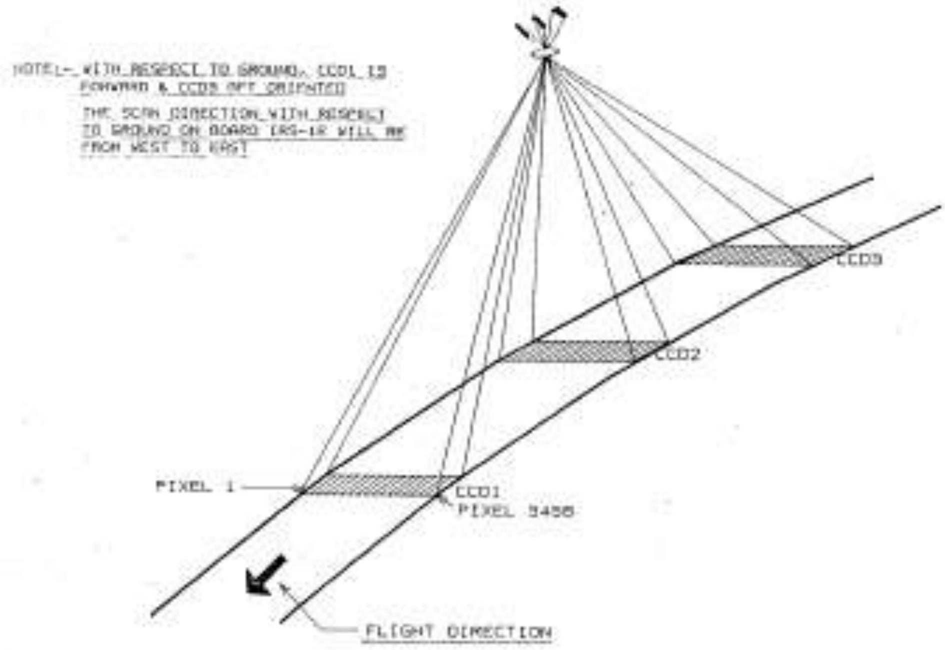


Figure 5.3 View direction of MEOSS

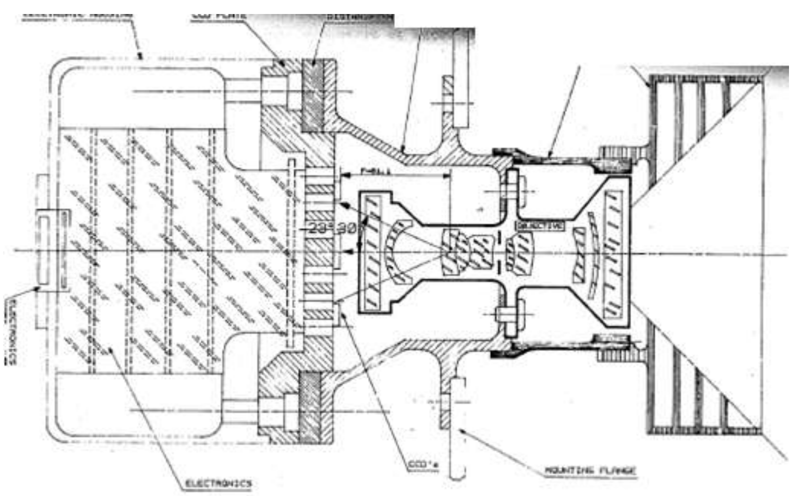


Figure 5.4 EO module of MEOSS

6 IRS-P2

6.1 Introduction

IRS-P2 was the fourth in the series of Indian Remote Sensing operational Satellites. It was launched into the sun synchronous orbit of 817 Kms on October 15, 1994. This is the first Spacecraft successfully orbited onboard by the second developmental flight of PSLV.

6.2 Mission Objective

The mission objective of IRS-P2 is to be the payload of the second developmental flight of PSLV

6.3 Orbit details

Parameter	Values
Orbit	Polar sun synchronous Orbit
Altitude	817 Km
Inclination	98.68º
Repetivity	24 days
Equatorial crossing time	10.30 AM
Launch date	October 15, 1994
Launch site	SHAR Centre, Sriharikota, India
Launch vehicle	PSLV-D2
Mission completed on	1997

6.4 Salient Features of Spacecraft

Table 6.1: Salient features of IRS-P2

Parameter		IRS-P2
Structure		Aluminium and aluminium honeycomb structure 4 vertical and 2 horizontal Al Honeycomb panels.
Thermal	Components	Passive control using tapes , OSR, MLI Blankets and semi-active/active control using proportionate temperature controller and heaters
	Temp. Range	20±5 deg. C for imaging sensors electro-optics 5±5 deg. C for Chemical Batteries 0 to 40 deg. C for electronic packages
Mechanism	Solar Panel	Solar Panel deployment and drive mechanism
Power	Solar Array	6.424 m^2 area,(2 x 2 panels) deployable and sun tracking panel, Power generation at EOL is 620 Watts

	Battery	42V, Ni-Cd(2), 21 AH, 28 cells each, 27.64 Kg
	Electronics	TCR, domestic regulators, battery individual cell monitoring, K relay emergency Relay Bus parallel relays, DC/DC Converters
Communication	Telemetry	House Keeping (HK) information in S-Band; PCM/PSK Real Time rate 256 bps and play back rate 4 Kbps; Onboard storage capacity of 98 minutes of HK data
	Telecommand	S-Band : PCM/PSK/FM/PM, and VHF : PCM/FSK/AM
	Tracking	Facility for ON/OFF and Data commands S-Band tone ranging and two way Doppler X-band beacon
Attitude and Orbit Control (AOCS)	Attitude sensors	IR Horizon sensors(Conical and Static), Star sensor, Yaw sun sensors, Dynamically Tuned Gyros (DTG)
	Actuators	Reaction Wheels (three 5NMS and one 10 NMS), Magnetic torquers, Hydrazine thrusters(16 one Newton)
	Orbit-Determination accuracy	1 Km
	Attitude Determination Accuracy	0.1 deg.
Payload	LISS-II*	LISS-II* was achieved by mounting two CCDs per optical lens system in staggered mode (Shown in fig.)
Data Handling		10.4 Mbps
Mass	Spacecraft+ P/L	975 kg
	Payload	98 Kg.

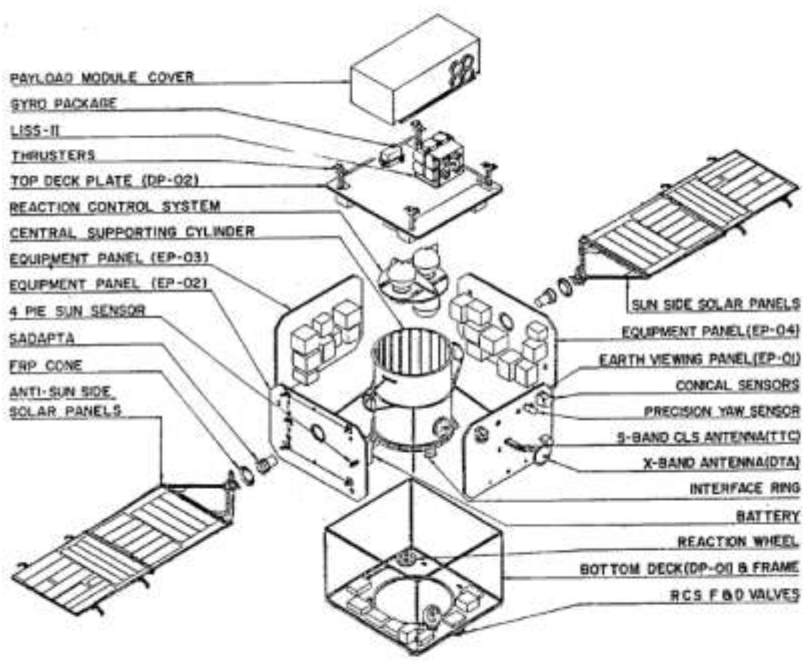


Figure 6.1: Exploded view of IRS-P2

6.5 Payload

The LISS-II payload is a solid state camera operating in four spectral bands in the visible and near IR range using 2048 elements linear array CCDs as sensors. Unlike in IRS-1A/1B satellites in which the LISS-II camera was made of two separate electro optical modules, in this camera two CCDs per band are placed in the focal plane of the same optics in a staggered configuration. These are designated as LISS-IIA and LISSIIB. Each camera provides an IGFOV of 32.74 meters and individual swath of 67 Km the along track separation between the two CCDs is above 62 Kms on ground which will result in a combined swath of 128 Kms.

The data handling system, consisting of Base band and RF Modules, receives the digital data from Payload, formats it and after modulation transmits the data to ground station as a PCM stream.

Table 6.2 Features of IRS-P2 Payload

Sl.No	Parameter	Value
	OPTICS	
1	Type of Optics	Refractive F/4.5
2	Equivalent Focal Length(EFL)mm	324.4
3	Spectral Bands (Microns)	Band1 : 0.45 - 0.52

		Band2: 0.52 - 0.59 Band3 : 0.62 - 0.68 Band4: 0.77 – 0.86
4	Field of view	±5.2 degs
	Detector	
5	Detector Type	CCD 143 Linear Array
6	Number of Pixel	2048
7	Pixel Size (Microns)	13 x 13
	System	
8	Geometrical IGFOV (m)	32.74
9	Along Track Sampling (m)	37.24
10	Angular IFOV (microradians)	40
11	Swath (Km)	67 km each CCD (128 km Combined)
12	Integration Time (ms)	5.6
13	Quantisation	7 Bits
14	Data Rate	10.2 Mbps
15	Signal to Noise Ratio (SNR) @ saturation exposure	>128
16	Square Wave response SWR @ 40 lp/mm	Band1: >0.4 Band2: >0.4 Band3: >0.3 Band4: >0.2
17	Band to Band registration(Pixels)	Less than ± 0.25
18	Operating Temperature Range	EO module 20±5 deg C Electronics 0 to 40 deg. C
19	Power in watts	Imaging mode :32 Calibration mode :34
20	Mass (Kg)	72

Payload configuration

The payload consists of three major elements

- Electro-optical Module
- Payload electronics
- Payload Power Supply

6.5.1.1 Electro optical Module

The EO module contains imaging optics including the spectral band pass filters and neutral density filters (ND), CCD detectors and detector electronics. The four band assembles in the camera use refractive optical systems and these are coupled to the detectors through Invar housings. These four single band assemblies are mounted on a welded aluminum bracket with their optical axes parallel to each other. To minimize the variation of BBR with temperature gradients, the four band assemblies are coupled through Invar plates at lens end, detector end and middle flanges. Two CCDs are mounted in the focal plane of each lens separated by a distance (in along track direction) of about 25 mm and a gap of 4 pixels (in the across track direction). Two LEDs per CCD mounted at an angle of 60 deg are used for on board calibration. DE packages mounted on EO module Houses the Bias Voltage generator, clock driver as well as pre-amplifier circuits for the operation of each CCD.

The payload electronics are similar to IRS-1A/1B.

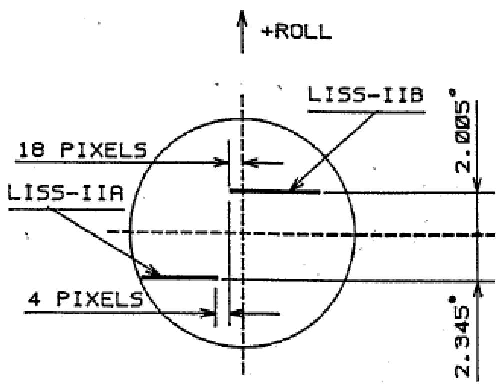


Figure 6.2: CCD arrangement in detector plane as seen from detector Plane

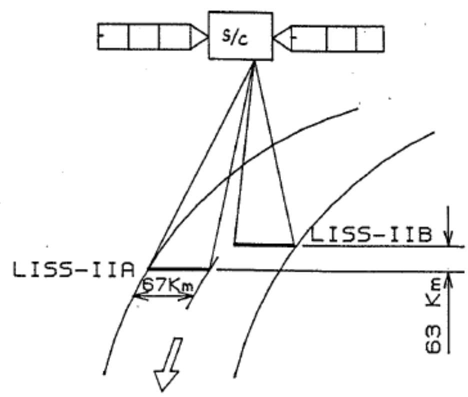


Figure 6.3: Swath coverage of LISS-IIA and LISS-IIB of IRS-P2

7 IRS-P3

7.1 Introduction

IRS-P3 was an experimental EO (Earth Observation) mission, a follow-up mission to IRS-P2, considered to be pre-operational, and served in parallel for technology evaluation and scientific methodology studies. A portion of the payload was provided by DLR (German Aerospace Center). In addition, DLR provided data reception support (Neustrelitz) and launch phase support. The secondary use of the mission is to enhance and improve the IRS mission capabilities toward operationalisation and application. This mission had two payload pointing modes, ie Earth pointing and stellar/inertial pointing.

7.2 Mission Objective

The Mission Objectives of IRS-P3 are

- *To provide the opportunity for RS application in the areas of land, atmosphere and oceanographic investigations.*
- *To validate new RS methods and develop affiliated application potential.*
- *To provide opportunity for experiments in X-ray astronomy.*
- *As payload for the third developmental flight of PSLV.*

Objectives of Earth pointing mode

- *To provide continued remote sensing data services in the areas of improved crop discrimination, crop yield, crop stress and disaster management.*
- *Remote sensing of ocean atmosphere system and coastal waters and to retrieve quantitative values about the co-existing c-varying water constituents like chlorophyll sediments and gelbstoff*
- *To provide dynamic target for calibrating PCMC radars during Indian Launch campaigns.*

Objective of Stellar pointing mode

- *To study periodic and aperiodic intensity and spectral variations of galactic and extragalatic X-ray sources by making pointed mode observations of specific X- ray objects.*
- *To discover pulsations of binary nature and quasi-periodic oscillations of X-Ray sources*
- *Study of light curves and spectral evolution of transient & flaring X-ray sources*

7.3 Orbit details

Table 7.1: IRS-P3 Orbit Details

Orbit	Sun-synchronous
Altitude	817 Km
Orbital Period	101.35 minutes
Orbit inclination	98.7 deg
Equatorial Crossing Time	10.30 AM
Repeat Cycle	24 Days
Launch vehicle	PSLV-D3

7.4 Salient features of Spacecraft:

The IRS-P3 spacecraft structure was of IRS-P2 heritage. The bus design had of four vertical panels and two horizontal decks supported on a central load-bearing cylinder of 930 mm diameter and 1188 mm height. The payload was accommodated on the outer side of the upper deck, which was oriented in flight direction (Roll axis). The onboard power generation was achieved by a pair of deployable, sun-tracking, un canted solar panels (9.636 m^2), which generates a power of 873 W. Two Ni-Cd batteries (21 Ah/24 Ah) catered to the eclipse and peak load demands.

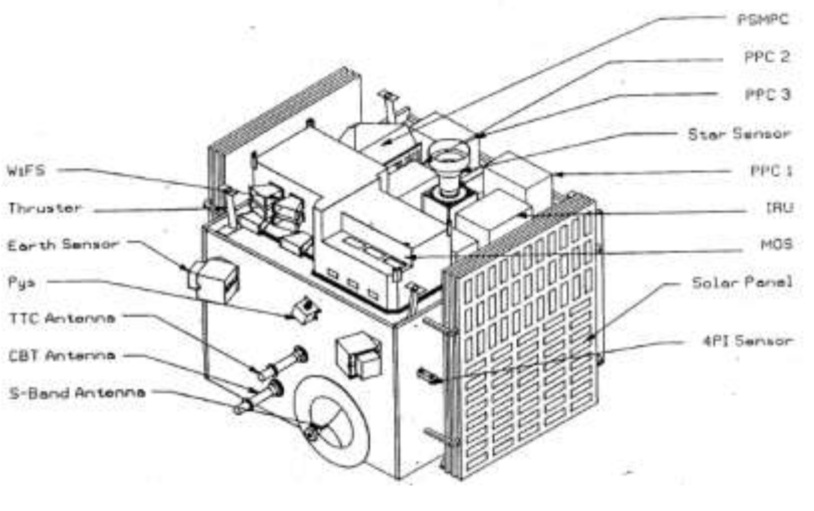


Figure 7.1: Stowed configuration of IRS-P3

The spacecraft was three-axis stabilized. The AOCS employed Earth sensors, sun sensors and dynamically tuned gyros as attitude sensors; actuation was provided by reaction wheels, magnetic torquers and an RCS (Reaction Control System). An Earth pointing accuracy of better than 0.20º in all axes and better than 0.05º in all axes for stellar pointing (X-ray observation mode) was provided. In addition to these attitude sensors, AOCS also employed a star sensor in control loop in order to maintain the attitude during stellar pointing mode. The star sensor was an area array CCD imager of 288 x 384 pixels (FOV of 6º x 8º). It worked as a star tracker with respect to a set of optical stars, identified a priori in conjunction with the X-ray package. The star sensor was mounted on positive roll axis and co-aligned with the X-ray payload's optical axis. When the spacecraft was inertially oriented and locked to a specified X-ray source, the star sensor works in a static mode. Therefore, the star sensor always locks to a specific scene about the roll axis.

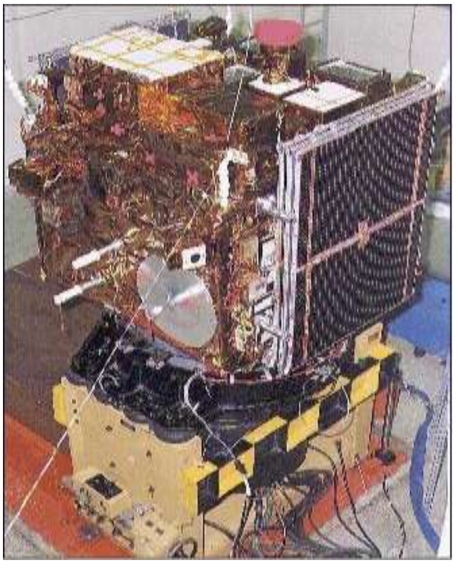
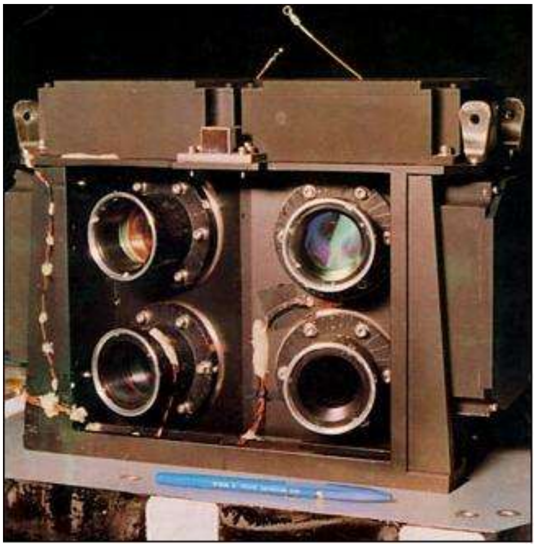
Total S/C mass = 922 kg, a hydrazine propulsion system (84 kg of fuel sufficient for three years) with 16 thrusters is used for orbit maintenance.

The IRS-P3 bus was derived from the flight proven IRS-1A,1B buses. New systems were the processor based attitude and orbit control system (AOCS) which was derived from INSAT-II for large angle maneuvers, the processor based telecommand system and FPGA based telemetry system. ISRO developed Ni-Cd batteries (24 Ah) were used.

Table 7.2 Salient features of IRS-P3

Subsystem		IRS-P3
Structure		Four vertical and two horizontal decks supported on a central load bearing cylinder of 930 mm dia. And 1188 mm height. Decks are made up of Aluminum/aluminum honeycomb panel. On Inner surfaces packages were mounted. Outside of Earth viewing panel carried payload data antennae, the TTC antenna and attitude sensors. The payloads were on outside of top deck
Thermal	Control	The design philosophy was maximum use of passive elements and minimum use of semi-active elements. This was achieved by extensive use of thermal control coatings, Thermal control tapes, optical solar reflectors (OSRs), multilayer insulation blankets(MLI), conductive grease etc.
	Limits	Electronic packages: between 0 to 40 deg C Battery: 5±5 Deg C
Mechanism	Solar Panel	Solar Panel Hold down deployment and drive mecghanism

Power system	Solar Panel	Two sections feeding two batteries (Total 870 W generated) 9.7 Square Meter rigid panels. Controlled by Shunt switches. Battery charging control by dissipation less PWM taper charge regulators.
	Battery	Battery : Two 24 AH, Ni-Cd batteries comprising 28 cells each
	Electronics	370 W continuously, 40 V Bus
Communication	Telecommand	Operated in S-Band PCM/FSK/FM/PM modulation
	Telemetry	System Based on PCM/PSK modulation in S-Band with dwell mode facility. One orbit data storage was implemented..
	Tracking	The Tracking is provided by range and Doppler measurements using S-band TTC transponder.
AOCS	Pointing Accuracy	AOCS Supported Nadir mode WiFS and MOS payloads and Stellar mode for X-Ray Payloads. Pointing accuracy : 0.2 deg. Nadir Mode 0.01 deg. Stellar mode
	Sensors	Sensors: Earth,Sun and star sensor Star sensor inloop mode was used for stellar pointing mode.
	Actuator	Actuators: Two Magnetic torquers, four Wheels, 8 one newton thrusters and one 8 newton thruster. Fuel loaded : 84 kg
Payload Data		The payload data was transmitted in S-Band 2280 MHz with BPSK modulation (Data rate 55.2 MBPS)

7.5 Payloads

7.5.1WiFS (Wide Field Sensor):

WiFS was an pushbroom imager of IRS-1C and IRS-1D heritage. WiFS was an extended version of 3 channels on IRS-P3: 0.62 - 0.68 µm, 0.77 - 0.86 µm, with an additional channel at 1.55-1.75 µm (SWIR). Each band had two detectors centered at a FOV of ±13.6º to achieve a swath of 770 km (repeat cycle of 5 days). The optics system consists of eight lenses with spectral bandpass and neutral density filters for each spectral band. The dynamic range in each gain was 7 bits. The absolute radiometric accuracy was better than 10% with relative in-band accuracy of 2%. The data rate for the VNIR data (2 channels) was 2.6 Mbit/s, for the SWIR data it was 1.73 Mbit/s. WiFS had a mass of 25 kg and used 50

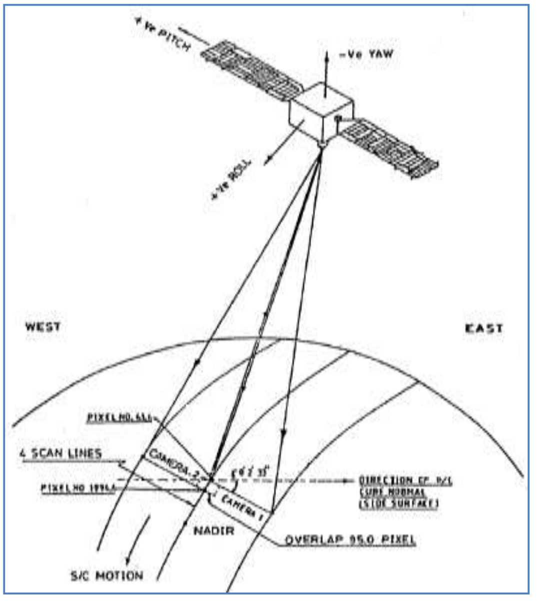


Figure 7.2WiFS Swath coverage on earth

W. The objectives of WiFS observations were to monitor the vegetation index on land and to observe the ocean surface.

Table 7.3: WIFS camera specifications

Spectral bands (µm)	0.62 - 0.68, 0.77 - 0.86, 1.55 - 1.75 (SWIR)
Spatial resolution	188 m
Swath width	770 km (FOV of ±13.6º), 4096 pixels
Repetition cycle	5 days
SNR at saturation radiance	>128
Misregistration	0.25 pixel
Data quantization	7 bit (radiometric resolution of 128 grey levels)
Integration time	28.42 ms
Data rate	2.06 Mbit/s
Mass	25 Kg
Power	50 W

7.5.2MOS (Multispectral Optoelectronic Scanner):

MOS is an experimental imaging push-broom spectrometer for VNIR/SWIR range observations. MOS is provided by DLR (German Aerospace Center), Berlin. The objective is to monitor the Earth's surface (surface-atmosphere interaction, ocean color, phytoplankton, regional and global distributions of man-made aerosols and their links to gaseous admixtures, spectral and spatial cloudiness characteristics, etc.) in the VNIR/SWIR region of 0.4 - 1.6 µm.

The goals of MOS payload are

- To design and build a spectral imaging instrument, dedicated for ocean colour Remote Sensing with many > 10 narrow spectral channels in the VIS-NIR range (400-1000nm)
- To separate the problem of object signature and atmospheric disturbance by independent measurements in different spectral regions and with special designed optical means.
- To make experiments to prove the instrument concept and to get experience in high spectral data handling and image processing.
- To develop algorithms and test the methodological concept with emphasis on CASe-2 coastal water
- To make measurements at different ocean/coastal regions, by satellite and synchronous ground truth to verify the algorithm or carry out its " regional tuning, if necessary.

The sensor apparatus consists of three complementary instruments. MOS operation requires at least one calibration per month (with respect to the sun).

• **MOS-A** is an atmospheric spectrometer with four narrow channels in the O_2A-absorption band at about 760 nm for the measurement of atmospheric turbidity. The data from MOS-A are used for correction of the atmospheric influence (scattering) on the multispectral data of MOS-B. In addition the O_2A-method permits the measurement of aerosol content and profile.

• **MOS-B** is a 13-channel spectrometer in the spectral range of 408 to 1010 nm. The center wavelengths of the channels are chosen with the objective for the quantitative retrieval of ocean and coastal zone parameters. They also provide a capability for vegetation signature determination (red edge) and estimation of H_2O (water vapor) content in the atmosphere from the NIR-measurements.

• **MOS-C** is a line camera at 1.6 µm with a bandwidth of "50 nm. The SWIR channel data is used for improved surface term and roughness estimation. In addition the data of the SWIR channel may be used for the following applications: cloud/snow/ice discrimination, cloud type discrimination, estimation of sea surface roughness, and for the improvement of atmospheric correction algorithms.

Table 7.4: Specifications of the MOS instruments

Parameter	MOS-A	MOS-B	MOS-C
Spectral range (nm)	755 - 768 nm	408 - 1010	SWIR
No. of channels	4	13	1
Wavelengths (nm)	756.7; 760.6; 763.5; 766.4 (O_2A-band)	408; 443; 485; 520; 570; 615; 685; 750; 870; 1010; 815; 945 (H_2O-vapor)	1600
Spectral resolution	1.4 nm (FWHM)	10 nm (FWHM)	100 nm (FWHM)
FOV along-track FOV across-track	0.344º 13.6º	0.094º 14.0º	0.14º 13.4º
Swath width	195 km	200 km	192 km
No. of pixels per row	140	384	299
Spatial resolution (ground pixel size)	1.57 km x 1.4 km	0.52 km x 0.52 km	0.52 km x 0.64 km
Measuring range L_{min}-L_{max} \[$\mu Wcm^{-2}nm^{-1}sr^{-1}$\]	0.1 - 40	0.2 - 65	0.5 - 18
Data quantization	16 bit		
Data rate	1.3 Mbit/s		

MOS calibration: In-orbit calibration measurements are performed using internal reference lamps (prior to each data take). In addition sun calibration measurements are performed once a month. This is achieved with a diffuser in front of the entrance optics of the sensor. The following calibration functions are performed:

- DSNU (Dark Signal Non-Uniformity) and PRNU (Photo Response Non-Uniformity)
- Absolute sensitivity calibration
- Linearity control
- Spectral alignment control

MOS in-orbit inter calibrations with sensors from other missions are attempted when orbital opportunities arise for a common target area or test sites. Examples are: MOS on IRS/P3 with MOS on Priroda, or with SeaWiFS on Seastar, or with OCTS on ADEOS.

Principle of the imaging pushbroom spectrometer operation: A strip (swath) of the Earth's surface is imaged through the entrance optics on the field stop. The collimator optics realizes parallel light rays falling onto the grating. The grating disperses the different "colors" that are focussed by the imager into the focal plane. Corresponding to the desired wavelength, CCD line arrays are mounted into the focal plane.

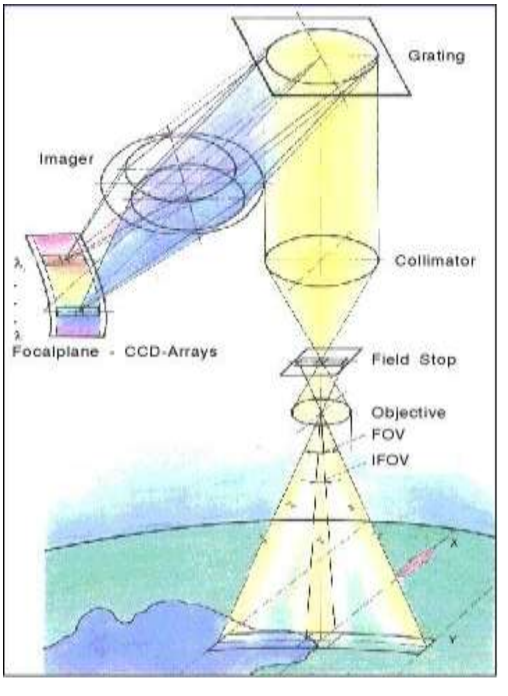


Figure 7.3 Optical schematic of the MOS

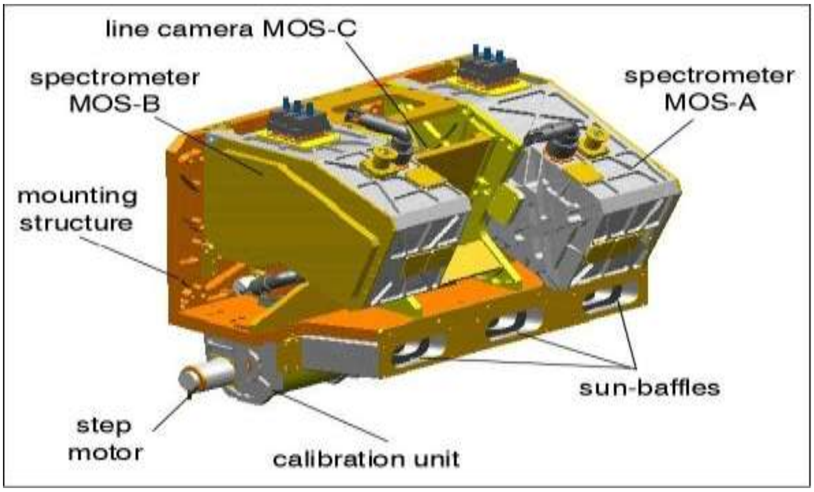


Figure 7.4 Illustration of the MOS (Modular Optoelectronic Scanner) instrument

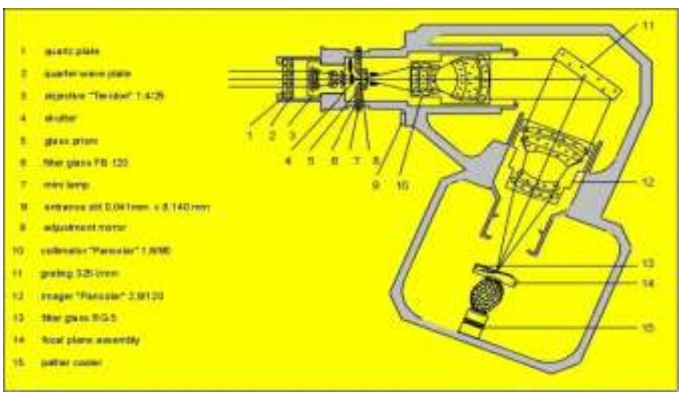


Figure 7.5 Schematic illustration of the optical block of MOS-B

Sensor calibration

The demanded radiometric data quality was guaranteed by two on-board calibration concepts realized in hardware. 1. An internal sensitivity check 2. an external calibration to the sun (SUNCAL). The internal check is made in each block with two small filament lamps mounted besides the entrances slit. Through the auxiliary slits the lamps are illuminating the collimator optic and after dispersion at the grating are illuminated the CCD – lines in the focal plane. By powering the lamps in four high stabilized current levels and superposing of both lamps we have

16 levels of different illumination intensities for each channels in MOS-A and MOS-B. In MOS-C CCD was illuminated directly by the lamps.

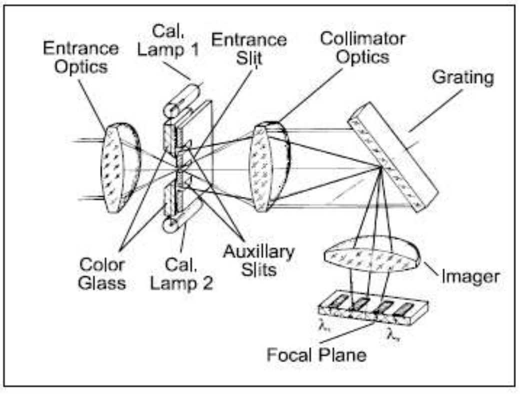


Figure 7.6: Optical Schematic of MAS-A and MOS-B

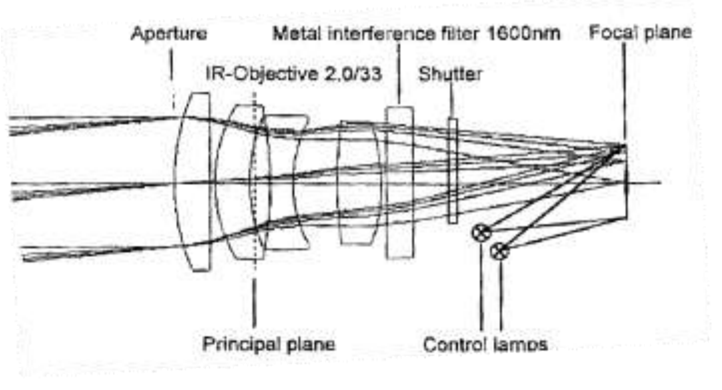


Figure 7.7 Optical Schematic of MOS-C

7.5.3IXAE (Indian X-ray Astronomy Experiment):

IXAE is an ISRO/ISAC and TIFR (Tata Institute of Fundamental Research, Mumbai, India) cooperative experimental astronomy instrument package with the objective to study periodic and aperiodic intensity and spectral variations in X-ray sources. Source observation is achieved by `pointed mode observations,' employing an array of three co-aligned collimated **PPC** (Pointed Proportional Counter). The system operates in mutual anti-coincidence fashion for significant reduction of background noise (cosmic rays and Compton interaction of gamma rays).

Another objective is the study of light curves and the spectral evolution of transient and flaring X-ray sources as well as long-term intensity monitoring of known binary X-ray stars and other bright X-ray sources. This is achieved by means of **XSM** (X-ray Sky Monitor), based on the principle of a pin hole placed above a position sensitive to PPC in anti-coincidence mode.

Table 7.5 PPC and XSM instrument specification

PPC		XSM	
Energy range	2 - 20 keV	Energy range	2 - 8 keV
FOV	2º x 2º	FOV	90º x 90º
No of PPC	3	Pin hole size	1 cm^2
No of layers per PPC	3	Distance to detector	16 cm
No. of anode cells/layer	18	Detector	32 proportional counters
Size of cell	1.1 cm x 1.1 cm	Detector cell size	1 cm x 1 cm x 32 cm
Entrance window	25µm , 500 Å, Al coated	Window	25 µm Mylar, Al coated
Filling gas	Ar+CH_4, at 800 torr	Filling gas	Ar+CH_4

The principle objective of the IXAE is to carry out timing studies of X-ray pulsars, X-ray binaries, and other rapidly varying X-ray sources. The XSM detects transient X-ray sources and monitors the light intensity of bright X-ray binaries. Each of the detectors (PPC, XSM) are controlled by independent microprocessor based processing electronics. A common electronics subsystem acts as an interface with the satellite bus. An oven controlled oscillator (accuracy one part in 109) provides high timing accuracy.

The PPC is a multi-cell multi-layer proportional counter array with active anticoincidence on three sides. The total geometric area is about 400 cm^2, the filling gas is 90% Argon + 10% Methane. A 25 µm aluminized mylar acts as the entrance window. The field of view is restricted to 2º x 2º using a passive collimator. The detector has a command controlled high voltage unit. The processing electronics for the PPC has an onboard memory of 512 kByte, the spectra (64 channels spanning 2 to 30 keV) and light-curves are stored onboard with the command selectable integration times.

The XSM is a planar position sensitive proportional counter with a pin-hole of 1 cm^2 positioned 16 cm above the detection plane. The FOV is 90º x 90º. The detection plane consists of 32 proportional counter cells with a resistive wire (NiCr) as the anode. Position resolution along the wires is achieved by charge division and perpendicular to the wires it is achieved by cell placement (1 cm). The energy range of the detector is 2 to 8 keV.

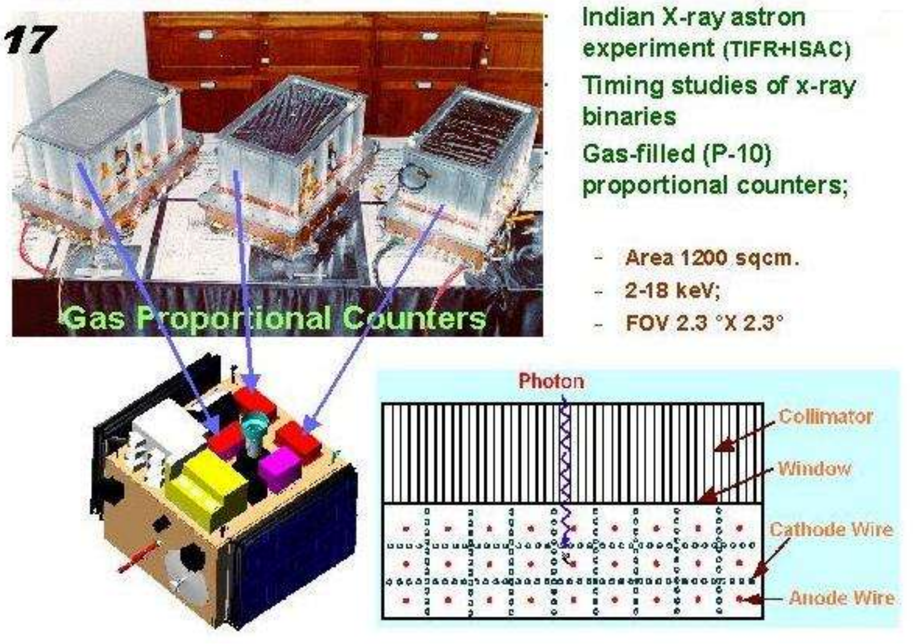


Figure 7.8 Schematic view of the IXAE instrumentation

7.5.4C-Band Transponder

The C-Band transponder system consists of three portions as given below and is used for calibrating ground radars at SHAR

1. Receiving section which operates at 5.660 GHz with sensitivity of -70 dBm
2. Transmitting section which operates at 5510 MHz and 5800 MHz with a peak power of 400 watts
3. DC/DC converter which provides constant output voltages

Single antenna is used for receiving and transmitting Operations.

Receiver: The RF input received by the antenna is fed to the circulator. The signal passes from circulator to the pre-selector filter. This filter is used as selector. Output from this filter/selector is fed to a mixer. Output of local oscillator (LO) which is fundamental oscillator generates C-Band frequency is also fed into the mixer. Mixer performs as a down converter and converts C-Band signal to the IF frequency. The amplified IF signal is detected by a solid state detector, filtered by a low pass filter, am0plified and passed to digital section through a buffer. The digital circuits provide triggers to the modulator which produces a high voltages negative pulse for cathode pulsing of the magnetron.

Transmitter: The Transmitter is a mechanically tuned C-Band magnetron oscillator. The power output is provided to the unit through 4 port circulator.

DC/DC converter: The DC/DC converter provides input to CBT at 23 V +2% and 1.2 A. the initial surge current requirement under all conditions is 1.5A.

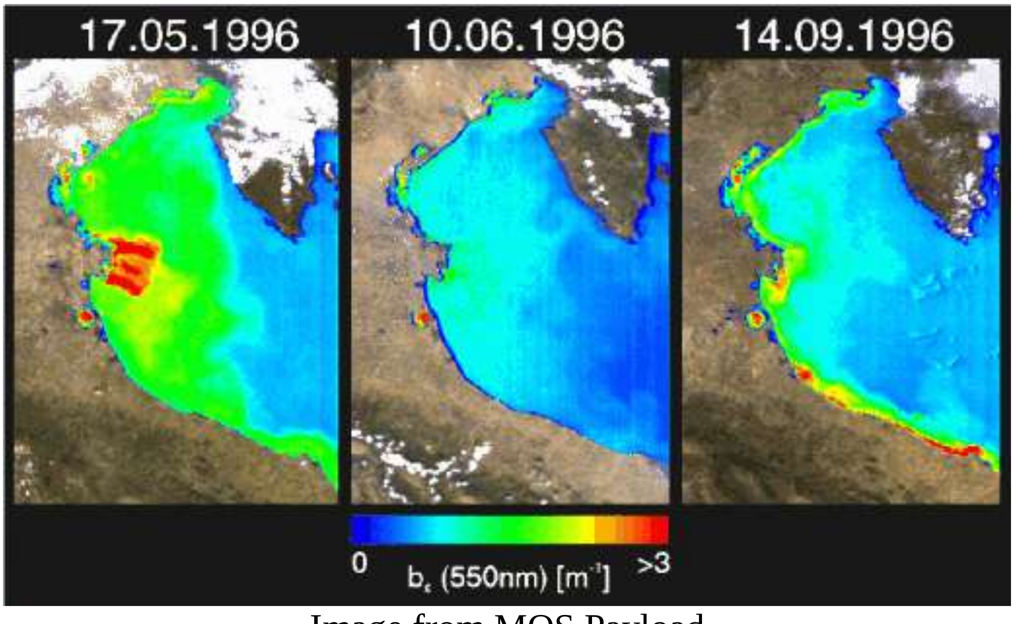


Image from MOS Payload

8 IRS-1C&1D

8.1 Introduction

IRS-1C is the second generation Remote sensing operational satellite developed by ISRO that carried three distinct and mutually complementary imaging payloads. The combination of payloads enhanced the capabilities of IRS-IC as compared to IRS- IA/1B in terms of spatial resolution, provision of an additional spectral band, ability to acquire stereoscopic images and inclusion of a wide field sensor for improved temporal resolution. IRS-1D was the follow-on mission.

8.2 Mission Objective of IRS-1C and 1D

Mission objectives of IRS-1C and 1D are as given below

- *To design develop launch and operate state of art three axis body stabilised satellite for providing continued space based remote sensing services to the user community with enhanced resolution capability compared to IRS-1A/1B*
- *Further develop new areas of user applications to take fiull advantages of the enhanced resolution and capacity of IRS-1C/1D spacecraft.*

8.3 Orbit Details

IRS-1C and 1D were launched into polar sun syncronous near circular orbit to ensure ground illumination conditions are nearly the same for imageries collected on different days. Local time equtorial crossing was chosen 10.30 AM based on application needs of the users. .

Table 8.1: Orbital parameters of IRS-1C&1D

Sl.No	Parameter	IRS-1C	IRS-1D
1	Orbit	Polar sun synchronous	Polar sun synchronous
2	Altitude	817 Km	740 x 817 Km
3	Inclination	98.69 deg	98.6
4	Period	101.35 minutes	101.35 minutes
5	Local Time	10.30 A.M	10.30 A.M
6	Repetivity Cycle	24 Days (For Liss-3) 5 Days (for Pan 5 Days (for PAN revisit)	24 Days (For Liss-3) 5 Days (for Pan 5 Days (for PAN revisit)
7	Distance between adjacent Traces	117.5 Km	117.5 Km

8	Minimum Picture Overlap for LISS-3	22.5 Km	22.5 Km
9	Off Nadir coverage +/- 26 deg (for PAN)	398 Km	398 Km
10	Distance between successive Ground tracks	2828 Km	2828 Km
11	Ground Trace velocity	6.65 Km/s	6.65 Km/s

8.4 Salient features of IRS-1C&1D

Though most of the systems were fabricated similar to IRS-1B, based on the onboard experiences of IRS-1A and IRS-1B satellites, and in view of launching the satellite using Indian launch vehicle (PSLV), some modifications/ improvements were carried out in IRS-1D spacecraft. Features comparison of 1C/1D with IRS 1A/1B is given in table 8-2.

Table 8.2. Salient features of IRS-1C/1D

Subsystem	IRS-1A/1B	IRS-1C/1D
Structure	Al. honeycomb structure with central load bearing Al. Cylinder	Shear webs added to increased the frequency to cater to PSLV launch. CFRP cylinder (370 mm height 930 mm dia) for thermal isolation of payload deck incorporated.
Thermal	Passive, Semi-active with heaters	Experience gained from IRS-1A for evolving IRS-1C thermal design, Payload module had new configurations and power dissipation in IRS-1C was more and hence a new design and analysis made.
Mechanism	Solar Panel deployment mechanism	Solar panel deployment mechanism used as it is 'PAN' camera deployment and steering mechanism newly developed.
Power	Solar Panel	9.636 m^2, 6 panels 1.1 x 1.46 m^2 (Each) BSR (SCA) 813 watts (10% area increased)
	Battery	2 batteries, 42V, 28 Cells, Ni-Cd 21 AH
	Power electronics	More efficient power electronics

		developed. Additionally CUK type of DC/DC converters developed.
TTC	S-Band transponder	S-band transponder used as it is
	PROM based telemetry	Modified to meet mission specific requirements
	Telecommand system (418 ON/OFF, 21 data commands)	Modified to meet mission specific requirements including time tag commands (704 ON/OFF and 46 data commands)
	X Band for LISS_2(10.4 x 2 MBPS) with 20 watts TWTA	40 watts TWTA used . 84 MBPS and 42 MBPS data Handling system Developed.
AOCS	Sensors	Sun sensors (4 PI, TWSS, FSS, PYS) PYS improved to reject any spurious signals Conical earth sensors ,
		Dry tuned gyro for yaw control. Two gyros in a cluster Three gyros in a cluster. All three axis to be controlled by gyro.
		Star sensor based-on linear CCD Star sensor based on area array CCD (for providing attitude information about all three axes)
	Actuator	Mono propellant 1 Newton system. 80 Kg Capacity. 11 Newton thruster developed for IRS-1C, 5 NMS Reaction Wheels
	AOCE	Hardwired system PWPFM controller. Hardwired system as a back up only for microprocessor based linear controller. Improved KF used
Payloads	LISS-I and LISS-II	LISS-III, PAN and WiFS
Data Handling	S-Band for LISS-1(5.2 MBPS)	PAN and LISS-3 data in two independent X-band chains. QPSK modulator developed.

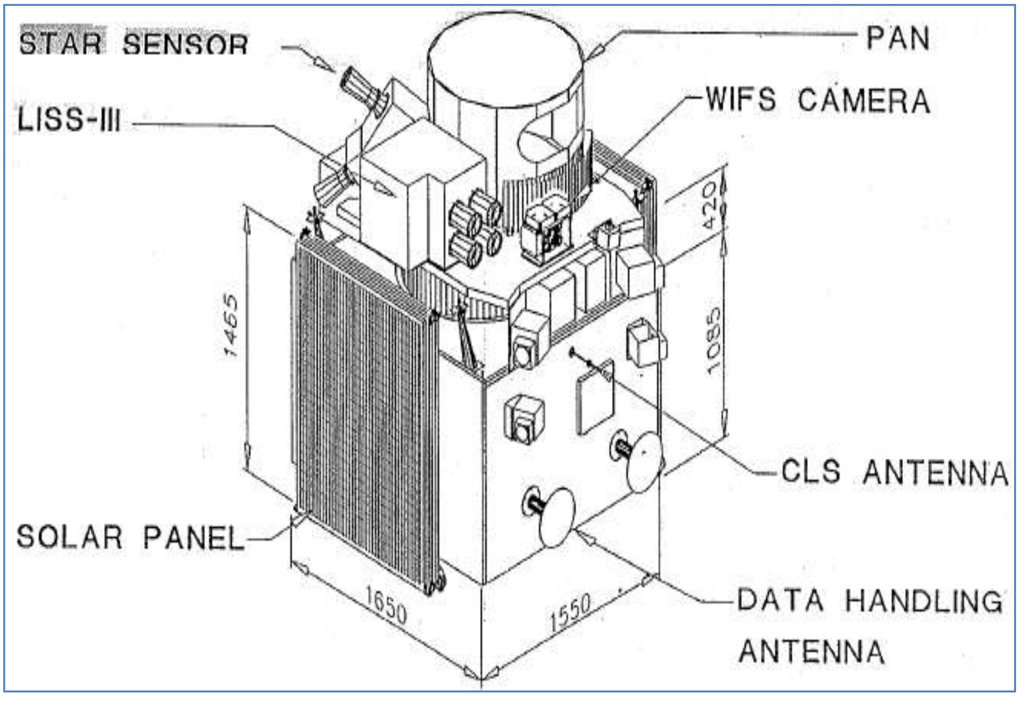
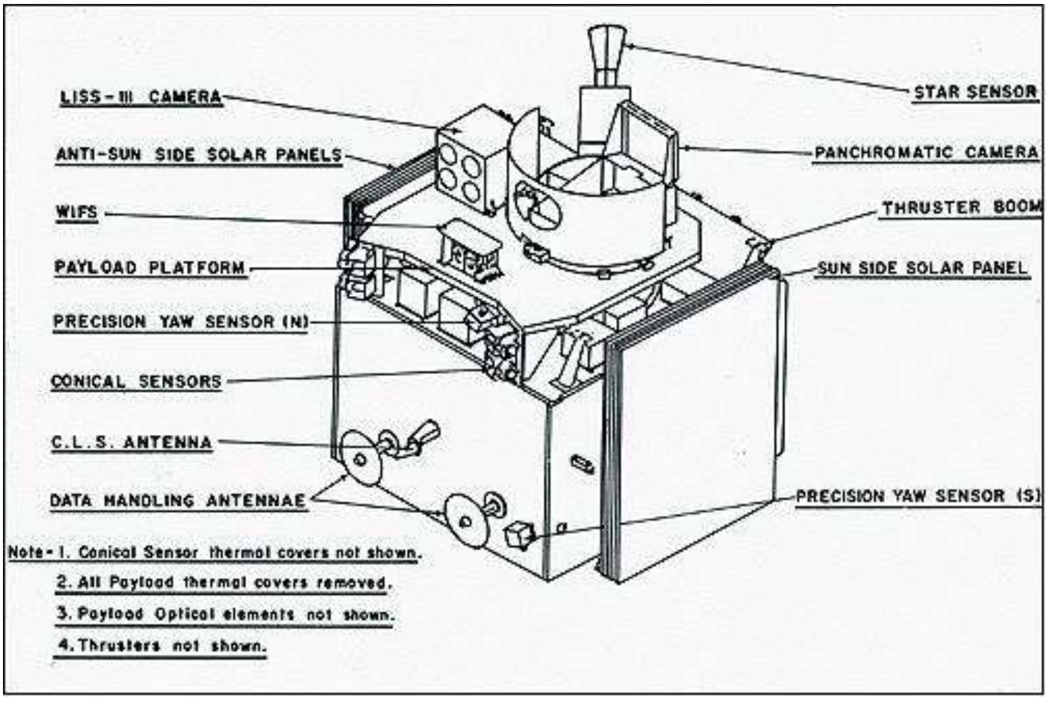


Figure 8.1 IRS-1D spacecraft Stowed View



8.5 Payloads

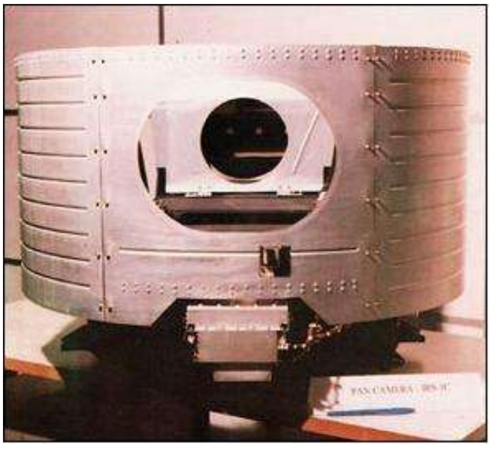
The payload system of IRS-1C&1D consists of three cameras namely

- Panchromatic camera (PAN),
- Linear Imaging Self scanning Sensor (LISS-III) and
- Wide Field Sensor (WiFS)

All cameras operate in the push-broom scanning mode employing linear array charge coupled devices (CCD).

8.5.1Panchromatic camera (PAN)

The PAN camera provides a spatial resolution of 5.8 meters at nadir and operates in a single (0.5- 0.75) panchromatic spectral band. This camera covers a ground swath of 70 kms which is steerable upto 26 deg. from nadir in the across track direction. This off nadir viewing provides the capability to revisit any given site with a maximum delay of five days. The major specifications of the IRS-IC PAN camera are given in table 8.3



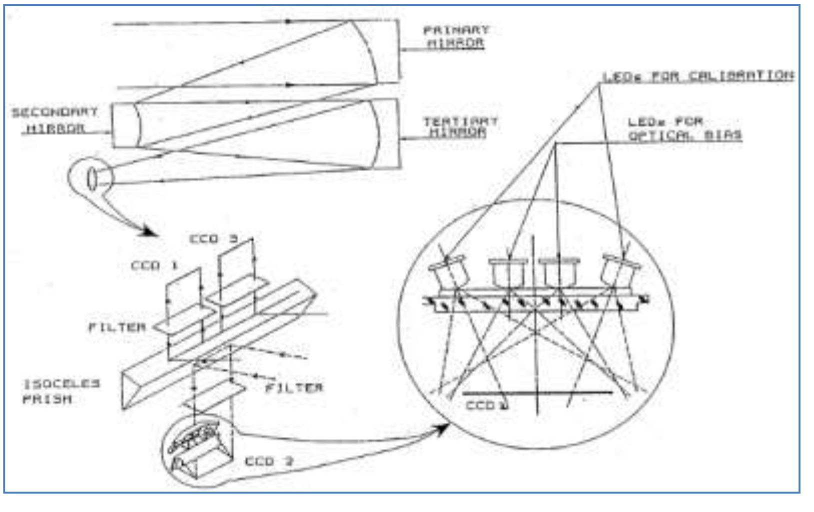


Figure 8.2 CCD Arrangement in IRS-1C/1D PAN camera

Optical design Of PAN

The PAN camera uses an all reflective off axis telescope, while LISS-III and WiFS are realised using refractive optics. The PAN optical system is a 980mm focal length (f/4.5) unobscured three mirror system i.e there is no obstruction to the incoming beam by any part of the optical system. The optical design features an off axis primary hyperboloid mirror, a spherical secondary mirror and an off axis ellipsoidal tertiary mirror. By using off axis sections of conic surfaces, obstruction of the incoming radiation is avoided resulting in higher modulation transfer function for a given aperture. Since the image format (85mm) is too large to be covered by a single CCD, an arrangement of 3 CCDs is used to cover the full swath. A prism with two reflecting sides is placed slightly ahead of the image plane. The light rays from the tertiary mirror falling on the sides of the prism are reflected out in opposite directions. The prism angles are so configured that the light rays from 0.3 deg. of nadir, along track, form two image lines on either side of the prism. These two image lines when projected on ground are separated by 8.6 km. One of the image lines is covered by two CCDs with a gap corresponding to the coverage by one CCD between them. The second image line is imaged by a single CCD which is centrally located.

The telescope mirrors are fabricated out of zerodur and are mounted in multi bladed mirror mounts using an appropriate glue in such a way that surface deformation on the mirrors do not occur. The super invar mirror mounts have been designed to withstand storage temperature and mechanical loads generated during the launch. The use of zerodur mirrors with the invar structure reduces the drop in MTF due to temperature variation within the operating temperature of 17-23°C. Further, the mirror surface does not show any non elastic behavior in the storage temperature range of -30°C to +60°C. Baffles in the optical assembly have been designed to reduce out of field radiation and reduce the drop in MTF from stray light. The baffles have been located near secondary and tertiary mirror mounts. The design value of MTF is greater than 0.6. In practice after taking to account the fabrication, tolerance, alignment etc., it is possible to realize MTF of 0.5.

Table 8.3: Characteristics of PAN

S.No	Parameters	Parameters
1	Instantaneous Geometric field of view * (meters)	5.8
2	A) Swath* (km) B) Swath Steering Range (degree) C) step Size (Degree)	70 ± 26 ± 0.09
3	Spectral Band (micron)	0.50-0.75
4	Camera SWR (At Nyquist frequency)	0.20

5	Quantization (bits)		6
6	System Noise		1 LSB
7	Saturation radiance (nominal) (MW/Cm2- STR-micron)		47
8	Detector		3 x 4096 pixel CCD (7 x 7 micron)
9	Size of EO Module (Envelope) (mm)		605 (R) X 903 (P) X 861 (Y)
10	Weight (kg)	EO Module	105 (without PSM)
		PLE Package	20
11	Power (W)	Imaging Mode	55
		CAL Mode	65
12	Data Rate (MBPS)		84.9

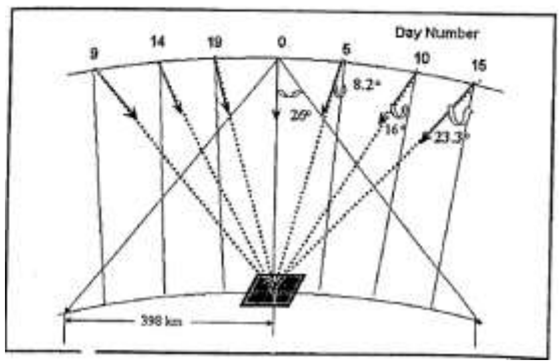


Figure 8.3 PAN Off nadir viewing capability /Swath coverage of PAN

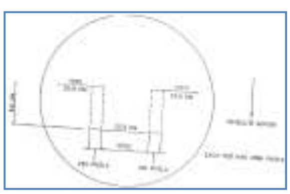


Figure 8.4
Swath coverage of IRS-1C/1D

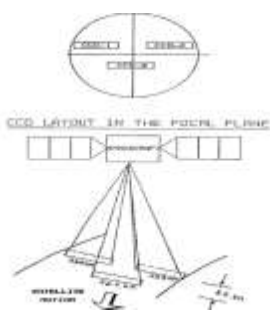


Figure 8.5 Swath coverage of IRS-1C/1D

8.5.2LISS-3 Camera

The LISS-3 camera is a multispectral imaging system operating in four spectral bands, three in the visible and Near IR (VNIR) region which are identical to B2, B3 and B4 of IRS- IA/1B and one in short wave infrared (SWIR)-band B5. LISS-3 provides a ground resolution of 23.5 m in VNIR and 70.5 m in SWIR with a swath of 141 km and 148 km respectively for VNIR and SWIR. Following Table gives the specifications of LISS-3 camera.

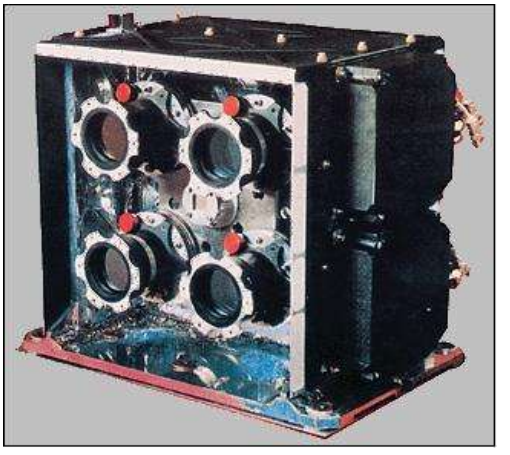


Figure 8.6 LISS-3 Camera

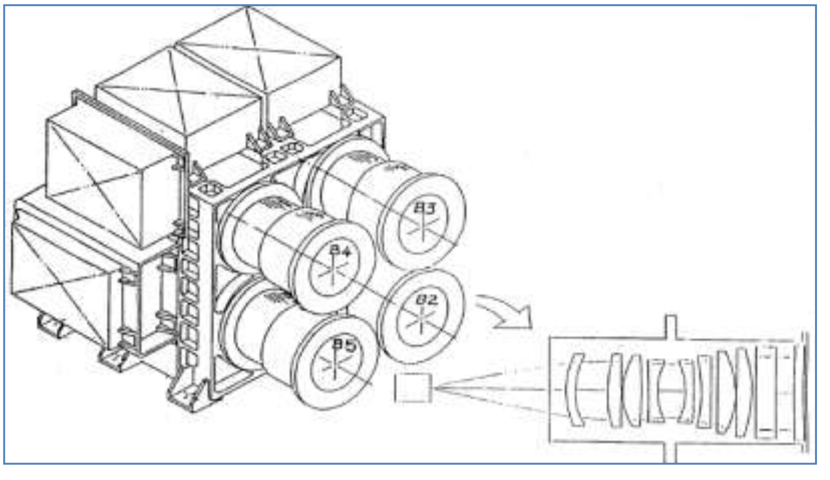


Figure 8.7 LISS-3 EO Module

The lens design is derived from double Gauss concept. The design is optimized separately for each spectral band to obtain the best MTF performance. The design features a very low sensitivity of EFL, FD and collinearity to temperature variation. The lenses for bands B2, B3 and B4 having an f/no. of 4.35, and a focal length of 347.5 mm operate at 50 lp/mm whereas band B5 has focal length of 301 .04 mm with f/no. 4.35 and operates at 20 lp/mm .

To minimize the impact of surface reflections, each surface of the optical elements carries antireflection (AR) coatings. The AR coatings have been provided on all lens elements, thermal filter and outer surfaces of the interference filter. The lens is purged with dry Nitrogen and sealed with a membrane. After the launch, when the differential pressure is more than 500 mbar the membrane ruptures and allows the evacuation of the lens assembly. The assembly of the camera takes into account the change in focal length from laboratory environment to the vacuum conditions in orbit.

Hard coated four cavity interference filters have been used in these lenses, for spectral selection. The thermal filter made of fused silica, makes an angle of one degree with the optical axis of the lens assembly to avoid ghost images at the CCD plane. It has a provision to allow rotation of this angle around the optical axis to take into account the CCD detector orientation with respect to the mounting holes of the flange.

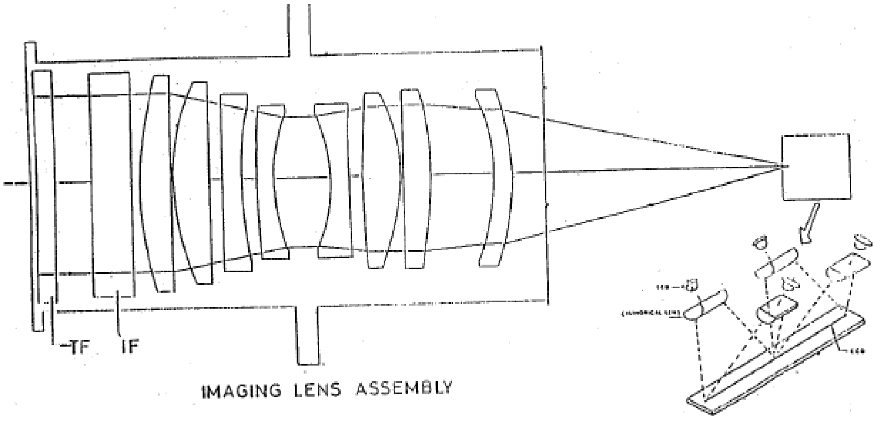


Figure 8.8 Calibration LEDs arrangement In LISS-3

Table 8.4 Characteristics of LISS-3 Payload

S.No	Parameters	Parameters
1	Instantaneous Geometric field of view * (meters)	23.5 B2, B3, B4 70.5 SWIR(B5)
2	Swath* (km)	>141
3	Spectral Band (micron)	B2 0.52-0.59 B3 0.62-0.68 B4 0.77-0.86 B5 1.55-1.70
4	Camera SWR (At Nyquist frequency)	B2 40 B3 40 B4 35 B5 30
5	Quantization (bits)	7
6	System Noise	>1 LSB
7	Saturation radiance (nominal) (MW/Cm2- STR-micron)	B2 29± 1.5 B3 28 ± 1.5

			B4 31 ± 1.5 B5 3.5 ± 0.3
8	Detector		10 x 7 micron 6000 element CCD for Visible 26 x 26 micron 2100 element CCD for NIR
9	Size of EO Module (Envelope) T(mm)		455 (R) X 522 (P) X 500 (Y)
10	Weight (kg)	EO Module camera	76.5 95
11	Power (W)	Imaging Mode CAL Mode	74 78
12	Data Rate (MBPS)		B2,B3,B4 35.8 B5 1.4

8.5.3WiFS Camera

The WIFS camera has a spatial resolution of 188 meters covering a swath of 804 km. This wide swath coverage results in a repeatable observation of the same ground location after every 5 days. The WIFS operates in two spectral bands B3 and B4 of LISS-III (0.62 - 0.68 and 0.77 - 0.86). Performance parameters of WiFS are given in

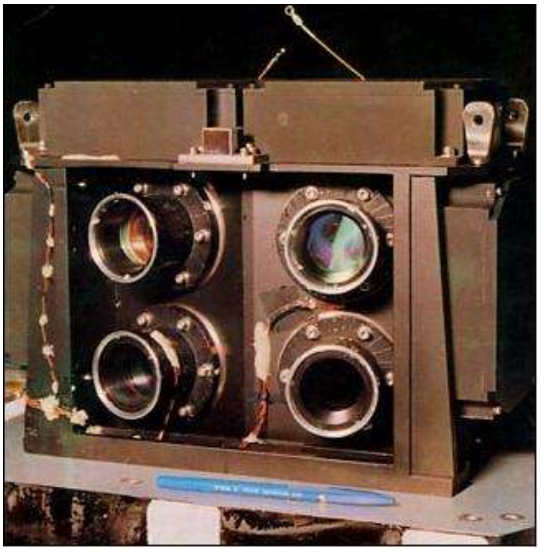


Figure 8.9Wifs Camera of IRS-1C

In the case of LISS-III , each band is realized using a lens and detector at the focal plane. The basic design WiFS Camera

For the WiFS camera, the total field to be covered was 52°. If this was realized using single lens for each band, due to the large variation in the incidence angle at the interference filter, there will be considerable shift in the band edge positions over the field of view. To minimize the above effect, the total The two lenses are mounted with their optical axes canted 13° on either side of nadir. The basic optical design is similar to LISS III except for the focal length of 56 mm.

Table 8.5: Characteristics of WiFS Camera

S.No	Parameters	Parameters
1	Instantaneous Geometric field of view * (meters)	188
2	Swath* (km)	804
3	Spectral Band (micron)	B3 0.62-0.68 B4 0.77-0.86
4	Camera SWR (At Nyquist frequency)	B3 >34 B4 >20
5	Quantization (bits)	7
6	System Noise	<1 LSB
7	Saturation radiance (nominal) (MW/Cm2- STR-micron)	B3 28 ± 1.5 B4 31 ± 1.5
8	Size of EO Module (Envelope) (mm)	250 (R) X 335 (P) X 170 (Y)
9	Weight (kg) EO Module camera	18 23
10	Power (W)	28
11	Data Rate (MBPS)	2.1

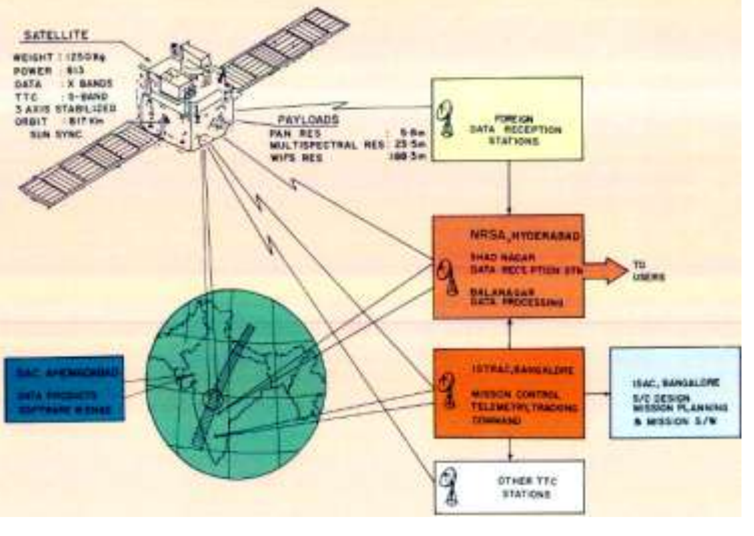
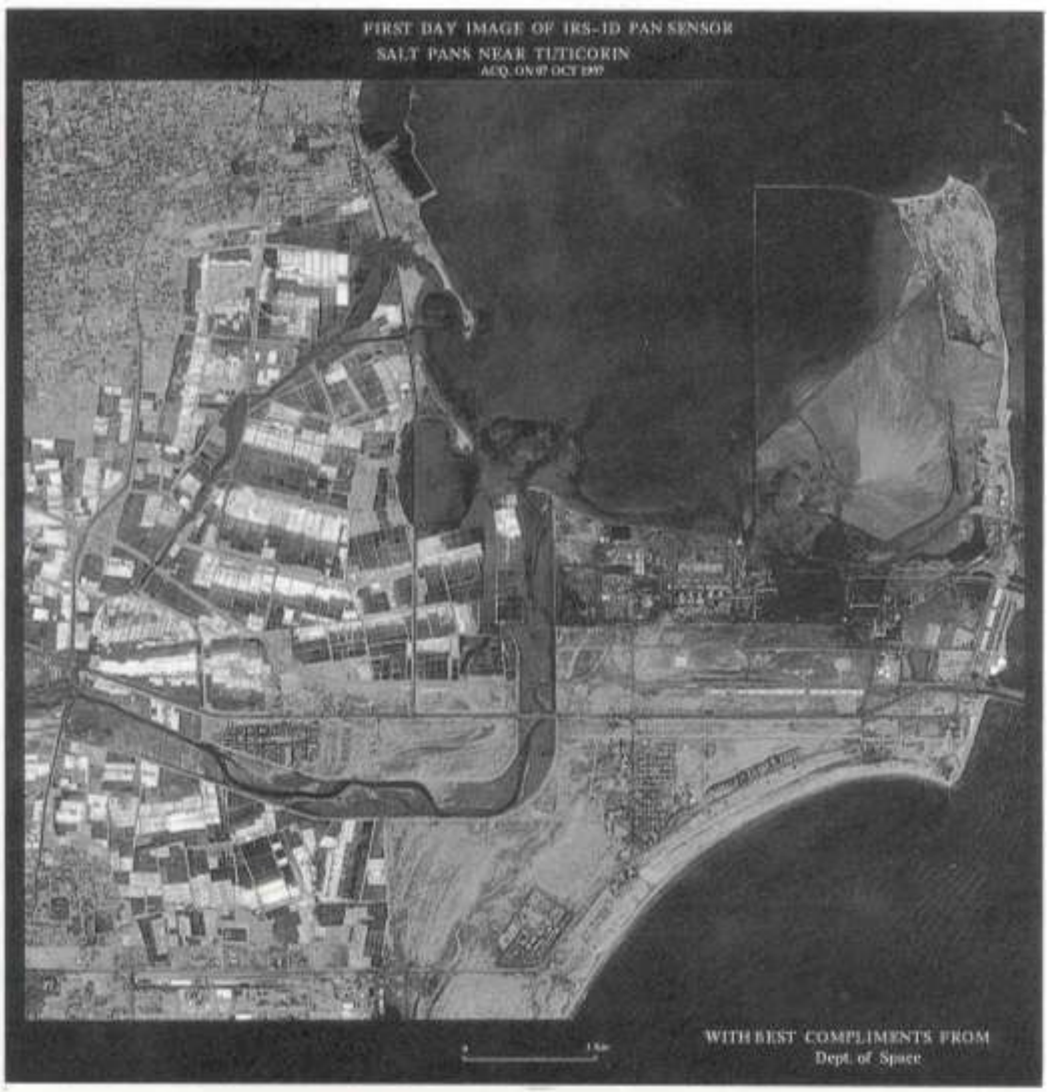


Figure 8.10 Ground Segment of IRS-1C



Picture taken by PAN camera of IRS-ID

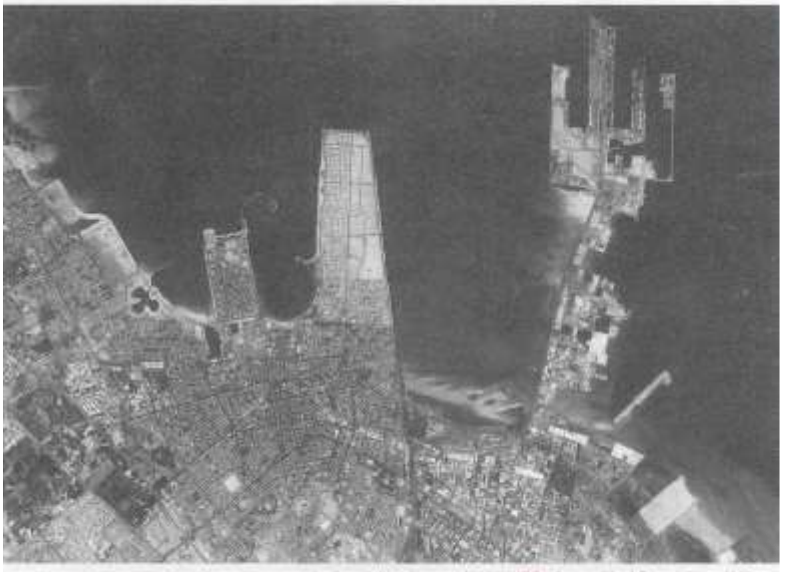
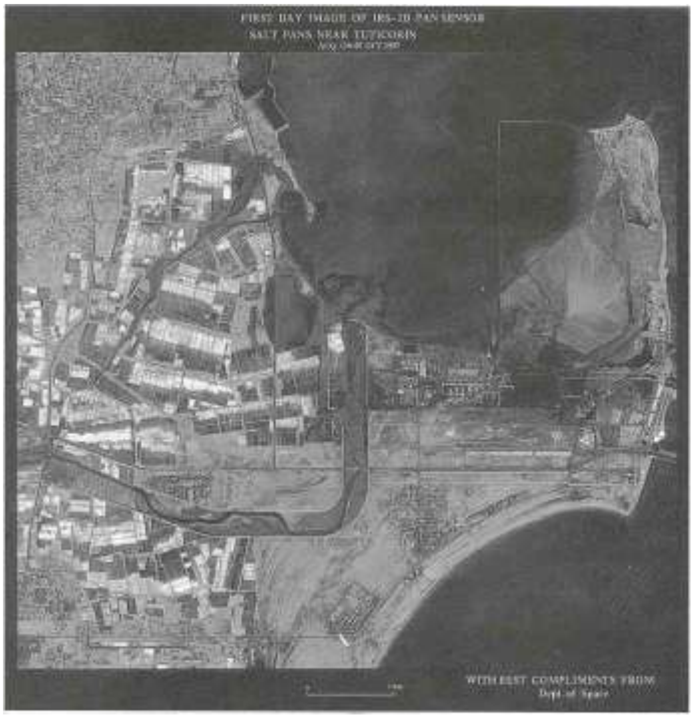
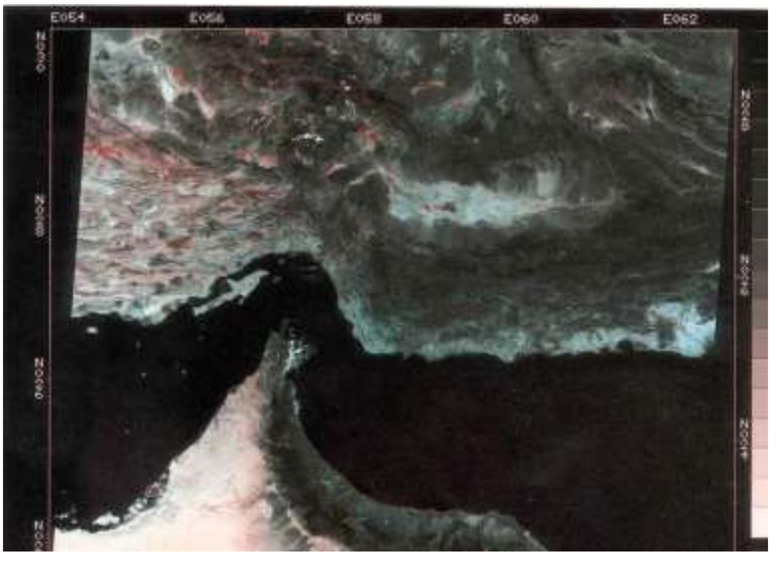


Fig 1. OBTR PAN image of Dhahran in Saudi Arabia, acquired by IRS-1D , on 22nd December , 1997


FIRST DAY IMAGE OF IRS-1D PAN SENSOR
SALT PANS NEAR TUTICORIN
WITH BEST COMPLIMENTS FROM
Dept of Space


E054
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9 IRS-P4 (OCEANSAT-1)

9.1 Introduction

The oceans occupying more than two-third surface area of Earth, have great influence on the global climate, affecting the economy and day-to-day life of people. As the measurement of the oceanic parameters by conventional methods using ships, buoys and other in-situ methods is difficult and expensive, remote sensing method which give frequent, accurate updates and economical is preferred .

IRS-P4 in the series of Indian Remote Sensing Satellites (IRS) was designed to serve the applications in the area of oceanography. Ocean Colour Monitor (OCM) and Multi-frequency Scanning Microwave Radiometer (MSMR) were the two payloads. The OCM operated in the visible and near infra-red bands and MSMR in Microwave bands. Both the payloads are configured to serve the application areas related to oceanography. Accordingly the satellite is called OCEANSAT-1.

These instruments were used to 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, identifying the potential fishing zones, coastal zone management, ship routing, operations of offshore oil rigs and water content in clouds.

The 720 Km altitude orbit was selected to achieve systematic coverage of the whole globe in two days considering the swaths of 1400 km. The satellite mainframe derives its heritage from the earlier IRS mission. The data from both the payloads were received and processed by National Remote Sensing Agency (NRSA) at Hyderabad.

9.2 Mission Objective

Mission objective of IRS-P4 are as follows

- *To gather data for oceanograpics, land (vegetation dynamics) and atmospheric applications.*
- *To develop new application areas, using IRS-P4 data as complimentary / supplimentary to the data from already operating remote sensing satellites.*
- *To provide opportunity for conducting technological / scientific experiments that are of relevance for future developments.*

9.3 Orbit Details

Table 9.1 Orbit details of IRS-P4

Parameters	Values
Orbit	Polar Sun-synchronous
Altitude (Km)	720
Inclination (Deg)	98.27°
Equatorial Crossing Time (ECT)	12.00 noon (descending node)
Orbital period (Min)	99.31
Distance between adjacent orbital traces (km)	1382
Distance between successive ground traces (km)	2764
Repetivity	2 days (29 orbits)

9.4 Salient features of Spacecraft

Table 9.2 Salient features of IRS-P4

Subsystem		IRS-P4
Structure		Aluminum / aluminum honey comb with CFRP elements for MSMR payload structures
Thermal	Thermal control	Passive/ semi active thermal control with paints, MLI blankets, OSR and close loop temperature control
	values	All electronics 0-40degC, Battery 0-10 degC, OCM 15$\pm$2 deg, MSMR 10-30 degC
Mechanism	Solar panel	Solar panel hold down and deployment mechanism Sun pointing through SADA
	OCM	Hold down and tilt mechanism
	MSMR	Payload antenna scanning mechanism
Power	Solar panel	9.636 m^2, 6 panels 1.1 x 1.46 m^2 (Each) BSR (SCA) 800 watts (EOL)
	Batteries	2 x 21 AH, 42V, 28 Ni-Cd Cells,

	Electronics	More efficient power electronics developed. Two raw buses (28-42V) supplying power to all subsystems. Modular type of DC-DC converters for payload and data handling
TTC	Telecommand	Modulation, Time tag command facility Conventional systems backed by micro processor based, both for main and redundant.
	Telemetry	ASIC based telemetry system. Storage capacity of 4 orbits, modulation
	Transponder	Uplink frequency , Downlink frequency
Data Handling		Data rate 2 X 10.4 MBPS Transmission frequency: X-band Modulation QPSK Recording facility: global data for MSMR and 10 minutes average data anywhere in the orbit for OCM
AOCS	Specification	Pointing accuracy: Pitch : $\pm 0.15^o$ Roll: $\pm 0.15^o$ Yaw: $\pm 0.20^o$ Drift rate: 3.6×10^{-4} ^{o}/s
	Sensors	Conical Earth sensor (2), Dual cone earth sensor(1), PYS (2), 4 pi sun sensors(4), Magnetometers(2), IRU
	Actuators	Magneto torquers(2), Reaction wheels(4), 1 N thrusters (8) and 11 N thruster (1)
	AOCE	1750 architecture based micro processor system for main and redundant
	Orbit	Orbital Accuracy 100-150 m (Autonomous mode using SPS)
Mass		1050 Kg

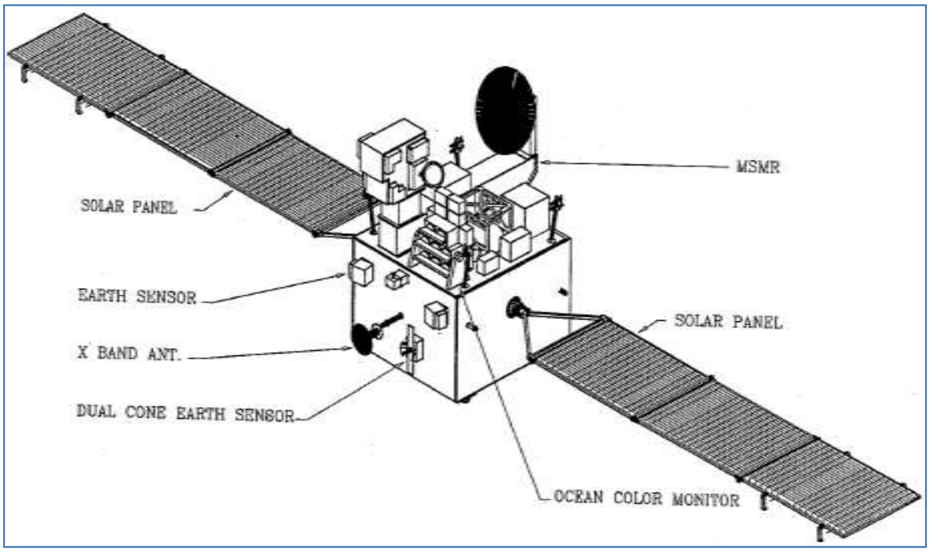


Figure 9.1 Deployed view of IRS-P4

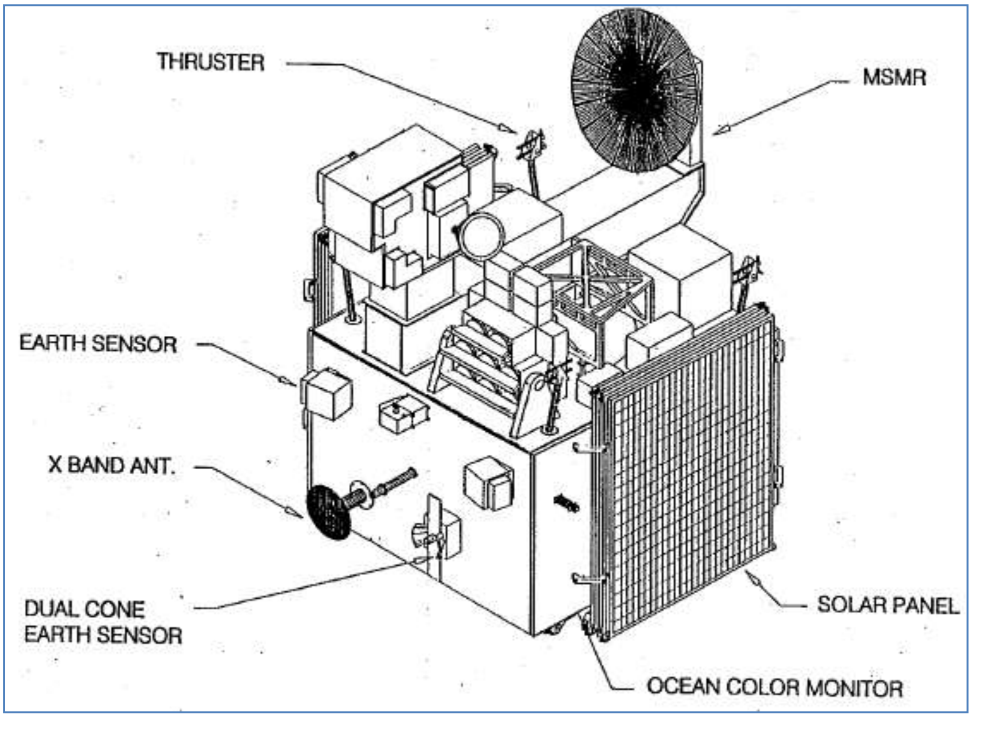


Figure 9.2 Stowed mode view of IRS-P4

9.5 Payloads

9.5.1 OCM payload

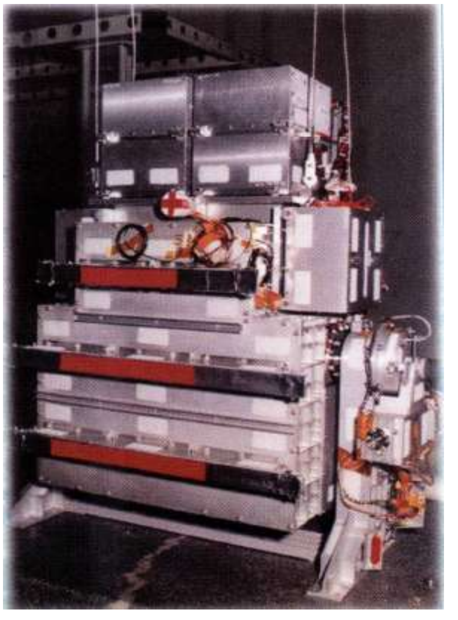


Figure 9.3 OCM Payload

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 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 of each band to the data handling system.

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. 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 by coarse spatial resolution, eight narrow spectral bands, high radiometric resolution, large field of view (± 43° providing a swath of 1420 km). Designing OCM for low ocean surface radiance and wide FOV were some of the challenges in its realization.

While only about 20% of the signal received by the OCM optics in the orbit comprises ocean radiance, 80% is the contribution from intervening atmosphere. Thus, to extract information on ocean colour, the contribution from atmosphere needs to be eliminated, and, therefore, accordingly correction is carried out by using data from band 7 and 8. Ocean radiance being low, 12 noon has been chosen as the time of equatorial crossing for descending pass to maximize the signal. This has an associated phenomenon of sun glint entering into the field of view of OCM, time of which is a function of season and latitude. To get over the problem of sun glint, a provision to tilt the OCM payload by ± 20° in steps has been provided. Its position can be fixed according to the latitude of observation and season. Tilt mechanism ensures a glint-free observation anywhere on the globe.

Table 9.3 OCM specifications

S.No	Parameters	Specifications	
1.	IGFOV	360m (across track) X 252m (along track)	
2.	Swath	>1420 Kms	
3.	Repetivity	2 days (29 orbits)	
4.	Quantisation	12 bit	
5.	Spectral range	402-885 nm	
6.	Spectral bandwidth	20 nm (B1-B6) 40 nm (B7, B8)	
7.	SNR @ saturation radiance	>512	
8.	Spectral bands (microns)	Spectral Bands B1: 402-422, B2: 433-453, B3: 480-500, B4: 500-520, B5: 545-565, B6: 660-680, B7: 745-785, and B8: 845-885	Saturation radiance B1: 35.5, B2: 28.5, B3: 22.8, B4: 25.7, B5:22.4 , B6: 18.1, B7: 9.0, B8: 17.2
9.	Integration time (ms)	34.75	
10.	Detector	CCD191A	
11.	Number of pixel	Total : 6000 Used: 3730	
12.	Video readout rate/port	86.6 KHz	
13.	Data rate / band	2.08 Mbits	
14.	Total data rate generated	16.64 Mbits	
15.	Camera MTF @ Nyquist frequency	>0.2	
16.	Size (mm) E-O module	701 (R) x 527 (P) x 420 (Y)	
17.	Weight(Kg)	EO module: 64 and camera: 78	

9.5.1.1 E.O Module

The EO module consists of Imaging lens assembly, EOM Structure, Detector head assembly, Detector electronics and payload tilt mechanism.

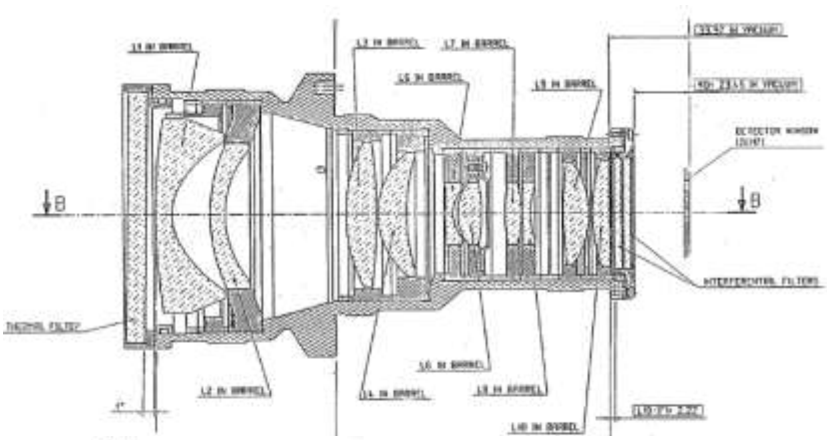
9.5.1.2 Optical system

It consists of eight spectral bands in visible and near infrared region having spectral bands between 0.4 um and 0.885 um with 20nm band width for bands B1 to B6 and 40 nm bandwidth for B7 & B8. Each band consists of its own collecting optical system and a linear array detector (CCD). The optical system consists of 10 refractive lens elements, a thermal filter in front and interference filter at back end close to the detector. The rear surface of the first lens is aspherical. A "telecentric" optical system is selected to provide minimum distortion, uniformity of illumination and good MTF over wide field angle which provides two days repetivity. The optical system is composed of a divergent component at the front end and a convergent group at the back end. This configuration gives longer back focal length than effective focal length and the main ray for each FOV goes out parallel to the optical view. The maximal angle of ray allowed to reach the focal plane is just 7 deg. This allows placing the band pass filter behind the optical system just in front of the CCD.

Table 9.4 OCM Optics specifications

S.NO	Parameters	values
1.	Equivalent focal length (EFL) (mm)	20.0+ 0.1
2.	F-number	4.3 for B1 & 62 4.5 for B3 to 68
3.	Field of View (degrees)	> + 43 (86 deg total)
4.	Clear working distance (mm)	>16
5.	Distortion	<+0.02%

Figure 9.4 OCM Lens assembly



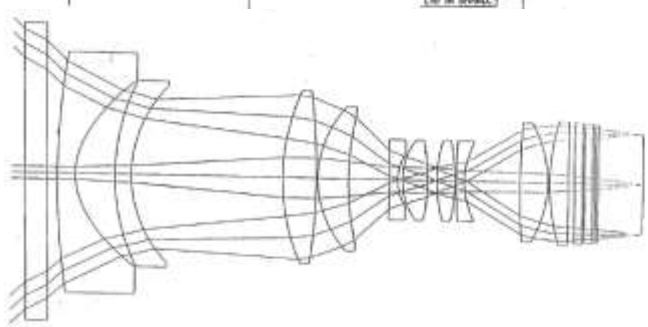


Figure 9.5 Optical Ray trace Diagram of OCM

9.5.1.3 EOM structure

The main structure of EO module is made out of single block of Al. Alloy 6061 material. This material is selected for its matching coefficient of thermal expansion, which helps in maintaining the separation between the lens focal plane and detector within ±2.0 micron over a temperature variation of 15± 2°C. Eight Detector Electronics boxes are mounted on a support structure of four DE mounting's which are mounted on the EOM main structure.

Four thermal covers fitted on the EOM will cover the EO module on +ve Yaw, -ve Yaw, +ve pitch and -ve pitch direction. Thermal cover is black painted on its inside surfaces and covered by thermal blanket outside. Auto-control heaters are mounted on the inside surface of thermal cover. Lens side and detector side thermal covers have one cut-out for viewing and wire harness. A common hood with a slit aperture is placed in front of each row of the lenses. These hoods limit the Field of View of the lenses to ± 45° along pitch axis and + 2° along the roll axis.

9.5.1.4 OCM Electronics

The OCM electronics is modular, takes into account the realizability and testability, satisfies the mission goal that no single point failure shall lead to non-availability of two or more bands data. It has separate electronics for each band without any redundancy. But cross coupling exists between camera electronics and BDH.

OCM Electronics consists of Detector Head, Detector Electronics

9.5.1.5 Detector Head

A 6000 element 7 x 10 um pixel size linear array CCD (CCD191A same as that used in IRS-1C/1D LISS-3 VNIR bands) is used as detector. This detector needs four bias voltages and nine clocks for its operations. The detector electrical interfaces, voltage levels are similar to IRS-1C except the readout speed. In IRS-1C to meet the high readout rate (866 KHz per port), two shift registers of the detector are read out simultaneously but in OCM phased readout mode of CCD operation is implemented like in CCD 143A of IRS-1A. This reduces 8 video processors.

Each lens assembly has different back focal length. Suitable spacers are used to place the Detector in focal plane. Considering the variation of the focal length with reference to temperature the most matching material is found to be Aluminium. However CCD is made out of ceramic which has very low Coefficient of Thermal Expansion (CTE). Hence Invar material is chosen for CCD Holder. Thermal stability among these two dissimilar materials will be achieved by using a dowel screw at one end and free screw at other end. In addition to these two LED holders are located on detector head. Each LED holder would accommodate two LEDs.

9.5.1.6 Detector Electronics

The detector electronics consists of bias generator and clock drivers located on the Electro Optic Module. The configuration of these circuits are similar to IRS-1C/1D except for additional drivers for reset clock and integration control, two phased readout and exposure control.

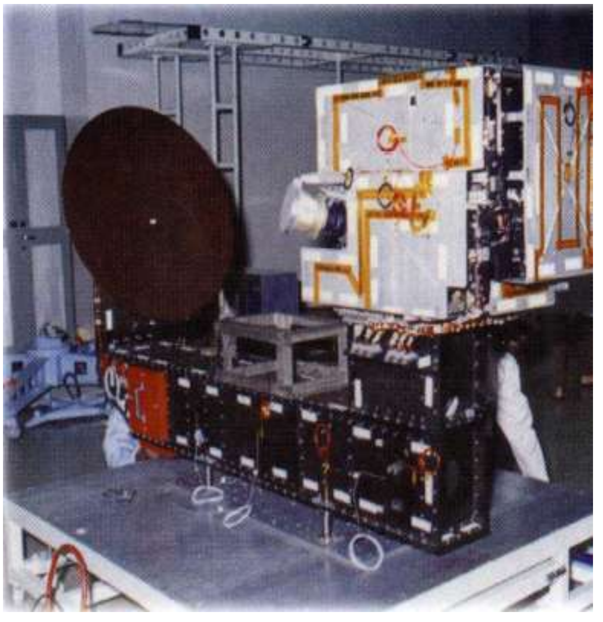
9.5.1.7 Calibration

Four LEDs of type HP 1 N6092 are mounted on the detector mount. Their optical axis is at 71deg from the normal due to the limited space between the detector and the imaging optics. In view of this large angle, the LEDs illuminate a larger photosensitive area compared to the imaging mode in the lateral direction of the detector array.

Table 9.5: Comparison of OCM and SeaWiFS Parameters

Parameters	OCM	SeaWiFS
Band 1	404-424 nm	402 – 422 nm
Band 2	432-452	433- 453
Band 3	479-499	480-500
Band 4	502-522	500-520
Band 5	547-567	545-565
Band 6	660-680	600-680
Band 7	748-788	745-785
Band 8	847-887	845-885
Quantization bits	12	10
Sensor type	Pushbroom linear array CCD	Whiskbroom scan mirrors
Orbit Type	Sun synchronous	Sun synchronous
Altitude	720 Km	705 Km
Equator Crossing	Noon +20 min, Descending	Noon +20 min, Descending
Tilt	Along track, +20,0,20	Along track +20, 0 -20
Swath	1420 Km	2801 Km
Spatial Resolution	0.36 Km along track 0.236 Km cross track	1.1 Km
Revisit	2 days	1 Day

9.5.2Multi-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.

MSMR has a 862 mm x 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 multi-frequency and multi-polarization 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.

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.

The MSMR is a dual polarised radiometer system and is designed to estimate and monitor geophysical parameters related to the land, the ocean and the atmosphere. The frequencies and polarisation for MSMR have been arrived at by considering the applications like atmospheric water vapour, Sea Surface Temperature (SST), over oceans, ocean surface winds, cloud liquid water, snow/ice coverage etc.

S.No	Specifications	Values
1	Swath	1360 Km
2	Repetivity	2 days (29 orbits)
3	Frequencies	6.6GHz(V&H) 10.65 GHz (V & H) 18GHz(V&H) 21 GHz(V&H)
	Temperature	Better than 1°K

MSMR consists of following systems

- Antenna
- Receiver
- Data acquisition and control system (DACS)
- Analog & Digital telemetry sub-systems(ADTMS)

9.5.2.1 MSMR antenna system

The MSMR is configured with a scanning antenna system which consists of an offset parabolic reflector with a 80 cm diameter collecting aperture and a multifrequency feed assembly. The antenna reflector is mechanically rotated with a constant angular velocity for scanning the antenna beam across the satellite trace in order to give the required swath of 1360 Km

MSMR antenna consists of following subsystems

- Offset parabolic reflector
- Multifrequency Dual Polarised Feed
  - Multifrequency Ortho mode Transducers
  - Calibration Horn for 6.6 & 10.65 GHz
  - Calibration Horn for 18 & 21 GHz
  - Support structure
  - Antenna Scan Mechanism (ASM)

Table 9.6: Specifications of MSMR Antenna

Frequency(GHz)	6.6	10.65 18	21	6.6
Bandwidth(MHz)	+ 112	+ 112 + 160	+ 170.5	+ 112
Beamwidth	42° ± 0.2°	2.6° ±0.15°	1.6° ± 0-1°	1.4° ± 0.1°
Polarisation	V&H	V&H	V&H	V'&H
Cross Pol.(dB)	< - 23	< -23	< -23	< - 23
Return loss(dB)	<-17	<-17	<-17	<-17
Beam efficiency	90%	90%	90%	90%
Scan offset angle	43.32°	4332°	43.32°	43.32°

9.5.2.2 Reflector

The offset parabolic reflector is of elliptical shape (862mm x 800 mm) and renders a projected diameter of 800 mm aperture. The offset reflector is having F/D=1.8 and an offset angle of 43.32°. This helps in achieving a clear field of view as well as 50° the Earth incidence angle of the beam. The reflector is having embedded copper mesh on the reflecting surface to enable the operation at 18 & 21 GHz of the system. The overall RMS variation of surface accuracy is 0.10 mm over the elliptical size of (8 62.0 X 862.8) the reflecting surface. The reflector is fabricated out of CFRP sandwich of aluminium-honey comb.

9.5.2.3 Feed

The feed consists of Horn and Ortho Mode Transducers (OMT). Corrugated horn has been used because of the pattern symmetry, low cross polarisation and low side lobe levels are achievable with this type of horn.

9.5.2.4 Support structure

In MSMR payload antenna, reflector and multifrequency feed are at a distance of 1667 mm apart. The phase centre of the feed being 337 mm from the aperture of the feed, the resulting seperation of 1330 mm between the reflector and the feed aperture plane has been considered in achieving overall 2029 mm length of CFRP support structure. The support structure supports the view of Scanning Mechanism (ASM) and the reflector at one side and the feed, front end electronic packages, two number of calibation horns which are interconnected with each other by plumbing waveguides and RF cables on the other side.

9.5.2.5 Antenna Scanning Mechanism

The spatial resolutin of MSMR is decided by the foot print of the antenna beam. Circular scan is adopted for the MSMR because it provides more integration tme and least torque requirement due to continuous constant angular rotation. In additon to this, due to non reversal of angular momentum, the scan mechanism will have minimal effect on the satellite attitude. The scan geometry of constant incident angle of 50 degrees makes the elliptical footprint with larger axis across the scan direction. The 3 dB foot print in scan direction is decided by the slant range and the antenna 3 dB beamwidth.

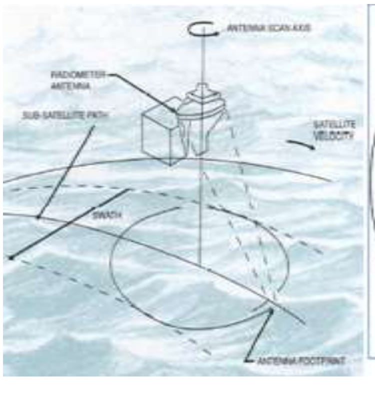


Figure 9.5 Scan Path illustration

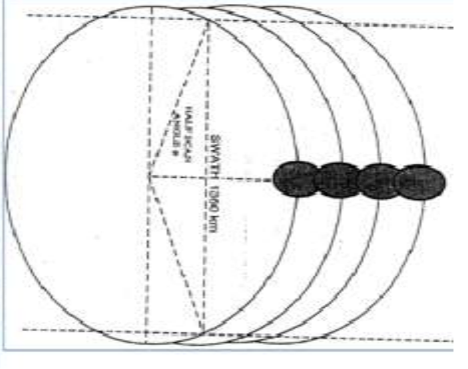


Figure 9.6 Swath generation by MSMR

Frequency (GHz)	Beam Foot Print (KM)		Cell dimention (After ground processing) KM^2
	Along Scan	Across scan	
6.6	77	119	120 X 120
10.65	47	73	80 X 80
18	30	46	40 X 40
21	25	39	40 X 40

The scan period is fixed in such a way that 10 % overlap is provided for the smallest footprint ie. 21 GHz channel. This corresponds to an angular scan speed of 11.173 RPM (5.37 seconds per rotation). The integration time corresponding to 11.173 RPM for various frequencies are listed below. The onboard integration time implemented corresponds to half that for 21 GHz channel which provides smallest foot print. The temperature sensitivity of MSMR depends upon receiver predetection bandwidth, Integration time, type of receiver, antenna and receiver temperature and gain measurement accuracy.

Table 9.7 Integration time

Frequency (GHz)	Integration Time(oveall in msec)	Integration time implemented (msec)
6.6	96	18
10.65	60	18
18	36	18
21	32	18

9.5.2.6 MSMR receiver

MSMR payload has six receiver chains, catering to 21 GHz-V pol, 21 GHz -H pol, 18 GHz- V pol, 18 GHz-H pol, 10.65 GHz and 6.6 Ghz bands. For 6.6 and 10.65 GHZ bands single receiver is used to collect both polarisations using a polarisation select switch at the input.

Table 9.8 Specifications of MSMR Receiver

Frequency (GHz)	6.6	10.65	18	21
No of channels	1(V/H)	1(V/H)	2(V/H)	2(V/H)
Predetection bandwith (MHz)	100	100	150	150
Noise Figure of receiver (dB)	4	4	4.5	4.5
Dicke clock	1 KHz			
Integration Time	18 msec			
Input dynamic range	2.7 degK-330 degK			
Output signal level	0-10V			
Sensitivity	~1degK			
Receiver stability	0.01db			

The function of radiometer is to measure the noise power incident at the antenna. In MSMR dicke type configuration is used for the receiver. In dicke type radiomater, a SPDT switch used to periodically switch the receiver input between the antenna and a constant noise sourse (Tref) at a switching rate higher than the highest significant spectral component in the gain variation spectrum.

9.5.2.7 Local Oscillators (LO)

While dielectric Resonators are used for 6.6 GHz and 10.65 MHz oscillators, Gunn diodes mounted in short circuited half guide wavelength cavity used for 18 GHz and 21 GHz oscillators. Schottky barrier diode is being used as the device for detection. The diode is biased and designed arround flat detector configuration to achieve the required banwidth.

9.5.2.8 Precision baseband processing subsystem (PBPS)

This lies between the RF front end and the quantiser of the DACS (Data Acquisition and control System), forming tail end of receiver. PBPS has to generate a DC signal demodulation, and converts it to a format suitable to the quantiser.

9.5.2.9 Data acquition and control subsystem

The Data Acquisition and Control Subsystem (DACS) is the tail end of the MSMR payload. DACS carries out data digitisation, timing sequence generation and control signal generation for the MSMR payload electronics. The on-board integration time selected is 18 msec. The MSMR data will be digitised in 12 bits/sample to achieve digitisation accuracy better than 0.1 deg K over the specified range of antenna temperature. 12 bit data of each radiometer channel is serialised at 8 KHz rate, multiplexed and transferred to on-board baseband data handling system (BDH). Alongwith serial data, an additional strobe at every 12th bit is also provided to spacecraft BDH.

The six channel MSMR sensor and calibration data are digitised with 12-bit resolution to achieve the required accuracy for specified range of antenna temperature. Uniform onboard integration and sampling intervals of 18 msecs amd 9 msecs have chosen for all the six channels to reduce overall MSMR hardware complexity. The table gives the polarisation switching sequence & sampling interval details for the different MSMR channels. The total data rate is about 5.6 Kbps.

Frequency	Polarization		Sampling Interval (msec)	
	Even cycle	Odd cycle		Even cycle
21.0 GHz	V	V	9	g
21.0 GHz	H	H	9	9
18.0GHz	V	V	9	9
18.0 GHz	H	H	9	9

Frequency	Polarization		Sampling Interval (msec)	
10.65 GHz	V	H	9	9
6.6 GHz	V	H	9	9

The MSMR Antenna Scan Mechanism (ASM) provides an anti-clockwise scanning of antenna footprint on ground. A scan Start pulse which corresponds to the angular position of - 90 Deg with reference to roll axis in each circular scan cycle, is provided by BDH to DACS. The first half cycle from the SCAN START in each scan cycle is utilised for sensor data collection and the remaining period is utilised for calibration sequence and collection of temperature information from Analog & Digital Telemetry Subsystem (ADTMS).DACS acquires the multichannel radiometer data and also generates the timing and control signals required for Precision Base Band Processing Subsystem (PBPS), ADTMS and data transfer to BDH.

The timing and sequence generator receives 8 kHz clock and SCAN START from BDH. All timing windows and clock signals required to acquire the sensor, calibration and data acquisition slot for ADTMS are generated with reference to the SCAN START.

S.No	Parameter	Specification
I	No. Channels	6
2	Analog Input	0 to 10
3	*AID* Resolution	12 bits
4	Sampling period	9 msec.
5	Total Cycle duration	5376 ms
6	Data words per cycle	2521
7	Data rate	~ 5.6 Kbps
8	Digitizer	± I LSB rms

The time sequencer generates various timing waveforms with reference to the Scan Start pulse signal from BDH. In addition to these it generates Dickie switching clock (1 KHz) and sampling clock (9 ms). All the timing windows are generated with 9 msec resolution and realised using a programmable synchronous counter chain.

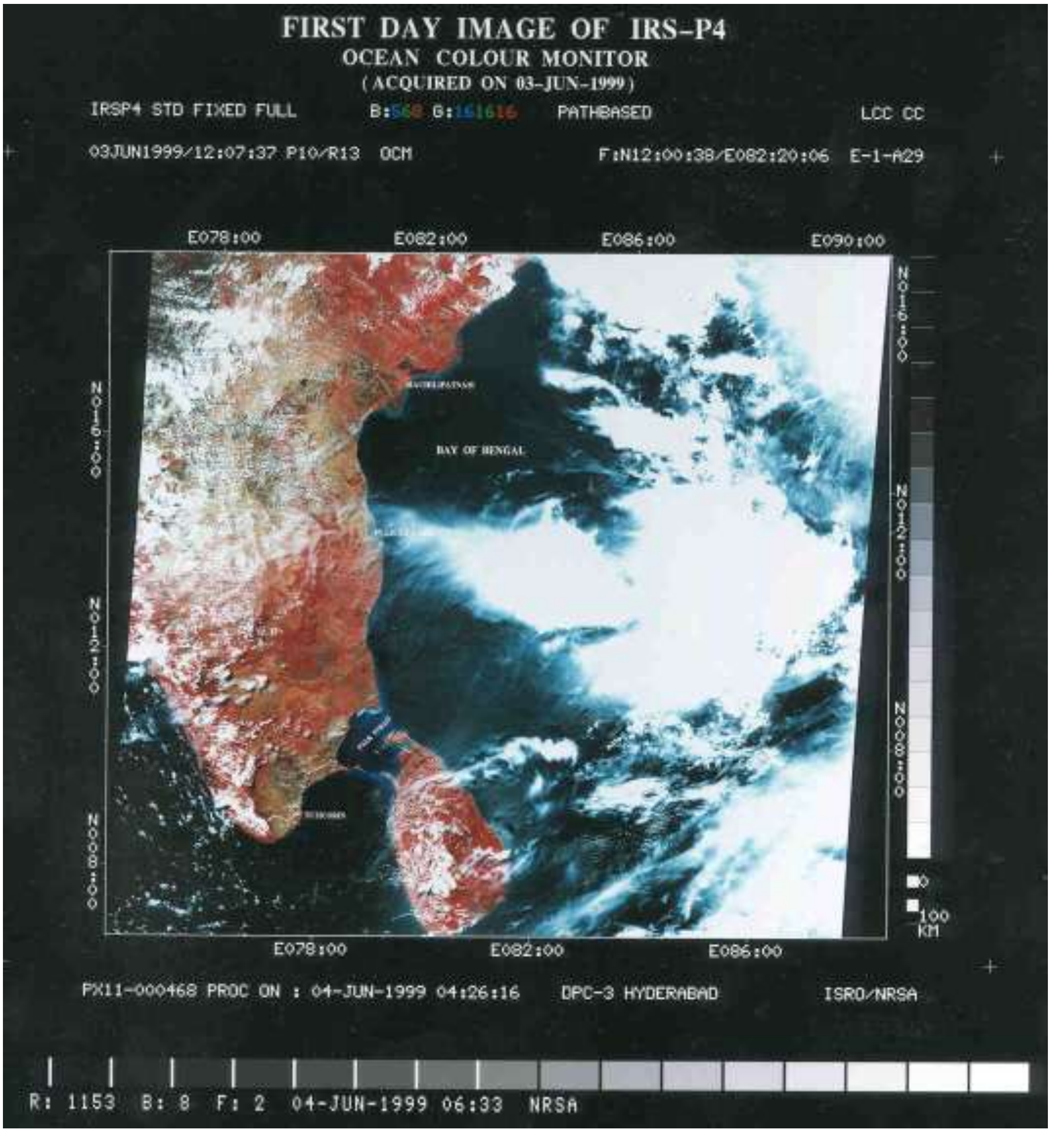
9.5.2.10 Analog & Digital telemetry subsystem (ADTMS)

The MSMR payload has several systems, the physical temperatures of which form the part of the system calibration data. The knowledge of the absolute temperatures of these is necessary in order to model/calibrate the system functionally. The analog & Digital Telemetry subsystem (ADTMS) of the MSMR payload is meant for this precision temperature monitoring application.

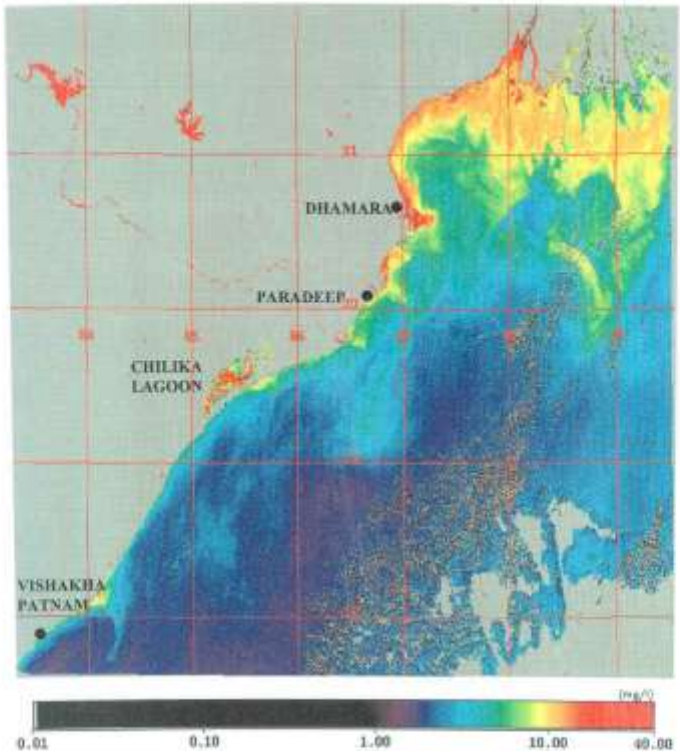
Temperature is monitored at 51 points to an accuracy of $\pm$ 0.1 deg. C. By using thermisters and platinum Resistance Devices. The voltages sensed are quantised using a 12 bit ADC. The total ADTMS data stream consists of 64 words of 12 bits each which are transferred to S/C data handling unit using a synchoronous serial transmission philosophy. This transfer is carried out in the time slot of MSMR pay!oad at the basic clock frequency of 8 KHz. The digital interfaces for ADTMS are the basic clock input. ADTMS acquisition slot. 9 ms sampling clock from DACS and data, strobe and gate lines to the S/C.

9.5.2.11 Calibration

In MSMR two point internal calibration approach has been utilised by using dedicated horn antennas viewing the cold space (2.7 deg K) and a black body at a high temperature will be used for the hot reference. As the circular conical scan method is used in MSMR, the fore half period is utilised for data collection whereas the aft half period be utilised for cold and hot calibration sequences. During the aft half cycle, two sets of internal calibration are envisaged just before and after data collection cycle.


FIRST DAY IMAGE OF IRS-P4
OCEAN COLOUR MONITOR
(ACQUIRED ON 03-JUN-1999)
IRSP4 STD FIXED FULL
PATHBASED
LCC CC
03JUN1999/12:07:37 P10/R13 OCM
F:N12:00:38/E082:20:06 E-1-A29
E078:00
E082:00
E086:00
E090:00
BAY OF BENGAL
E078:00
E082:00
E086:00
100 KM
PX11-000468 PROC ON : 04-JUN-1999 04:26:16
DPC-3 HYDERABAD
ISRO/NRSA
R: 1153 B: 8 F: 2 04-JUN-1999 06:33 NRSA

PRE-CYCLONE IRS-P4 OCM DERIVED IMAGE OF SUSPENDED SEDIMENTS CONCENTRATION AROUND ORISSA COAST



DATE
OCTOB

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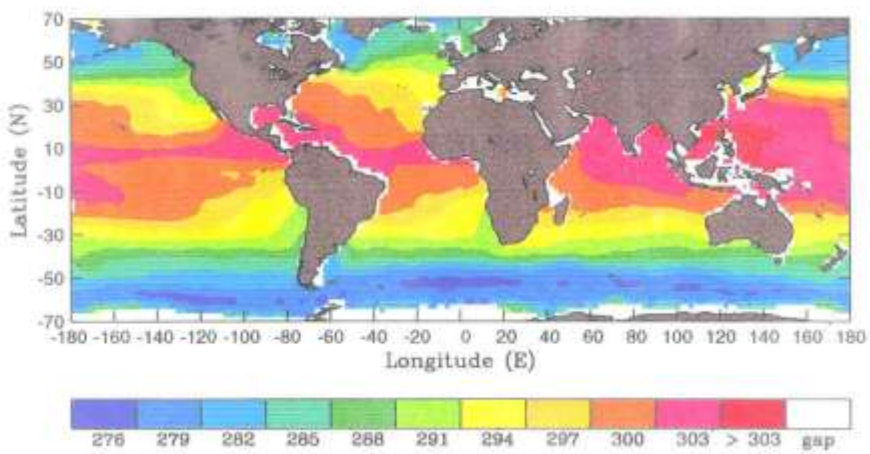
Monthly Average (15 June – 11 July 1999)
Sea Surface Temperature (K). From MSMR



10 TECHNOLOGY EXPERIMENT SATELLITE (TES)

10.1 Introduction

The TES (Technology Experimental Satellite) is the first high resolution (<1 m) satellite launched by ISRO. It was launched to demonstrate more than eleven new technologies developed by various design groups across the centres

Critical technologies tested in the TES are given below

- Attitude and orbit control system (AOCS) for step and stare imageries in desired direction.
- Two mirror on-axis optics (RC Type) for payload (providing <1m nadir resolution at 560 kms altitude)
- X-band phased array antenna (PAA) with two beam generation capability for payload data transmission
- Single surface tension propellant tank of large capacity RCS tank
- High torque reaction wheels : 0.1 NM and 10 NMS
- standardized PW, TM, TC system
- Tetrahedral wheel configuration which provides 0.23 NM torque and 23 Nm sec. angular momentum capacities about each axis.
- Improved satellite positioning system
- Two Advanced solid state recorder with 32 Gb each for storage of 6 mins of payload data
- Data security by encryption technique (encryption by stream ciphering scheme inclusion/exclusion option and key changing provision.
- Honeycomb type central cylinder.

10.2 Mission Objective

The mission objectives of TES are

To design and develop a technology experimental satellite incorporating a set of critical technologies to provide on-orbit demonstration and validation of these technologies for future enhanced capability missions, and also to provide hands on experience in complex mission operations like step and stare maneuvers and onboard earth rotation compensation etc.

10.3 Orbital parameters

Parameter	Normal Orbit	Special orbit 1	Special orbit 2
Altitude (Km)	560	410	501
Repeat Cycle(Days)	1	2	5

Parameter	Normal Orbit	Special orbit 1	Special orbit 2
No. of orbits per cycle	15	31	91
Inclination (Deg)	97.65	97.08	97.45
Ground trace Velocity (Km/s)	6.97	7.2	7.04
Decay rate (m/day)	61 to 27	410 to 232	125 to 61
Orbital Time (min)	96	92.9	94.73
Local Time (descending) AM	10.30	10.30	10.30

10.4 Salient Features of Spacecraft

Subsystem		TES
Structure		Aluminum / Aluminum honey comb elements, Cuboid main frame similar to IRS-P4
Thermal	Thermal control	Passive/ semi active thermal control with paints, MLI blankets, OSR and close loop temperature control
	Thermal Limits	All electronics 0-40deg C, Battery 0-10 deg C, PAN : 20±3 deg C
Mechanism	Solar panel	Solar panel hold down and deployment mechanism similar to 1A/1B Sun pointing through SADA
Power	Solar panel	Rigid ,Sun tracking, 9.636 m^2, 6 panels 1.1 x 1.46 m^2 ,(Each), BSR (SCA) , 800 watts (EOL)
	Batteries	2 batteries, 28-42V, 28 Cells, Ni-Cd, 21 AH
	Electronics	More efficient power electronics developed. Two raw buses (28-42V) supplying power to all subsystems. Modular type of DC-DC converters for payload and data handling
TTC	Telecommand	Conventional systems backed by micro processor based, time tagged and payload sequencer both for main and redundant.
	Telemetry	ASIC based telemetry system.
	Transponder	Uplink frequency Downlink frequency S-band
Data Handling		Data rate :2 X 42.4515 Mbps Transmission frequency X-band Modulation : QPSK

		Recording facility: 2 x 32 GB (SSR)
AOCS	Specification	Pointing accuracy Pitch : ±0.15° Roll: ±0.15° Yaw: ±0.20° Drift rate: 3 X 10^{-4} °/s
	Sensors	Earth sensor (2+1), PYS (1), 4 pi sun sensors(4), Magnetometers(2), IRU
	Actuators	Magneto torquers(2), Reaction wheels(4), 1 N thrusters (8) and 11 N thruster (1)
	AOCE	1750 architecture based micro processor system for main and redundant

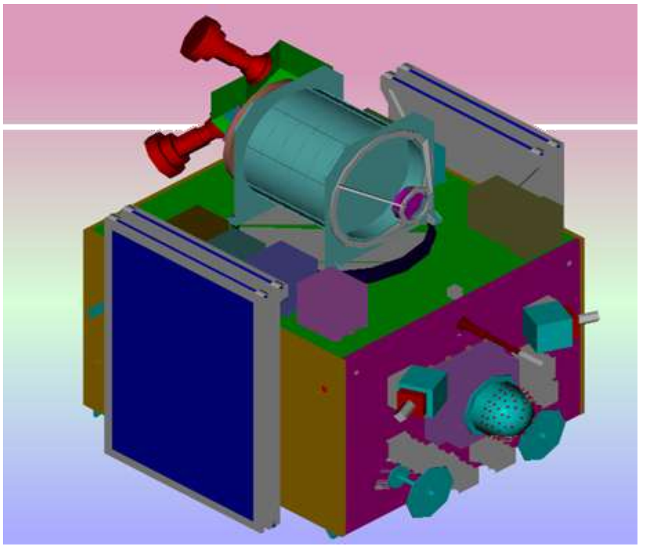


Figure 10.1 Stowed View of TES S/C

10.5 Payload

10.5.1 Panchromatic Camera

The Technology Experiment Satellite (TES) carries one PANchromatic camera called PAN-TES. This camera works on the ‘push-broom scanning’ concept using linear array Charge Coupled Devices (CCD) as sensors. Four 4K, 7um x 7um are used to cover a swath of about 13.5 km at Nadir. In this mode of operation, each line of the image is electronically scanned and contiguous lines are imaged by the forward motion of the satellite. The improved along track resolution is achieved by step and stare method.

The PAN-TES camera is a high resolution camera with a Instantaneous Geometrical Field of View (IGFOV) of better than 3 meters. Totally this camera covers a swath of better than 13.5 Kms. The satellite is agile and can be rotated to +/-

45 deg w.r.t pitch axis and +/- 26 deg w.r.t roll axis. The focal length of 3920 mm provides an across track IGFOV of better than 3 meter at nadir view from 560 km altitude. The pitch bias and rate enable the camera to provide better than 3 meter along track resolution. The capability of having maximum +/- 26 deg. bias w.r.t roll axis provide 5 days revisit of the same location as well as stereo viewing capability in across the track direction.

10.5.1.1 System configuration

The PAN-TES camera had three elements. They are

- Electro-optics module (EOM)
- Payload electronics
  - Detector electronics
  - Payload electronics packages
- Payload power supply
  - Payload power converters
  - Payload power regulators

Electro-optics module (EOM)

PAN-TES camera is a single band camera covering the spectral range from 0.5 to 0.85 microns wavelength. The EOM contains

- Imaging Optics
- Detector Head assembly
- Detector electronics

The imaging optics is a Ritchy-chretian (RC) type reflective system with three field correction lens covering a FOV of $\pm$0.85 deg. The optical system has a F/no of 7 and effective focal length of 3920 mm. The two mirror system is chosen because of its compactness. The use of hyperboloids for both mirrors allows simultaneous correction of third order spherical aberration and third order coma. The lenses extend the FOV of the telescope by reducing the Field aberrations and give a flat image. The optical design of the telescope features an on-axis concave hyperboloidal primary mirror and a convex hyperboloidal secondary mirror and three spherical field correcting lens elements(for extending the FOV of telescope) The lenses are housed in a barrel with an appropriate flange and are refereed as lens assembly. Bothe primary and secondary mirrors are coated with enhanced aluminum coating, To avoid the oxidization of aluminum a protective layer of MgF_2 coated on the aluminum coating

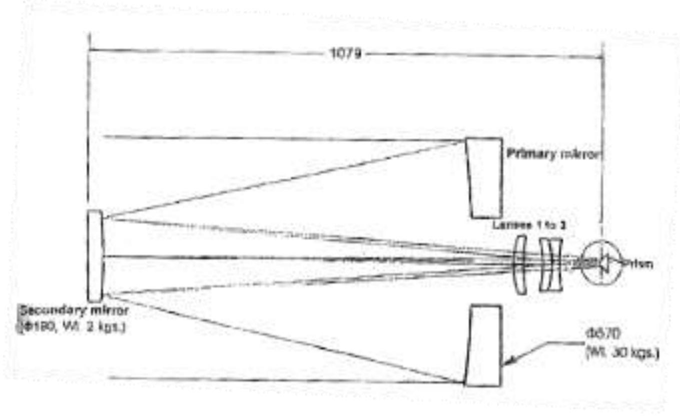


Figure 10.2 Optical Schematic of TES PAN Payload

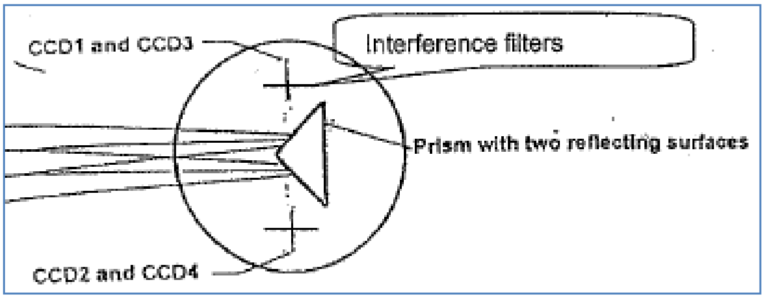


Figure 10.3 Multiple focal plane generation

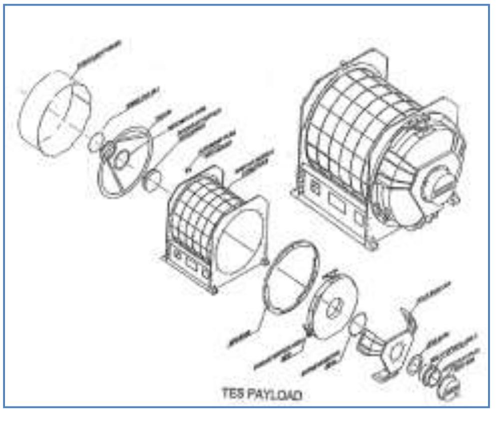


Figure 10.4Exploded View of TES Payload

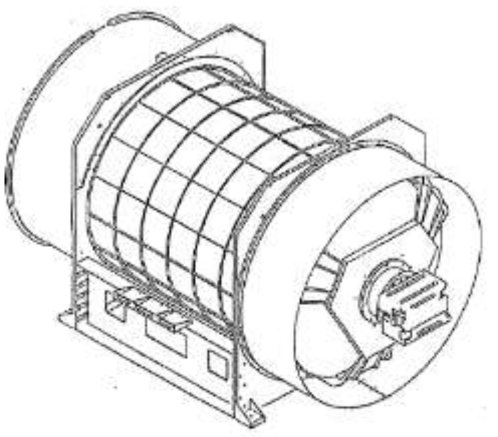


Figure 10.5 TES PAN camera and Detector Head

The Optical elements specifications are as given below.

10.5.1.2 PAN TES Specification

OPTICS

Type	: RC Type

Primary mirror

Material	: Zerodur
Diameter (mm)	: 570 mm (Usable (560 mm)
Center thickness (mm)	: 65
Weight (kg)	: 30
Aspect ratio	: 1: 10
Obscuration	: 11.5 %
Opening radius at the center(mm)	: 190

Secondary mirror

Material	: Zerodur
Radius of curvature Ro	: 905 +/- 2 mm
Conic Constant	: -5.057
Surface figure	: lambda/10(rms(lambda/67)
Center thickness (mm)	: 35
Diameter (mm)	: 190
Weight (kg)	: 2

Field corrector

No. Lenses	: 3
Max. lens diameter	: 128 mm
Focal length	: 1310 mm
Housing material	: titanium

Optical system specification

Effective focal length (EFL)	: 3920 mm
Spectral Band (micron)	: 0.5 – 0.85
F-Number	: F/7
Field of View	: ± 0.85 deg.
Optical system length	: 1068 mm
Diffraction limited MTF	: 0.42
Design MTF	: 0.39
Achieved optical system MTF (Optics level)	: 32

The four numbers of 4k CCD with 7 x 7 micron size pixels were used to cover a swath of greater than 11 kilometers. The rays come out from the secondary are spilt by a isosceles prism and two image planes are created. To mount four devices a specific assembly was designed and detector 1 & 3 are mounted on one side and 2 & 4 were mounted on another side of the detector head. The CCDs are mounted on PCBs which in turn are supported by a carrier plates. Detector 1 & 3 view along nadir where as detectors 2 & 4 are shifted in the image plane in the along track direction. The actual along track distance between these two planes was 22.533 mm. Each detector had separate interference filter and LED Panels (consisting of four LEDs, two for optical bias and two for calibration mode operation). The earth rotation effects on the swath are taken care by adjusting the location of CCDs. Detector parameters are given below.

Detector

Type	: Charge Coupled Devices
Detector material	: Silicon
Spectral response	: 0.4 um to 0.85 um
No. of pixels	: 4096/CCD (TH7833)
Pixel arrangement	: inline
No. Output ports	: 4/CCD
No. of CCD devices	: 4

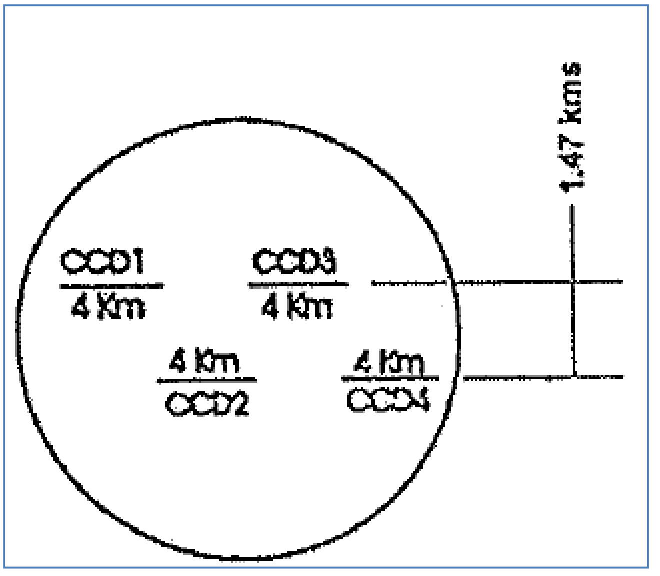


Figure 10.6: illustration of CCD projection on Ground

Payload electronics

Payload electronics is similar to IRS-1D payload electronics with four chains. The payload electronics consists of

1. Detector electronics
2. Payload electronics

10.5.1.3 Detector electronics (DE)

Each DE package consists of four preamplifiers, bias voltage generators, clock drive optical bias LED drivers. Detector driver electronics supplies bias voltages and clocks required for CCDs. The two LEDs required for Optical Bias of CCDs are driven in series with a constant current drive. Designed around LM 723 regulator. The power supply lines to the DE are filtered Using Line filters before being fed to the circuits. The charge collected by the detector pixels are read simultaneously from all four ports and converted to voltages. This signal is amplified by the DE and pre-amplified signals from DE are provided to the Payload electronics (PLE) package.

10.5.1.4 Payload electronics

The signals from the DE are amplified in the programmable gain amplifier. The three levels pulse amplitude modulated (PAM) signals of 1.2 MHz is pre-amplified in DE and is further processed in PLE. A constant DC bias is subtracted from total signal to subtract the optical bias in the summing amplifier. There are four Gain settings for the amplifier for each Band which are selectable through ON/OFF commands. The amplified signal is DC restored and digitized. The seven bit parallel data with hot redundancy is available at PLE output on separate buffers for BDH main and BDH redt.

The timing logic receives the Line start pulse(WLS repetition Rate: 0.8836 ms, pulse width 1.48 microseconds) and Bit Rate Clock (BRC) of 28.301 MHz with 50% duty cycle from baseband data handling system and generates the required clock wave forms to read out the data from CCDs The input clocks from BDH main and redt,. are cross coupled with logic main and redt. and also the output signals of timing logic are cross coupled and given to BDH.

On-board calibration scheme

In calibration mode the detectors were directly illuminated by the two LEDs which were mounted at an angle of 15 deg. to the optical axis. Calibration mode operations were done during night passes. Provision to operate the individual CCDs or all CCDs together in Cal Mode was provided.

System Specifications

IGFOV (m)	: < 3meters
Swath kms	: better than 13 kms
Integration time (msec)	: 0.883
Quantization level	: 128 (7 bits)
Number of gains	: 4
Signal to noise ratio	: > 128 (at saturation)

Step and Stare method

A new imaging method called Step and Stare method implemented first time in this mission. In this method the ground trace is slowed down by changing the look angle continuously and the along track resolution is improved..

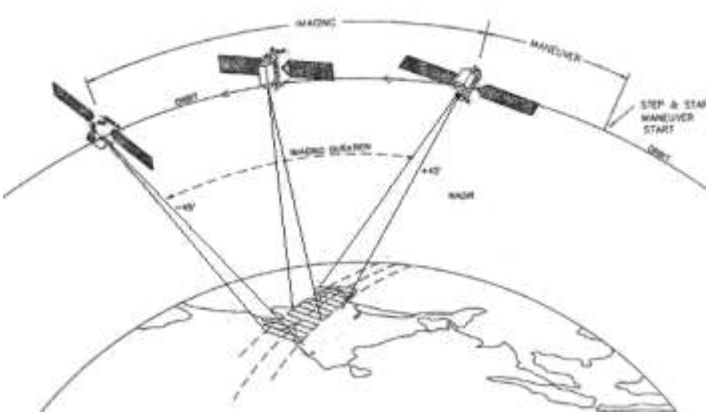


Figure 10.7 Step and Stare method of TES

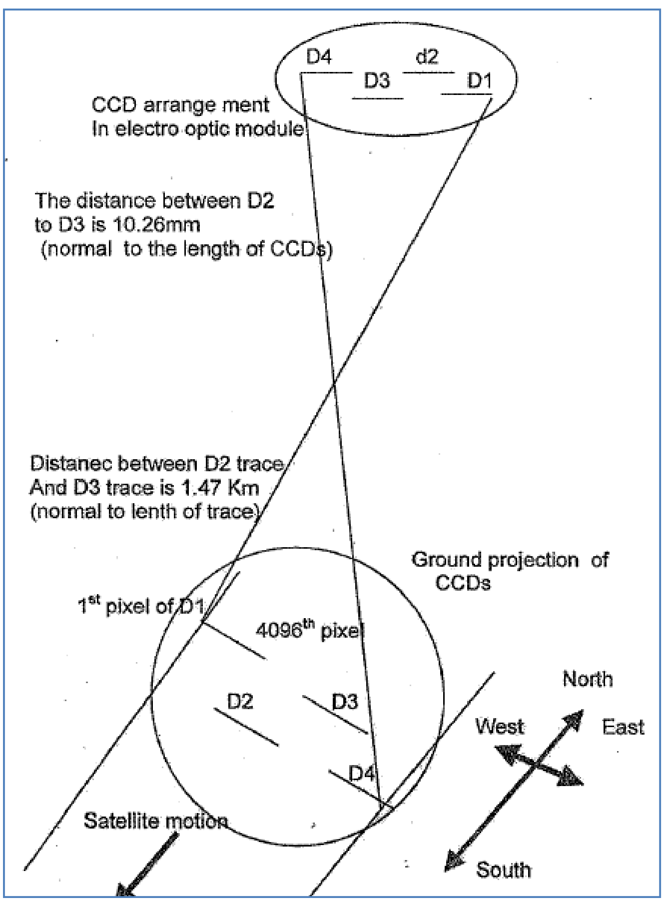
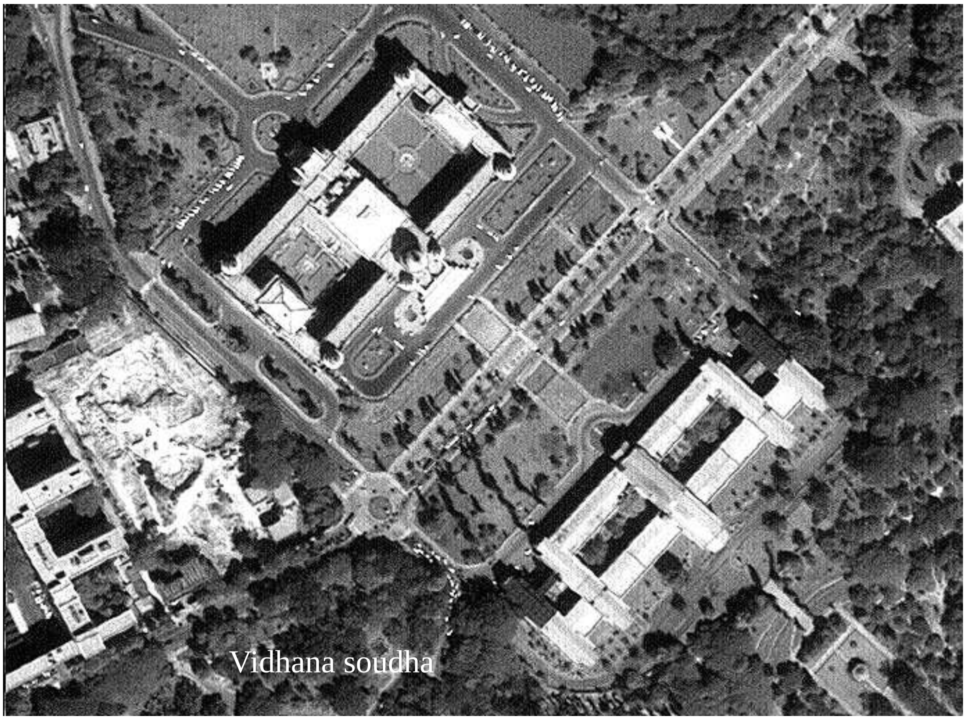
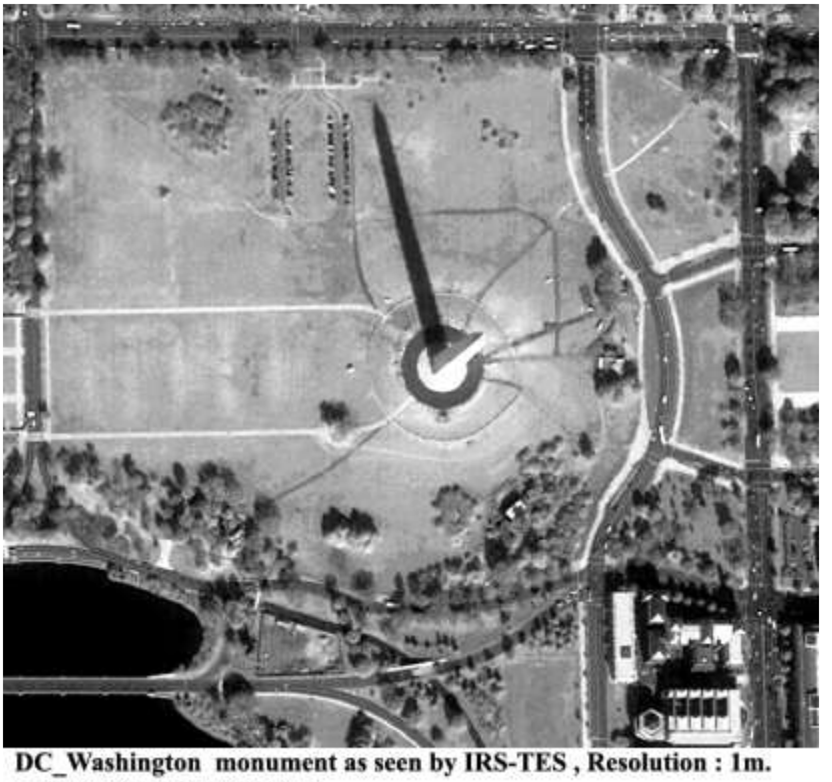


Figure 10.8: Ground Projection of Detector


Vidhana soudha


Majastic Bus Station



DC_Washington monument as seen by IRS-TES , Resolution : 1m. Date of pass : 30-OCT-2001

11 IRS-P6 (RESOURCESAT-1)

11.1 Introduction

IRS-P6 is the continuation of IRS-1C/1D missions with enhanced capabilities. Panchromatic camera of IRS-1C/1D is improved to Multispectral by using three 12 K detectors. The spatial resolution of AWIFS is improved to 56 m from ~188m.

11.2 Mission Objective

Mission objectives of the IRS-P6 are as given below

- *To provide continued Remote Sensing data services on an operational basis for integrated land and water resources management at micro level with enhanced multi spectral/ spatial coverage and stereo imaging*
- *To further carry out studies in advanced areas of User applications like improved crop discrimination, crop yield, crop stress, pest/disease surveillance, disaster management etc.*

11.3 Orbit Details

The IRS-P6 is with payloads similar to the IRS-1C/1D. Choice of the orbit is same as that of IRS-1C i.e Sun synchronous orbit at an altitude of 817 Kms

Table 11.1 Orbit details of IRS-P6

Sl.No	Parameter	IRS-P6
1	Orbit	Polar sun synchronous circular
2	Altitude	817 Km
3	Inclination	98.69 deg
4	Eccentricity	0.0004
5	Period	101.35 minutes
6	Local Time	10.30 A.M
7	Repetivity Cycle	24 Days (For LISS-3) 5 Days (for AWiFS) 5 Days (for LISS-4 revisit)
8	Distance between adjacent Traces	117.5 Km
9	Minimum Picture Overlap for LISS-3	22.5 Km
10	Off Nadir coverage +/- 26 deg (for PAN)	398 Km
11	Distance between successive Ground tracks	2820 Km

Sl.No	Parameter	IRS-P6
12	Ground Trace velocity	6.65 Km/s
13	Liss-4 Coverage with steering of $\pm$ 26 Deg	$\pm$ 398 Km

11.4 Salient features of IRS-P6

The S/C mainframe is of IRS-1C/1D -P3 heritage. The S/C structure consists of two modules, the main platform and the payload module. The main platform is built around a central load bearing cylinder of 915 mm diameter and consists of four vertical panels and two horizontal decks. The bottom of cylinder is attached to an interface ring which interfaces with the launch vehicle. The vertical panels and the horizontal decks carry various subsystem packages. Various attitude sensors, SPS (Satellite Positioning System) and data transmitting antennas are mounted on the outside surfaces of the equipment panels and the bottom deck. Two star trackers are mounted with skewed orientation on the top deck. The payload module in turn is comprised of a two-tier system, the payload module deck and the rotating deck. The payload module deck accommodates LISS-3, AWIFS-A and AWIFS-B camera modules.

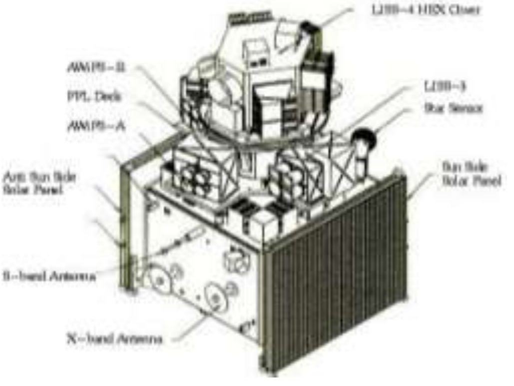


Table 11.2 Salient features of IRS-P6

Subsystem		IRS-P6
Structure		Shear webs added to increase the frequency to cater to PSLV launch. CFRP cylinder (370 mm height 930 mm dia) for thermal isolation of payload deck incorporated.
Thermal	Control	Temperature control is with passive techniques using Paints, multilayer blankets, Optical solar Reflector, and active thermal elements like heaters also. Heat pipe radiator panel is used to maintain the temperature of LISS-4 detector head assembly.
	Limits	All electronics packages 0-40ºC, Battery 0-10ºC, Payload EO modules : 17 to 23ºC
Mechanism	Solar Panel	Solar panel deployment mechanism and Drive Mechanism
	LISS-4	Deployment and steering mechanism for the LISS-4 Payload to cover +/- 26 deg. w.r.t. roll .
Power	Solar Panel	Sun tracking, rigid,15.12 M^2 6 panels 1.4 x 1.8 m^2 (Each), 1250 W at EOL, BSR(SCA)
	Battery	2 batteries, 28 to 42V, 28 Cells, Ni-Cd 24 AH
	Power Electronics	PWM TCR, FCL, 10 Strings
TTC	Telemetry	1024 words/frame, , storage: 6.29 x 10^6 Bits PCM/PSK/PM, 16 Kbps
	Telecommand	PCM/FSK/FM/PM,.
Data Handling		The payload data are transmitted in X-band at a data rate of 105 Mbit/s. The BDH (Baseband Data Handling) system consists of two separate chains, one for LISS-3 and AWiFS data, and the second chain for LISS-4 data. The LISS-4 data

Subsystem		IRS-P6
		are transmitted on carrier-1 and LISS-3 + AWiFS data are transmitted on carrier-2
Data Transmission		40 watts TWTA used. 105 MBPS data Handling system
AOCS	Spec.	Pointing Accuracies: Yaw: ± 0.05° Roll: ± 0.05° Pitch: ± 0.05° (3 sigma) Drift rate : 5 x 10^{-4} deg/sec (3 sigma)
	Sensors	Earth sensor(1), DSS(2), Star Sensors(2), 4Pi SS(4), Magnetometer (2) IRU(3 DTG), SPS(2)
	Actuators	Reaction Wheels, 5 NMS(4 in tetrahedral), Magnetic Torquers (2) , 1N Thrusters(8) 11 N Thruster(4) Fuel (100 Kg)
SADA		Improved SADA used to increase the torque margin
AOCE		Hardwired system as a back up only for micro processor based linear controller. Improved KF used
Payloads		LISS-III, PAN and AWiFS
Mass		1360 Kg

11.5 Payload

Resourcesat-1 carries three payloads. They are

- A high resolution linear imaging self-scanner (LISS-IV)
- A medium resolution linear imaging self-scanner (LISS-III)
- AWiFS (Advanced Wide Field Sensor).

11.5.1 LISS-4 (Linear Imaging Self-Scanning Sensor-4)

The LISS-4 multispectral high-resolution camera is the prime instrument. LISS-4 is a three-band pushbroom camera of LISS-3 heritage (same spectral VNIR bands as LISS-3) with a spatial resolution of 5.8 m and a swath of 70 km. LISS-4 can be operated in either of two support modes:

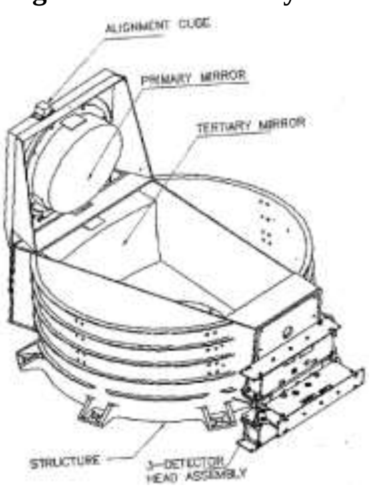
Multispectral (MS) mode: Data is collected in 3 bands corresponding to pre-selected 4096 contiguous pixels with a swath width of 23.9 km (selectable out of 70 km total swath). The 4 k detector strip can be selected anywhere within the 12 k pixels by commanding the start pixel number using the electronic scanning scheme.

Mono mode: Data of the full 12 k pixels of any one single selected band, corresponding to a swath of 70 km, can be transmitted. Nominally, band-3 data (B3) are being observed and transmitted in this mode.

LISS-4 has ±26º steering capability in the cross-track direction which provides a 5-day revisit cycle. The optoelectronic module of LISS-4 is identical to that of the PAN camera of IRS-1C/1D. The CCD array features 12,288 elements for each band. The instrument has a mass of 169.5 kg, power of 216 W, and a data rate of 105 Mbit/s. The detector temperature control is implemented using a radiator plate coupled to each band CCD through heat pipes and copper braid strips.

The LISS-4 camera is realized using the three mirror reflective telescope optics (same as that of the PAN camera of IRS-1C/1D) and 12,288 pixels linear array CCDs with each pixel of the size 7 µm x 7 µm. Three such CCDs are placed in the focal plane of the telescope along with their individual spectral bandpass filters. An optical arrangement comprising an isosceles prism is employed to split the beam into three imaging fields which are separated in along track direction. The projection of this separation on ground translates into a distance of 14.2 km between the B2 and B4 image lines. While B3 is looking at nadir, B2 is looking ahead and B4 is looking behind in the direction of velocity vector. Detector type: THX31543A of Thomson.

Figure 11.1 LISS-4 Payload



Schematic

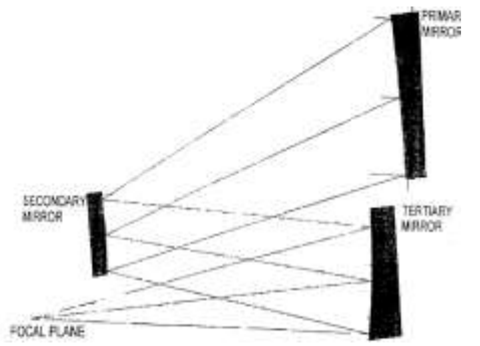


Figure 11.2 Optical Schematic of LISS-4

LISS-4 calibration: An in-flight calibration scheme is implemented using LEDs (Light Emitting Diodes). Eight LEDs positioned in front of the CCD (without obstructing the light path during imaging). These LEDs are driven with a constant current and the integration time is varied to get 16 exposure levels, covering the dynamic range in a sequential manner. This sequence repeats in a cyclic form.

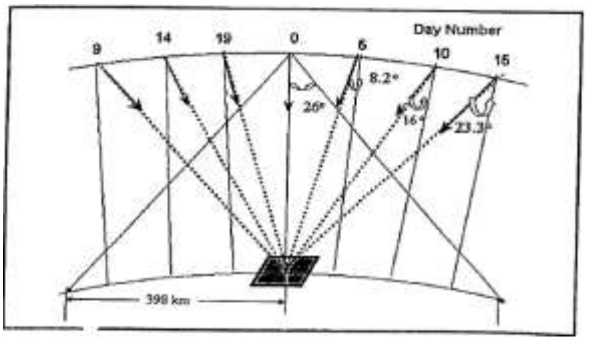


Figure 11.3 Possible Image coverage due to Steering of LISS-3

11.5.2 LISS-3 (Linear Imaging Self-Scanning Sensor-3):

LISS-3 is a medium-resolution multispectral camera. The pushbroom instrument is identical to LISS-3 on IRS-1C/1D (with regard to lens modules, detectors, and electronics) in the three VNIR bands, each with a spatial resolution of 23.5 m. The resolution of the SWIR band is now also of 23.5 m on a swath of 140 km. The optics design and the detector of the SWIR band are modified to suit the required resolution; B5 uses a 6,000 element Indium Gallium Arsenide CCD with a pixel size of 13 µm. The SWIR CCD is a new device employing a CMOS readout technique for each pixel, thereby improving noise performance. The VNIR CCD array features 6,000 elements for each band. The instrument has a mass of 106.1 kg, a power consumption of 70 W, and a data rate of 52.5 Mbit/s.

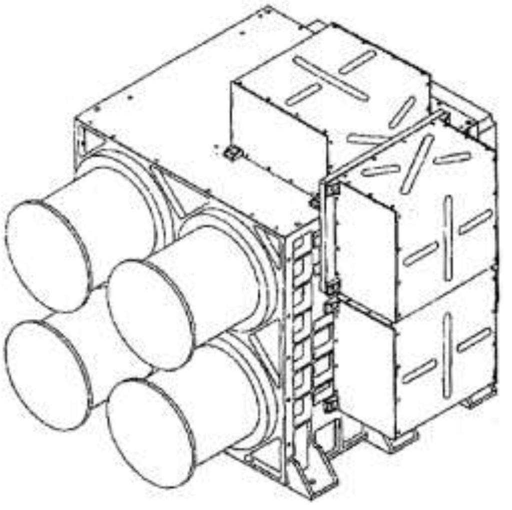
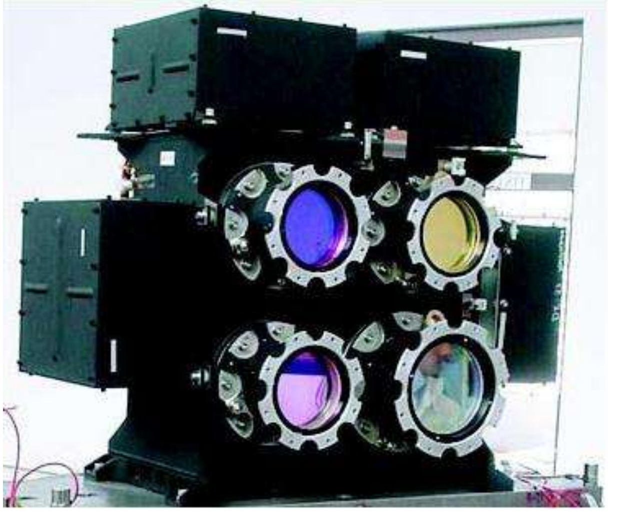


Figure 11.4 LISS III Payload

The in-flight calibration of the LISS-3 camera is carried out using 4 LEDs per CCD in the VNIR bands and 6 LEDs for the SWIR band. These LEDs are operated in pulsed mode and the pulse duration during which these LEDs are ON is varied in specific steps. Each LED has a cylindrical lens to distribute the light intensity onto the CCD. Each calibration cycle consists of 2048 lines providing six non zero intensity levels.

11.5.3 AWiFS (Advanced Wide Field Sensor):



AWiFS is a wide-angle medium resolution (56 m) camera with a swath of 740 km (FOV=±25º) of WiFS heritage. The pushbroom instrument operates in three spectral bands which are identical to two VNIR bands (0.62 - 0.68 µm, 0.77 - 0.86 µm) and the SWIR band (1.55-1.70 µm) of the LISS-3 camera. The AWiFS camera is realized using two separate optoelectronic modules which are tilted by 11.94º with respect to nadir. Each module covers a swath of 370 km providing a combined swath of 740 km with a side lap between them. The wide swath coverage enables AWiFS to provide a five-day repeat capability. The optoelectronic modules contain refractive imaging optics along with band pass interference filter, a neutral density filter and a 6000 pixels linear array CCD detector for each spectral band.

The in-flight calibration is implemented using 6 LEDs in front of each CCD. For the VNIR bands (B2, B3, B4), the calibration is a progressively increasing sequence of 16 intensity levels through exposure control. For the SWIR band, the calibration sequence is similar to that of LISS-3 through a repetitive cycle of 2048 scan lines.

Table 11.3 Summary of the IRS-P6 instrument parameters

Parameter/Instrument	LISS-4	LISS-3	AWiFS
Spatial resolution or IFOV (Instantaneous Field of View)	5.8 m	23.5 m	**56 m (nadir) (70 m a swath edge)**
Spectral bands (µm)	B2: 0.52-0.59, (green) B3: 0.62-0.68, (red) B4: 0.77-0.86 (NIR)	B2: 0.52-0.59, (green) B3: 0.62-0.68, (red) B4: 0.77-0.86, (NIR) B5: 1.55-1.70 (SWIR)	**B2: 0.52-0.59, (green)** **B3: 0.62-0.68, (red)** **B4: 0.77-0.86, (NIR)** **B5: 1.55-1.70 (SWIR)**
Swath width	23.9 km in MS mode 70 km in PAN mode	141 km	**740 km**
Detector line arrays x No of elements	1 x 12,288 PAN mode 3 x 12,288 MS mode	4 x 6,000	**4 x 2 x 6,000**
Data quantization	10 bit (selected 7 bit are provided to the data handling system)	7 bit (VNIR), 10 bit (SWIR)	**10 bit**
Square wave response at Nyquist	> 0.20	B2> 0.40, B3> 0.40 B4> 0.35, B5> 0.20	**B2> 0.40, B3> 0.40** **B4> 0.35, B5> 0.20**
Power consumption	216 W	70 W	**114 W**
Instrument mass	169.5 kg	106.1 kg	**103.6 kg**
Date rate	**105 Mbit/s**	**52.5 Mbit/s**	**52.5 Mbit/s**

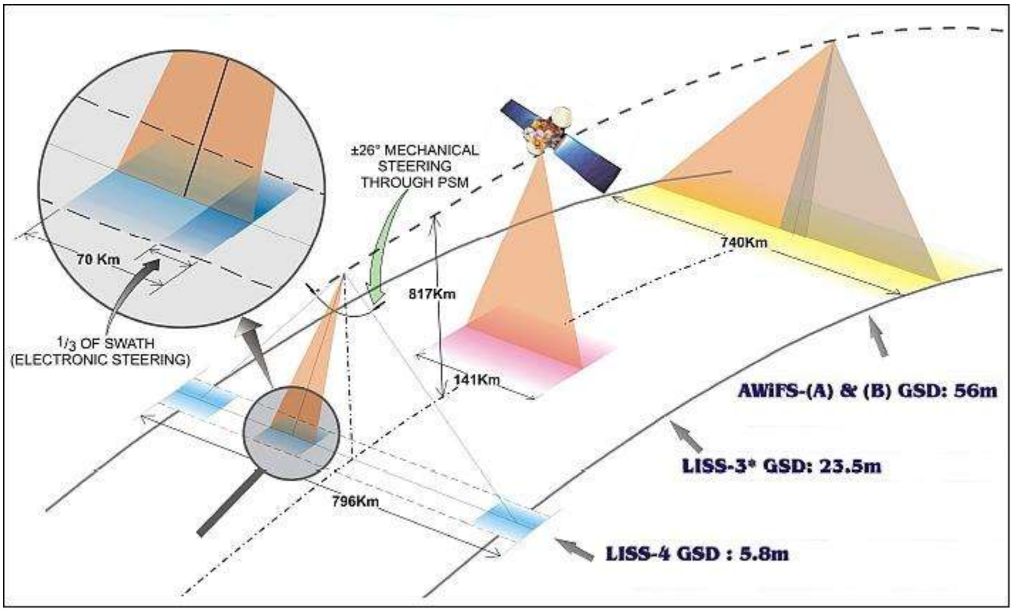
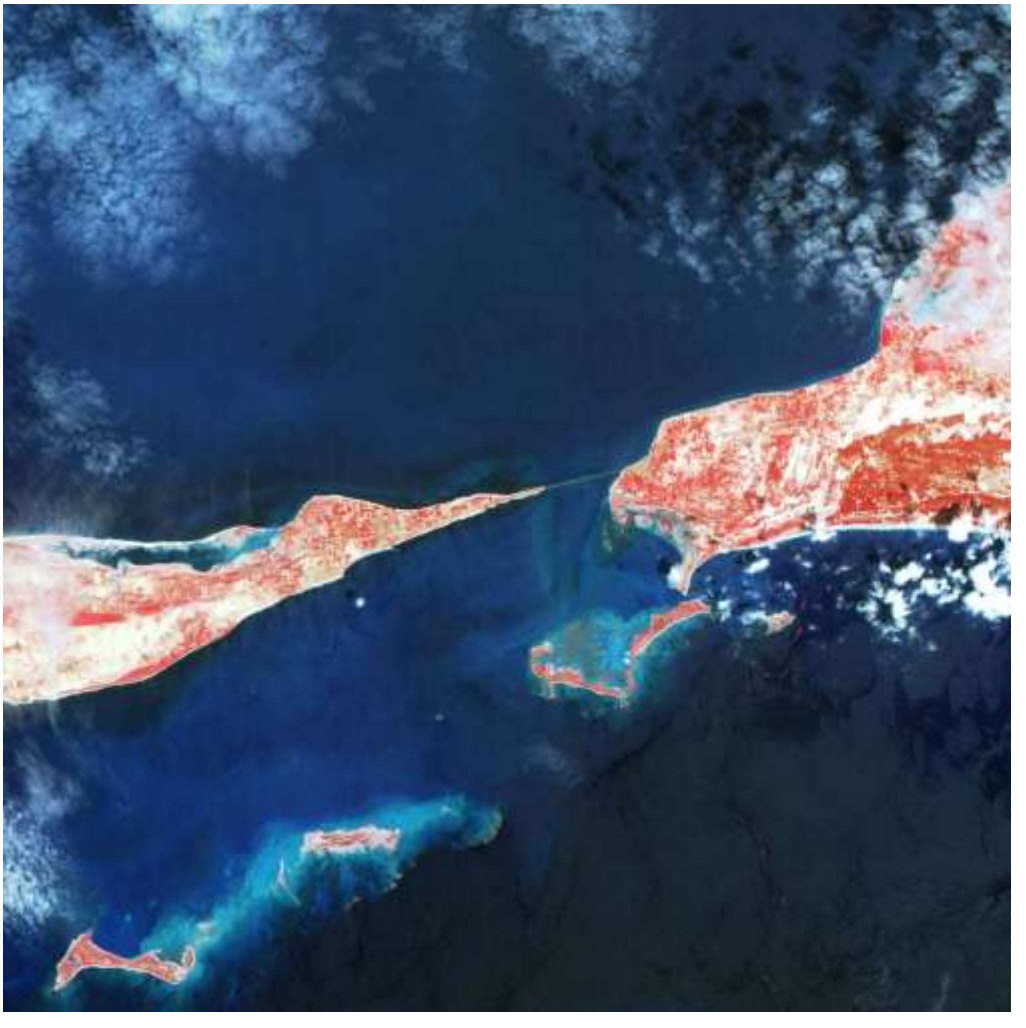
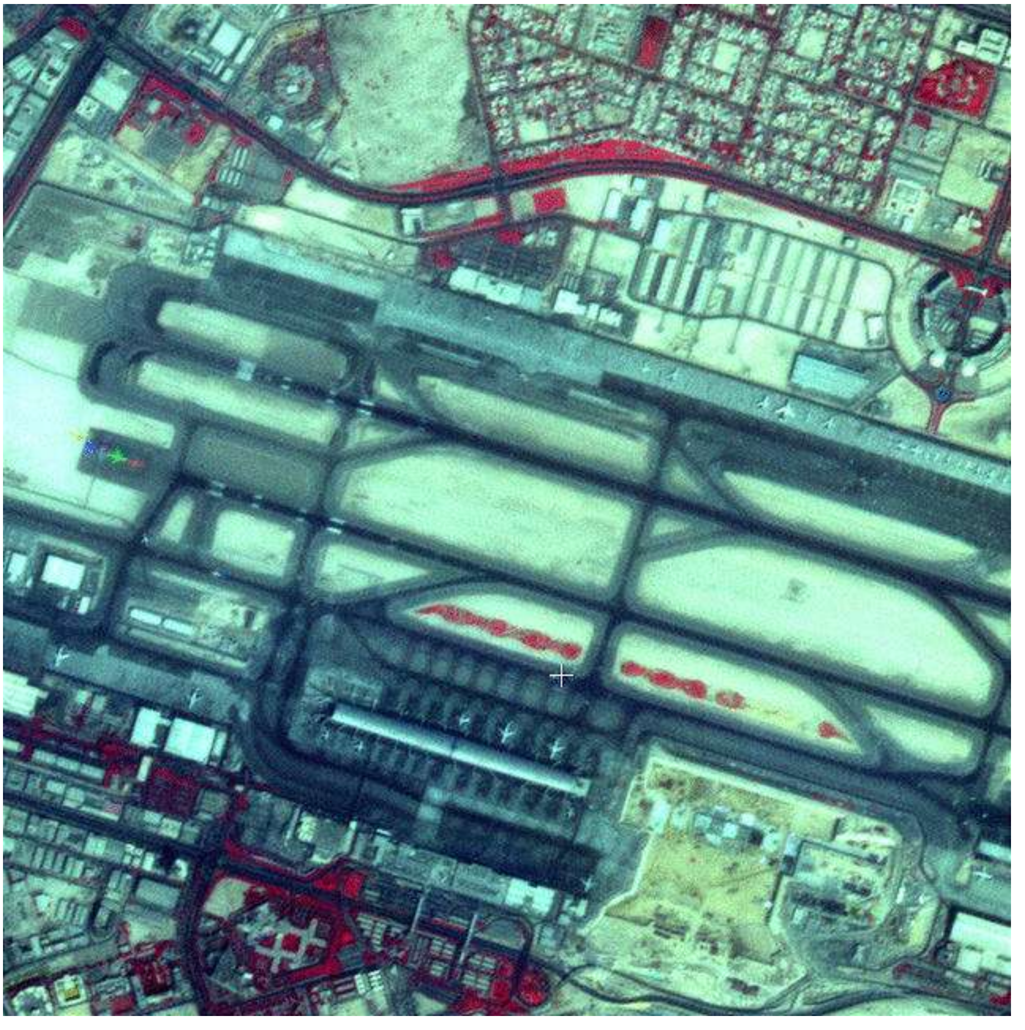


Figure 11.5 IRS-6 Three tier imaging and swath coverage



IRS-P6 IMAGERY, BANGALORE LISS-4, MONO, & LISS-3 MERGED



IRS-P6 IMAGERY SHARJAH


INITIAL IMAGE OF RESOURCESAT-1
LISS-IV MULTISPECTRAL IMAGE COVERING PART OF DELHI ACQUIRED ON 04 - NOV - 2003
nrsa
NATURAL COLOR COMPOSITION
km
BEST COMPLIMENTS FROM NRSA / DOS
04 Nov 2003 fotorite 1040C (Upgraded) 2320x3175x2x100 u
A.B. Vajpayee
(PRIME MINISTER OF INDIA)
My Greetings from the excellence of ISRO team
A.P.J. Abdul Kalam
7/11/03
(PRESIDENT OF INDIA)

12 IRS-P5 (CARTOSAT-1)

12.1 Introduction

IRS-P5 is a first spacecraft designed to acquire stereoscopic Imageries. The objectives of the IRS-P5 mission are directed at geo-engineering (mapping) applications, calling for high-resolution panchromatic imagery with high pointing accuracies. The spacecraft features two high-resolution panchromatic cameras for in-flight stereo imaging. Hence, IRS-P5 is also referred to as **Cartosat-1.** The data products are intended to be used in DTM (Digital Terrain Model)/DEM (Digital Elevation Model) generation in such applications as cadastral mapping and updating, land use as well as other GIS applications.

12.2 Mission Objective

Followig are the mission objectives

- *To design and develop an advanced 3-axis body stabilised remote senisng satellite for providing the enhanced spatial resolution (better than 2.5 m) with stereo imaging capability for the cartographic applications.*
- *To further stimulate new areas of user applications in the areas of cartographic applications; urban management; disaster assesment, relief planning and management; environmental assesment and other GIS applications.*

12.3 Orbit Details

In selection orbit following factors were considered.

- A marching orbit
- Early revisit of adjacent path
- A faster revisit to cover the region of interest

Two orbits were selected for envisage two different operation modes called stereoscopic image mode and wide swath mode.

Table 12.1 Orbit Details of IRS-P5

Parameter	Stereoscopic Mode	Wide swath Mode
Altitude (Km)	~618	~618
Orbit	Polar sun synchronous Orbit	Polar sun synchronous Orbit
Semi Major Axis (Km)	6996.14	6996.14
Inclination (deg)	97.87	97.87
Orbital Period (min)	97.1826	97.1826

Parameter	Stereoscopic Mode	Wide swath Mode
Equatorial crossing time	10.30 AM	10.30 AM
Cycle Time	126 days	131 Days
Orbits in cycle	1867	1941
Launch Vehicle	PSLV-C6	

12.4 Salient Features of Spacecraft:

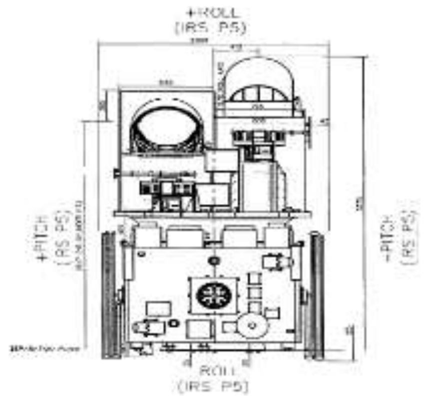
The spacecraft structure is of IRS-P6 heritage, having a size of about 2.4 m x 2.7 m (height). The structure of the spacecraft consists of the MPL (Main Platform) and the PPL (Payload Platform). The MPL consists of main cylinder assembly, four vertical panels, top deck and bottom deck. The cylinder assembly comprises of a central load bearing cylinder, satellite interface ring and top ring. The top ring of the cylinder interfaces with the top deck. The PPL consist of a CFRP cone, PPL deck, wedges for camera mounting, bracket to mount the payload electronic package near to the Detector Head assembly, and star sensor mounting wedge. The CFRP interface cone isolates the PPL Deck and the MPL. The two cameras are encompassed within a thermal cover assembly with two hoods and anchored to the PPL deck

AOCS (Attitude and Orbit Control Subsystem): The platform is three-axis stabilized (star sensors in loop, magnetic bearing reaction wheels in tetrahedral configuration, 16 nozzles with 1 N thrusters, 4 nozzles with 11 N thrusters). The pointing accuracies are ±0.05º in all axes, attitude knowledge = 0.01º, the stability (attitude drift) is 5×10^{-5} º/s, and the ground location accuracy is < 220 m. The S/C provides a body-pointing capability in the cross-track direction to facilitate a better observation coverage of points of interest, the FOR (Field of Regard) is ±26º. The AOCS employs a MIL-STD 31750 processor.

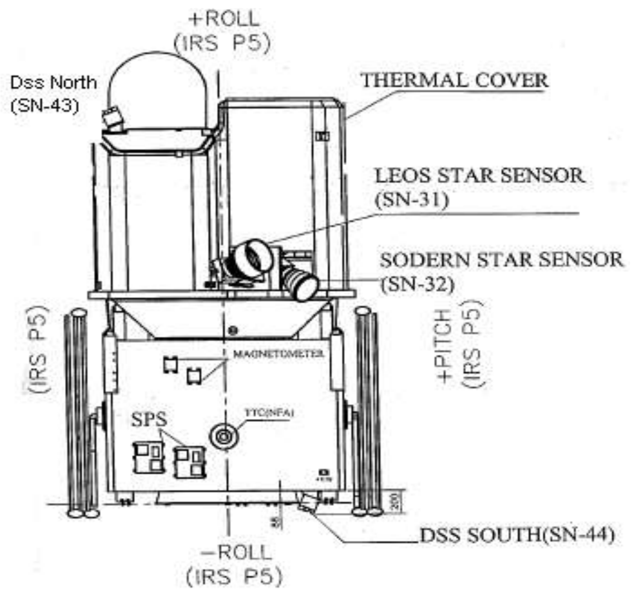
A power of about 1.1 kW (EOL) is provided. The power subsystem of Cartosat-1 consists of six deployable solar panels, with three panels in each wing (sun side and anti sun side), each panel of size 1.4 m x 1.8 m. A SADA (Solar Array Drive Assembly) is employed for maximum power tracking. Two NiCd batteries, each of 24 Ah capacity, provide power during the eclipse phases of the orbit. The power bus is formed by ohmic interconnection of solar array strings (current source) and battery (voltage source). There are two raw bus lines called Bus-A and Bus-B. The raw bus is essentially the battery whose voltage ranges from 28 - 42 V. Bus control is by PWM based TCR (Taper Charge Regulator).

RCS (Reaction Control Subsystem): The RCS of Cartosat-1 is a monopropellant hydrazine system using nitrogen as pressurant and operating in a blow-down mode. The RCS is used for correcting the satellite injection errors in attitude and inclination, attitude acquisition and maintenance of the desired sun synchronous orbit. Eight nozzles of 1 N and four 11 N thrusters are mounted on the bottom deck.

The Thermal control subsystem maintains the temperature of different subsystems within the specified limits using semi-active and active thermal control elements like paints, MLI (Multi Layer Insulation) blankets, optical solar reflectors and auto-temperature controllers All the surfaces of PAN cameras are thermally treated with black paint. All MFD (Mirror Fixing Devices) are provided with black tapes. The payload CCD cold finger is connected to heat pipe by a copper braid. Each CCD has one heat pipe which runs over the thermal cover and gets attached to the sun side radiator plate and anti-sun side radiator plate respectively.



12.1. IRS-P5 Viewed from EP-01 side



12.2 IRS-P5 Viewed from EP-03 side

Table 12.2 Salient features of IRS-P5

Subsystem		IRS-P5
Structure		Cuboid, Aluminum aluminum Honeycomb structure, Payload support structure with CFRP to separate payload platform from main bus
Thermal	Control	Temperature control is with passive techniques using Paints, multilayer blankets, Optical solar Reflector, and active thermal elements like heaters also. Heat pipe radiator panel is used to maintain the temperature of LISS-4 detector head assembly.
	Limits	All electronics packages 0-40°C, Battery 0-10 °C , Payload EO modules : 17 to 23°C
Mechanism	Solar Panel	Solar panel deployment mechanism and Drive Mechanism SADA with microstepping
Power	Solar Panel	Rigid, deployable, Sun tracking, CFRP Faceskin, 15.12 M^2 , 6 panels 1.4 x 1.8 m^2 (Each), 58.8 Kg, 50 mic. Kaptan insulator, 133 cells in series, 35 in parallel 8 string. 1020 W at EOL, BSR
	Battery	2 batteries, 28 to 42V, 28 Cells, Ni-Cd 24 AH
	Power Electronics	2 buses, PWM TCR, FCL, 8 Strings
TTC	Telemetry	1024 bits, storage: 6.29 x 10^6 Bits PCM/PSK/PM, 16 Kbps
	Telecommand	PCM/FSK/FM/PM,
Data Handling		The payload data are transmitted in X-band at a data rate of 105 Mbit/s. The BDH (Baseband Data Handling) system consists of two separate chains, one for LISS-3 and AWiFS data, and the second chain for LISS-4 data. The LISS-4 data are transmitted on carrier-1 and LISS-3 + AWiFS data are transmitted on carrier-2
Data Transmission	BDH	X-Band, PCM/QPSK, 2 carriers, data rate: 2 x 52.5 Mbps/carrier PAA(64 elements) RHCP JPEG like compression(3.2:1)
	SSR	120 Gbit(EOL),
AOCS	Spec.	Pointing Accuracies: Yaw: $\pm$ 0.05° Roll: $\pm$ 0.05° Pitch: $\pm$ 0.05° (3 sigma) Driftrate : 5 x 10^{-5} deg/sec (3 sigma)
	Sensors	Earth sensor(1), DSS(2), Star Sensors(1 Indian, 1 imported)), 4Pi SS(4), Magnetometer (2), IRU(3

Subsystem		IRS-P5
		DTG), SPS
	Actuators	Reaction Wheels 5 NMS(4 in tetrahedral), Magnetic Torquers (2) , 1N Thrusters(8) 11 N Thruster(4) Fuel (131 Kg) Dry Mass(36 Kg)
AOCE		Hardwired system as a back up only for microprocessor based linear controller.
Payloads		PAN Aft, PAN Fore mass(250 Each)
Mass		1560 Kg

12.5 Payload

The payload instrumentation consists of two panchromatic cameras of PAN heritage as flown on the IRS-1C/D satellites. The objective is to obtain fore-aft stereo imagery with two fixed (body-mounted) instruments (i.e., a **two-line stereo configuration**). They are mounted with a tilt of + 26 deg. (Fore) -5 deg (Aft) from yaw axis in Yaw roll plane. Both cameras are identical in optical electrical and mechanical design. It also has off-nadir capacity up to ± 22 deg by providing roll biasing in the orbit ref. frame. The discrimination of elevation differences of better than 5 m make the data particularly suitable for map-making and terrain modeling

12.5.1 PAN-F

(Panchromatic Forward-pointing Camera) featuring a fixed forward tilt of 26º.

12.5.2 PAN-A

(Panchromatic Aft-pointing Camera), it is fixed at an aft tilt of -5º.

Each camera provides a spectral range of 0.5 - 0.85 µm, a spatial resolution of 2.5 m, a swath width of 30 km, and data quantization of 10 bits. Stereo imagery is acquired with a small time difference (about 50 s) due to the forward and backward look angles of the two cameras. The major change in imaging conditions during this time period is due to rotation of Earth. An algorithm for Earth rotation compensation is being used to eliminate the delayed observations of the two cameras.

Table 12.3 Features of IRS-P5 Payload

Parameter	PAN-F Camera	PAN-A Camera
Spectral range	500 - 850 nm	
Along-track tilt angle with respect to nadir	+26º	-5º
Spatial resolution (cross-track x along-track)	2.5 m x 2.78 m	2.22 m x 2.23 m
Radiometric resolution		

Parameter	PAN-F Camera	PAN-A Camera
a) saturation radiance	55 mW/(cm^2 sr µm)	
b) data quantization	10 bit	
c) SNR	345 at saturation radiance	
Swath width (for stereo imagery)	29.42 km	26.24 km
Swath width (for monoscopic observation mode)	55 km (with swath overlaps)	
CCD array (No of arrays x No of elements)	1 x 12,288	1 x 12,288
Detector element size	7 µm x 7 µm	7 µm x 7 µm
Optics:		
Telescope aperture diameter	50 cm	
No of mirrors	3	
Effective focal length	1945 mm	
F number	f/4	
FOV (Field of View)	±1.08º	
Integration time	0.336 ms	
Detector	12 K CCD	
Quantization	10 Bits	
SWR @ nyquist frequency	>0.20	
SNR Signal To Noise Ratio	≥256	
MTF (Modulation Transfer Function)	cross-track = 20, along-track = 23	
Onboard calibration	Relative, using LEDs	
Data compression	JPEG algorithm, compression ratio = 3.2:1 (max)	
Data rate	105 Mbit/s (source data rate of 340 Mbit/s)	
Nominal B/H ratio for stereo	0.62	
Power	110 W (Per Camera)	
Mass	< 250 Kg (Per Camera)	

Payload consists of

- Electro optical module
- Payload Electronics
- Power Electronics

12.5.2.1 Electro-optical Module

Each optical module consists of axis three mirror optical system and detector Head assembly consisting of 12K CCD, spectral Band filter and calibration LED

Optical system

The optical system is extended version of the panchromatic camera of IRS-1C/1D. i.e un-obscured off-axis reflective system. The focal length of the system is 1945 mm and the FOV is ±1.3 deg across track and ± 0.2 deg in along track. The optical system of each PAN camera is designed with a three-mirror off-axis reflective telescope with an off-axis concave hyperboloidal primary mirror, convex spherical secondary mirror and an off-axis concave ellipsoidal tertiary mirror - to meet the required resolution and swath width.

The mirrors are made from special Zerodur glass blanks. The mirrors are polished to an accuracy of lambda/80 and are coated with enhanced AlO_2coating. The mirrors are mounted to the electro-optical module using iso-static mounts, so that the distortion on the light weighted mirrors are reduced to a minimum.

Interference spectral filter

Shape	: Rectangular
Dimension	: 115 x 20 x 6 mm^3
Coated area	: 110 x 18 mm^2

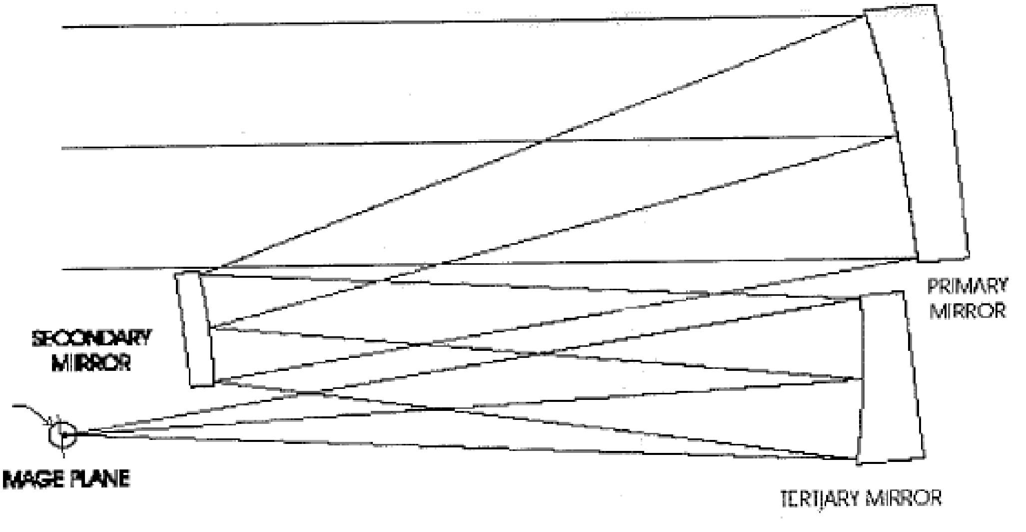


Figure 12.3 Optical schematic of IRS-P5 PAN

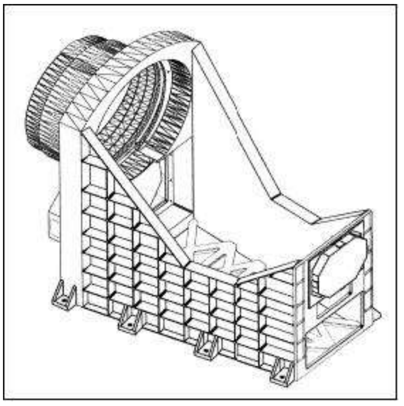
 

Figure 12.4 Electro optical Module of IRS-P5 Camera

Figure 12.5 PAN camera under testing

12.5.2.2 Detector Head Assembly

Each camera has separate DHA. The Detector is a linear CCD detector array of 12,288 pixels which is mounted in a DHA.

The DHA Consists of DHA Housing, 12K Linear CCD, CCD Holder, 16 LEDs per CCD, LED Holder, Interference Spectral Filter, cold finger, Bias voltage generating circuits, clock driver circuits and Thermal control systems.

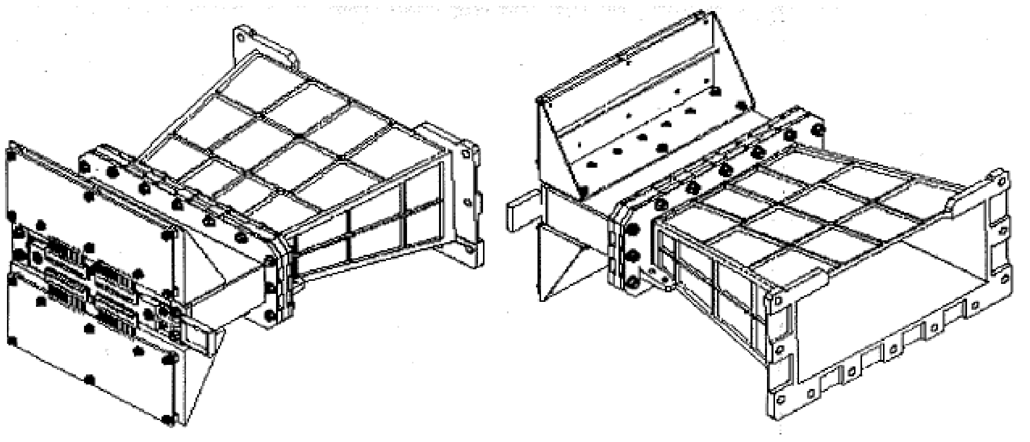


Figure 12.6 Detector Head Assembly

12.5.2.3 Detector

Each DHA uses 12 K element linear CCD Thomson make (THX31543A) with a pixel size of 7 micron x 7 micron staggered by 35 microns. Silicon is used as photo sensitive element which is sensitive upto 1.1 micron. The detector provides video data on 8 ports 4 ports for odd pixel and 4 ports for even pixels. Each port provides video data for 1520 pixels including 20 prescan pixels.

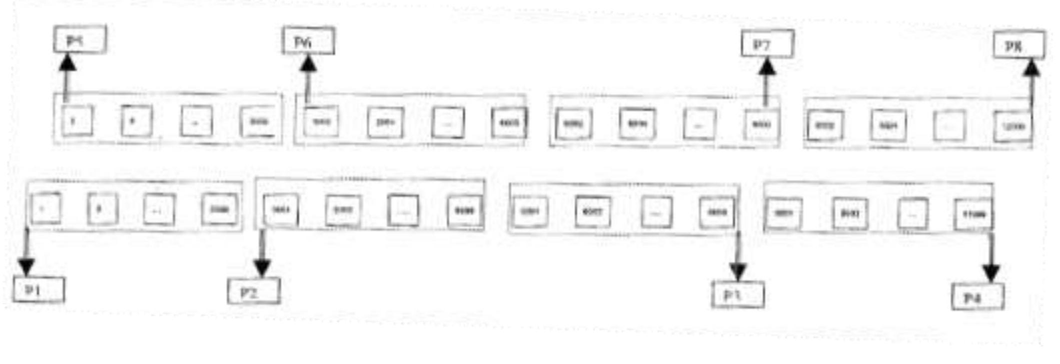


Figure 12.7: Staggered arrangement of pixels in 12 K CCD

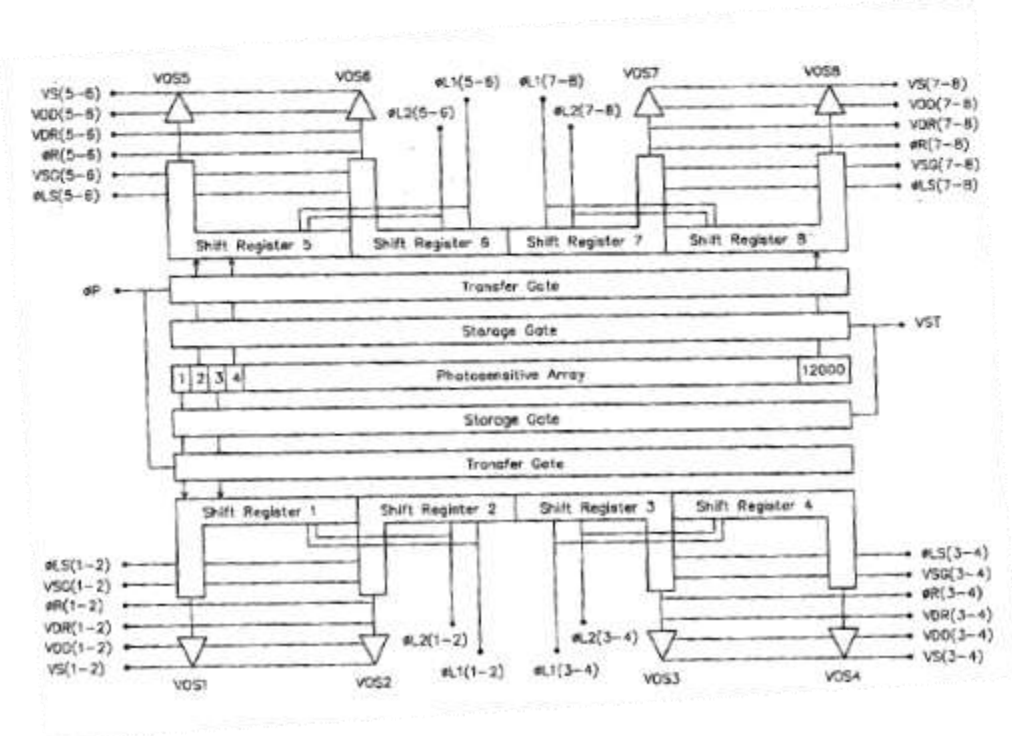


Figure 12.8 12K CCD Architecture

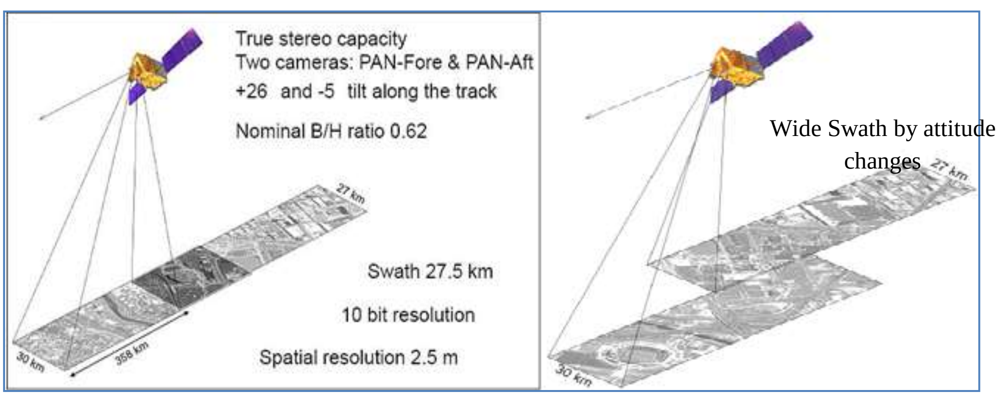


Figure 12.9: Schematic of imaging modes of IRS-P5

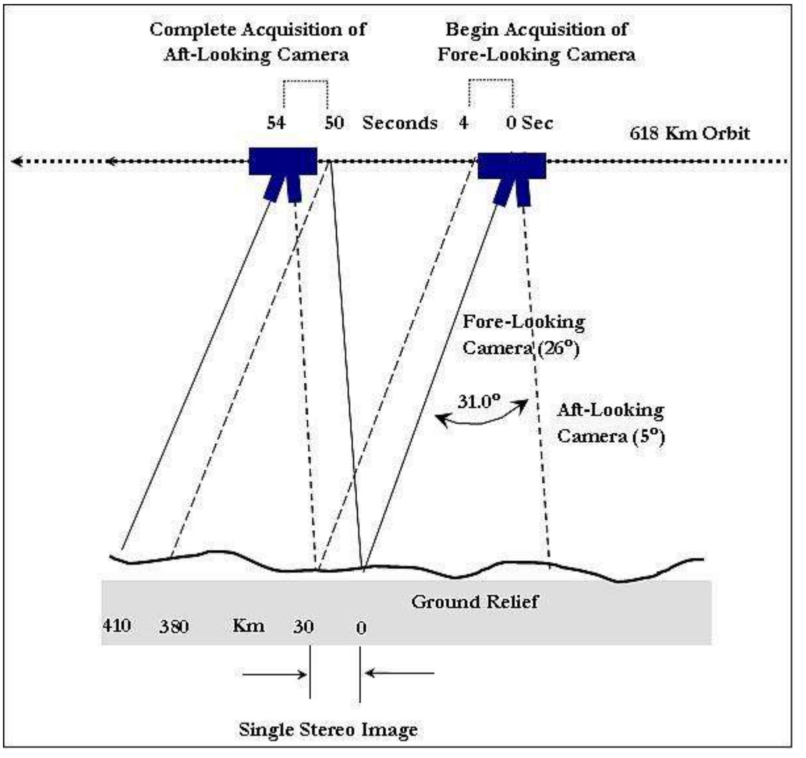
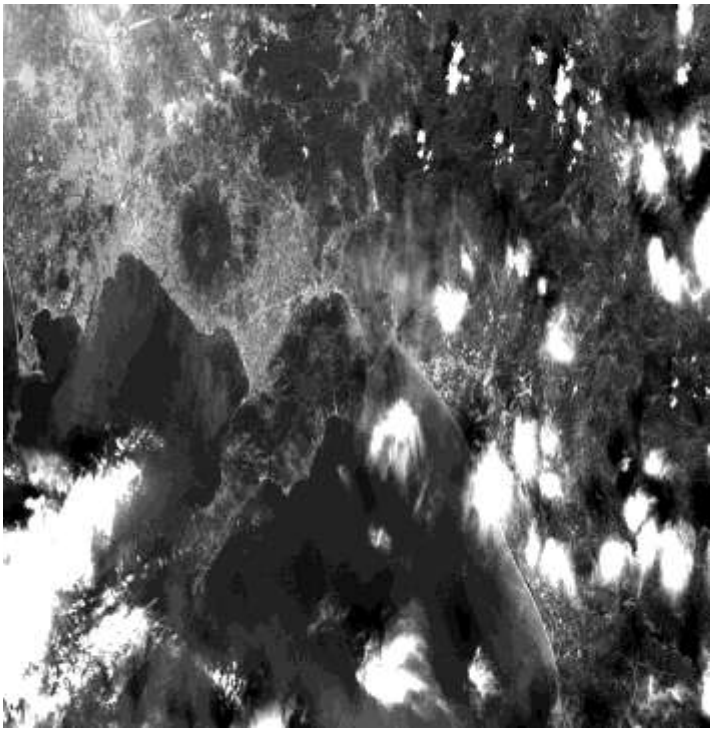
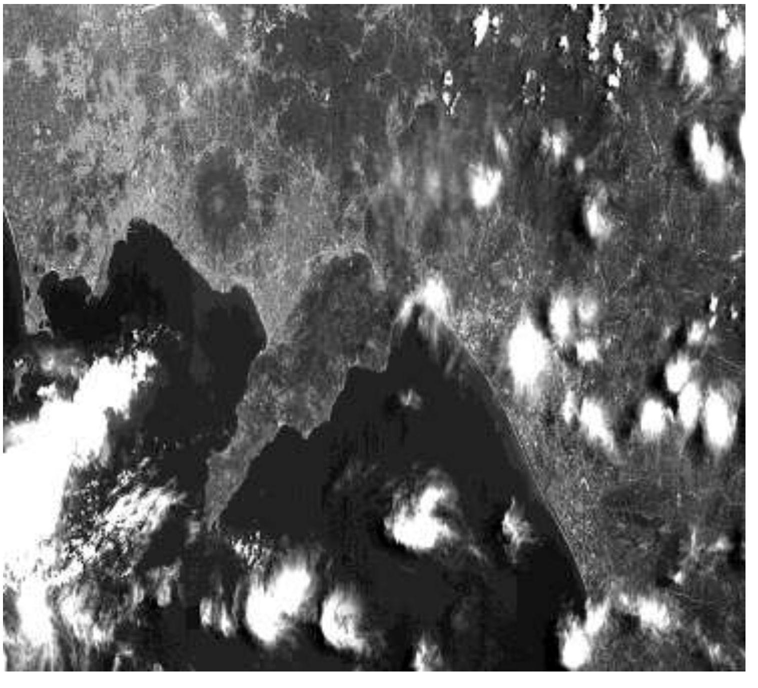


Figure 12.10: Along-track imaging geometry of the CartoSat-1 fore- and aft-viewing cameras

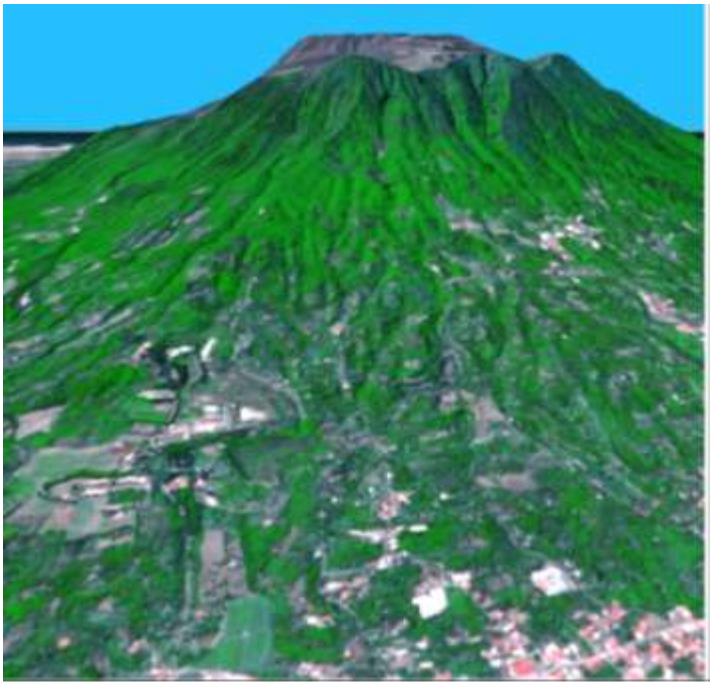
The imagery of the 2-line along-track stereo camera may be used for a variety of applications, among them for the generation of DEMs (Digital Elevation Models). The data is expected to provide enhanced inputs for large scale mapping applications and stimulate newer applications in the urban and rural development.

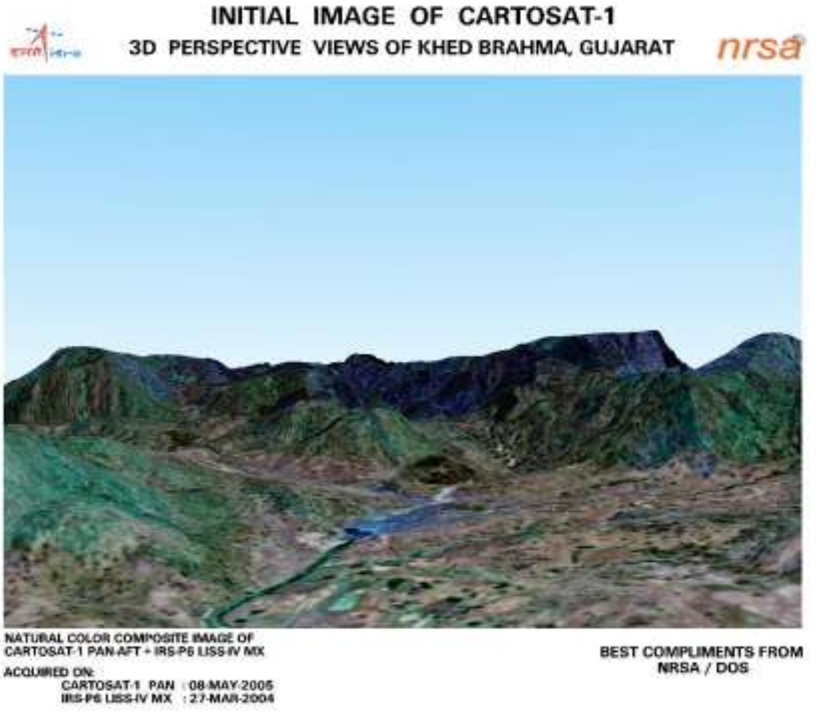


FRONT view



Rear view




INITIAL IMAGE OF CARTOSAT-1
3D PERSPECTIVE VIEWS OF KHED BRAHMA, GUJARAT
nrsa
NATURAL COLOR COMPOSITE IMAGE OF
CARTOSAT-1 PAN-AFT + IRS-P6 LISS-IV MX
ACQUIRED ON:
CARTOSAT-1 PAN : 08-MAY-2005
IRS-P6 LISS-IV MX : 27-MAR-2004
BEST COMPLIMENTS FROM
NRSA / DOS

13 CARTOSAT-2/2A/2B

13.1 Introduction

The Cartosat-2 series is a set of high resolution agile satellites with less inertia. This satellite is used to acquire spot images and strip images up to 200 km. The various type of image pattern possible is provide in the figure 13.4

13.2 Mission Objective

The main objectives of the Cartosat-2 mission are –

- *To design and develop a high agility advanced satellite with a high spatial resolution of around 1.0 m in panchromatic band with an operational life of 5 years and mission reliability of 0.75.*
- *To meet the ever – increasing user demands for cartographic applications at cadastral level urban and rural management, coastal land use and regulation, utilities mapping and development and various other GIS applications.*

13.3 Orbit Details

Table 13.1: Orbit details of Cartosat-2/2A/2B

Parameters	Nominal	Recurrent
Altitude (Km)	630.6	560
Semi Major Axis (Km)	7008.6	6938.1
Eccentricity	9.999 E-004	
Inclination (Deg)	97.914	97.91
Argument Of Perigee(Deg)	90	87.19
Local Time	9 .30 A.M	9.30 AM
Revisit (Days)	4	1
Repetivity	310 days	1
Orbits/day	14.	15
Period(min)	97.446	96

13.4 Salient features of Spacecraft

Table 13.2: Salient features of Cartosat-2/2A/2B

Parameter		Cartosat-2/2A/2B
Structure		Hexagon shaped Aluminum and aluminum honeycomb structure
Thermal	Components	Passive control using tapes , OSR, MLI Blankets and semi-active/active control using proportionate temperature controller and heaters, Detector cooling via heatpipe
	Temp. Range	20±5 deg.C range for imaging sensors electro-optics 5+5 deg. C for Chemical Batteries 0 to 40 deg.C for electronic packages
Mechanism	DGA Drive	Dual Gimbal antenna hold down and drive mechanism.
	Solar Array Deployment	Solar arrays deployment is done by solar array hold down and deployment mechanism.
Power	Solar Array	Four (2+2), 4.64 m^2 (1.45m x 0.8 m each), Rigid deployable panels, without SADA, Sun pointing. 23 cells(Triple junction) series, 60 in parallel 9 strings. 1200 W @ EOL
	Battery	42V, SAFT, NiCd, 18 AH, 2 Batteries, 28 cells in series
	Electronics	Modularized distribution Package, Mother Board-daughter Board control Package.
Communication	Telemetry	S-Band; HK Real Time rate 4 Kbps; PB/SPS/Star sensor Data : 16 Kbps, Dwell data : 4Kbps
	Telecommand	S-Band : 4 Kbps
	Tracking	Facility for ON/OFF and Data commands S-Band tone ranging and two way Doppler X-band beacon
BMU (AOCE+TM/TC)	Attitude/Orbit sensors	Star sensor(2), 4 PI sun sensors(4), Dynamically Tuned Gyros (DTG)(3), Magnetometers(2), SPS for orbit determination)
	Attitude control	15 NMS, 0.3 Nm RW (4) mounted in tetrahedral configuration, Magnetic torquers(3), Hydrazine thrusters(8 one Newton) 63 Kg Fuel

	Orbit Control	Monopropellant hydrazine thrusters
	Orbit-Determination accuracy	<40 meters
	Attitude Determination Accuracy	40 Arc sec along bore sight of Star Sensor 10 Arc sec across bore sight
Data Handling		105 Mbps ; QPSK; X band
Payload	Panchromatic	~1 m resolution ; RC type optics
Mass	Bus Payload	C2:678.Kg (Bus+ Payload) Payload:119.5 Kg

13.5 Payload

13.5.1 Panchromatic camera

Optical system is a modified RC system consisting of two-mirror RC type telescope, three lenses, a window and a band pass filter. Field correcting optics consisting three lens elements is used to correct the aberrations at the larger field of view (+/- 0.5 deg.) and also to flatten the image. A band pass filter placed close to the CCD defines the band shape. The camera operates in the spectral band of 0.5 – 0.8 μm using 12000 elements CCD array. The CCD covers a swath of about 9.6 km.

The two CCDs are located within the focal plane along with band pass filters and calibration system using LEDs. Two independent chains of Camera Electronics are planned to cater to two CCDs.

13.5.1.1 Panchromatic camera specifications:

Camera	
Resolution	: ~1m
Swath	: ~9.6 Km
Spectral Band	: 0.5 to 0.8 M
Detector	: 12 K Linear Array CCD
Optics Type	: RC type
Optics	: F/8, 5.6m Focal Length
Spectral Band	: 0.5 To 0.85 μm
FOV	: ± 0.43 Across track)
	± 0.2 (along Track)
Size of The Primary Mirror	: 700mm
Size of The Secondary Mirror	: 199mm
<u>CCD</u>	
No. Of Pixels /Detector	: 12000
Pixel Size	: 7 μm X 7μm
No. Of Output Ports / Detector	: 8
System	
IGFOV	: ~1 M (for non- tilt conditions)
Integration time	: 366µsec
Radiometric Quantization	: 10 bits
Quantization Levels	: 1024 (for 10 bits)
SNR (at saturation)	
55 Mw/Sr/µM	: 180
10 Mw/Sr/µM	: 80
Camera Size	: 760mm (dia) X 1600mm (height)
Camera Weight	: ~ 120 Kg
Power	: < 60 W

13.5.1.2 Payload Configuration

The payload consists of a Telescope-having an obscured two-mirror system with field correcting optics, two CCDs located within the focal plane along with the band pass filters and calibration system using LEDs. The payload is a single panchromatic camera (0.5 to 0.8 microns) with a spatial resolution of around 1m and swath of 9.6 km. Two CCD's – One main and one redt. have been provided. The main CCD interfaces with the BDH (M) and RF (M), while the redt. CCD interfaces with BDH (R) and RF (R). The camera is mounted on a highly agile platform capable of being steered across and along the track to provide spot imageries of the desired locations.

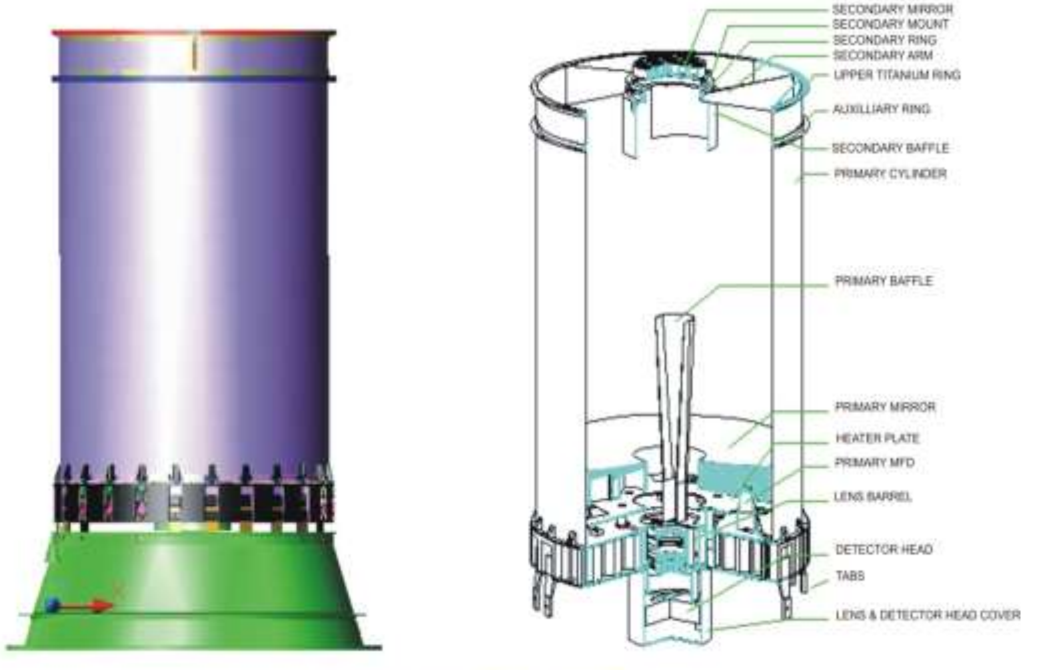
The camera system requirements are as follows:

Provide images with ground projection of better than 1 m in panchromatic band.

Provide swath of about 10 Km.

Cover 100% albedo for an observation time of around 09.30 AM

Configuration shall have low moment of Inertia.



PAYLOAD ASSEMBLY

Two independent chains of Camera electronics to cater to two CCDs and are planned to be located close to the detector. The CCDs are mounted in two identical DHAs (Detector Head Assembly) and are configured to have cold redundancy and one of them will be ON at a time.

Each DHA consists of:

- 12 K Linear array CCD.
- Bias voltage generating circuits
- Clock driver circuits
- LEDs for onboard calibration
- Heaters and thermistors for thermal control.

13.5.1.3 Detector

Detector is a 12 K element linear charge coupled device THX31543A with a pixel size of 7 µ x 7µ staggered by 35 µ. It provides video data on 8 ports; four ports for odd pixels and four ports for even pixels. Each port provides video data for 1520 pixels including 20 pre-scan cells. CCD has anti blooming & integration control facilities the Integration time selected is 366 µs.

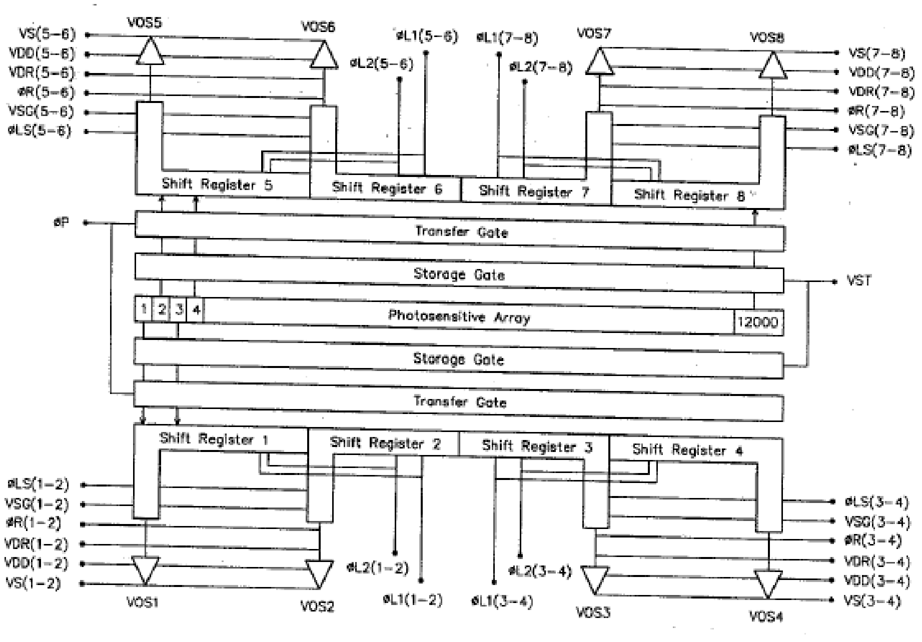


Figure 13.1 12K CCD architecture

13.5.1.4 CCD Drive

CCD requires a total of 20 bias voltage lines for its operation. These are generated using the series regulators with an input supply of 18 V.CCD needs a total of 20 clocks for operation. DHA receives clock signals at TTL level from timing and control logic circuits and are conditioned to suitable voltage levels to drive the required loads of CCD.

13.5.1.5 Calibration:

There is provision for in-flight calibration. Total eight LEDs are provided in each DHA as two sets of four LEDs in series.

13.5.1.6 Heaters and thermistors for CCD temp control

CCD temperature variation is required to be controlled to a narrow range of about 20 $\pm$ 2 deg. C to minimise the impact of photo response variation on radiometer. The heaters are put ON whenever CCD is OFF to minimise temperature variation near the CCD. These heaters are mounted on cold fingers. DHA also requires to maintained at a nominal setting of 20 deg. C and control range of ± 2 deg. C; for this DHA requires to be cooled. This is achieved by attaching copper braids to the cold finger used for holding the CCD. The copper braid in turn is attached to radiator plate through heat pipes. There are control heaters along with controller to maintain the DHA at 20 ± 2 deg.

13.5.1.7 Camera electronics:

The camera electronics consists of:

Port wise video processing chain
Timing and control logic
Exposure control logic for imaging and calibration modes
Clock distribution circuit
Calibration drivers.

Camera electronics provides necessary clocks for detector operation and constant current for calibration LEDs. It receives video signal from detector, processes and digitises it, extract true video and provide it to BDH subsystem for further processing. Fig: 3.1.6 Shows the Block Schematic of Camera Electronics.

13.5.1.8 Video Processor

It receives analog video from DHA, amplifies the signal, restricts the bandwidth, and extracts digitised data corresponding to true video by converting analog data. After processing the data it transmits the same to the Base Band Data Handling System.

The major specification of Video Processor is given below:

Signal Type	:	3 level PAM
DC Offset	:	11V typical
Signal Range (mV)	:	0 –138 mV
Total number of pixels to be read/port	:	1536
Pixel Duration (ns)	:	238
Video Time	:	119
Settled Video time(ns)	:	51
Settled reference time (ns)	:	42
Detector output impedence	:	220 ± 5
Terminating resistor at VP end (ohm)	:	274
Cable Type	:	RG 316

Output Specification:

Quantization	:	10-bit
SNR	:	>512
No. of gains	:	One

Compatibility : LSTTL

13.5.1.9 Data Handling

The imaging modes/profiles are new this mission so as to use the imaging time more efficiently with respect to the coverage.. The payload consists of two 12K element linear CCDs. The video data is quantised to 10 bits. The total data rate per ports of the CCD works out to be 336MBPS. The video data at this rate from the 8 ports of the CCD video processor electronics required to be formatted and transmitted to the ground by DH system through the X-band carrier. The video data is also to be suitably encrypted and additionally stored in a SSR for later playback and transmission. CCD1 data is to be transmitted through the main DH chain and the CCD2 data is to be transmitted through the redundant DH chain.

13.5.1.10 Data Interface Package

Data Interface Package receives eight ports of data each at 4.2 Mpixels/sec from Payload Electronics. Each port data bus is 10 bits parallel. The JPEG like compression system requires data in a 8x8 block form. There is also a requirement to bypass the compression and transmit the original data in bypass.

Electrical Specifications

No. of input ports	:	8 (4I + 4Q)
Port data rate	:	4.2M words/Sec
Port data format	:	10 bit parallel
No. Of Pixels/Port	:	1504 (2 prescan+1500 Valid video+2 post scan)
Integration time	:	~ 365.71µsec.
Output data to DCS	:	2 ports, LVDS, 10 bit parallel @ 17.5 MBPS
Output data to BDH	:	2 ports, TTL 10 bit parallel @ 5.25 MBPS
Power	:	~ 10W

The order in which video pixels of each port are coming out from payload is as shown below:

Odd Ports

Port1: Prescan 19 &20,, Pixel#1, #3,……,#2997, #2999, post scans 1&2
Port2: Prescan 19 &20,Pixel#3001, #3003,……,#5997, #5999 post scans1&2
Port3: Prescan 19 &20,, Pixel#8999, #8997,……,#6003, #6001, post scans1&2
Port4: Prescan 19 &20, Pixel#11999, #11997,……,#9003, #9001, post scans1&2

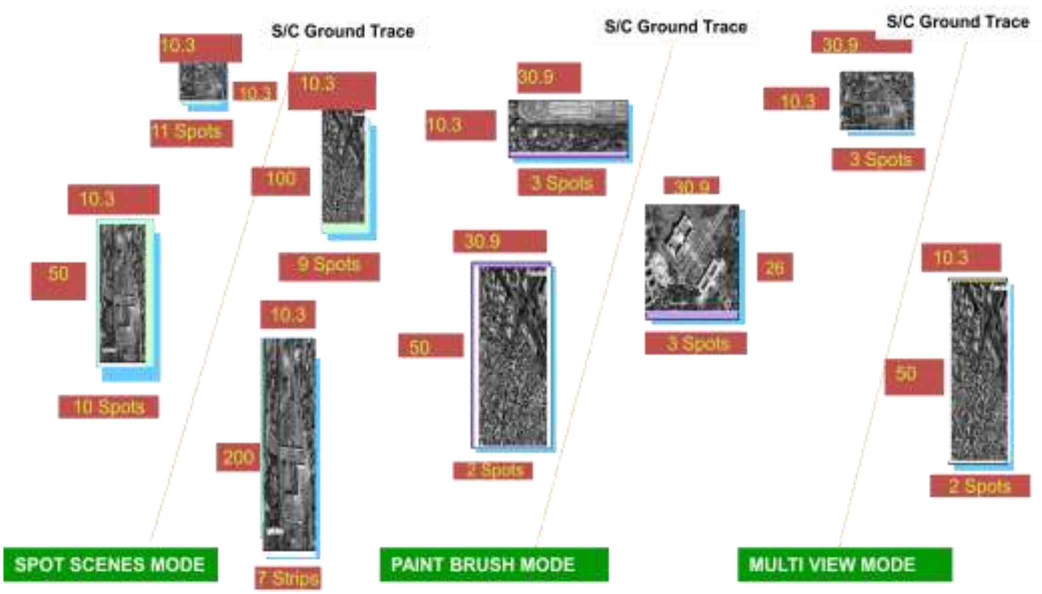
Even Ports

Port5: Prescan 19 &20, Pixel#2, #4,……,#2998, #3000, post scans1&2
Port6: Prescan 19 &20, Pixel#3002, #3004,……,#5998, #6000, post scans1&2

Port7: Prescan 19 &20,Pixel#9000, #8998,……,#6004, #6002,   post scans1&2
Port8: Prescan 19 &20,Pixel#12000, #11998,……,#9004, #9002,   post scans1&2

13.5.1.11 Imaging Pattern of Cartosat-2 satellites

The imaging modes of Cartosat-2 series employs step and stare method to get required along track resolution. Based on the requirement different size imaging strips are imaged.



Strip Length (km)	No of targets	Total (sq. km)
9.6	10	922
28	8	2150
50	6	2880
290	2	5568

Cartosat-2B

Figure 13.2 Image pattern of Cartosat-2

14 IMS-1 (TWSAT)

14.1 Introduction

IMS-1 (earlier it was called as TWSAT) is the first micro satellite fabricated for remote sensing application purpose.(Other microsatellites are Rohini, SROSS, HAMSAT). These satellites can be launched mounted on the EB of PSLV with no additional cost for launch. The redundant philosophy is not implemented in IMS-1 bus

14.2 Mission Objective

- *To build, launch, and operate a 3 axis stabilized remote sensing micro satellite for launch, onboard PSLV, as auxiliary satellite, providing easy access of remote sensing data to the educational institutions, research organizations, and government agencies in the developing countries. The spacecraft bus is developed as a versatile Micro Satellite bus in order to carry in future, a number of different payloads without significant changes in the bus.*
- *To develop low cost user terminals that can be used by users in Universities or Institutions of developing countries to receive the payload data.*
- *The Hyper-spectral imager being flown in Chandrayaan-1 is also being flown in IMS-1 to evaluate and validate the payload.*

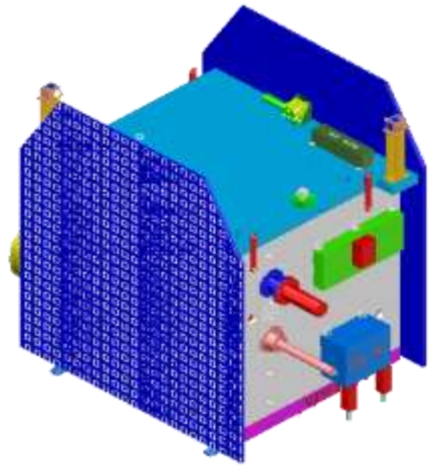
14.3 Orbit Details

Altitude	638 Km
Inclination	97.94 º
Orbit	Polar Sun Synchronous
Eccentricity	0.001
Local time	09. 44 AM (descending node)
Orbits/day	14
Repeat cycle	369 orbits in 25 days
Period	97minutes
Path to Path separation	108.6 km

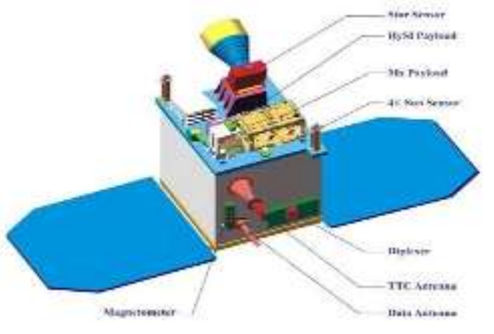
14.4 Salient Features of Spacecraft

Mechanical systems: IMS-1 is designed with Aluminum Honeycomb sandwich panels as a Cuboid structure with a bottom deck, top deck and four cross ribs in a staggered fashion connecting the top and bottom deck. This configuration generates a central core to house the fuel tank, thruster and plumbing while transferring the loads effectively to the interface ring. Payloads are mounted on the top deck.

The electronic packages are mounted on the four cross ribs / cover panels for mounting external appendages like antennas etc, forming the cuboid. The structure is a cuboid of size 552 x 600 x 600 mm. The overall size of spacecraft with stowed solar panel is 604 x 980 x 1129 (h) mm. IBL-298 interface ring interfaces with PSLV.



Thermal System: Thermal control is achieved by passive means using semi-active elements like paints, MLI, OSR and thermal tapes. However, provision is made for heaters wherever necessary. Thermistors, Platinum Resistance Temperature sensors and Thermocouples are used for temperature monitoring at required locations of IMS-1. The temperature sensor data is processed in BMU for heater control and telemetry to ground.



Data Handling System: The Payload consists of 4 band multi-spectral CCD camera (MxT) and 64 bands HYSI payload. Either MX data or HYSI data will be recorded and transmitted at a time. The BDH consists of P/L interface unit, Data Compression, RS coding and formatting unit. TheCompression ratio is 3.401:1 for MXT Payload and no compression for HYSI P/L data. Compressed, RS encoded and formatted data is stored in SSR @ 10.66Mbps and simultaneously played back @ 8 Mbps in compression mode for MXT Payload. In compression bypass mode RS encoded, formatted data is stored in SSR @ 32 Mbps and simultaneously played back @ 8Mbps for MX. The transmission time required is 1.33 times (10.66Mbps / 8 Mbps) the imaging time in compression mode for MX. The transmission time required is 4 (32 Mbps / 8 Mbps) times the imaging time in compression bypass mode for MX. The playback data @ 8Mbps is differential encoded in BDH before transmission to RF Transmitter. Data transmission is S band BPSK.

Solid State recorder: A Solid State Recorder of 16 GB is configured to meet the mission requirement. The data from the payloads are formatted and a single stream is input to SSR. The basic operating modes of the SSR are Normal, Diagnostics, BER or Self Test.

RF Systems: A standard S-band (RF) TTC system supported by global network of ISTRAC will be used for Telemetry, Telecommand of IMS-1. To minimize the transmitted power and bandwidth and thereby cost of user terminals, it is designed that Payload and Telemetry data transmission as well as Telecommand reception are in S-band. A single Telemetry / Data transmitter is used for TM (4Kbps) / Payload data (8 Mbps). The transmitter will have RF output power of 5W for payload data transmission and 100 mW for telemetry data transmission. The modulation scheme is PCM / BPSK for both Payload and Telemetry. Payload data will be transmitted through a separate data transmission antenna with higher gain (+3dBi) and telemetry data will be transmitted through TTC antenna (0dBi). The common TM / DATA transmitter output will be switched between the TTC antenna and DATA antenna using a coaxial switch. A filter is used in the data transmission path to restrict the out of band emission. IMS-1 also has on-board a miniature SPS which is used for generating accurate position and velocity parameters used for onboard orbit determination.

Power Systems: Power system is designed to meet the requirements of a micro satellite. IMS-1 Power system supports a nominal load of 72W, peak load of 132W during MxT Payload and peak load of 120 W during HySi-T Payload operation. Power system is based on a single bus of 28 – 33V. The solar array consists of two wings, each having one panel of 0.810m x 0.720m. In order to meet the higher specific power requirements, Triple Junction Solar cells are used for power generation.. To meet the powering requirements of new packaging concept, involving cards (instead of packages) for different subsystems, common DC / DC converters are used. Additionally, a new centralized power switching and distribution scheme is used for switching and distributing the outputs of DC/DCs & Raw Bus, to different user systems. This reduces the total number of DC/DC converter requirements.

BMU & Attitude and Orbit control system: The Bus Management Unit (BMU) executes the attitude and orbit control functions like TM, TC, and attitude orientation and orbit maintenance of the spacecraft to the required accuracies. Apart from this, the BMU does the 3-axis auto acquisition and control from the moment of injection into the orbit and puts the spacecraft in safe mode sun pointing orientation in the case of contingency.

The AOCS specifications are:

Pointing accuracy	: 0.1 deg (3σ)
Drift Rate	: 5.0 X 10^{-04} ° / sec.

Four heads of 4 π Sun sensor, a miniature tri-axial magnetometer, a single head Star Sensor and Inertial Reference unit (2 DTGs) are used for attitude sensing. In Magnetometer, for one axis, a MEMS sensor is used in place of conventional sensor. There are four Micro Reaction Wheels with 0.36Nms angular momentum arranged in tetrahedron configuration for attitude control and two magnetic torquers of dipole moment of 9 Am^2 along Roll and pitch axis used during detumbling. A monopropellant Reaction control System comprising a fuel tank with 3.5 kg fuel and one 1N thruster is planned for orbit correction.

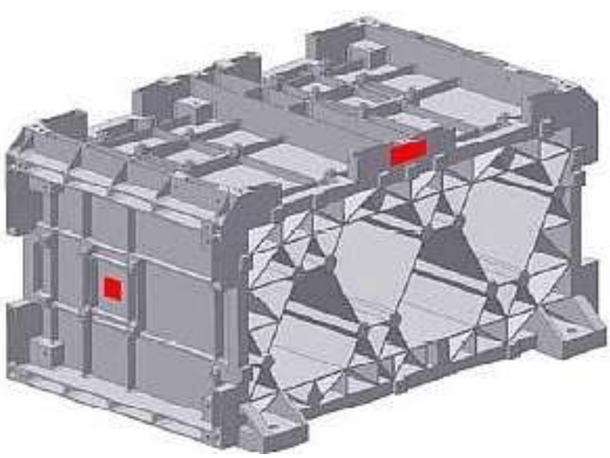
Parameter		IMS-1 (TWSAT)
Structure		Aluminum Honeycomb sandwich based Cuboid structure with a bottom deck, top deck and four cross ribs in a staggered fashion connecting the top and bottom deck.
Thermal	Components	Passive control using tapes , OSR, MLI Blankets and semi-active/active control using proportionate temperature controller and heaters
	Temp. Range	20±5 deg.C range for imaging sensors electro-optics 0 to 40 deg.C for electronic packages
Mechanism	Solar Panel	Paraffin based actuator for solar panel deployment mechanism.
Power	Solar Array	The solar array consists of two wings, each having one panel of 0.810m x 0.720m. Multi-junction cells, 206 watts @ the end of 2 years. Nominal load :72W, peak load of 132W
	Battery	Li-ion, 10.5 AH, 8S x 7P, one battery
	Electronics	Power system is based on a single bus of 28 – 33V.
Communication	Telemetry/data transmission	A single Telemetry / Data transmitter is used for TM (4Kbps) / Payload data (8 Mbps). The transmitter will have RF output power of 5W for payload data transmission and 100 mW for telemetry data transmission. The modulation scheme is PCM / BPSK for both Payload and Telemetry
	Telecommand	Modulation scheme is FM//FSK/PCM.
BMU (AOCE+TM/TC)	Attitude/Orbit sensors	Star sensor(1), 4 PI sun sensors(4), Dynamically Tuned Gyros (DTG)(2), Magnetometer, (Y) Mems (R&P) normal, SPS for orbit determination

	Attitude control	0.36 NMS, 0.018 Nm RW (4) mounted in tetrahedral configuration, Magnetic torquers(2),
	Orbit Control	Hydrazine thrusters (1 one Newton) 3.5 Kg Fuel
Payloads		MX, HYSI
Mass		87 kg

14.5 Payloads:

Payload system consists of two Payloads, namely Multi Spectral Camera and Hyper Spectral Camera

14.5.1 Multi Spectral Camera



The Mx-T is a four-band multi spectral camera with modular configuration having individual optics, detector assembly and Electronics separately for each band. The four bands selected for the instrument are identical to the previous IRS missions. The camera operates in a push broom scanning mode to image the earth. The Payload will be used for the purpose of natural resource management like Agriculture, Forest coverage and deforestation, urban infrastructure development, land use as well as disaster management.The major challenge in the design and development of camera has been to minimize size, weight and power and realization in shortest time.

14.5.1.1 Payload Configuration

The TWSAT camera is configured to be a highly compact, low weight camera commensurate with the overall mission requirements of developing a low cost and lightweight micro-satellite.

The camera, which operates in push broom mode, is multispectral with four bands in the visible and near infra red (VNIR) spanning 0.45 microns to 0.86 micron. The spectral bands, viz., Band 1 (0.45 to 0.52 micron), Band 2 (0.52 to 0.59 micron), Band 3 (0.62 to 0.68 micron) and Band 4 (0.77 to 0.86 micron) are identical to the ones used in the previous IRS missions. The nominal ground resolution is 36.87 meters from an altitude of about 638 km.

All the four bands are nadir viewing with the linear detector array being used to image the scene in across track direction of the satellite motion.

The TWSAT camera has a modular configuration with each of the four spectral bands having its individual optics, detector and associated electronics.

14.5.1.2 Multi Spectral Camera Specifications

Ground Resolution	:	36.87m
Altitude	:	636.18 km
Swath	:	151 Km
Spectral Band	:	B1 (0.45 – 0.52 μm) B2 (0.52 – 0.59 μm) B3 (0.62 – 0.68 μm) B4 (0.77 – 0.86μm)
Integration time	:	5.23 ms
Camera SWR (at Nyquist frequency) (%) (TWSAT: 70lp/mm)	:	B1:≥ 20 B2:≥ 20 B3:≥ 20 B4:≥ 10
Saturation Radiance (mW/cm^2/str/μm)	:	B1:55 B2:53 B3:47 B4:31.5
SNR (at Saturation radiance)	:	>400
Quantization (bits)	:	10
Data Rate	:	32 Mbps
No of ports	:	4
Detector	:	4 K Elements Linear CCD
Pixels per port Active	:	1024
Pixel size	:	7 x 7 Micron
Size (EOM) mm	:	300.2 x 151.7 x 227
Camera Weight (kg)	:	5.905 kg
Power (W)	:	10.4W (Four Bands) 160 mA @ 5.6V (Single Band) 90mA @ 18.7V (Single Band)

14.5.1.3 Description

The major subsystems of the Mx-T payload are

- Optics (Lens assemblies)
- Detector Head Assemblies

- Camera Electronics
- Mechanical System

Optics: The collecting optics for each of the spectral bands is an eight-element lens assembly with a thermal filter at the front and a band pass filter (to select the respective spectral range) at the rear. The optics is f/5 operating at a spatial frequency of 70 lp/mm over a field of view (fov) of ± 7 degrees.

The optical configuration consists of a multi-element lens assembly with a thermal filter at the front and a band pass filter at the rear end. All the lens elements have spherical surface profiles. The last element is a plane parallel glass window with a band pass filter coating. The choice of two types of glass for elements ensures that the focus does not change appreciably within operating temperature of 20±10°C.

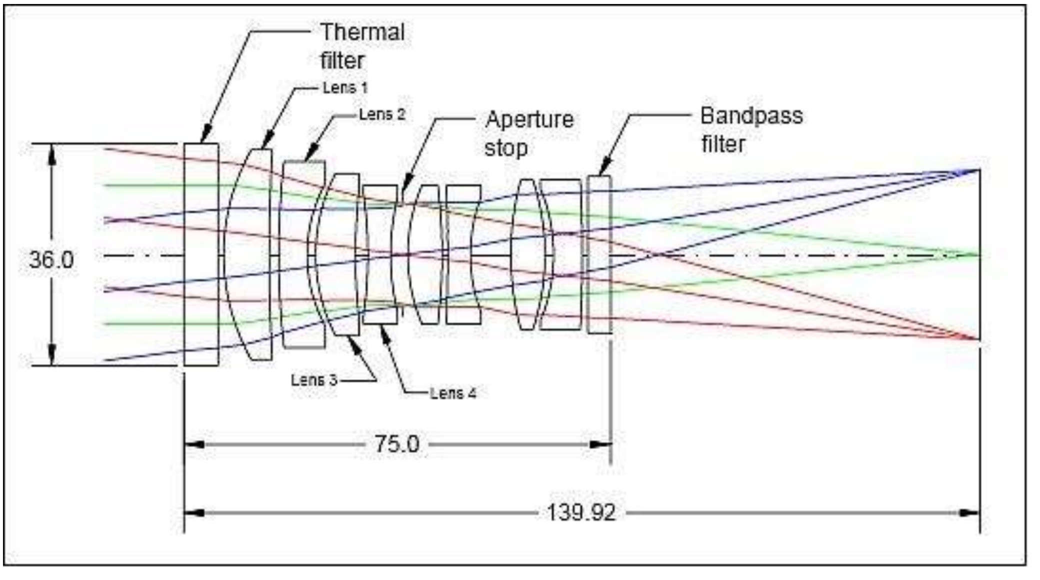


Figure 14.1 Optical Schematic of Mx

14.5.1.4 Detector Head Assembly:

Each of the four bands has a separate and identical detector head assembly (DHA), which essentially consists of a 4k linear array CCD (sc 3925a) with a pixel size of 7 micron x 7 micron, a PCB and mechanical housing. The detector is indigenously developed and qualified.

SC 3925A, 4096 elements 7X7 micron linear CCD, manufactured indigenously by SCL, Chandigarh, is used.

At each output channel, signal corresponding to 16 dummy pixels (6 isolation pixels + 4 dark pixel + 6 isolation pixels) arrives first, followed by the signal from sensitive 1024 pixels. After the 16 dummy pixel outputs, signal corresponding to end photosensitive pixels is delivered (pixel # 1 for V_{os1}, pixel #2 for V_{os2}, pixel # 4095 for Vos3 and pixel # 4096 for V_{os4}). These output signals can be processed to reconstruct the image.

All four bands have the same detector type. These devices have been source screened and qualified by the manufacturer, the SCL.

14.5.2 Hyper Spectral Camera

Hyper spectral imager (HySI-T) is the other payload in TWSAT. The Hyper-spectral imager being flown in Chandrayaan-1 is also being flown in TWSAT to evaluate and validate the payload.

Inclusion of Hyper-spectral imager in TWSAT will enhance the mission capability. The data from this instrument will be useful for ocean and atmospheric studies.

Hyper-spectral Imager is already being developed for Chandrayaan-1 using Lens, wedge filter, active pixel detector, miniaturized camera electronics etc. Same configuration is used for TWSAT hyper-spectral imager. Necessary changes have been carried out in camera electronics FPGA logic design to match the TWSAT configuration and data rate. HySI-T will be an independent chain in TWSAT. Considering the transmittable data rate limits and power availability of spacecraft, it is planned to have either the multi-spectral or hyper-spectral payload operation at a time.

14.5.2.1 Specifications

Spectral range	:	400-950nm
No of bands	:	64 fixed
Spectral separation	:	8 nm
Ground track velocity	:	6.9302 Km/s
Spatial resolution	:	505.6m
Along track sampling interval	:	543.6m
Swath	:	129.5Km
Bandwidth	:	<15nm

MTF	:	>0.2
SNR at saturation	:	>400 - 1500
No. of gains	:	1
No. of exposure settings	:	8
Clock input (BRC)	:	16MHz
WLS period	:	78.45ms
Digitization	:	16 bit
Data rate	:	4.0Mbps
Data type	:	16 bit serial
Power	:	0.8W (176mA @ 3.8V, 25mA @5.6V)
Weight	:	4 kg

14.5.2.2 Description

The major subsystems of the HySI-T payload are

- Optics (Lens assemblies)
- Detector Head Assemblies
- Camera Electronics
- Mechanical System

Optics: The collecting optics for HySI-T is a multi-element lens assembly with a thermal filter at the front. Effective focal length and F/No. are 62.5mm and 4 respectively.

Detector: A custom built area array with 512 rows and 256 columns based on active pixel technology with inbuilt 12 bit digitiser is used in HySI-T.

Spectral separation: Spectral separation is done using a wedge filter. The wedge filter is an interference filter with varying thickness along one dimension so that the spectral content transmitted through it varies in that direction. Thus when placed in front of the area array, all pixels in a given row will receive irradiance from same spectral (but different spatial) region. The pixels along a given column will receive irradiance from different spectral as well as different spatial regions. This arrangement of spectral dispersion results in spectral sampling at 1nm intervals and bandwidth of 8 nm for each row at system level.

Camera Electronics: Camera Electronics is designed around area array active pixel detector. It receives the 12 bit, 512 bands parallel data from detector. These 512 bands of over sampled data is processed to 64 bands and given to Base band data handling system. As the data is distributed in multiple integration times, the data from detector is stored. Real time data storage is incorporated in camera electronics.

Mechanical System: Camera structure is designed to hold various components like lens assembly, detector head assembly, hood etc. CE and power supply are in separate trays which are stacked together and mounted behind the camera.

Power System: HySI-T camera requires 3.8V and 5.6V power supplies and is similar to HySI Chandrayaan-1. Detector is powered though a filter which is part of power distribution system.

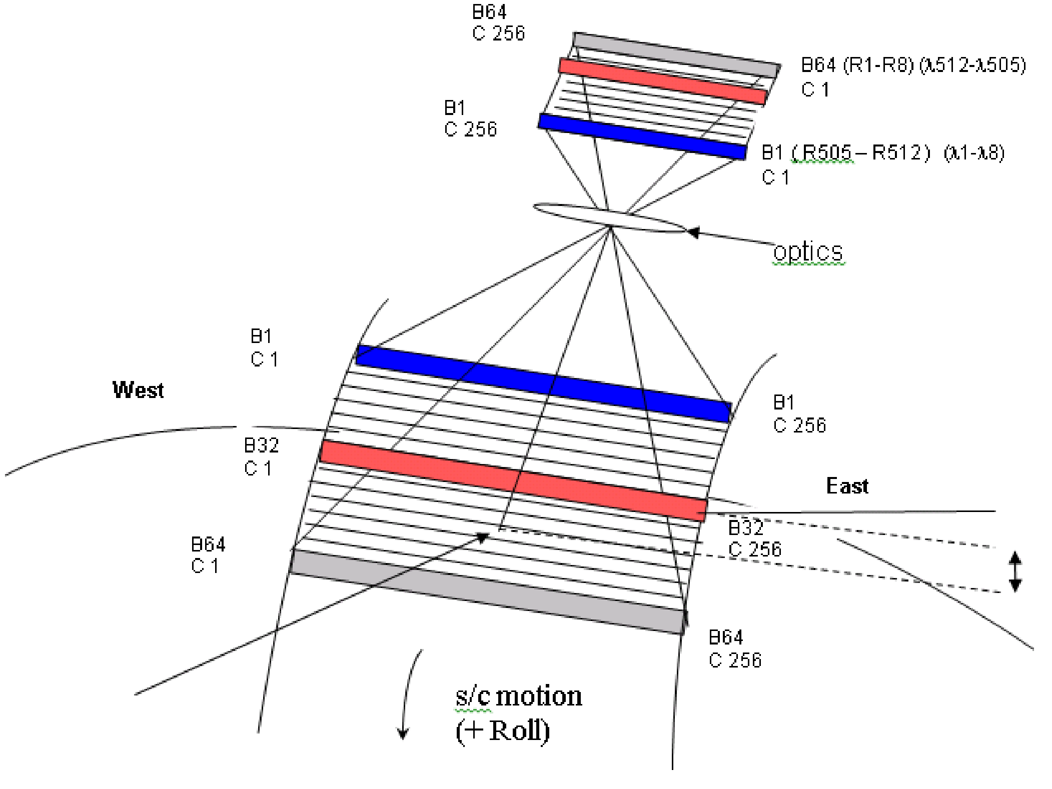


Figure 14.2 Spectral scanning and swath coverage of HySI

15 CHANDRAYAAN-1

15.1 Introduction

Chandrayaan-1 is the first Indian planetary exploration mission that performed remote sensing observation of the Moon to enhance our understanding about its origin and evolution. Chandrayaan-1 was launched successfully on October 22, 2008 from SDSC SHAR, Sriharikota. The spacecraft was orbiting around the Moon at a height of 100 km from the lunar surface for chemical, mineralogical and photo-geologic mapping of the Moon. The spacecraft carries 11 scientific instruments built in India, USA, UK, Germany, Sweden and Bulgaria.

After the successful completion of all the major mission objectives, the orbit has been raised to 200 km during May 2009.

15.2 Mission Objectives

Mission Objectives of Chandrayaan-1 are as follows

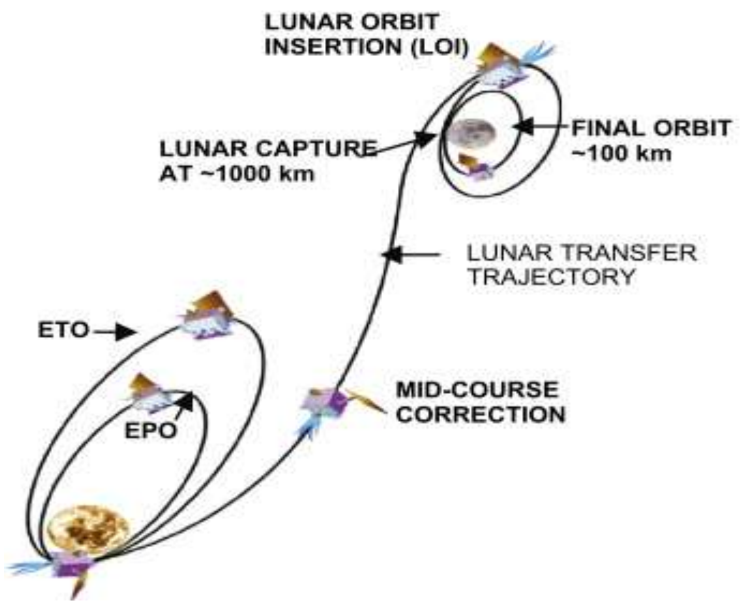
- *To realise the mission goal of harnessing the science payloads, lunar craft and the launch vehicle with suitable ground support systems including Deep Space Network station.*
- *To realise the integration and testing, launching and achieving lunar polar orbit of about 100 km, in-orbit operation of experiments, communication/ telecommand, telemetry data reception, quick look data and archival for scientific investigation by identified group of scientists.*

15.3 Orbit Details

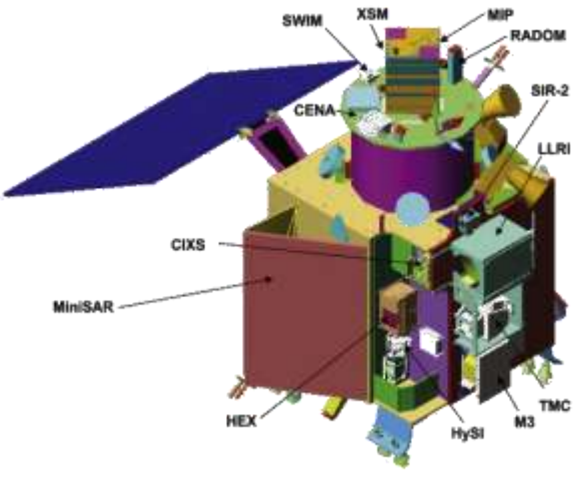
Chandrayaan-1 Mission sequence and Final orbit are shown in following picture

Table 15.1 Orbit Details

Mission	Remote Sensing, Planetary Science
Orbit	100 km x 100 km : Lunar Orbit
Launch Date	22 October 2008
Weight	1380 kg (Mass at lift off)
Launch Site	SDSC, SHAR, Sriharikota
Launch Vehicle	PSLV - C11



15.4 Salient features of Satellite



The spacecraft design is adopted from flight proven Indian Remote Sensing Satellite bus coupled with suitable modifications specific to the lunar mission. Apart from the solar array, TTC and data transmission, that are specific to the lunar mission, other aspects of system design have flight heritage. However, some changes specific to lunar mission is also incorporated. These include extending the thrust cylinder and having an upper payload deck to accommodate Moon Impact Probe(MIP) and few other payloads. Additionally, Chandrayaan-1 had a canted solar array since the orbit around the Moon is inertially fixed resulting in large variation in solar incidence angle. There is a need to have a gimbaled high gain antenna system for downloading the payload data to the Indian Deep Space Network (IDSN).

The spacecraft is a cuboids in shape of approximately 1.50 m side, with a liftoff mass of about 1.380 ton with bus element accounting for about 0.4 ton, payload about 0.1 ton and propellant about 0.8 ton. At lunar orbit it will be about 0.6 ton. This is a three-axis stabilized spacecraft generating about 750 W of peak power using canted single sided solar array and supported by a Li-Ion battery for eclipse operations. The spacecraft used bipropellant system to carry it from EPO through lunar orbit, including orbit and attitude maintenance in lunar orbit. The propulsion system carried required propellant for a mission life of two years, with adequate margin. The TTC communication is in the S-band. The scientific payload data that stored in a solid-state recorder is later played back and down linked in X-band through 20 MHz bandwidth by a steerable antenna pointing at DSN.

Table 15.2 Salient feature of Chandrayaan -1

Parameter		Chandrayaan-1
Structure		Cuboid, 1.5m x 1.3 m x 1.56m , aluminum honeycomb panels
Thermal	Components	Passive control using tapes , OSR, MLI Blankets and semi-active/active control using proportionate temperature controller and heaters, Detector cooling via heat pipe
	Temp. Range	Electronics packages ~ 0 to 40 deg. C Battery 0 to 20 Deg. C RADOM – 20 to 50 deg. C HEX -10 to 0 Deg. C
Mechanism	DGA Drive	DGA Mechanism
	Solar Array Deployment	Sada Hold down and Drive Mechanism
Power	Solar Array	709 watts, Multi junction MTJ , 3.87 m^2 Solar Array
	Battery	27 AH Li ion, 28-42 volt
	Electronics	TCR
Communication	Telemetry	HK 2 Kbps/ 1 Kbps/ 0.5 Kbps (command selectable)
	Telecommand	CCDS compatible TC system 125 bps
BMU (AOCE+TM/TC)	Attitude/Orbit sensors	CASS/ Star sensor(2),DTGs
	Attitude control	4 reaction Wheels mounted in tetrahedral , Bipropellant thrusters Accuracy: +/- 0.05 deg. Drift rate 3 x 10-4 deg/sec
	Orbit Control	Bipropellant system 440 N LAM orbit rising, 8 nos. of 22 N thrusters canted along –ve roll direction. 815 Kg Fuel Loaded
Data Handling		QPSK, 2x 8.4 Mbps

Mass (Kg)		1380

15.5 Payloads

There are 11 instruments on chandrayaan-1. Among them five are from India and six are from other space agencies.

Sl.No	Payload	Description	Organisation & Country
Scientific Payloads from India			
1	Terrain Mapping Camera (TMC)	camera in the panchromatic band having 5m spatial resolution and 40 km swath, to prepare a high resolution atlas of moon	**SAC, ISRO, India**
2	Hyper Spectral Imager (HySI)	imager operating in 400-900nm band with a spectral resolution of 15nm and spatial resolution of 80 m with a swath of 40 km, for mineralogical mapping	**SAC, ISRO, India**
3	Lunar Laser Ranging Instrument (LLRI)	for determining accurate altitude of the spacecraft above the lunar surface for topographical mapping	**LEOS,ISRO,India**
4	High Energy X - ray Spectrometer (HEX)	with a ground spatial resolution of approximately 20 km, for measuring 210Pb, 222Rn degassing, U, Th etc	**ISAC,PRL, India**
5	Moon Impact Probe(MIP)	payload for exploration of the moon from close range and impacting on the moon	**VSSC, ISRO, India**
Scientific Payloads from abroad			
1	Chandrayaan-I X-ray Spectrometer (CIXS)	X-ray spectrometer	**Rutherford Appleton Laboratory (RAL)& ISAC**
2	Near Infrared Spectrometer (SIR - 2)	Ihttp://www.cbk.waw.pl/teledetekcja/chandrayan/sir2ang.htmlnvestigations of the process of basin, Maria and crater formation on the Moon	**Max-Planck Institute, Lindau,**

3	Sub keV Atom Reflecting Analyzer (SARA)	for imaging the Moon surface using low energy neutral atoms as diagnostics in the energy range 10eV-2keV	**Swedish Institute of Space Physics**
4	Miniature Synthetic Aperture Radar (Mini SAR)	for detection of water ice in the permanently shadowed regions on the Lunar poles up to a depth of a few meters	**(NASA) Developed by JHU/APL and NAWC**
5	Moon Mineralogy Mapper (M3)	spectrometer for characterization and mapping lunar surface mineralogy in the context of lunar geologic evolution	**(NASA) Brown University and JPL.**
6	**Radiation Dose Monitor (RADOM)**	**To qualitatively and quantitatively characterize, in terms of particle flux, dose rate and deposited energy spectrum, the radiation environment in near moon space**	**Bulgarian Academy of Sciences**

15.5.1 Terrain Mapping Cameara(TMC)

The terrain mapping stereo camera (TMC) in the 500–850 nm band with three linear array detectors for nadir, fore and aft viewing and has a swath of 20 km. It provide 3D image of the lunar surface with a ground resolution of 5 m with base to height ratio of one.

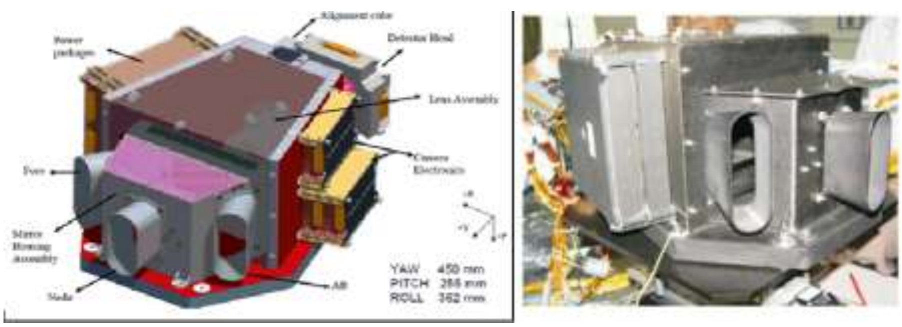


Figure 15.1 Terrain mapping Camera

Scientific Objective:

The aim of TMC is to map topography of both near and far side of the Moon and prepare a 3-dimensional atlas with high spatial and elevation resolution of 5 m. Such high resolution mapping of complete lunar surface will help to understand the evolution processes and allow detailed study of regions of scientific interests. The digital elevation model available from TMC would improve upon the existing knowledge of Lunar Topography.

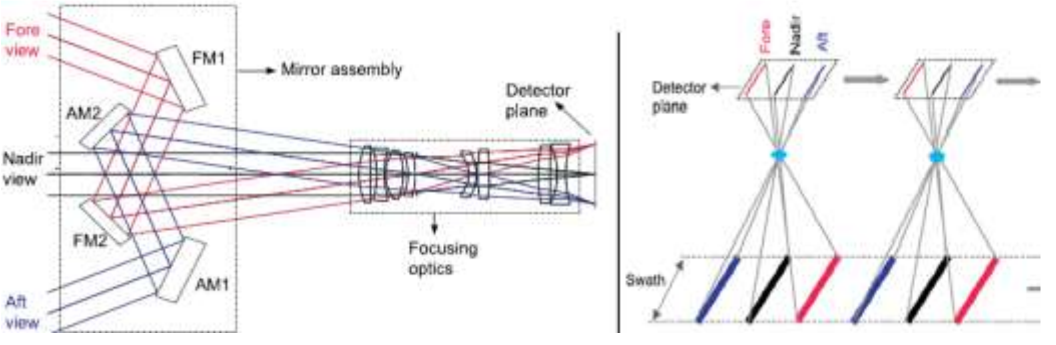


Figure 15.2 Optical Schematic and View angles of TMC

Payload Configuration Details:

The TMC images in the panchromatic spectral region of 0.5 to 0.85 µm, with a spatial/ ground resolution of 5 m and swath coverage of 20 km. The camera is configured for imaging in the push broom mode, with three linear 4k element detectors in the image plane for fore, nadir and aft views, along the ground track of the satellite. The fore and aft view angles are ±25º respectively w.r.t. Nadir.

TMC measures the solar radiation reflected / scattered from the Moon's surface. The dynamic range of reflected signal is quite large and is represented by the two extreme targets – fresh crust rocks and mature mare soil.

TMC uses Linear Active Pixel Sensor (APS) detector with in-built digitizer. Single refractive optics covers the total field of view for the three detectors. The optics is designed as a single unit catering to the wide field of view (FOV) requirement in the direction along the ground track. The incident beams from the fore (+25°) and aft (-25°) directions are directed on to the focusing optics, using mirrors. Modular camera electronics for each detector is custom designed for the system requirements using FPGA. The data rate is of the order of 50 Mbps. The dimension of TMC payload is 370 mm x 220 mm x 414 mm and mass is 6.3 kg.

15.5.2 Hyper spectral imager (HySI)

The hyper spectral imager for mineralogical mapping is operating in the 400–950 nm range employing a wedge filter coupled to an area array detector. It has 64 continuous channels with a spectral resolution better than 15 nm and a spatial (pixel) resolution of 80 m with a swath of 20 km

Scientific Objective:

To obtain spectroscopic data for mineralogical mapping of the lunar surface. The data from this instrument help in improving the available information on mineral composition of the surface of Moon. Also, the study of data in deep crater regions/central peaks, which represents lower crust or upper mantle material, helps in understanding the mineralogical composition of Moon's interior.

Payload Configuration Details:

The uniqueness of the HySI is in its capability of mapping the lunar surface in 64 contiguous bands in the VNIR, the spectral range of 0.4-0.95 µm region with a spectral resolution of better than 15 nm and spatial resolution of 80 m, with swath coverage of 20 km. HySI collects the Sun's reflected light from the Moon's surface through a tele-centric refractive optics and focus on to an APS area detector for this purpose. The dispersion is achieved by using a wedge filter so as to reduce the weight and compactness of the system compared to using a prism / grating.

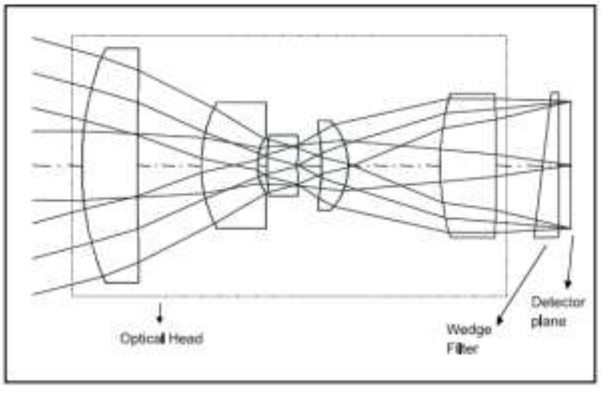


Figure 15.3 Optical Ray trace of HySI

The wedge filter is an interference filter with varying thickness along one dimension so that the transmitted spectral range varies in that direction. The wedge filter is placed in close proximity to an area detector. Thus, different pixels in a row of the detector will be receiving irradiance from the same spectral region but different spatial regions in the across track direction. In the column direction of the detector, different rows will receive irradiance of different spectral as well as spatial regions in the along track direction. The full spectrum of a target is obtained by acquiring image data in push broom mode, as the satellite moves along the column direction of the detector. An Active Pixel Sensor (APS) area array detector with built-in digitizer maps the spectral bands. The payload mass is 2.5 kg and its size is 275 mm x 255 mm x 205 mm.

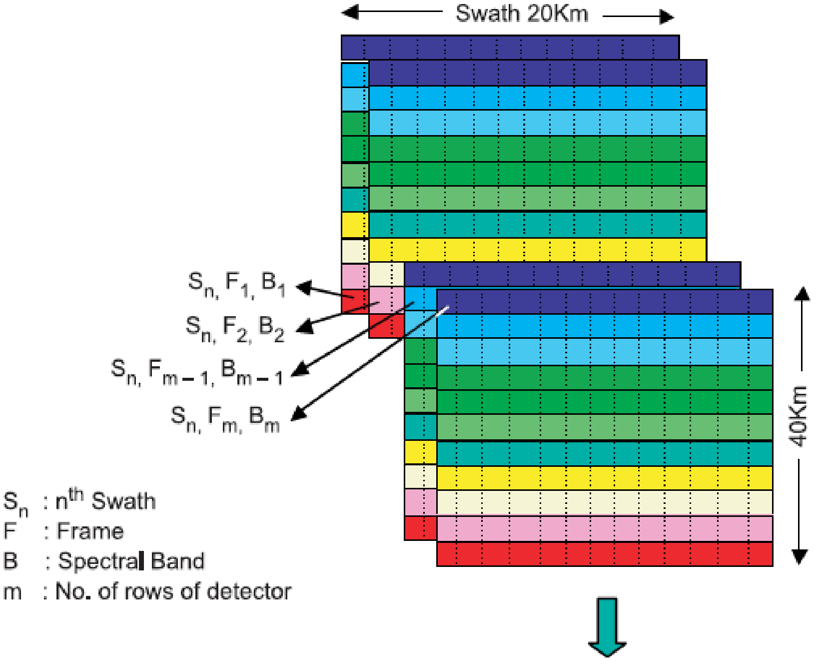
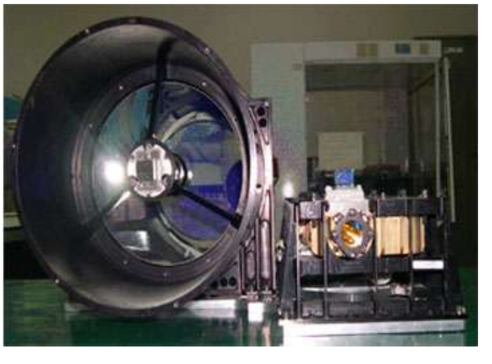


Figure 15.4 Mapping Scheme of HySI

15.5.3 Lunar laser ranging instrument (LLRI)



The LLRI employs an Nd–Yag laser with energy 10 mJ and employ a 20 cm optics receiver coupled to a Si–APD (Avalanche Photo Diode). It is operating at 10 Hz (5 ns pulse) and can provide a vertical resolution better than 5 m. The LLRI and TMC provide complementary data for generating a topographic map of the Moon and the LLRI, in particular, provide the first such data set for the polar region at higher than 80° latitude.

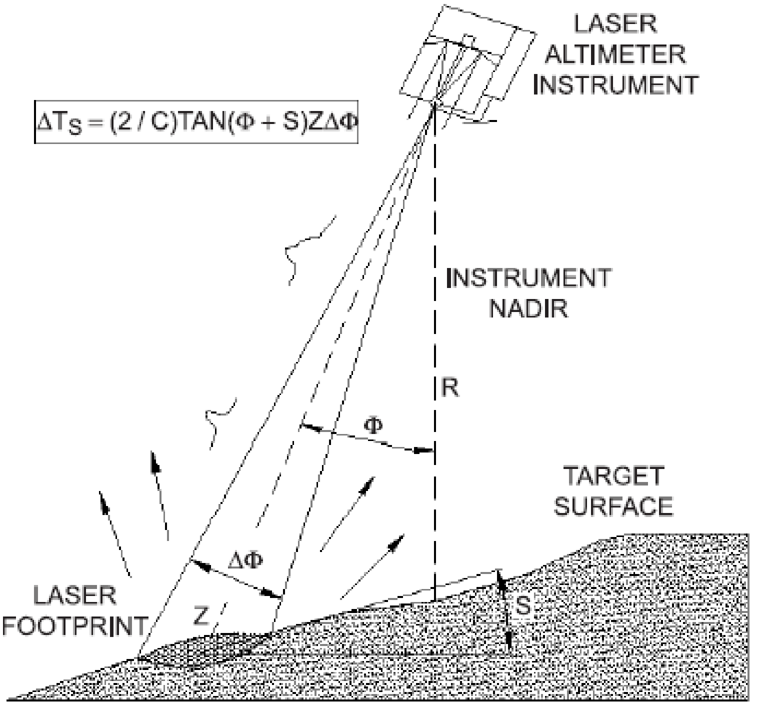


Figure 15.5: Laser pulse roundtrip - illustration

Payload Configuration Details:

LLRI works on the time-Of-Flight (TOF) principle. In this method, a coherent pulse of light from a high power laser is directed towards the target whose range is to be measured. A fraction of the light is scattered back in the direction of the laser source where an optical receiver collects it and focuses it on to a photoelectric detector. By accurately measuring the roundtrip travel time of the laser pulse, highly accurate range/spot elevation measurements can be made.

LLRI consists of a 10 mJ Nd:YAG laser with 1064 nm wave source operating at 10 Hz pulse repetition mode. The reflected laser pulse from the lunar surface is collected by a 200 mm Ritchey-Chrétien Optical receiver and focused on to a Silicon Avalanche Photodetector. The output of the detector is amplified and threshold detected for generating range information to an accuracy <5m. Four constant fraction discriminators provide the slope information in addition to range information. The different modes of operation of LLRI and the range computations from the detector output are controlled and computed by a FPGA based electronics. The processed outputs of LLRI are used for generating high accuracy lunar topography. The payload mass is 11.37 kg with base plate.

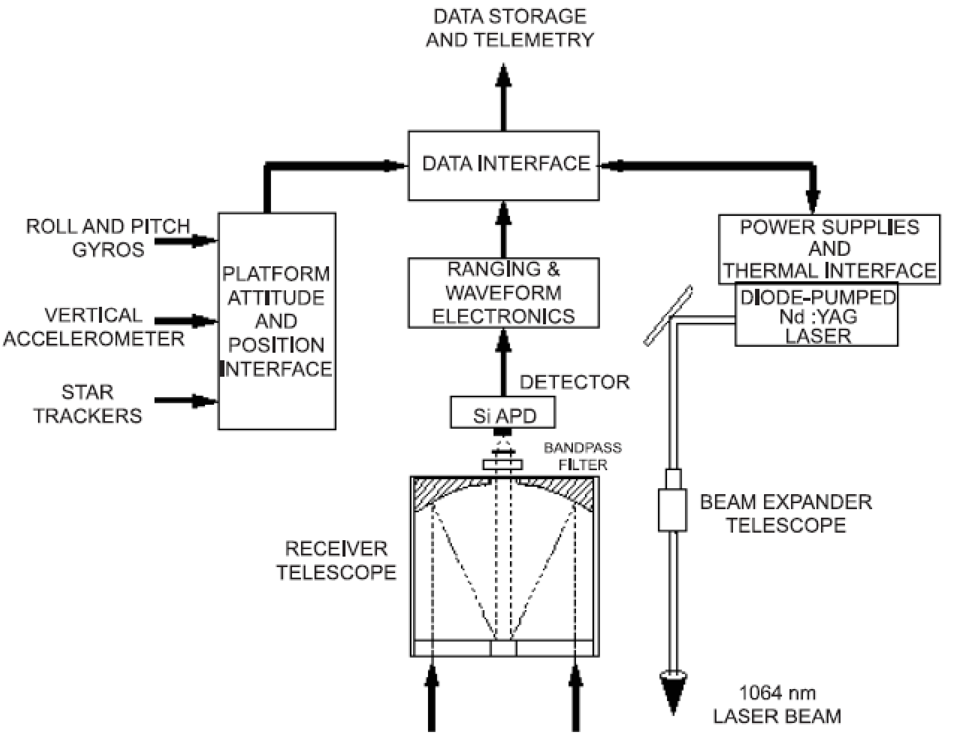


Figure 15.6: Block Schematic of LLRI

15.5.4 High energy X– *γ* ray spectrometer (HEX)

The high-energy X–*γ* ray (30–270 keV) spectrometer (HEX) employs CdZnTe solid-state detectors and has a suitable collimator providing an effective spatial resolution of 40 km in the low energy region (<60 keV). It employs a CsI anticoincidence system for reducing back-ground and is primarily intended for the study of volatile transport on Moon using the 46.5 keV *γ* ray line from ^{210}Pb decay as tracer. ^{210}Pb is a decay product of volatile ^{222}Rn and both belong to the ^{238}U decay series. The instrument has a detection threshold of <30 keV and a resolution of better than 10% at 60 keV. This instrument is to infer compositional characteristics of lunar terrain from a study of the continuum background in this energy range as well as low resolution Th and U mapping of terrains enriched in these elements

The High-Energy X-ray spectrometer covers the hard X-ray region from 30 keV to 270 keV. This is the first experiment to carry out spectral studies of planetary surface at hard X-ray energies using good energy resolution detectors. The High Energy X-ray (HEX) experiment is designed primarily to study the emission of low energy (30-270 keV) natural gamma-rays from the lunar surface due to ^{238}U and ^{232}Th and their decay chain nuclides.

15.5.5 Moon impact probe (MIP)

In addition to the primary scientific payloads, an impactor carrying a high sensitive mass spectrometer, a video camera and a radar altimeter was included in this mission. The impact probe of 35 kg mass was attached at the top deck of the main orbiter. The impactor was released at the beginning of the mission after reaching 100 x 100 km lunar polar orbit and allowed to impact in a predetermined location on the lunar surface.

During the descent phase, it is spin-stabilized. The total flying time from release to impact on Moon was around 25 minutes. Apart from the video imaging of the landing site, the onboard mass spectrometer tried to detect possible presence of trace gases in the lunar exosphere.

The primary objective is to demonstrate the technologies required for landing the probe at a desired location on the Moon and to qualify some of the technologies related to future soft landing missions.

Payload Configuration Details:

There were three instruments on the Moon Impact Probe

Radar Altimeter – for measurement of altitude of the Moon Impact Probe and for qualifying technologies for future landing missions. This is operating at 4.3 GHz ± 100 MHz.

Video Imaging System – for acquiring images of the surface of the Moon during the descent at a close range. The video imaging system consists of analog CCD camera.

Mass Spectrometer – for measuring the constituents of tenuous lunar atmosphere during descent. This instrument is based on a state-of-the-art, commercially available Quadrupole mass spectrometer with a mass resolution of 0.5 amu and sensitivities to partial pressure of the order of 10^{-14} torr.

The dimension of the impact probe is 375 mm x 375 mm x 470 mm

MIP System Configuration

The Moon Impact Probe (MIP) essentially made up of honeycomb structure, which housed all the subsystems and instruments. In addition to the instruments, it comprised of, the separation system, the de-boost spin and de-spin motors, the avionics system and thermal control system. The avionics system supported the payloads and provided communication link between MIP and the main orbiter, from separation to impact and provided a database useful for future soft landing.

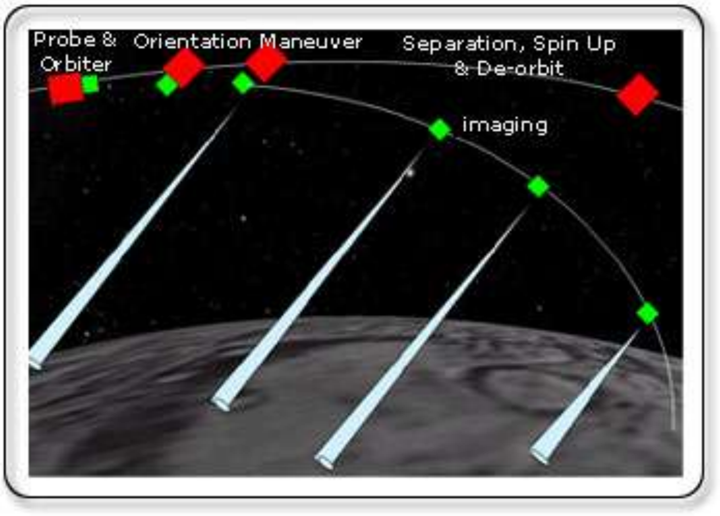


Figure 15.7 Impact Probe Mission Profile

15.5.6 Chandrayaan Imaging X-ray Spectrometer (CIXS)

Two options were considered for detection of low energy (1–10 keV) fluorescence X-rays from lunar surface; use of a thermoelectrically cooled X-ray CCD (LEX) or of a swept-charge X-ray detector (SCD) array. The final choice was SCD and CIXS, a modified version of D-CIXS instrument on board SMART-1, proposed by RAL, UK, and supported by ESA was selected in place of LEX.

This collimated LEX had a field of view of ~30 km and aimed to provide detail chemical mapping of the lunar surface for the elements, Mg, Al and Si and also for Ca, Ti and Fe during solar flare times. An X-ray solar monitor (XSM) is a part of this payload and will continuously monitor the solar X-ray flux essential for analyzing the data on fluorescence X-rays to infer absolute elemental abundance.

CIXS is collaborative payload between ISRO and RAL with a group of ISRO scientists and engineers involved in various aspects of payload design and fabrication and detector characterization.

Scientific Objective:

The primary goal of the CIXS instrument is to carry out high quality X-ray spectroscopic mapping of the Moon, in order to constrain solutions to key questions on the origin and evolution of the Moon. CIXS used X-ray fluorescence spectrometry (1.0-10 keV) to measure the elemental abundance, and map the distribution, of the three main rock forming elements: Mg, Al and Si. During periods of enhanced solar activity (solar flares) events, it was planned to determine the abundance of minor elements such as Ca, Ti and Fe on the surface of the Moon.

Payload Configuration Details:

The instrument utilised technologically innovative Swept Charge Device (SCD) X-ray sensors, which were mounted behind low profile gold/copper collimators and aluminium/polycarbonate thin film filters. The system had the virtue of providing superior X-ray detection, spectroscopic and spatial measurement capabilities, while also operating at near room temperature. A deployable proton shield protects the SCDs during passages through the Earth's radiation belts, and from major particle events in the lunar orbit. In order to record the incident solar X-ray flux at the Moon, which is needed to derive absolute lunar elemental surface abundances, CIXS also includes an X-ray Solar Monitor.

The XSM sensor unit:

The X-ray Solar Monitor (XSM) was provided through collaboration between Rutherford Appleton Laboratory (RAL) and University of Helsinki. With its wide field-of-view of ± 52 degrees, XSM provides observation of the solar X-ray spectrum from 1-20 keV with good energy resolution (< 250 keV@5.9 keV) and fast spectral sampling at 16 s intervals. The onboard solar monitor acting in real time will greatly enhance the capability of CIXS to determine absolute elemental abundances as well as their ratios. The total mass of CIXS and XSM is 5.2 kg.

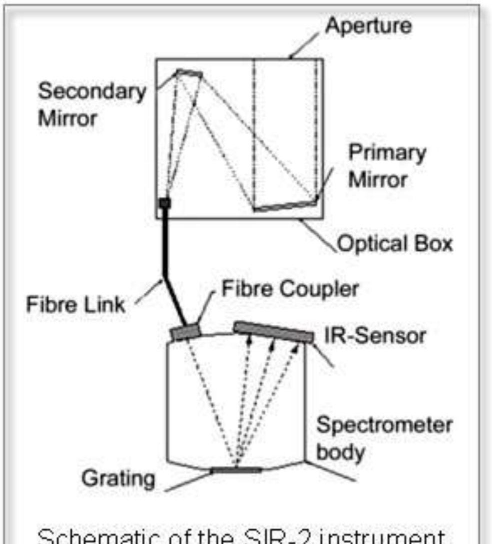
Heritage:

The CIXS instrument was primarily based on the D-CIXS instrument on the ESA SMART-1 mission. The hardware was developed at the Rutherford Appleton Laboratory, UK in collaboration with the ISRO Satellite Centre, Bangalore, and exhibits significant improvements over the instrument flown on SMART-1.

15.5.7 Near infrared spectrometer (SIR-2)

SIR-2 is an upgraded, compact, monolithic grating, near infrared point spectrometer based on SIR flown on board ESA's SMART-1 mission and covered the wavelength region 0.9–2.4 µm. The instrument has a spectral resolution of 6 nm. It is a linear CCD array based instrument with a resolution of ~80 m per pixel.

Scientific Objectives:



Schematic of the SIR-2 instrument

SIR-2 is to address the surface-related aspects of lunar science in the following broad categories:

- Analyse the lunar surface in various geological/mineralogical and topographical units;
- Study the vertical variation in composition of crust;
- Investigate the process of basin Maria and crater formation on the Moon;

- Explore “Space Weathering” processes of the lunar surface;
- Survey mineral lunar resources for future landing sites and exploration.

The determination of the chemical composition of a planet’s crust and mantle is one of the important goals of planetary research. Diagnostic absorption bands of various minerals and ices are located in the near-IR range, thus making near-infrared measurements of rocks, particularly, suitable for identifying minerals.

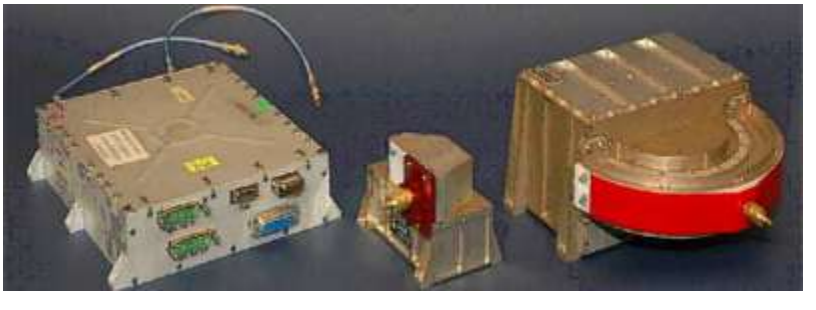
Payload Configuration:

SIR-2 is a grating NIR point spectrometer working in the 0.93-2.4 microns wavelength range with 6 nm spectral resolution. It collects the Sun’s light reflected by the Moon with the help of a main and a secondary mirror. This light is fed through an optical fiber to the instrument’s sensor head, where it is reflected off a dispersion grating. The dispersed light reaches a detector, which consists of a row of photosensitive pixels that measure the intensity as a function of wavelength and produces an electronic signal, which is read out and processed by the experiment’s electronics. The mass of the instrument is 3.3 kg and the instrument unit dimension is 260 mm x 171 mm x 143 mm.

15.5.8 Sub-keV Atom Reflecting Analyzer (SARA)

The SARA payload consists of two major subsystems, Chandrayaan-1 low energy neutral atom (CENA) and solar wind monitor (SWIM). CENA detects neutral atom sputtered from the lunar surface by solar wind ions. The CENA sensor has an energy range of 10 eV to 2 keV with an energy resolution of ~50% and can resolve groups of elements such as H, O, Na/Mg group, K/Ca group and Fe. SWIM is a simple ion mass analyzer consisting of a sensor and an energy analyzer that provides information on the energy and mass of the incident solar wind ions. Space Physics Laboratory, Thiruvananthapuram, is responsible for developing the data processing unit.

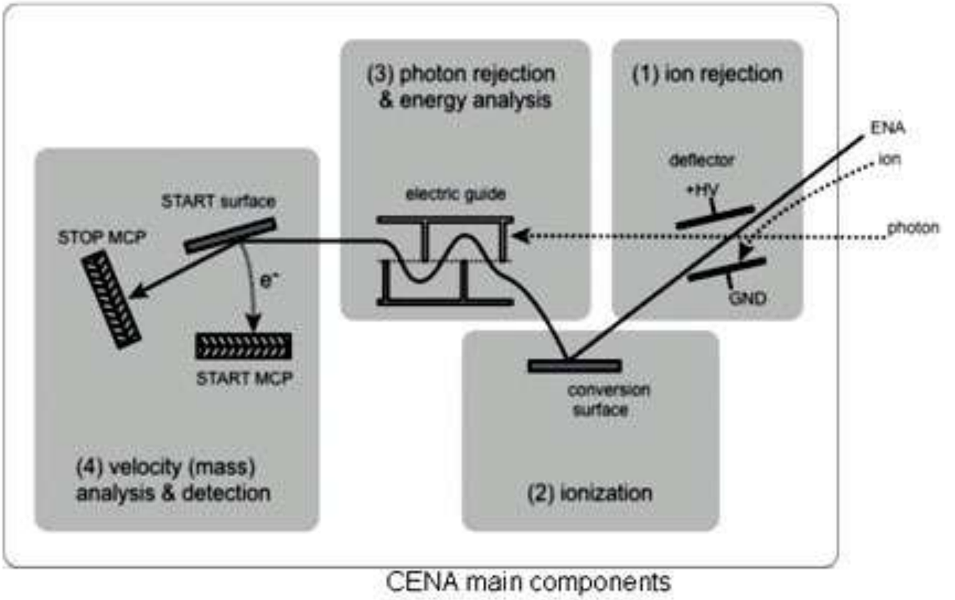
Sub keV Atom Reflecting Analyser (SARA)



Scientific Objectives: SARA will image the Moon surface using low energy neutral atoms as diagnostics in the energy range 10 eV - 3.2 keV to address the following scientific objectives:

- Imaging the Moon's surface composition including the permanently shadowed areas and volatile rich areas
- Imaging the solar wind-surface interaction
- Imaging the lunar surface magnetic anomalies
- Studies of space weathering

The Moon does not possess a magnetosphere and atmosphere. Therefore, the solar wind ions directly impinge on the lunar surface, resulting in sputtering and backscattering. The kick-off and neutralized solar wind particles leave the surface mostly as neutral atoms. The notable part of the atoms has energy exceeding the escape energy and thus, such atoms propagate along ballistic trajectories. The SARA instrument is designed to detect such atoms with sufficient angular and mass resolution to address the above scientific objectives. SARA is the first-ever energetic neutral atom imaging mass spectrometer. Payload Configuration Details: The SARA instrument consists of neutral atom sensor CENA (Chandrayaan-1 Energetic Neutrals Analyzer), solar wind monitor SWIM and DPU (Data Processing Unit). CENA and SWIM interface with DPU, which in turn interfaces with the spacecraft. The masses of CENA, SWIM and DPU are 2 kg, 0.5 kg and 2 kg respectively, totaling the SARA mass as 4.5 kg.



CENA main components

The functional blocks of CENA are shown in above figure: Low-energy neutral atoms enter through an electrostatic charged particle deflector (1), which sweeps away ambient charged particles by a static electric field. The incoming low energy neutral atoms are converted to positive ions on an ionization surface (2), and then passed through an electrostatic analyzer of a specific ("wave") shape that provides energy analysis and effectively blocks photons (3). Particles finally enter the detection section (4) where they are reflected at grazing incidence from a start surface towards one of several stop micro channel plate (MCP) detectors. Secondary electrons generated at the start surface and the stop pulses from the stop MCP detectors preserve the direction and the velocity of the incident particle. SWIM is an ion mass analyzer, optimized to provide monitoring of the precipitating ions. Ions first enter the deflector, which provides selection on the azimuth angle, following a cylindrical electrostatic analyzer. Exiting the analyzer the ions are post-accelerated up to 1 keV and enter the time-of-flight cell, where their velocity is determined by the same principle (surface reflection), as in the CENA instrument.

15.5.9 Miniature synthetic aperture radar (MINI-SAR)

Multifunction miniature radar consisting of SAR, altimeter, scatterometer and radiometer operating at 2.5 GHz will explore the permanently shadowed areas near lunar poles to look for signature of water ice. The mini-SAR system will transmit right circular polarization (RCP) and receive both left circular polarization (LCP) and RCP. The SAR system has a nominal resolution of 150 m per pixel with 8 km swath.

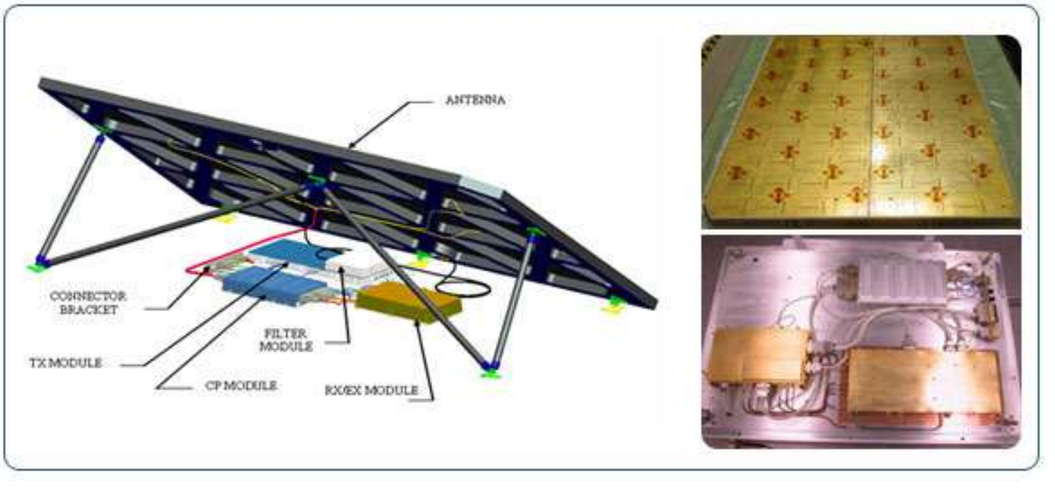


Figure 15.8: Miniature Synthetic Aperture Radar (Mini-SAR)

Scientific Objectives: To detect water ice in the permanently shadowed regions on the Lunar poles, upto a depth of a few meters. Although returned lunar samples (from earlier missions) show the Moon to be extremely dry, recent research suggest that water-ice may exist in the Polar Regions. Because its axis of rotation is perpendicular to the ecliptic plane, the poles of the Moon contain areas that never receive light and are permanently dark. This results in the creation of “cold traps”, zones that, because they are never illuminated by the sun, may be as cold as 50–70°K. Cometary debris and meteorites containing water-bearing minerals constantly bombard the Moon. Most of this water is lost to space, but, if a water molecule finds its way into a cold trap, it remains there forever – no physical process is known that can remove it. Over geological time, significant quantities of water could accumulate. An onboard SAR at suitable incidence would allow viewing of all permanently shadowed areas on the Moon, regardless of whether sunlight is available or the angle is not satisfactory. The radar would observe these areas at incidence angle near 45 degrees, recording echoes in both orthogonal senses of received polarization, allowing ice to be optimally distinguished from dry lunar surface. The Mini-SAR radar system can operate as an altimeter/scatterometer, radiometer, and as a synthetic aperture radar imager. Payload Configuration Details: The Mini-SAR system will transmit Right Circular Polarization (RCP) and receive, both Left Circular polarization (LCP) and RCP. In scatterometer mode, the system will measure the RCP and LCP response in the altimetry footprint, along the nadir ground track. In radiometer mode, the system will measure the surface RF emissivity, allowing determination of the near normal incidence Fresnel reflectivity. Meter-scale surface roughness and circular polarization ratio (CPR) will also be determined for this footprint. This allows the characterization of the radar and physical properties of the lunar surface (e.g., dielectric constant, porosity) for a network of points. When directed off nadir, the radar system will image a swath parallel to the orbital track by delay/Doppler methods (SAR mode) in both RCP and LCP. The synthetic aperture radar system works at a frequency 2.38 GHz, with a resolution of 75 m per pixel from 100 km orbit and its mass is 8.77 kg.

15.5.10 Radiation dose monitor (RADOM)

RADOM is a miniature spectrometer–dosimeter that uses a semiconductor detector and measure the deposited energy from primary and secondary particles using a 256 channel pulse analyzer. The deposited energy spectrum can then be converted to deposited dose and incident flux of charged particles on the silicon detector.

Scientific Objectives:

RADOM will qualitatively and quantitatively characterise the radiation environment in near lunar space, in terms of particle flux, dose rate and deposited energy spectrum.

The specific objectives are to

- Measure the particle flux, deposited energy spectrum, accumulated radiation dose rates in Lunar orbit;
- Provide an estimate of the radiation dose around the Moon at different altitudes and latitudes;
- Study the radiation hazards during the Moon exploration. Data obtained will be used for the evaluation of the radiation environment and the radiation shielding requirements of future manned Moon missions.

Radiation exposure of crew members on future manned space flight had been recognised as an important factor for the planning and designing of such missions. Indeed, the effects of ionising radiation on crew health, performance and life expectancy are a limitation to the duration of man's sojourn in space. Predicting the effects of radiation on humans during a long-duration space mission requires i) accurate knowledge and modeling of the space radiation environment, ii) calculation of primary and secondary particle transport through shielding materials and through the human body, and iii) assessment of the biological effects of the dose.

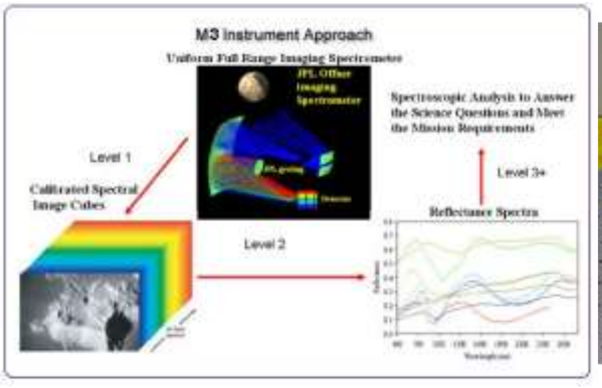
The general purpose of RADOM is to study the radiation hazards during the Moon exploration. Data obtained will be used for the evaluation of radiation environment and radiation shielding requirements for future manned lunar missions.

Payload Configuration Details:

RADOM is a miniature spectrometer-dosimeter containing one semiconductor detector of 0.3 mm thickness, one charge-sensitive preamplifier and two micro controllers. The detector weighs 139.8 mg. Pulse analysis technique is used for obtaining the deposited energy spectrum, which is further converted to the deposited dose and flux in the silicon detector. The exposure time for one spectrum is fixed at 30 s. The RADOM spectrometer will measure the spectrum of the deposited energy from primary and secondary particles in 256 channels. RADOM mass is 160 g.

15.5.11 Moon mineral mapper (MMM)

The MMM (M^3) is a high throughput push broom imaging spectrometer operating in 0.7–3.0 µm range with high spatial (70 m per pixel) and spectral (10 nm sampling) resolution. It will have a swath of 40 km. It uses a 2D HgCdTe detector array for measuring reflected solar energy in the above wavelength range.



High-resolution compositional maps by Moon Mineralogy Mapper will improve the understanding of the early evolution of a differentiated planetary body and provide a high-resolution assessment of lunar resources.

Scientific Objectives:

The primary Science goal of M3 is to characterize and map lunar surface mineralogy in the context of lunar geologic evolution. This translates into several sub-topics relating to understanding the highland crust, basaltic volcanism, impact craters, and potential volatiles. The primary exploration goal is to assess and map lunar mineral resources at high spatial resolution to support planning for future, targeted missions. These M3 goals translate directly into the following requirements:

- Accurate measurement of diagnostic absorption features of rocks and minerals;
- High spectral resolution for deconvolution into mineral components;
- High spatial resolution for assessment geologic context and active processes;

Payload Configuration Details:

The M3 scientific instrument is a high throughput pushbroom imaging spectrometer, operating in 0.7 to 3.0 µm range. It measures solar reflected energy, using a two-dimensional HgCdTe detector array featuring.

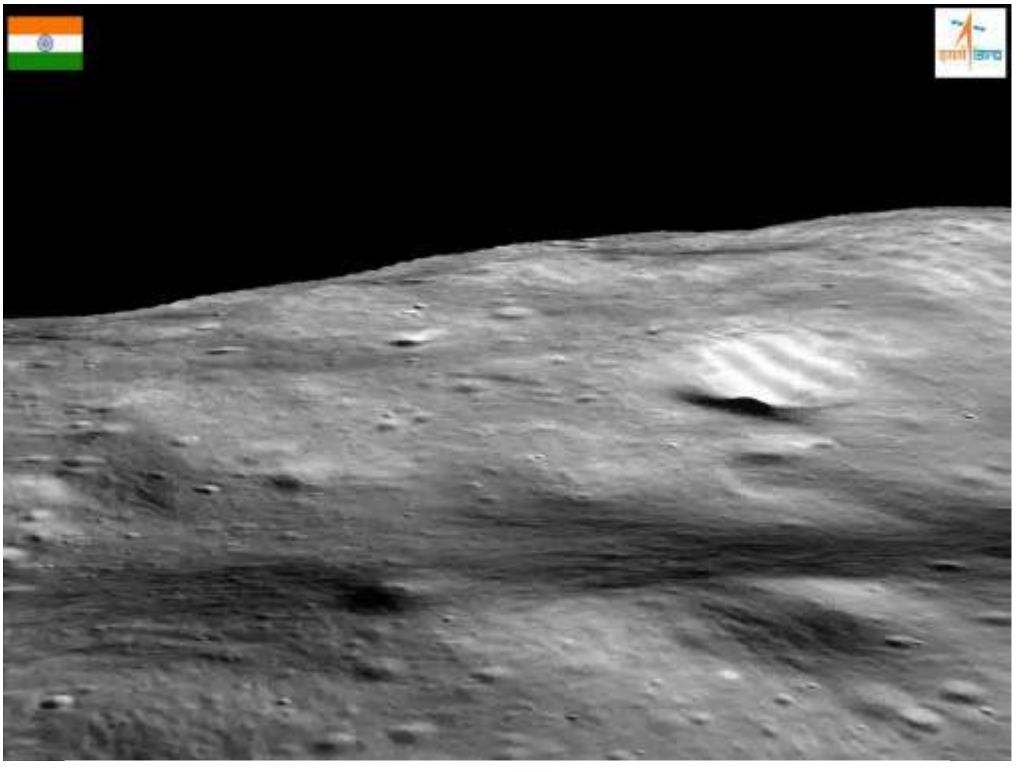
Sampling : 10 nanometers

Spatial resolution	: 70 m/pixel [from 100 km orbit]
Field of View	: 40 km [from 100 km orbit]
Mass	: 8.2 kg

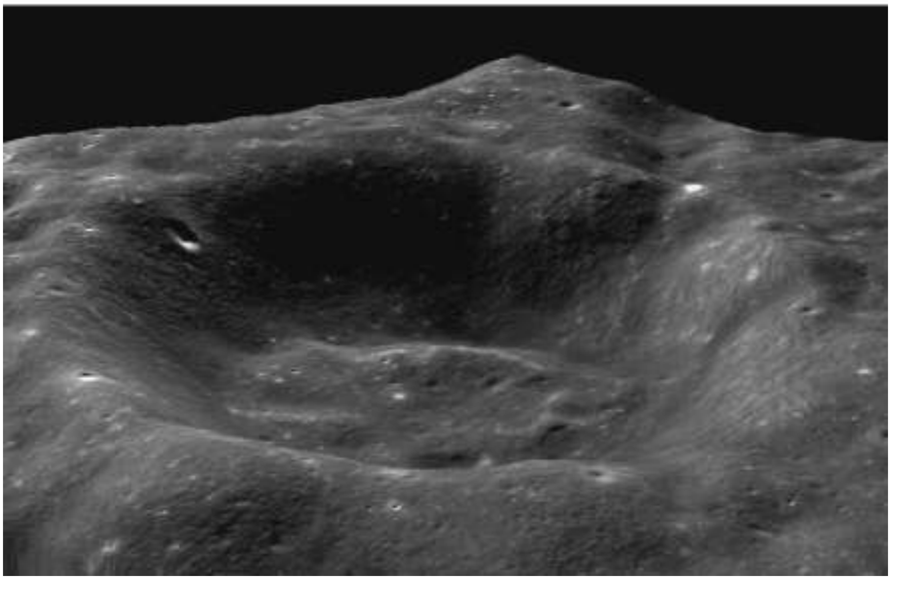
The spectral range 0.7 to 2.6 µm captures the absorption bands for the most important lunar minerals. In addition, the spectral range 2.5 to 3.0 µm is critical for detection of possible volatiles near the lunar poles. The presence of small amounts of OH or H_2O can be unambiguously identified from fundamental absorptions that occur near 3000 nm. M3 measurements are obtained for 640 cross track spatial elements and 261 spectral elements. This translates to 70 m/pixel spatial resolution and 10 nm spectral resolutions (continuous) from a nominal 100 km polar orbit for Chandrayaan-1. The M3 FOV is 40 km in order to allow contiguous orbit-to-orbit measurements at the equator that will minimize lighting condition variations.

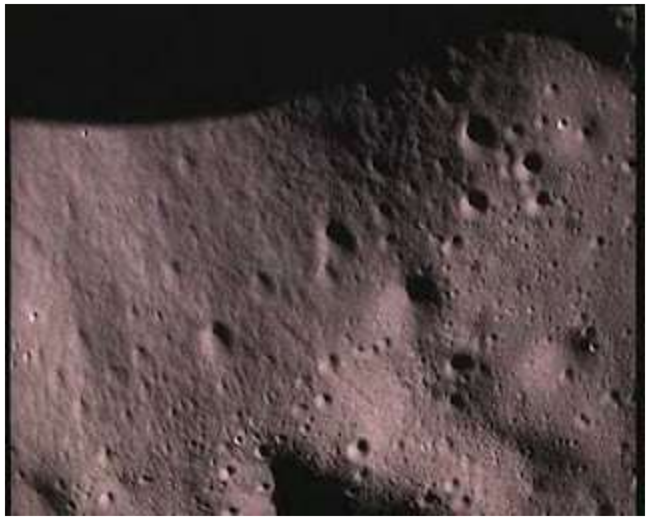
Chandrayaan-1: Summary

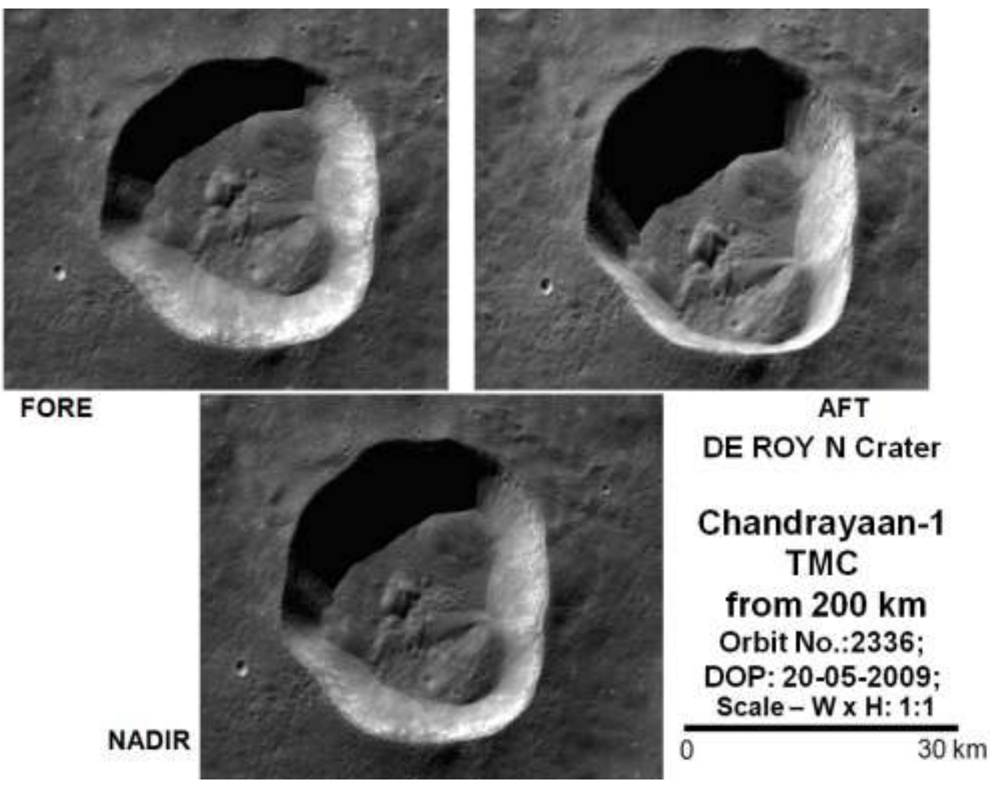
Scientific Objectives:	**Simultaneous chemical, mineralogical and photogeologic mapping of the whole moon in visible, near infrared, low and high energy X-rays with high spatial resolution**
Scientific Payloads	**Terrain Mapping Camera-TMC** **Hyper Spectral Imager-HySI** **Lunar Laser ranging Instrument-LLRI** **Low Energy X-ray Spectrometer-LEX** **Solar X-ray Monitor- SXM** **High Energy X-ray /γ-ray Spectrometer-HEX**
Payload Weight	**55kg (Including 10kg Announcement of Opportunity payload)**
Launcher	**Polar Satellite Launch Vehicle-PSLV-XL**
Mission Strategy	**Elliptic Parking Orbit. Trans Lunar Injection. Lunar Orbit Insertion**
Lunar Orbit	**100 X 100 km Circular Polar**
Operational Life Time	**Two Years**
Spacecraft	**Cuboid shape, 1.5 m side, 3-axis stabilized**
Spacecraft Mass	**Dry mass-440kg, Initial Lunar Orbit Mass with propellant-524kg**
Communication System	**S-Band uplink for telecommand, S-Band downlink for telemetry, X-Band for Payload data reception**
Deep Space Network (DSN) Station	**Location : Bangalore, Fully steerable dual feed 32m-dia antenna**
Mission Control Centre	**Location : Bangalore-responsible for all spacecraft operations, running of ground infrastructure**
National Science Data Centre (NSDC)	**Act as repository of scientific data Centre (NSDC) from experiments conducted on-board Chandrayaan-1**



2.5D Visualisation (Coulomb C Crater)



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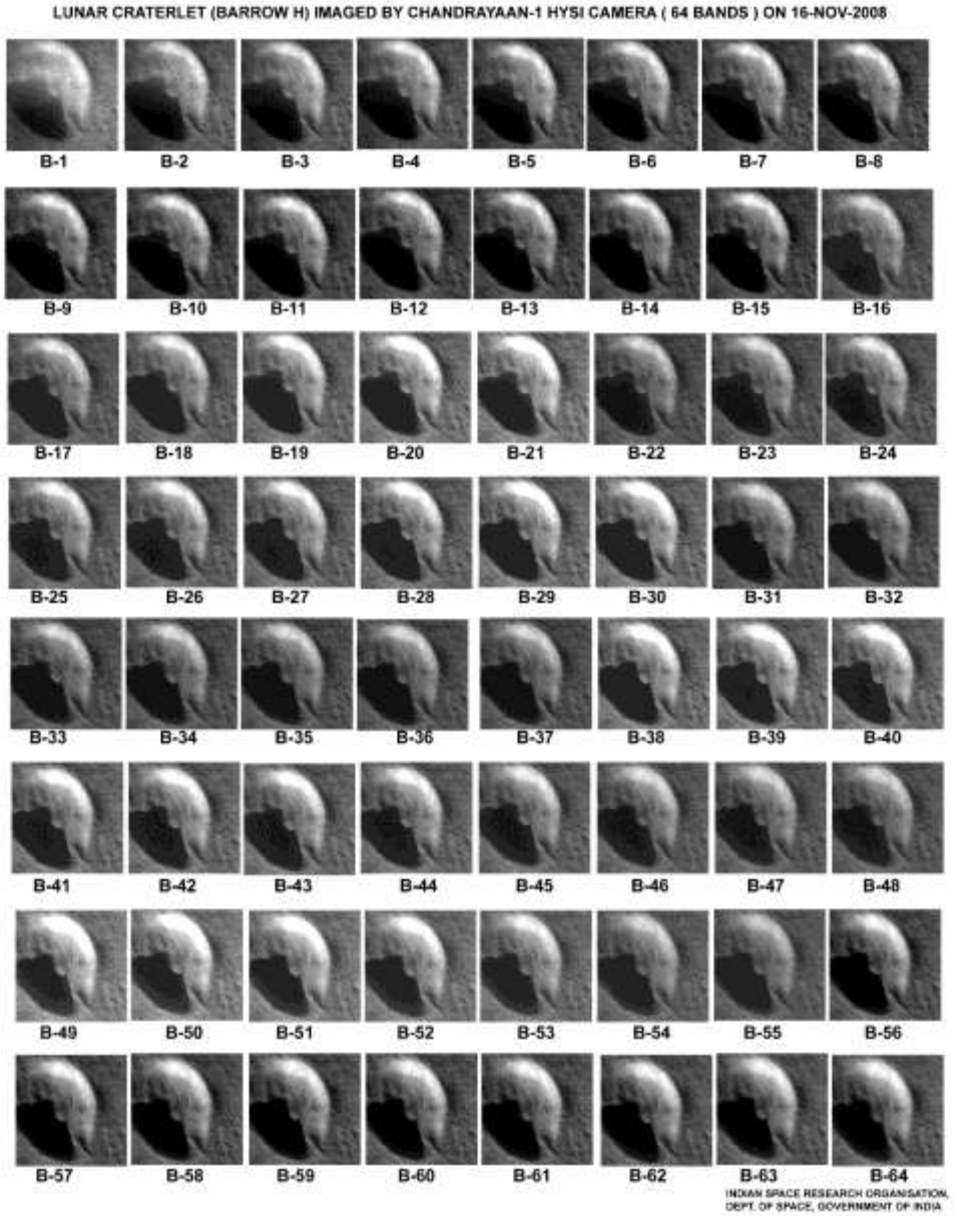
LUNAR CRATERLET (BARROW H) IMAGED BY CHANDRAYAAN-1 HYSI CAMERA (64 BANDS) ON 16-NOV-2008
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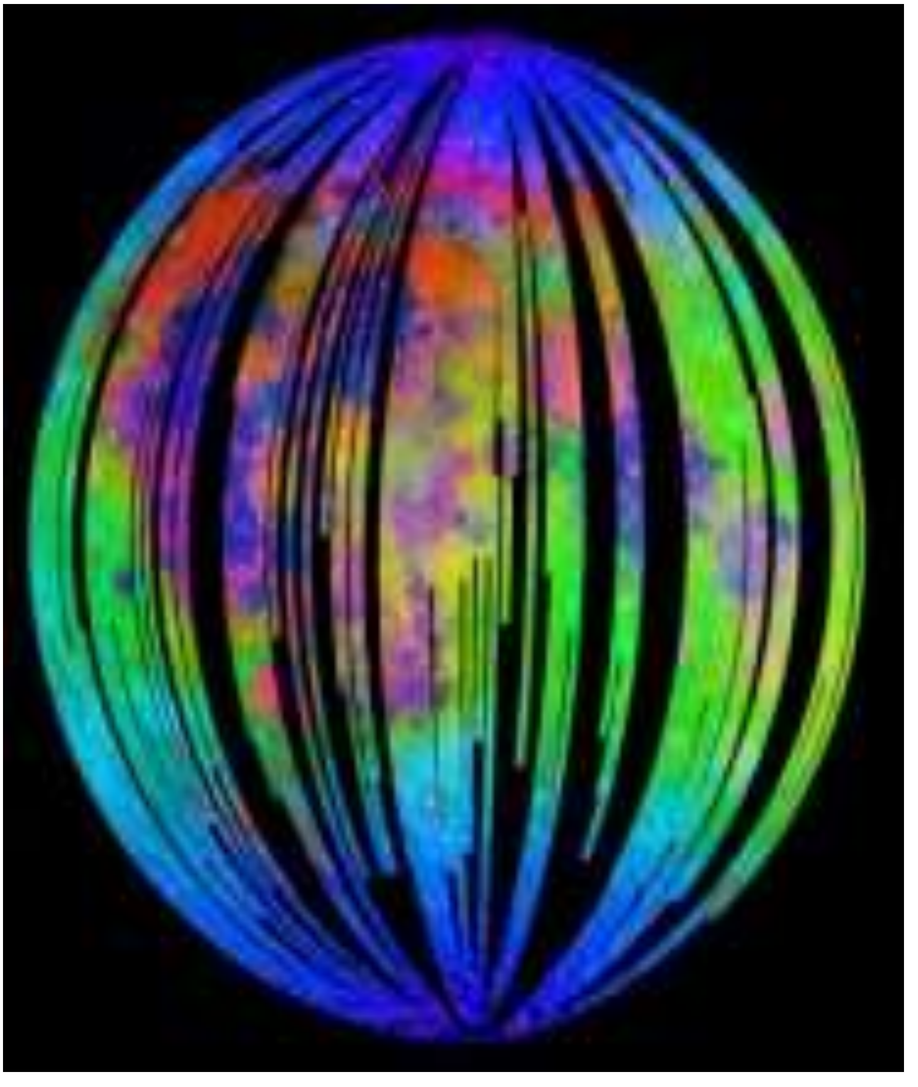
INDIAN SPACE RESEARCH ORGANISATION,
DEPT. OF SPACE, GOVERNMENT OF INDIA



Water mapping of moon from M^3 Payload

16 OCEANSAT-2

16.1 Introduction

Oceansat-2 spacecraft provides continuation of services of IRS-P4 with enhanced application areas. Oceansat-2 is a 3-axis stabilized spacecraft basically derived from I-1.5K IRS bus with proven mainframe systems.

Oceansat-2 carries three payloads - Ocean Colour Monitor (OCM-2), Ku-band Scatterometer and Radio Occultation Sounder for Atmosphere (ROSA). OCM is a multi-spectral optical camera, providing ocean colour data with repetivity of two days. It provides a ground IFOV of 360 m in across track and 246 m in along track directions covering a swath of 1420 Km. The camera can be tilted by ± 20 ° with respect to nadir in the along-track direction to avoid sun glint from sea surface.

The Ku band pencil beam scatterometer is an active microwave sensor for measurement of wind speed and wind direction. It consists of a parabolic dish antenna of 1m diameter that is continuously rotated at 20.5 rpm using a scan mechanism with the scan axis along the +Yaw axis. This antenna is arrested during launch and released in orbit for the operations.

The ROSA is a GPS Receiver for atmospheric sounding by radio occultation. The GPS receiver determines position, velocity and time using GPS signals. Besides, ROSA receives RF signals from the 'rising' GPS satellites near Earth's horizon through its occultation antenna and from the excess phase delay and Doppler measurements, atmospheric parameters (Temperature, humidity, pressure) can be derived.

During operational phase of the spacecraft, Scatterometer and ROSA payloads are continuously ON and OCM will be switched ON during sun-lit passes over oceans as per user requirements.

16.2 Mission Objective

The mission objectives of Oceansat-2 are

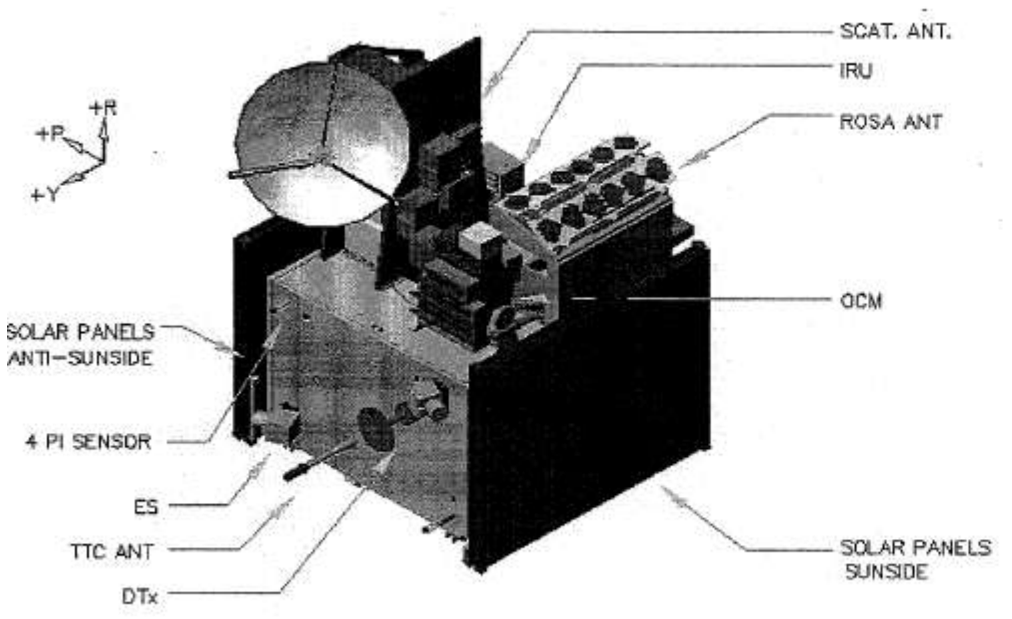
- *To design, develop, launch and operate a state of art 3 axis body stabilized satellite providing ocean based remote sensing services to the user communities*
- *To develop remote sensing capabilities with respect to Ocean resources*
- *To establish ground segment to receive and process the payload data.*
- *To develop related algorithms and data products*

- *To serve in well established application areas and also to ensure the mission utility.*

16.3 Orbit details

Type	SSPO
Altitude (Km)	720
Inclination (Deg)	98.28
Period (Min)	99.31
Local Time	12.00 Noon ± 10 min
Repeat Cycle	2 Days
Distance between adjacent traces	1382 Km.
Distance between successive ground track	2764 Km
Ground Track Velocity	6.7818 Km/s

16.4 Salient features of Oceansat-2



16.5 Payloads

There are two main payloads in Oceansat-2, namely, an Ocean Colour Monitor (OCM) and Ku-band Pencil beam Scatterometer. In addition, a piggy-back payload called the Radio Occultation Sounder for the Atmosphere (ROSA) developed by the Italian Space Agency will also be flown on-board Oceansat-2. While the OCM provides data on the bio-physical properties of global oceans like Chlorophyll concentration, suspended sediments, algal blooms etc., the Scatterometer provides data from which the surface Wind velocity (both speed and direction) over ocean surface will be derived. ROSA is an atmospheric sounder and provides data on Temperature and Humidity profiles in the troposphere as well as space weather.

A brief description of these payloads is given in the following paragraphs.

16.5.1 OCEAN COLOR MONITOR

The Ocean Color Monitor (OCM) is a solid state CCD camera and operates in eight narrow spectral bands with 360m along-track and 243m across-track ground resolution covering a swath of 1420Km from 720Km altitude. All the eight bands are in Visible and Near Infrared region having spectral bands between 0.4µm and 0.885µm. Since the local time of pass for Oceansat-2 is 12noon, provision is made to tilt the Electro-Optics module about the Pitch axis by ±20º with reference to nadir to avoid the sun glint from sea surface. During launch the EO Module will be held by hold-down mechanism, which will be released in-orbit using a pyro cutter.

The OCM payload consists of the following systems

Electro-Optics Module (EOM)
Payload Electronics (PLE)
Power converters and regulators (OPC / OPR)

16.5.1.1 Specifications of OCM

IGFOV	:	360m (Across track)
GSD	:	252m (Along track)
Swath	:	>1420Km
Repetivity	:	2 days
Quantisation	:	12 bits
SNR @ saturation	:	> 512

Spectral bands (missions)

Band-1	0.402-0.422	Band-5	0.545-0.565
Band-2	0.433-0.453	Band-6	0.610-0.630
Band-3	0.480-0.500	Band-7	0.725-0.755
Band-4	0.500-0.520	Band-8	0.845-0.885

Saturation Radiance (mW/cm^2/sr/µm) @ max exposure

Band-1	35.5	Band-5	22.4
Band-2	28.5	Band-6	18.1
Band-3	22.8	Band-7	9.0
Band-4	25.7	Band-8	17.2

Integration time	:	34.75ms
Detector	:	CCD191A
Number of pixels	:	Total 6000
		Used 3730
Video readout rate /port	:	86.6KHz
Data rate / band	:	2.08Mbits/s
Total Data rate generated	:	16.64Mbits/ s
Band-to-band registration	:	<$\pm$ 0.25 Pixel
Camera MTF (@ Nyquist frequency)	:	>0.2

Size (mm) E-O module	:	Roll	701
		Pitch	527
		Yaw	420
Weight (Kg)			
EO module	:	64	
Camera	:	78 (w/o power modules)	
Power (Regulated)			
Imaging mode	:	130W	
Calibration mode	:	132W	

16.5.1.2 Electro-Optics Module (EOM)

The EO Module consists of imaging lens assemblies, EOM Structure, Detector head assembly; Detector electronics and payload tilt mechanism

Optical system

It consists of eight spectral bands in visible and near infrared region having spectral bands between 0.4µm and 0.885µm with 20nm band width for bands B1 to B6 30nm bandwidth for band B7 and 40nm bandwidth for B8. Each band consists of its own imaging Lens assembly and a linear array detector (CCD). The optical system consists of 10 refractive lens elements, a thermal filter in front and interference filter. To cover the wide field-of-view ($\pm$ 43º), the first lens element is realized with parabolic surface. A "tele-centric" optical system is selected to provide minimum distortion, uniformity of illumination and good MTF over the wide field angle.

Transmission of the lens is improved by providing anti-reflection coating. The band pass function is achieved by using an interferential filter located after the lenses, at the end of the objectives. This filter has two substrates, each one having two faces coated.

16.5.1.3 Optical system specification

Equivalent focal length (EFL) (mm)	:	20.0±0.1
F-number	:	0.3 for B1 & B2
	:	0.5 for B3 to B8
Field of View	:	± 43º (86º total)
Clear working distance (mm)	:	>16
Distortion	:	< ±0.02%
MTF(@ 50 lp/mm)	:	> 0.6

16.5.1.4 EOM structure

The main structure of EO module is made out of single block of Al. Alloy 6061 material. This material is selected for its matching coefficient of thermal expansion, which helps in maintaining the separation between the lens focal plane and detector within ± 2.0µ over a temperature variation of 15 ± 2º C. Four thermal covers fitted on the EOM will cover the EO module on +ve Yaw, -Ve Yaw, +ve pitch and –ve pitch direction. Thermal cover is black painted on its inside surfaces and covered by MLI blanket outside. Auto-control heaters are mounted on the inside surface of thermal cover. Lens side and detector side thermal covers have one cutout for viewing and wire harness. A common hood with a slit aperture is placed in front of each row of the lenses. These hoods limit the Field of View of the lenses to ±45º in pitch-yaw plane and ±2º in roll-yaw plane w.r.t the optical axis. The interface for the Tilt mechanism gimbal shaft is provided on the Pitch axis sides of EOM. The EOM is held-down at an angle of –23º in the launch configuration.

16.5.1.5 OCM Electronics

The OCM electronics is modular and satisfies the mission goal that no single point failure shall lead to non-availability of two or more bands data. It has separate electronics for each band without any redundancy. But cross coupling exists between camera electronics and BDH.

OCM Electronics can be functionally divided into following three portions

- Detector Head Assembly
- Detector Electronics
- Video processing Electronics

16.5.1.6 Detector head assembly

A 6000 element of 7 x 10µm pixel size linear arrays CCD (CCD191A same as that used in IRS-P4) is used as detector. Out of 6000 active pixels available in the CCD, 3730 central pixels are used for imaging. For the dark current estimation and subtraction from video data, 150 pixels on either edge of the CCD are used.

Each band lens assembly has different back focal length. Suitable spacers are used to place the Detector in the focal plane. Considering the variation of the focal length with reference to temperature the most matching material is found to be aluminum. However CCD is made out of ceramic, which has very low coefficient of Thermal Expansion (CTE). Hence Invar material is chosen for CCD Holder. Thermal stability among these two dissimilar materials will be achieved by using a dowel screw at one end and free screw at other end. Two LED holders are located on the detector head. Each LED holder would accommodate two LEDs used for on-board calibration.

16.5.1.7 Calibration

Four LEDs of type HP 1N6092 are mounted on the detector mount. Their optical axis is at 71º from the normal due to the limited space between the detector and the imaging optics. In view of this large angle, the LEDs illuminate a larger photosensitive area compared to the imaging mode in the lateral direction of the detector array. Sixteen distinct calibration levels will be set using digitally altered exposure time method. The signal range coverage would be about 70% of the full range. The expected non-uniformity of the illumination using calibration LEDs is better than ± 50% with respect to the array mean calibration count.

16.5.2 Ku-BAND SCATTEROMETER

16.5.2.1 Introduction

The main objective of the Scatterometer Payload onboard OCEANSAT-2 is to gather the information about the near surface winds over oceans at a global level which form a very important input to the global weather forecasting system.

The near surface wind mostly modulates the capillary waves on the ocean surface whose wave length is of the order of centimeters. Previous missions carried Scatterometers operating in both C-band and Ku-band frequencies. The examples of the C-band Scatterometer are ERS-1 & 2, and the recent Advanced Scatterometer (ASCAT) onboard METOP satellite. Ku-band missions include SeaSAT, NSCAT and SeaWinds Scatterometer on QuickScat and ADEOS-II satellites. Looking at the already established sensitivity of the Ku-Band frequencies to the wind vector and the wide applications and significant research being carried out using the data from NSCAT and SeaWinds and the available primary allocation, Ku-band was chosen for the Oceansat-2 mission.

Figure 16.1 Scatterometer

Characteristics of System

Parameter	Inner beam	Outer beam
Satellite Altitude	720Km	
Principal Axis Pointing angle	46º	
Frequency	13.515625GHz	
Wavelength	0.0221965m	
Wind Speed	4 – 24m/s with accuracy of 10 % or 2 m/s whichever is higher	
Wind direction	0 – 360ºwith accuracy of 20º deg.	
Swath (qualified)	1400Km	
Polarization	HH	VV

Parameter	Inner beam	Outer beam
Basic Sigma naught cell (Center)	26Km x 6.8Km	**31Km x 5.8Km**
Kp over Basic sigma naught Cell without error (4 m/s cross wind)	1.32-3.49 over 5 cells around beam centre	**1.89-3.02 over 5 cells around beam centre**
Kp over Basic sigma naught Cell without error (24m/s cross wind)	0.28-0.3 over 5 cells around beam centre	**0.3-0.33 over 5 cells around beam centre**
Slant Range(Km) 1208	1031	**1208**
One Way 3dB Foot Print Az(Km)xEl(Km)	26 X 46	**31 X 65**
Along Track Spacing (Km)	19.7	**19.7**
Along Scan Spacing (Km)	16.3	**21**
Across Scan Overlap (Varies with Azimuth position)	28% to 48%	**29% to 71%**
Along Scan Overlap	41%	**34%**
Cell Center Doppler (Excluding Earth rotation) **-0.25 Deg Pointing Error (KHz)** **0.00 Deg Pointing Error (KHz)** **+0.25 º Pointing Error (KHz)**	 ± 455.69 ± 457.86 ± 460.03	 **± 510.54** **± 512.47** **± 514.38**
Earth Rotation Doppler (Equator)	± 29KHz	**± 31KHz**
σ_0Parameters (dB) **4m Cross Wind (Qualified)** **24m Up Wind (Qualified)**	 -31.3 -10.9	 **-29.8** **-12.4**
Antenna Specifications **Antenna Diameter** **Angular Separation of Feeds** **Peak Gain** **Beam width (Al. Scan. X Ac. Scan)**	 **1m** **6.76º** **39.5dBi** **1.47º x 1.67º**	
Transmitter Specifications **Transmit Power** **Transmit Duty Cycle**	 **100W** **27%**	

Parameter	Inner beam	Outer beam
Transmit PRF for system(Nominal) Transmit PulseWidth **Transmit Modulation** **Transmit Chirp Bandwidth**	**193Hz** **1.35ms** **LFM** **400KHz**	
Receiver Specifications **Receiver Type** **O/P Bandwidth** **Gain control (controlled by 6-bit gain control telecommand)** **Receiver Pathloss (dB)** **Noise figure (dB)** **Input Noise Power** **Receiver output**	**Single Channel Output on IF of 15.625MHz** **15.625MHz ±800KHz** **45dB to 109dB** **3** **3** **-109dBm over 1600KHz bandwidth** **500m V p-p across 50 Ω resistance**	

Antenna Sub-System

The 1 mtr dia antenna reflector is a prime focal parabolic dish with a focal length of 0.4 meter. The vertex of the dish is offset from the mounting interface by 180 mm (approx.). The reflector dish is fixed at a tilt of 46^0 about the + yaw axis in the yaw-wave-guide plane. In the launch condition, the reflector assembly is rotated by 30^0 clockwise, about the yaw axis (when viewed from the positive yaw axis). Three CFRP tubes (called Spars) support the feed horns of the antenna. The wave-guide is to be routed along one of the three Feed Support tubes. Two feed horns are used for generating the two beams (Outer & Inner) with different polarizations at specified look angles. The Antenna is attached to the Scatterometer scan mechanism to mechanically spin the parabolic reflector along with the feeds around scan axis coinciding with the +ve yaw axis of the satellite. The rear side of the antenna is white painted and the feed assembly is covered with MLI blanket as per the Thermal design.

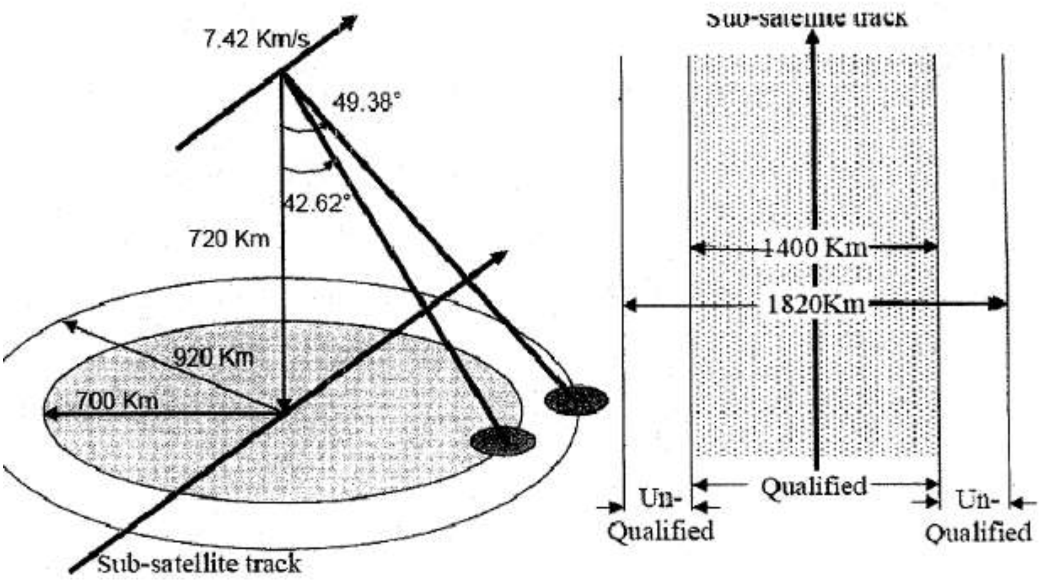


Figure 16.2 Scatterometer Swath coverage

Specifications of Scatterometer antenna reflector

Diameter of dish	:1000mm
Outer diameter of dish	:1014mm (max. permitted)
Focal length	:400mm
Shape	:Axis-symmetric paraboloid
Angle of tilt (With respect to spin axis)	: 46.0 ± 0.01^0
RMS error	:0.1mm
Mass	:<10Kg
No. of feed support tubes (FST)	:3
Diameter of FST	:20mm (max. permitted)
Feed bracket mass	:0.4Kg
Feed adjustment (along reflector axis)	: $\pm$ 10mm

16.5.2.2 Dual Channel Wave guide Rotary Joint

Space qualified dual channel microwave rotary joint for Ku-band has been developed in-house for pencil beam scanning scatterometer payload onboard Oceansat-2 after performing electrical, mechanical, thermal and environmental qualifications. The conical scanning is effected by mechanically rotating the scatterometer antenna about the yaw axis at 20.5 rpm using a scan mechanism. The two feeds of the reflector antenna for scatterometer payload are fed with microwave signal through the dual channel rotary joint. The stationary part of the joint is mounted to the satellite deck through waveguide plumbing. The specifications of the Rotary joint are given below.

Specifications for the Dual Channel Rotary Joint

Frequency	:	13.515625GHz
Bandwidth	:	± 25MHz
Return Loss (max)	:	Ch1: >19dB Ch2: >19dB
Insertion loss (max)	:	Ch1: 0.35dB Ch2: 0.35dB
Isolation	:	40dB
Insertion loss – variation within a single scan	:	Ch1: ± 0.05dB Ch2 : ±0.05dB
Peak power	:	Peak 140W, 34%DC
EMI/EMC Results	:	67 dB µVolt/m Test type – RE102 MIL-STD 461 E

16.5.2.3 SCATTEROMETER SCAN MECHANISM (SSM)

The Scatterometer Scan Mechanism is used to rotate the Antenna reflector along with its Feeds and waveguide assembly and Rotary joint at a constant rate of 20.5rpm. It consists of a brushless DC motor and its Drive Electronics.

The functional requirements of Scatterometer Scan Mechanism are

- To provide necessary mechanical interface and rotate antenna, feed system, which weighs 10Kg, at 20.5 rpm about the precision axis of rotation with scan stability of 0.1%.
- Provide necessary mechanical interface for microwave rotary joint stator & rotor part
- To accommodate the rotary joint stator part.
- Provide accurate scanning position information with accuracy of 0.01º on interrogation at PRF
- Provide mechanical interface to payload deck.
- Define scatterometer relative orientation and position w. r. to payload reference frame/bus reference frame.
- Precise static and dynamic balancing of rotating parts.
- Provide redundancy in drive motor, angular sensor and control electronics.

The SSM consists of a precision bearing unit with static reservoir, brushless DC outer rotating drive motor assembly, optical encoder assembly, cube assembly (both in stator part and rotor part) for optical alignment, housing, motor rotor housing, hollow central shaft and balancing arms.

Bearing Unit Assembly

The mechanism is outer rotating one. SSM consists of precision bearing unit assembly, which includes static central shaft that locates inner race of face to face mounted two pairs of duplex angular contact ball bearings. Outer races are axially supported by a single housing. Static reservoirs using nylasint are provided at both bearing pairs. This forms the bearing unit assembly. The criticality is the designing and achieving of labyrinth seal so as to avoid lubricant leakage as well as sufficient clearance between stator and rotor.

Encoder Assembly

Custom built 17 bit absolute optical encoder is used as angle sensor. It consists of three parts such as encoder rotor, encoder stator, and electronics on stator part. Configuration design ensures proper axial gap between stator and rotor disk of encoder.

The C.G. offset and cross inertia of scatterometer rotor has to be balanced for static and dynamic balancing. Balancing provisions are provided in rotating parts in two balancing planes sufficiently apart. Locations are identified in other two orthogonal directions for minor cross inertia unbalance correction. Static & dynamic balancing of QM SSM with antenna has been done using 4 component Kistler dynamometer. The residual unbalance and the location of unbalance w. r. t. scan start are obtained. S/C level drift rate performance analysis has been carried out using the above values and the results are satisfactory.

Pennzane lubricant oil with its matching grease (Rheolube 2000/ MAPLUB) is used for SSM. To ensure lubricant availability, the amount of oil that will be lost by evaporation over the mission life is compared to the oil quantity available in the bearings. The rate of lubricant mass loss per unit surface area of oil is calculated to be 4.0mg/ cm^2/year. For 200m radial gap between stationary shaft and rotating retainer, by providing a labyrinth passage estimated opening is $1cm^2$ on each side of the bearings. Hence the expected loss from each bearing during the 5 year life is only 56mg. Oil retained by each bearing cage is more than 450mg. Hence, factor of safety = 450 / 56 = 8.

16.5.3 ROSA (Radio Occultation Sounder for the Atmosphere)

16.5.3.1 Introduction

The ROSA Receiver is a GPS Receiver for space borne applications, specifically conceived for atmospheric sounding by radio occultation, which is able to determine position, velocity and time using GPS signals.

The ROSA, besides providing real-time navigation data, is able to accurately measure pseudo ranges and integrated carrier phase (raw data), to be later processed on ground for scientific purposes.

The ROSA processes the received GPS signals in both the L1 and L2 frequency bands, allowing compensation of ionospheric delays. A codeless tracking scheme is included, in order to process the encrypted P(Y) signals transmitted in the L2 frequency band.

The instrument is equipped with one hemispherical-coverage antenna that is mounted with bore-sight direction equal to the Zenith direction and is used to track the GPS signals for navigation purpose and for Precise Orbit Determination (POD). In addition, a directive Velocity antenna is mounted on the Oceansat-2 spacecraft. This antenna is oriented in such a way to be able to track signal from GPS satellites in Earth occultation (rising).

Sixteen (4 AGGA chips) dual-frequency channels are available in the ROSA Receiver, and can be freely assigned to any combination of satellites. ROSA is provided with a MIL-STD-1553 communication interface over which telecommand, telemetry and measurement data are exchanged. The Receiver digital section is based on an ADSP 21020 processor and four AGGA-2a channels ASIC.

16.5.3.2 Main elements of ROSA Payload

Zenith pointing Hemispherical Antenna and LNA:

Signals from this antenna can reach (through the RF/IF section) all the Receiver AGGA-2a HW channels. GPS signals received by this antenna are used to produce raw data measurements that are post-processed on ground for Atmospheric Sounding purposes and they are used also to compute the on-board real-time navigation and time solutions.

Velocity Antenna and LNA: This antenna is used only for Atmospheric Sounding applications to produce raw data measurements from satellites that are rising behind the Earth horizon. The Antenna is composed by two linear arrays, each pointing to a semi-plane (Velocity-Left, Velocity-Right). The RF/IF paths coming from Velocity arrays are connected to all AGGA-2a chips.

RF/IF sections: Five RF/IF sections (one for each antenna path) compose the Receiver front-end and include filtering and down conversion for the L1 and L2 frequencies. A 10 MHz reference OCXO oscillator is used in the frequency synthesizer from which all the Local Oscillators, and also clocks used internally to the Receiver, are derived.

Digital Section: This section includes the Signal Processing HW(AGGA-2a channels), the CPU Module that controls via SW all the Receiver functions and the Communication Module that handles communication with the external Host (On-board Computer or Test Equipment). Four AGGA-2a chips are mounted on ROSA, each AGGA being composed of 4 complex (12 single) channels.

Power Management: ON/OFF commands are required from spacecraft to switch ON/OFF ROSA receiver. These commands issued by the Spacecraft and to execute these commands DC/DC Converter provides the secondary voltages to the Receiver, starting from the Spacecraft primary line.

16.5.3.3 Navigation Antenna

The Navigation Antenna is dedicated to acquire the GNSS signals to determine with precision the orbit of the satellite where there is installed the ROSA Instrument.

The navigation solution, from which depends the orbit determination, is fundamental in this application, because the position's knowledge in the time is essential to trace all the occultation events during the observation phase of the Instrument. Its main features are summarized by the following information.

Specifications:

Frequency range	:	L1→ 1560 -□ 1590MHz L2 → 1212 - 1242MHz
VSWR	:	1.5:1
Gain	:	-5dBic at Zenith 4dBic at 5° elevation above the horizon
Polarisation	:	RHCP
Radiation Pattern	:	Omni-directional - Azimuth Hemispherical - Vertical
Weight	:	0.23Kg

16.5.3.4 Radio Occultation Antenna

The Radio Occultation Antenna is a special Antenna designed and developed for this application. Its main purpose is to acquire and amplify the signal from the high atmospheric layers (ideally up to 600Km) to ground earth surface (ideally 0Km). The major part of the gain of this Antenna (about 12dB) is concentrated on angle of view of the lower atmospheric layers (under 100Km) where the signal is weaker due to the atmospheric absorption, refractivity, and multipath effects.

The main functional and performance features of this Antenna could be summarized in the following information:

Frequency bands: The R.O. antenna shall operate in two L frequency bands:

L1 = 1565.19 - 1613.86MHz & L2 = 1217.37 – 1256.36MHz

VSWR: For both L1 & L2 bands the VSWR shall be □□1.4:1 (return loss □□15.5 dB)

Polarisation: Circular Right Hand Polarisation is requested for both L1 and L2 frequency band.

Axial Ratio: The 3.5dB value can be considered only in the baseline coverage region; outside the axial ratio will be limited as much as possible.

Gain inside the baseline coverage region: The minimum value of 12dBi for both L1 & L2 bands is critical related to the requested antenna dimension.

Gain inside the extended coverage region: The constraint of the minimum gain of -3dBi in the extended coverage reduces the minimum gain value of the baseline coverage region.

Azimuth Gain Ripple: The antenna gain ripple shall not vary by more than 2dB for any azimuth variation inside the baseline coverage region (0-100Km). For the extended region the gain ripple will be minimized.

Functional Description

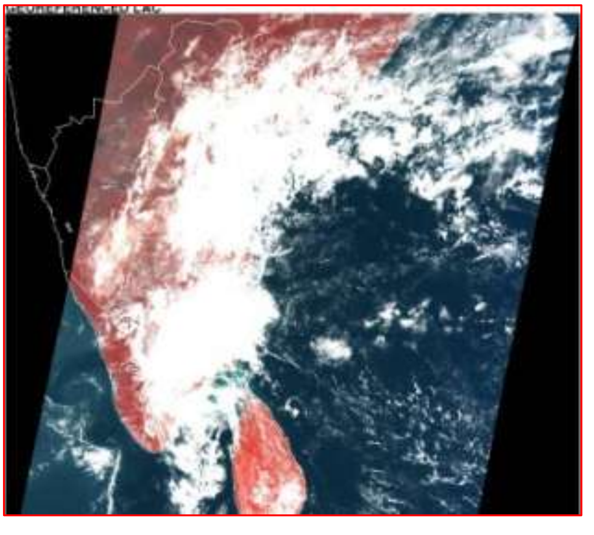
The main operations are:

- The ROSA Receiver performs the following main operations:
  - Allocates HW channels to GPS satellites
  - Receives L1/L2 C/A and P signals from GPS satellites
  - □Acquires and maintains Code Lock and Carrier Lock, demodulates and decodes data

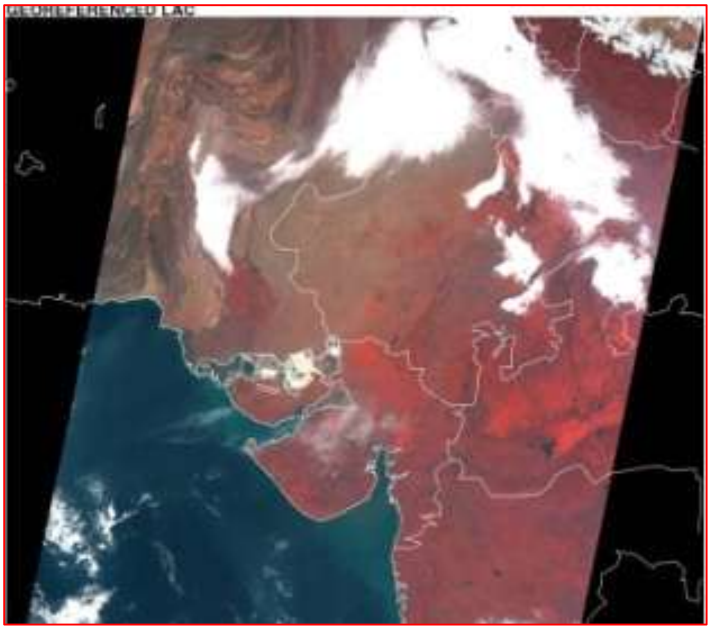
- message and recovers Navigation Data from each received GPS satellite

  When at least 4 GPS satellites are in view, performs position, time and velocity calculation based on a Least Squares algorithm (ECEFSPS solution)

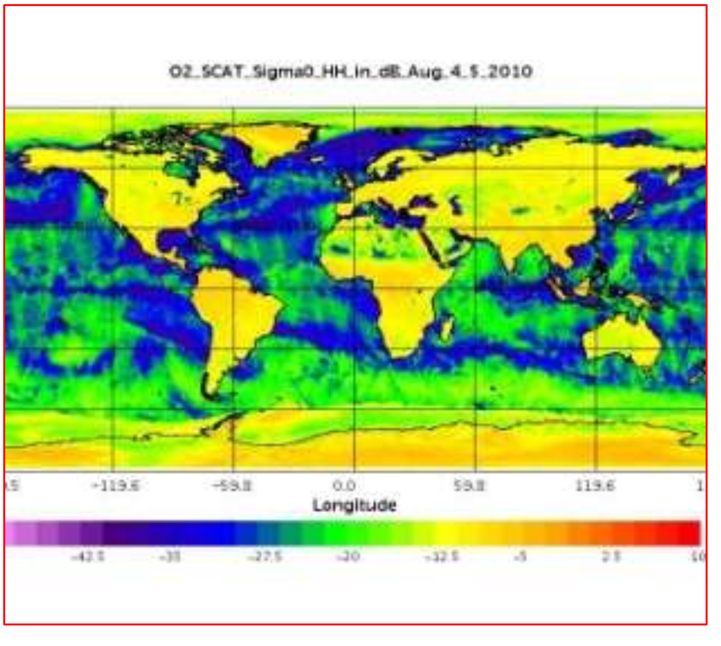
- In parallel, performs Filtered Navigation Solution (ECINKF solution); the Kalman filtered solution is able to propagate the solution also in absence of GPS measurements
- Uses calculated position information to establish geometrical line of sight information of each acquired GPS satellite with respect to the Receiver platform, maintains a tracking list of visible satellites and performs occultation events prediction
- For observation events, when Carrier Lock is not possible, performs Open-Loop high-rate sampling of raw observables for carrier reconstruction on ground
- Monitors and maintains Receiver Health & Status



Indian



OCM - Gujarat



SCATTERMETER - World

17 RESOURCESAT-2

17.1 Introduction

Resourcesat-2 is a follow on mission to provide service continuity to the Resourcesat-1 users. Hence Resourcesat-2 payload systems were conceived around IRS-P6 with certain improvements in payload electronics. Resourcesat- 2 spacecraft is configured with improved features like 70 Km Mx data, Enhanced SSR memory, new data handling system, 10/8 channels SPS, indigenously developed star sensor, AOCE with Mil-1553 interfaces. Apart from Resourcesat -1 payloads, a new payload called Hosted Indian payload from COMDEV, Canada for automatic identification of ship was also flown.

17.2 Mission Objective

Mission objective of Resourcesat-2 are

- *To provide continued remote sensing data services on an operational basis for integrated land and water resource management at a micro level with enhanced multispectral/ spatial coverage and stereo imaging.*
- *To further carryout studies in advanced areas of user applications like improved crop discrimination, crop yield, crop stress, and pest / decease surveillance and disaster management etc.*

17.3 Orbital Parameters

Table 17.1 Orbit details of Resourcesat-2

Sl.No	Parameter	Resourcesat-2
1	Orbit	Polar sun synchronous circular
2	Altitude	817 Km
3	Inclination	98.69 deg
4	Eccentricity	0.0004
5	Period	101.35 minutes
6	Local Time	10.30 A.M
7	Repetivity Cycle	341 Orbits 24 days for LISS-3 5 days for AWiFS 5 days Revisit (LISS-4)
8	Distance between adjacent Traces	117.5 Km
9	Off Nadir coverage +/- 26 deg	398 Km (for LISS-4)
10	Distance between successive	2820 Km

Sl.No	Parameter	Resourcesat-2
	Ground tracks	
11	Ground Trace velocity	6.65 Km/s

17.4 Salient features of Spacecraft

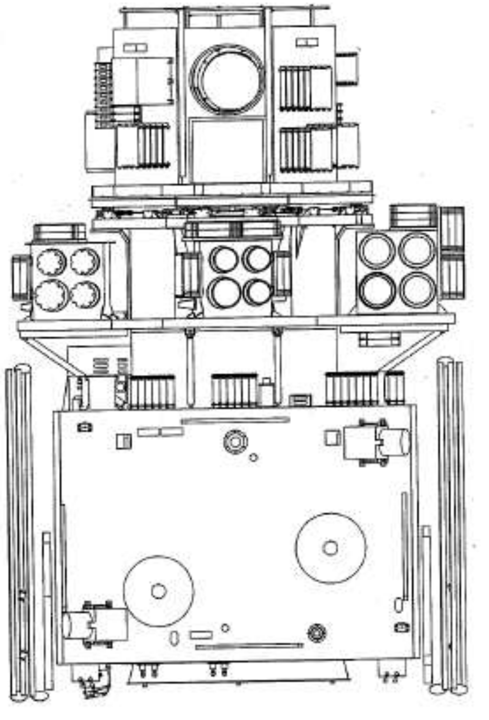


Figure 17.1 Stowed view of Resourcesat-2

17.5 Payloads

Resourcesat-2 payload system consists of Four Payloads namely

1. Linear Imaging Self Scanning Sensor-4 (LISS-4)
2. Linear Imaging Self Scanning Sensor-3 (LISS-3)
3. Advanced Wide Field Sensors (AWiFS)
4. HIP

17.5.1 Linear Imaging Self Scanning Sensor (LISS-4)

17.5.1.1 Introduction

LISS4 is a high resolution multi-spectral camera with three spectral bands namely B2, B3 and B4 similar to those of LISS 3* and AWiFS camera. This camera operates in three spectral bands B2 (0.52-0.59 µm), B3 (0.62-0.68 µm) and B4 (0.77-0.86 µm). The ground resolution of LISS-4 will be 5.8 m with the swath of 70 Km from an altitude of 817 Km.

The three spectral bands are realized using field-splitting technique near the focal plane. The final selection of the spectral bands is achieved by using appropriate band pass filters in front of the detectors.

17.5.1.2 LISS-4 Specifications

Optical system

Type	:	Off axis unobscured three-mirror telescope
Focal length	:	980 mm
F-Number	:	4.0
Spectral Bands	:	
B2	:	(0.52-0.59 µm),
B3	:	(0.62-0.68 µm)
B4	:	(0.77-0.86 µm)
Field of view (FOV)		
Across track	:	± 2.5°
Along track	:	+0.4° & -0.6°
Telescope MTF	:	>40% at 70 lp/mm
Optical Efficiency	:	0.6

Detector (CCD)

No. of pixels	:	12000
Pixel size	:	7 µm x 7 µm
No. of output ports	:	8
Separation between Odd - Even rows	:	35 µ (5 scan lines)

System

IGFOV (m)		
Across Track	:	5.83
Along Track	:	5.82
Swath (Km)	:	70.0 (Mono &Mx mode)
Integration time (ms)	:	0.8777142
Quantization	:	10 bits (7 bits transmission to BDH after DPCM)
SNR (at saturation)	:	>128
SWR (%)	:	>20

BBR (Pixel)	:	≤± 0.25
Saturation radiance (mW/cm^2/Sr/µm)	:	B2 53
		B3 47
		B4 31.5

Raw Bus Power (W) @37V

Imaging Mode	:	126(All Bands)
Calibration Mode	:	127.7 (All Bands)
Size (P x R x Y) (mm)	:	742 x 596 x 888
Weight (Kg)		
EO Module	:	95
Camera	:	104

17.5.1.3 System configuration

Electro optical module (EOM)

The Electro optical module (EOM) of LISS-4 consists of three mirror assemblies, focal plane splitter optics and Detector Head Assembly (DHA) at specified locations. The telescope is a three mirror off-axis reflective system (similar to IRS-1C/1D PAN telescope).

Optical System

The optical system of LISS-4 consists of three mirrors unobscured off-axis telescope (an off-axis concave hyperboloid primary mirror, a convex spherical secondary mirror, and an off axis concave oblate ellipsoid tertiary mirror), focal plane splitter assembly, and band-pass filters. A 245 mm diameter primary mirror collects the radiation from earth and reflects it on the secondary mirror. The beam reflected from secondary mirror falls on to tertiary mirror, which focuses the beam on to the detector. Three focal planes are realized by splitting the field in the along track direction using an isosceles reflecting prism with a slot. The beam corresponding to B3 is transmitted through the slot while the B2 and B4 are reflected by prism sides. The placement of band pass interference filter in front of CCD ensures the selection of required band.

The telescope has an effective focal length of 980 mm and covers a field of view of ± 2.5° in across track and + 0.4° and -0.6° in the along track directions.

Detector Head Assemblies (DHA)

LISS-4 payload has three detector head assemblies (DHA) corresponding to B2, B3 and B4 respectively. LISS-4 DHA for Resoucesat-2 is identical to

Resoucesat-1 in terms of interfaces and basic philosophy, but has been realized with reduced size and number of components. Also improvement has been carried out in thermal interface.

Each DHA consists of

- 12K linear array CCD
- Bias voltage generating circuits
- Clock driver circuits
- Heaters and thermistors for thermal control
- LEDs for On-board Calibration

The 12K element linear CCDs of Thomson make (TH31543) are used for each spectral band. Each CCD has a pixel size of 7 µm x 7 µm. The Odd and Even pixel rows are arranged in a staggered mode separated by 35 µ (equal to 5 scan lines). Each CCD gives analog data on eight output ports - four for odd pixels and four for even pixels. Each port provides data for 1520 pixels including 20 pre-scan/ white reference pixels. CCD has in-built anti-blooming and integration control.

DHA receives +18.3 V DC regulated voltage from power package and generates various bias voltages required for CCD operations using series regulator. DHA receives clock signals at a TTL levels from timing and control logic circuits of Camera Electronics (PLE12/13/14) and conditions them to suitable voltage levels and drives the required capacitive loads of CCD using clock driver circuits. CCD requires a total of 16 clocks for its operation.

Video data obtained from eight video ports are given to video processor circuit (PLE12/13/14 of camera electronics).

Each band DHA consists of two identical PCBs and each PCB caters to electrical requirements of four ports. DHA also receives +5.6 V regulated DC voltage from spacecraft to be applied to heaters to maintain CCD temperature.

The CCD temperature increases considerably whenever DHA is powered. In order to control the temperature excursion in the CCD, heaters are placed near the CCD, which are switched ON whenever DHA is switched OFF and vice versa. This ensures minimum change in CCD temperature at any time. CCD temperature needs to be maintained within 20±2 ºC, hence DHA is cooled. To achieve temperature control, control heaters are provided on the DHA. This is realized using a copper braid whose ends are terminated with copper blocks. A compensatory heater of 1.8 W (equal to CCD dissipation) is switched ON and OFF as complementary to LISS-4 OFF and ON respectively.

17.5.2 Linear Imaging Self Scanning Sensor (LISS-3*)

17.5.2.1 Introduction:

The LISS-3* Camera is a medium resolution multi-spectral camera operating in four spectral bands - B2, B3, B4 in Visible - Near infrared Range (VNIR) and B5 in Short Wave Infrared Range (SWIR) . This camera is similar to the LISS-3* of Resoucesat-1. LISS-3* will have four spectral bands with independent optical assemblies and a linear array detector for each channel providing identical IGFOV of 23.5 m. All bands will provide 100% albedo coverage with 1023 levels of quantization.

The SWIR band is designed using a new custom built 6000 element Indium Gallium Arsenide (InGaAs) CCD. Based on the experience of IRS-1C/1D in-orbit performance, certain improvements have been incorporated in the LISS-3* design. LISS-3* SWIR band has improved performance in terms of resolution with 23.5 m compared to 70 m in IRS-1C/1D. The focal length of the SWIR band is modified to meet the improved resolution.

17.5.2.2 LISS3* Specifications:

Optics		**B2, B3 & B4**	**B5**
EFL (mm)	:	347.5±0.3	451.75±0.3
F-No	:	<4.5	<4.5
FOV (deg)	:	±5	± 5
Spectral bands (μm)			
	B2 :	0.52-0.59	1.55 -1.70
	B3 :	0.62-0.68	
	B4 :	0.77- 0.86	
CCD			
No. of Pixels	:	6000	6000
Pixel size (μm)	:	7 x 10	13 x 13
Detector	:	Si	InGaAs
System			
IGFOV (m)	:	23.5	23.5
Along track sampling (m)	:	22.0	22.11
Swath (km)	::	141	141
Integration time (ms)	:	3.32	3.32
Quantization bits	:	10	7

SNR (at saturation)	:	>128	>128
SWR (%)	B2 :	>30	>20
	B3 :	>30	
	B4 :	>20	
BBR (Pixel)	:	≤± 0.25	≤± 0.25
Saturation radiance	B2 :	53	7.5
(mW/cm^2/Sr/µm)	B3 :	47	
	B4 :	31.5	
Regulated Power (W)			
Imaging Mode	:	29.44(VNIR), 4.78(SWIR) (w/o TC)	
Calibration Mode	:	31.15 (VNIR), 4.87 (SWIR) (w/o TC)	
Temperature Controller (TC)	:	2.3	
Raw Bus Power			
Imaging Mode	:	72.4 (All Bands)	
Calibration Mode	:	74.9 (All Bands)	
Size (PxRxY) (mm)	:	493x470.5x626.31	
Weight (Kg)			
EO Module	:	73.2	
Camera	:	74.9	

17.5.2.3 System Configuration

Each band has individual optics, DHA and camera electronics (CE). Four identical DHAs, one each per band forms part of the EO module. The major constituents of the payload are described below.

Optics:

The LISS-3* camera uses refractive optics for all four spectral bands. The collecting optics consists of 8 refractive lens elements with the interference filter and the thermal filter. The optical configuration consists of a multi-element lens assembly. All the lens elements have spherical surface profile. Lenses of all four bands are developed by LEOS.

Detectors:

VNIR bands, have 6000 elements devices (CCD 191A) with a pixel size of 10 µX7 µ on a pixel pitch of 10 µ with two video output ports. SWIR band, has 6000 element staggered array device with a pixel size of 13 µX13 µ on a pixel pitch of 13 µ and line pitch of 26 µ with two video output ports

Detector Head Assembly for VNIR:

DHA houses linear array CCD-detector, PCB, onboard calibration LEDs and mechanical mount. LISS 3* will have three VNIR band DHAs.

Description of CCD 191A Device:

The CCD 191A has 6000 photosensitive elements each of size 10µm along the array and 7 µm perpendicular to array length. The device has two video output ports and packaged in a custom build 40 pin DIP ceramic package. CCD 191A is fabricated using advanced n-channel isoplanner buried channel technology.

The photosensitive elements accumulate charges during integration period. These accumulated charges are transferred to two analog shift register using transfer clocks. Analog shift register transport these charge packets sequentially, with the help of 2-phase shift clocks, to charge amplifier where charge to voltage conversion takes place and three levels analog voltage signal is available on each port. The true video information is carried out by taking difference of reference level and video level. Both the ports start with 10 prescan reference pixels followed by 3000 photo-responsive pixels. The ports here correspond to the even and odd pixels respectively.

- **Anti-Blooming control**

In order to take care of the super saturation problems seen in IRS-1C/1D in-orbit, Anti-blooming control (ABC) feature of CCD191A is incorporated in the VNIR bands of LISS3*. This feature is used to arrest the Raw-Bus current increase when camera is exposed to higher illumination compared to its saturation settings. The ABC is implemented by proper setting of 'Integration Control' bias voltage (V_{IC}) available on the CCD pin and is adjusted by trimming the bleeder resistors in the bias supply circuit in the DE package. .

Onboard Calibration:

Calibration assembly consists of LED wired on PCB and mounted on LED holders. Four LEDs connected in series mounted on LED-holder. Two such holders one on each side of CCD are mounted on DHA plate/flange. All LEDs are connected in series. A DC current of 16±1mA is passing through LEDs. Calibration levels are generated using exposure control feature of the CCD.

Onboard calibration is to be carried out using 8 LEDs (02 sets of 4 LEDs) covering the complete array. LED profile depends on the LED mounting geometry. 16 levels will be generated using integration control feature. The LED intensity is expected to vary with temperature.

Mechanical Mount:

The PCB is mounted on the mechanical mount made from lnvar and back cover of aluminium. The calibration LED assembly is also mounted on the same mount.

Detector Head Assembly for SWIR:

The detectors used for SWIR channels in RS-1/2 are of type TH31906. This detector uses modular approach. Each module contains 600 photodiodes arranged in staggered fashion and CMOS multiplexers on either side of the array for even and odd pixels readout. A total of 10 such modules are butted together to form a linear array of 6000 pixels. Two consecutive pixels are lost at each splice due to butting.Photosensitive area of each pixelis13 µmX13 µm with 13 µm pitch along the length of the array. The odd and even lines of the staggered configuration are separated by 26 µm. the photodiodes and CMOS MUX are glued on a 2 mm thick co-fired ceramic plate.

The photodiodes in TH31906 are operated under near zero bias condition. This is ensured by placing a suitable resistance between VREF and ADJREF pins.

In order to avoid reflections from the focal plane which manifests itself as ghost image after re-reflection from interference filter which is part of camera optics, most of the focal plane is masked and 1 mm wide and 83 mm long slit which is 1mm above the surface of photodiode die exposes photodiodes to the incident radiation. But reflections from the edges of this slit cause some extra illumination in few of the pixels. In order to avoid this, two external slits of appropriate dimensions are placed near optics exit so that the edges of the slit on mask are properly shadowed.

17.5.3 Advanced Wide field sensor (AWiFS)

17.5.3.1 Introduction

The Advanced Wide Field Sensor (AWiFS) camera will be catering to the high temporal resolution requirement of RS-2 mission with revisit period of 5 days. It has IGFOV of 70m from an altitude of 817 Km. The AWiFS camera consists of four spectral bands, three in the visible and in near IR (VNIR B2, B3 and B4) and one in the short wave infrared (SWIR B5) similar to AWiFS of Resoucesat-1.

AWIFS is configured as a set of two identical camera modules i.e. AWIFS-A &AWIFS-B. Each camera consists of four lens assemblies, detectors and associated electronics pertaining to the four spectral bands B2, B3, B4 and B5. The two cameras are combined to generate the required field of vie commensurate with the desired swath. The imaging concept is based on push broom scanning that uses a linear array CCD placed in the focal plane of the optics. The 4 spectral bands are realized using independent refractive optical assemblies. To generate the required swath along with the desired overlap of 150±20 pixels, the two EO modules will be mounted on the spacecraft deck such that they are squinted with respect to nadir by ±11.84º. The field of view of each lens assembly is ± 12.5º. In nutshell, total field coverage of 47.94º is shared equally by two optical heads for each of the four bands.

AWiFS Specifications

			B2, B3 & B4	**B5**
Optics				
EFL (mm)		:	139.5 ± 0.15	181.35 ± 0.2
F-No		:	<5.0	<5.0
FOV (deg)		:	±12.5	± 12.5
Spectral bands (µm)				
	B2	:	0.52-0.59	
	B3	:	0.62-0.68	1.55-1.70
	B4	:	0.77- 0.86	
CCD				
No. of Pixels		:	6000	6000
Pixel size (µm)		:	7 x 10	13 x 13
Detector		:	Si	InGaAs
System				
IGFOV (m)				
Across track		:	56 (@ nadir), 70(off-nadir)	56 (nadir) 70(off-nadir)
Along Track		:	66	66
Swath (km)		:	740	740
Integration time (ms)		:	9.96	9.96
Quantisation (Bits)		:	12(MLG)	12(MLG)
SNR (at saturation)		:	> 512	> 512
SWR (%)				
	B2	:	30	
	B3		30	20
	B4		20	
BBR (Pixel)		:	≤± 0.25	≤± 0.25
Radiance @ Saturation (mW/cm2/Sr/um)				
	B2	:	53	
	B3	:	47	7.5
	B4	:	31.5	

Calibration levels	:	16 6 non-zero
Regulated Power (W)		
Imaging Mode	:	47.16(VNIR), 8.31(SWIR) (w/o TC)
Calibration Mode	:	48.81 (VNIR), 8.554 (SWIR) (w/o TC)
Temperature Controller (TC)	:	4.6 (SWIRTC)
Raw Bus Power (@37V)		
Imaging Mode	:	124.1(All Band AWiFS-A&B)
Calibration Mode	:	126.7(All Band AWiFS-A&B)
Size (PxRxY) (mm)		
AWiFS A	:	471 x 410 x 316
AWiFS B	:	418 x 410 x 316
Weight (Kg)		
EO Module	:	28(AWiFS A), 25.5 (AWiFS B)
Camera	:	55.8(AWiFS A + AWiFS B)

17.5.3.2 System Configuration

Each band has individual optics, DHA and camera electronics (CE). Four identical DHAs, one each per band forms part of the EO module. The major constituents of the payload are geven below.

Optics:

The optics of AWiFS camera consists of two optical heads (two lens assemblies) for each of the four spectral bands to cover the full swath. Each lens assembly comprises a Thermal Filter, interference Filter, and 8 lens elements. In view of the required geometric/radiometric performance, f/5 system is employed for both VNIR and SWIR bands. All the lens elements have spherical surface profiles. The optics for the same is being developed at LEOS.

Detectors:

For the 3 VNIR bands, 6000 elements devices (CCD191A) with a pixel size of 10 µX7 µ on a pixel pitch of 10 µ with two video output ports is used. For the SWIR band, a 6000 element staggered array device with a pixel size of 13 µ X 13 µ on a pixel pitch of 13 µ and line pitch of 26 µ with two video output ports is used.

Detector Head Assembly for VNIR:

DHA houses linear array CCD-detector, PCB, onboard calibration assembly and mechanical mount. AWiFS-A & B will have three VNIR band DHAs.

Onboard Calibration Assembly:

Calibration assembly consists of LED wired on PCB and mounted on LED holders. Four LEDs connected in series mounted on LED-holder. Two such holders one on each side of CCD are mounted on DHA plate/flange. All LEDs are connected in series. A DC current of 16±1 mA is passing through LEDs. Calibration levels are generated using exposure control feature of the CCD.

Mechanical Mount:

The PCB is mounted on the mechanical mount made from lnvar and back cover of aluminium. The calibration LED assembly is also mounted on the same mount.

Detector Head Assembly for SWIR:

The detectors used for SWIR channels in RS-1/2 are of type TH31906. This detector uses modular approach. Each module contains 600 photodiodes arranged in staggered fashion and CMOS multiplexers on either side of the array for even and odd pixels readout. A total of 10 such modules are butted together to form a linear array of 6000 pixels. Two consecutive pixels are lost at each splice due to butting. Photosensitive area of each pixelis13µmX13µm with 13µm pitch along the length of the array. The odd and even lines of the staggered configuration are separated by 26µm. the photodiodes and CMOS MUX are glued on a 2mm thick co-fired ceramic plate. Electrical interconnections are provided by either gold coated tracks or wires.

The photodiodes in TH31906 are operated under near zero bias condition. This is ensured by placing a suitable resistance between V_{REF} and ADJ_{REF} pins.

In order to avoid reflections from the focal plane which manifests itself as ghost image after re-reflection from interference filter which is part of camera optics, most of the focal plane is masked and 1mm wide and 83mm long slit which is 1mm above the surface of photodiode die exposes photodiodes to the incident radiation. But reflections from the edges of this slit cause some extra illumination in few of the pixels. In order to avoid this, two external slits of appropriate dimensions are placed near optics exit so that the edges of the slit on mask are properly shadowed.

Camera Electronics:

Each camera and detector have independent camera electronics to cater to various functional and performance requirements. AWiFS-A accommodates hardware for Detector 1 of all bands and similarly AWiFS-B covers hardware for Detector 2 of all bands. In RS-2, all four bands use Multi Linear Gain (MLG) technique to provide 12 bit performance retaining 10 bit hardware interface. RS-2 camera electronics (CE) hardware is realized using passive SMDs, FPGAs, double sided or multi-layered PCBs and tray packaging. This has resulted in improvements with respect to size, weight and power. Similar approach has been adopted for SWIR electronics.

VNIR:

Camera electronics is custom designed for Resourcesat-2 AWiFS camera. The system is configured to meet the functional and performance requirements with minimum hardware complexity. The salient features of AWiFS (VNIR) camera electronics are

- Separate camera electronics for each detector
- Separate detector-drive electronics for each detector
- Separate timing logic for each detector without redundancy(like in Resoucesat-1)
- Cross coupling of BRC and WLS
- Hot redundancy for data and telemetry

The electronic system design of Resourcesat-2 maximally uses the subsystems and circuit blocks designed and developed for Resourcesat-1, thereby improving reliability. Camera electronics is modular for each detector. The functional blocks of camera electronics consists of

- Bias generator
- Clock driver
- Cal LED Driver
- Video Processing Electronics
- Timing and Calibration Logic
- Telemetry and Telecommand Interface

Bias generator:

Bias generator circuit consist of linear regulators and capacitor multiplier filters, which provides 4 regulated low noise bias voltages for detector operation. The circuit also incorporates short circuit protection for VDD. The circuit configuration is same as that used in OCM.

Clock Drivers:

Detector electronics receives 9 clocks from payload electronics package for its operation in phased read out mode. Clock driver translate these TTL signals to MOS level with adequate capability to drive capacitive loads for realizing fast rise/fall times. The high level required by photo gate, transfer and reset clocks are typically 15 V and 10 V for transport and integration control clocks. Accordingly, two linear regulators are used to generate low noise supply voltages required for 15 V and 10 V.

CAL LED Driver:

Calibration requires a light source in front of the CCD. IRS payloads uses solid-state LED based source. To drive LEDs a low noise constant current is generated. A regulator ie wired with LEDs in the feedback loop. The output gain resistors and the current deciding resistor at the inverting input of the error amplifier control the required current.

17.5.4 HIP (Hosted Indian Payload)

17.5.4.1 Introduction:

The Automatic Identification System (AIS) Payload flown in Resourcesat-2 as an experimental payload for ship surveillance in VHF band to derive the position, speed, start point and end point of ships. The VHF antenna which is provided by CMG, ISAC consists of four orthogonally polarized monopole antennas (one is left hand circular polarized and another right hand circular polarized), placed at the edges of EP-01 panel, receive data from ships which may have horizontal or vertical movement because of sea tides. The data received from ships is stored in the onboard memory (4 GB) and it is transmitted through QPSK modulated S-Band carrier (2280 MHz) to ISTRAC and Canadian stations. VHF data (160-162 MHz) is uplinked to AIS payload at 2.5 Mbps and stored in onboard memory of 4 GB which can simultaneously record and playback the data.

The AIS is a shipboard broadcast system. The AIS will improve security by increasing the Coast Guard's awareness of vessels in the maritime domain, especially vessels approaching ports. The AIS corroborates and provides identification and position of vessels not always possible through voice radio communication or radar alone.

Ships can be identified anywhere in the Oceans/seas by receiving AIS signals. Unidentified ships, which can pose threat to security, can be figured out by spotting all the ships through radar network and isolating the unidentifiable ships near coastal zones.

AIS antennae Operate in the VHF maritime band (160 -162 MHz) standardized digital communication protocols. Each station transmits and receives over two radio channels to avoid interference problems. Transmissions use 9.6 Kb GMSK/FM modulation uses Self-Organizing Time Division Multiple Access (SOTDMA) technology to meet this high broadcast rate and ensure reliable ship-to-ship operation. Each station determines its own transmission schedule (slot), based upon data link traffic history and knowledge of future actions by other stations.

- The data received from satellite is processed offline at Bangalore and Canada.

- COMDEV agreed to provide ships data, processed at Bangalore and Canada, for Indian region and Indian ships data throughout the world to ISRO.

17.5.4.2 Mission Objectives:

The mission Objectives of the AIS program are as follows:

- Collect samples of AIS ship transmissions over the Indian Area of Interest within the limits imposed by the mission constraints (power, availability of ground stations)
- Collect samples of AIS ship transmissions over other parts of the globe within the limits imposed by the mission constraints (power, availability of ground stations)

The current system has been optimized using two ground stations, one in Bangalore and one in northern Canada

17.5.4.3 Payload Description

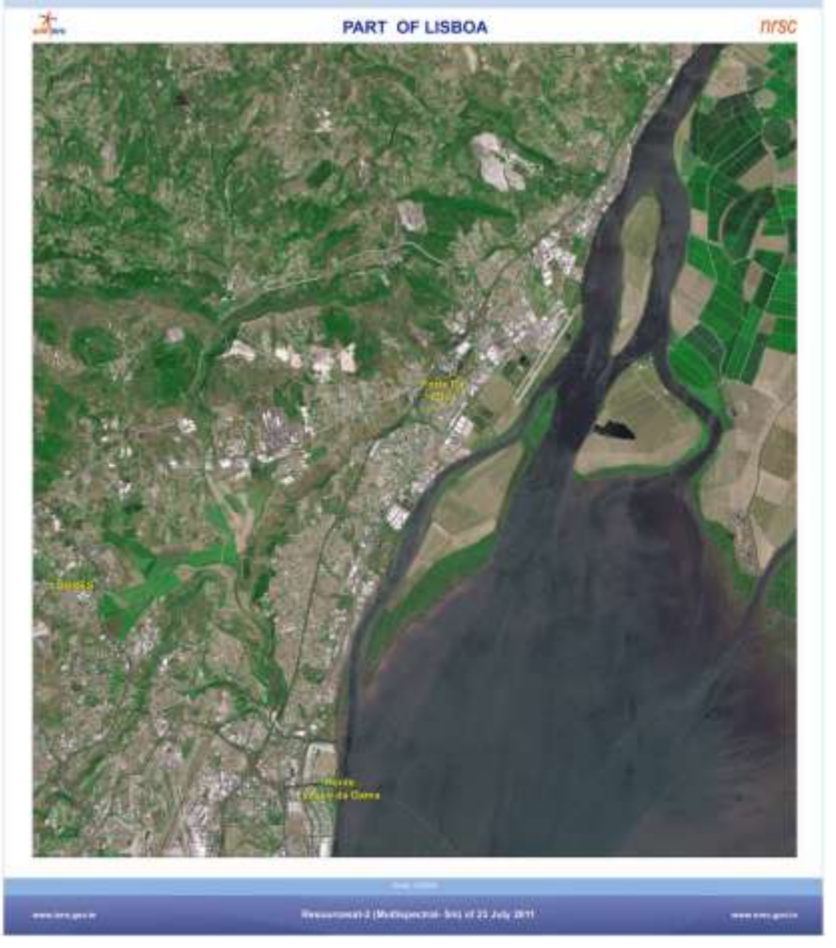
The AIS payload is designed to perform AIS signal receive, store and forward functions covering the two AIS frequencies of 161.975 MHz and 162.025 MHz.

The payload is comprised of

- Two AIS Receive antennas, circular polarization (one left handed, one right handed).
- Two RF cables between the AIS antennas and the AIS Receiver.
- An AIS Receiver provided by COMDEV that provides the power conditioning, RF front end, digital control, data storage, data conditioning and data transmission to the S-Band downlink
- ISRO's cables to carry the AIS data signal from the AIS Receiver to the S Band Transmitter.
- An S Band Transmitter provided by ISRO, 16 Mbps QPSK (the transmitter will receive two signals at 8Mbps each, used as I and Q signals for the modulation).
- An S Band Antenna provided by ISRO


KAKINADA ,A.P
nrsc
Hope
Resourcesat-2 (Multispectral-24m) of 09 May 2011


SHARJAH
nrsc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18 YOUTHSAT

18.1 Introduction

The Youthsat is the second small satellite fabricated by ISAC. Youthsat carried three payloads namely SOLRAD, LiVHySI and RaBIT. The remote sensing data from this micro satellite is used for scientific studies like research of solar flare activity, mapping of Total Electron Content (TEC) of the ionosphere and measuring airglow of the earth's atmosphere.

18.2 Mission Objective

Mission Objectives of Youthsat are

- *To build, launch and operate 3 axis stabilized Micro satellite for launch on-board PSLV as an auxiliary satellite with scientific payloads that are useful for observing solar flares and also for study of their impact on atmosphere.*
- *To involve the youth consisting of students, research scholars etc., for the development and use of payloads mentioned above, in order to inculcate interest and participation in space related activities and also to participate in the data analysis.*

18.3 Orbital Parameters

Orbital parameters of Youthsat is as given below.

Local Time	10.30 AM
Altitude (Km)	817
Semi Major Axis (Km)	7195.11
Inclination (Deg)	98.69
Orbits/Cycle	341
Orbit/Day	14.22
Repetivity	24 Days
Period (Min)	101.35
Ground track velocity (Km/s)	6.65

18.4 Payloads

Youthsat is second in the Indian Mini Satellite -1 Series carrying three payloads namely SOLRAD, LiVHySI and RaBIT.

- SOLRAD by Moscow University (**Sol**ar **Rad**iation Experiment)
- RaBIT by SPL-VSSC (**Ra**dio **B**eacon for **I**onosphere **T**omography)
- LiVHySI by VSSC & SAC (**Li**mb **V**iewing **Hy**per **S**pectral **I**mager)

18.4.1 SOLRAD Payload

SOLRAD (**Sol**ar **Rad**iation Experiment) is a co-operative joint scientific mission between India and Russia with participation of youth from both the countries. The payload is developed with an aim to inculcate interest in the youth in space research and space technology.

Scientific goals: SOLRAD instrument is designed in SINP/MSU to study time variations of solar x-ray and gamma-ray flux and spectra as well as the variations of the flux of charged particles generated in the Sun or in the Earth vicinity. Astrophysical gamma-ray bursts and some variable sources can be also studied.

SOLRAD experiment will provide the measurements in the range:

- X-rays and gammas 0.02-10 MeV
- Electrons 0.3-3.0 MeV
- Protons 3-100 MeV, Alphas 5 - 24 MeV/nucl., nuclei of C, N, O group 6 - 15 MeV/nucl.

The goal is research of solar flare activity by measuring temporal and spectral parameters of solar flare X-rays and gamma rays as well as of charge particle (electron and protons) fluxes in the Earth Polar cap regions which are sensitive to solar flare activity. The scientific objectives are met with an X-ray and Gamma ray detector – spectrometer system using a NaI(TI) / Cs(TI) phoswich unit and a charged particle detector system using a silicon detector telescope unit. SOLRAD payload consists of two modules namely detector module and electronics module. The Detector module consists of two independent units: Detector Unit for Electrons (DUE) and Detector Unit for X-rays and Gamma (DUXG). Based on the scientific objective, SOLRAD payload has to be pointing towards Sun during Sun Pointing period of the orbit.

Figure 18.1 Detector Box

Figure 18.2 Information Box

The phenomena to be studied with SOLRAD particle detector are:

- SEP events and solar charged particle penetration boundaries in the Earth's magnetosphere during geomagnetic disturbances;
- Dynamics of the relativistic electron fluxes in the Earth's magnetosphere;
- Energetic particle precipitation under the Earth's radiation belts (at low and high latitudes).
- The phenomena to be studied with SOLRAD x-ray and gamma detector are:
- Solar flares: fast x-ray and Gamma-ray flux variations
- Solar flares: thermal and non-thermal part of X-ray and gamma-ray spectra
- Solar flares: gamma-ray lines
- Astrophysical gamma-ray bursts (GRB)
- X-ray binaries, pulsars, SGR, etc

SOLRAD payload is always kept ON throughout the time in the orbit irrespective of the attitude geometry. SOLRAD payload data is stored in its internal memory. SOLRAD payload has a provision onboard to store the last 20 sessions payload data, which can be played back on requirement by issuing a SOLRAD multi data command appropriately. The estimated data volume is 100 Mbytes/day.

18.4.2 RaBIT Payload

Scientific Objectives: In the recent years it has become clear that the understanding of the ionosphere is central to the design of many modern communication, navigation and positioning systems. In the past, ionospheric studies have been confined to traditional areas of broadcast and radio communication. With the increasing use of satellites for navigation and positioning (GPS, GLONASS, etc.), characterizing and modeling of the ionosphere (its spatial and temporal variability) has become extremely important. This is because the position accuracy achievable from navigation satellites is largely affected by the intervening ionosphere. The range error is directly proportional to the total electron content (TEC) along the ray path. The equatorial ionosphere with its inter-related unique features like equatorial ionization anomaly (EIA), equatorial spread F (ESF), poses additional challenges due to their highly dynamical nature and large spatial and temporal variability which are not yet well quantified even for quiet conditions. The geomagnetic storms significantly alter the background ionospheric and thermospheric structure, energetic and dynamics and as a consequence modify the major equatorial ionospheric processes.

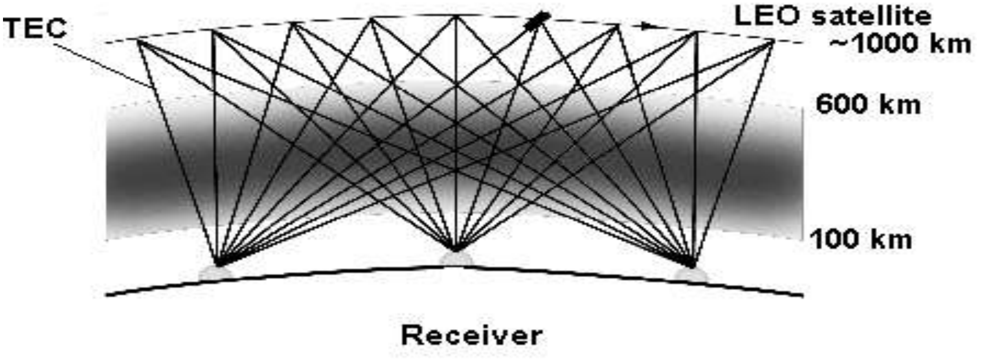
The morphological features of the equatorial ionosphere are well understood, but its day-to-day variability still remains enigmatic. These facts highlight the need for a comprehensive understanding of the complex processes of the ionosphere-thermosphere system including its response to the various external forcing so as to reach a level of predictive capability. One of the most important aspects still to be understood is the temporal and spatial variability in electron density distribution during space weather events. It has been established from the Indian Coherent Radio Beacon Experiment (CRABEX) program, using dual band coherent transmissions from Low Earth Orbiting Satellites (LEOS) that the tomographic techniques are very effective and useful in investigating the large-scale structures over low and equatorial latitudes, like equatorial ionization anomaly (EIA), equatorial spread F (ESF), their temporal and spatial variability, their inter relationship and response to space weather effects.

The main objective of RaBIT payload(**Ra**dio **B**eacon for **I**onosphere **T**omography) is to measure the Total electron content (TEC) of the Ionosphere. The position accuracy achievable from navigation satellites is largely affected by the intervening ionosphere. The range error is directly proportional to the total electron content along the ray path. It is understood that ionospheric TEC measurement simultaneously along a latitudinal chain of receivers could be used for tomographic imaging, i.e., for obtaining the latitude –altitude distribution of electron density of the ionosphere. RaBIT payload being an RF payload, it does not have any interface with Base Band Data handling system. RaBIT payload has to be on the earth-viewing side.

The scientific objectives of RaBIT payload are:

- To study the structure and dynamics of equatorial ionosphere over the Indian region using tomographic technique.
- To study the coupling between high and low latitudes during space weather events.
- To study the ionospheric effects of various solar and geophysical factors.
- Transcontinental studies of the ionosphere in Russia and India during different seasons and local time intervals

Ionospheric tomography: Ionospheric tomography is a powerful tool to address the spatial variability of the ionosphere. The advantage of tomography technique is that it can give a snapshot picture of the latitude-altitude variation of the ionosphere, using data from a chain of simple, inexpensive ground receivers, by recording coherent beacon signals from a low-earth orbiting satellite. The primary data for the tomographic inversion is the line of sight TECs estimated along a number of ray paths from a chain of ground receivers aligned along the same longitude. These TECs are then inverted to obtain the electron density distribution as a function of latitude and altitude over a given longitude. The schematic geometry of the CIT is shown in the figure below. In the simple case the ionosphere is replaced by pixels of appropriate size and electron density within each pixel is assumed to be a constant (piecewise constant).



Then mathematically, ionospheric tomography problem reduces to $Y = Ax + E$

Where *Y* is the observed TEC data, *x* is a the unknown electron densities, and *A* is the geometry matrix, which describes the relationship between the received TEC data and the electron densities on each ray path (the length of the ray in the corresponding pixel). Thus the electron density in each pixel is obtained as $x = A^{-1} Y$. In practice the inverse of the large geometry matrix is estimated by either truncated Singular Value Decomposition technique or Algebraic Reconstruction Technique.

Working Principle: The basic data for ionospheric tomography is the line of sight TEC (STEC). The STEC is obtained by Differential Doppler technique. Here the measured data, is the relative phase between 150 and 400 MHz, is proportional to the relative slant TEC (STEC) along the propagation path of the signal as

$$\phi = C_D \, x \, STEC \qquad (1)$$

Where, ϕ is measured in radians, STEC is in m^{-2} and $C_D = 1.6132 \times 10^{-15}$ for NNSS satellites (Leitinger, 1994). Since the phase measurements are accurate to < 5°when the receiver is at locked condition, and the data sampling is at 50 Hz, these observations yield accurate estimates of the relative TEC, with errors < 0.05%.

Estimation of TEC: The ground receiver measures the phase difference between the incoming signals, and the TEC is estimated by the method of Differential Doppler method. Here, based on the phase or frequency shift measurements which results from the changes in optical path length $P = \int n \, ds$: where n is the refractive index and is a measure of electron density, N_e.

RaBIT Electronics: The purpose of RaBIT is to measure the Total Electron Content (TEC) of Ionosphere. RaBIT will generate two phase coherent frequencies, 150MHz and 400MHz. The relative phase of 150MHz with respect to 400MHz is proportional to the slant relative TEC along the line of sight. The basic source is a coaxial resonator oscillator (CRO) at 1200MHz. This is phase locked using an integer PLL. The reference to the PLL is a Temperature compensated Oven Controlled Crystal Oscillator (TC-OCXO). A clock distribution IC with programmable internal frequency divider generates two coherent frequencies viz, 400MHz, and 150MHz. An 8-bit microcontroller is used to program the PLL and to issue a synchronization command for synchronizing 400MHz and 150MHz signals. These outputs are filtered using in-house made band pass filters, which improve the signal quality. For improving return loss, attenuator pads are used at both the outputs, before and after amplification. The amplifiers are realized using Monolithic Microwave Integrated Circuits (MMIC). The final stage in each chain consists of a power amplifier, which enhances the power to 1.58 Watts. The entire circuitry works with a single 3.3V power supply. This power is derived onboard using a hybrid DC/DC converter with built in EMI filter. The 150MHz and 400MHz signals are combined using a lumped element frequency combiner to get nominal output power of 1W.

Antenna systems: RaBIT antenna is a deployable antenna. The deployable antenna system consists of (i) Boom assembly, (ii) Dipole sub assembly, (iii) UHF and VHF reflectors, (iv) Retention and release mechanism and (v) Deployment and locking mechanism. The major subassemblies of the system are detailed below:

Boom Assembly: The deployable antenna system consists of a centrally positioned boom to which all subsystems are assembled. The boom assembly consists of two parts viz a conical lower part and a cylindrical upper part assembled using a lap joint at the center. The base of the boom is assembled to satellite deck. The top of the boom provides interface for mounting TTC antenna. Boom assembly is the central structural element of the antenna system. It provides the structural interface for various elements of the system. Dipole sub assemblies and reflector are attached to the boom assembly through specially designed hinges.

Dipole sub Assembly: The dipole sub assembly consists of tubes (OD 12 mm, WT 1mm) made of brass. Two dipoles sub assemblies are symmetrically attached to the top of the boom at diametrically opposite locations. Each dipole sub assembly is made of two brass tubes that is assembled using TRAP holder made of GFRP material to enable the system to work for dual frequency. The dipole sub assembly is electrically insulated from boom. The dipole tubes are bonded to TRAP holder using Hysol 9394. The trap holder houses the LC circuit which enables the antenna to work for dual frequencies.

UHF Reflector & VHF Reflector: The UHL reflector is made with rod made of Brass to meet the inertial constraint to avoid collision during deployment. The VHF reflector is made with tube made of Al alloy. The UHF reflector is a brass rod with OD 12 mm and the VHF reflector is an Al alloy tube with OD 12 mm. The UHF &VHF reflectors are positioned at a distance of 170mm and 425mm from dipole sub assembly respectively.

Retention and release Mechanism: In order to meet the envelope constraints, the dipole and reflectors are stowed during the ascent phase of the mission and deployed after injection of satellite into the orbit. The stowed dipole and reflectors are held in position using rope made of Nylon 6. The Nylon rope, either ends are attached to the strain gauged load links through bowline. The rope is finally assembled to the boom through a bracket at two locations. The antenna elements are preloaded against the boom by tightening the rope. The tension in the rope is controlled using preload bolts and monitored using the strain gauged load links. The rope is also touching the heating wire (SS 304 wire of dia 0.25 mm) routed through a block made of Machinable glass ceramic. The release of the antenna elements are achieved by fusing the rope using the heating wire. Two sets of heating wire are provided on the block to improve system reliability.

Deployment mechanism: The deployment mechanism moves the dipole and reflectors on release from the stowed configuration to the final position. Torsion springs are mounted at the hinge joint of dipole and reflectors to give necessary energy for deployment and also the necessary preload at the deployed condition.

Indian Block of Stations:		
Station	Lat. (˚N)	Long. (˚E)
Trivandrum	8.5	77.0
Bangalore	13	77.6
Hyderabad	17.8	78.0
Bhopal	23.2	77.2
Delhi	28.6	77.2

Russian Block of Stations:		
Station	Lat. (˚N)	Long. (˚E)
Norilsk	69.2	88.6
Turukhansk	65.46	87.56
Tomsk	56.3	84.55

18.4.3 LiVHySI Payload

In recent years the need for a comprehensive understanding of the complex processes of the ionosphere-thermosphere system, including its response to the various external forgings so as to reach a level of predictive capability, has been felt. As is known, the information regarding the thermosphere can be obtained through atmospheric emissions known as 'Airglow' while ionosphere variability's can be studied through radio wave propagation characteristics. As a consequence, simultaneous measurements of (i) airglow emission intensity from the menopause (height region around 90 km), ionosphere-thermosphere and, (ii) electron density distribution would provide important insight into the generation mechanisms and evolution of these processes. In this context, the combination of LiVHySI and RaBIT would provide excellent simultaneous measurements of neutral and plasma parameters respectively, complementing each other and also the solar radiation measurements through SOLRAD. Both these Indian experiments are the first of its kind indigenously built experiments onboard an Indian satellite.

The terrestrial upper atmosphere i.e. about 80 km to 1000 km is a closely coupled two component system where the neutrals (thermosphere) and plasma (ionosphere) coexist with linkages to magnetosphere higher above and the lower atmosphere below.

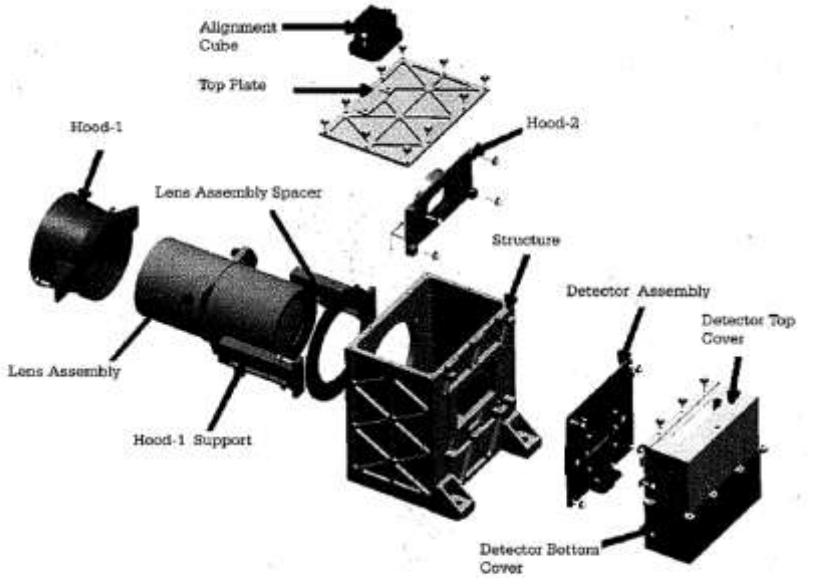
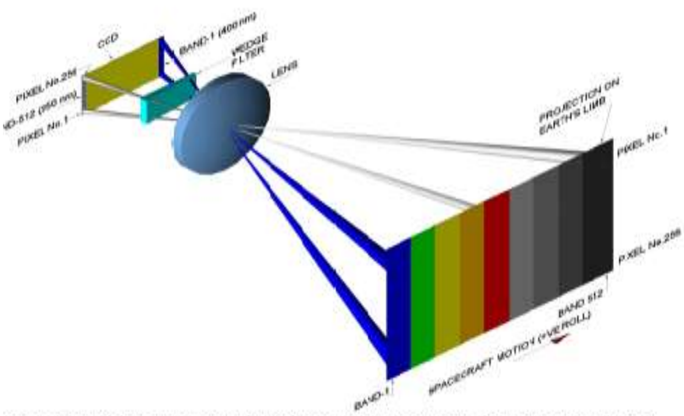


Figure 18.3: Exploded view of LiVHySI

This region consists of ionized matter (ionosphere) and neutral matter (thermosphere in the form of atoms and molecules). This part of the earth's atmosphere responds sensitively the solar radiation and wind reaching the earth through the interplanetary space. This region is controlled primarily by the solar EUV radiation through atmospheric heating, photo dissociation and photo ionization of the atmospheric species. The electrons and ions constitute the electrically conducting ionosphere with the neutral atmosphere (thermosphere) dominating the background.



SCHEMATIC OF SPECTRAL BAND PROJECTION ON EARTH'S LIMB

The state of thermosphere-ionosphere region at any given time and location is determined not only by chemistry but also by the transport through neutral winds, electric fields and field-aligned plasma diffusion. For instance, solar wind–magnetosphere interactions cause significant changes in the energies of this region over high latitudes. Over low and equatorial latitudes, the scenario is even more complicated as the energetic and dynamics is affected not only by the direct solar forcing but also by the non local forcing from the high latitudes and the atmosphere lower below it.

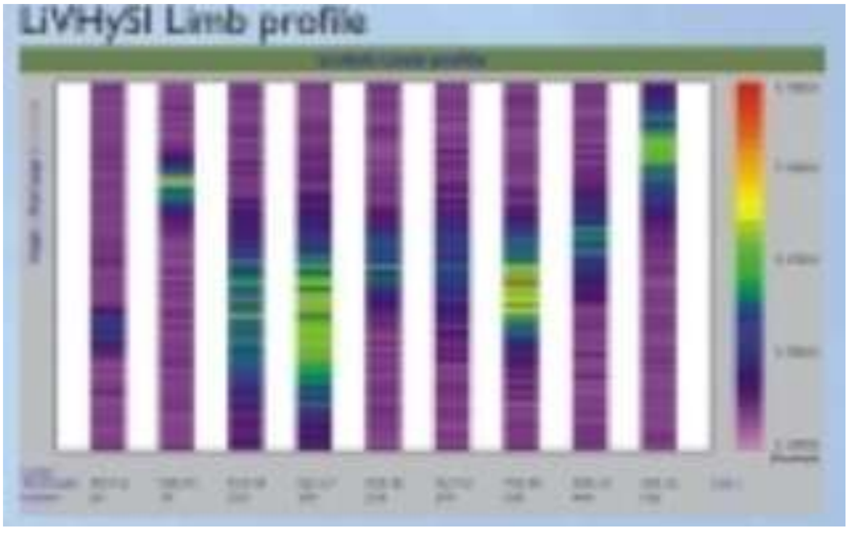


Figure 18.4 A typical product of LiVHySI

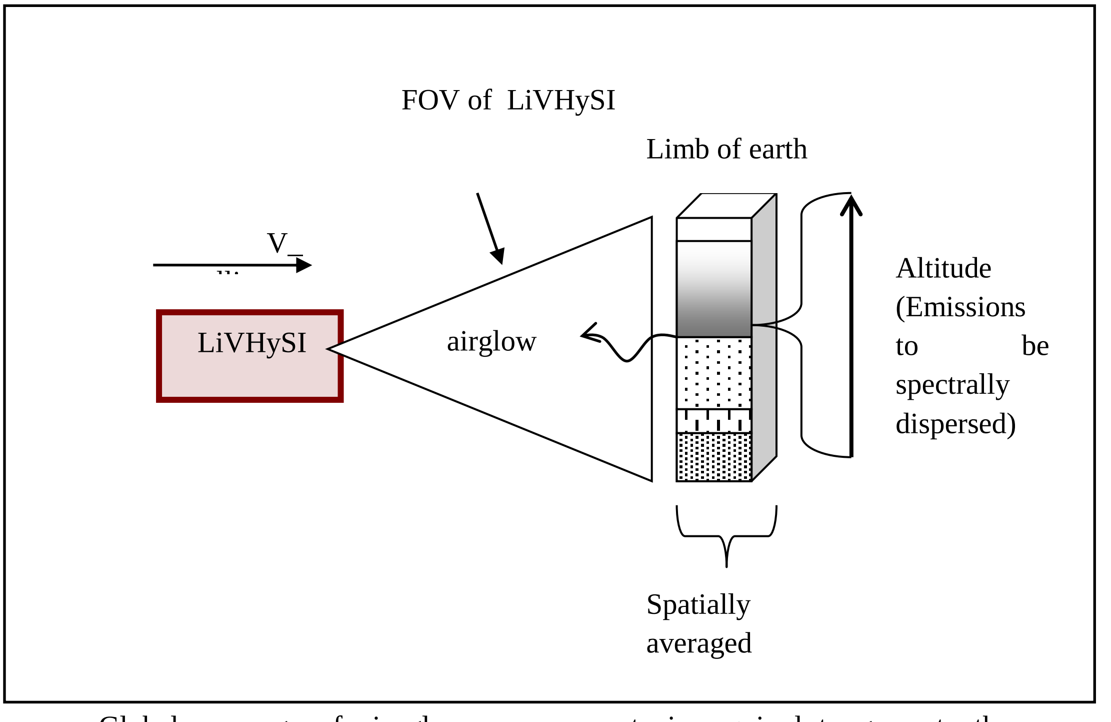
The individual constituents of the atmosphere whether they are atomic and molecular in nature play important role in the process of upper atmospheric energy balance. The lifetime of most of these species, to a large extent, are controlled by the photochemical processes involving them. A number of the atmospheric species get excited and undergo specific spectral transitions as a result of these processes. Consequently, atomic and molecular emissions occur depending on the lifetime of the meta stable state and the timescale of the ongoing quenching reactions. These atmospheric emissions are known as the `**Airglow'.** The broad classification of the airglow phenomenon is day glow, nightglow or twilight glow depending on the time of the day it is being observed. Twilight glow can also be termed as the day glow as seen from the night sky. The phenomenon of excitation and de-excitation over the polar-regions is known as **Aurora.** Though, the variations in the airglow intensity would primarily be caused by the changing relative contribution of the various chemical channels causing the particular excitation, transport effects would also modulate the observed airglow intensity at any given time. As a consequence, these airglow emissions thus serve as a perfect tracer for the processes occurring in the altitude regions from which they emanate. LiVHySI is a wedge filter based instrument that is capable of making simultaneous measurements of the intensity of many airglow emissions at different wavelengths, emanating within 80-600km altitude region within the limb of earth. The airglow emissions that are of interest to us are listed here giving details of the emitting species and corresponding wavelengths.

	Wavelength(λ in nm)	Emission Altitude Range(km)	Type of emission
1.	First negative band of N2427.8	120-250	Band
2.	NI 520.0	100-220	Atomic
3.	OI 557.7	90-120 & 150-200	Atomic
4.	NaI 589.0	90-100	Atomic
5.	OI 630.0	160-500	Atomic
6.	OI 636.4	160-500	Atomic
7.	OH 731.6	80-98	Band
8.	OII 732.0	100-200	Atomic
9.	OH 740.2	80-98	Band
10.	O2 762.0	80-100	Band
11.	OI 777.4	250-350	Atomic
12.	OI 844.6	250-350	Atomic
13.	O2 864.5	100-200	Band

Payload Operating Principle:

The 'Limb Viewing Hyper Spectral Imager' referenced to as LiVHySI would be continuously imaging the earth's limb along the meridian between ~ 80-600 km as it moves in the polar orbit. As mentioned earlier, the atmosphere in this altitude region is emanating a range of prominent airglow emissions at different wavelengths maximizing at different heights. The details of these emissions have been given in Table above. Further, the signals coming from the limb of earth would be spectrally dispersed only along the altitude while spatial variability that could exist horizontally would be time averaged depending upon the temporal resolution of the proposed measurements, since the satellite is moving with a velocity of ~8-10 km/s. In this context, the 256 pixels side of the detector would be aligned vertically (Yaw axis) along the altitude axis, while the 512 pixel side i.e. wavelength side of the detector would be employed horizontally (Band 1 is along +Roll side, Band 512 is along – Roll side). In this configuration, the imaged airglow emissions would not only provide the altitudinal distribution of the emitting species but also give us an insight into the physical, chemical and transport processes operating at different altitude regimes of upper atmosphere.

The main objective of the instrument is to perform airglow measurements in the Earth's upper atmosphere (80 to 600 km) in a spectral range of 450 nm to 950 nm. The observations would be carried out in the earth's limb viewing mode with a range of about 3172 km from a LEO sun-synchronous polar orbital platform (altitude of 817 km). Sensor Development Area (SEDA) at Space Applications Centre has developed this Hyper-spectral Imager as a part of scientific payload onboard Youthsat. This instrument has taken the advantage of the design and development of similar instrument hardware that was developed at SAC and used in Chandrayan-1 and IMS-1 missions.



Global coverage of air glow measurements is required to generate the required database to study and understand various aspects of the space weather. This is possible by satellite based observations. The Earth's Limb viewing geometry is chosen because it provides a number of advantages as compared to the nadir viewing geometry. The horizontal line of sight through the Earth's limb contains up to sixty times more emitting material than a corresponding nadir view, providing greater sensitivity for measurement of tenuous species. The combination of the spherical geometry of the Earth's atmosphere and the exponential decrease of gas density with altitude provides data heavily weighted around the tangent point altitude of viewing and also provides high vertical resolution. Further, the background viewed by the instrument is cold blackness of the space, which reduces the dark signal and noise and hence simplifies data interpretation.

This imaging spectrometer is based on a wedge filter as a dispersive element placed very close to an Active Pixel sensor (APS) area array which in turn is placed at the focal plane of F#2, f = 80 mm telecentric lens system. The principal advantages of wedge spectrometer approach are its relative simplicity, lack of complex aft optics, a compact and easily ruggedized instrument design, uncomplicated layout that results in minimal sensor integration and test time, reduced cost and delay time.

The estimated radiometric performance of the proposed instrument is < 50 Rayleighs at noise floor through the signal integration for 10 seconds. The pixel projection turns out to be 2 km/pixel at a range of about 3172 km with altitude coverage of 80 km to about 600 km and horizontal swath of 1024 km from a spacecraft altitude of 817 km. The spectral sampling distance is 1.1 nm. The observations could be carried out only during the eclipse due to the constraints imposed by the observational modes of other on-board SOLRAD payload.

The subsystems of the LiVHySI P/L are:

- Optics (f/2, f=80mm, telecentric lens)
- Wedge filter
- APS (Active Pixel Sensor) & its Temp. Controller
- Camera electronics
- Power supply
- EOM structure

Payload subsystems are detailed below:

Optics:_The imaging system for LiVHySI consists of a collecting optics, a wedge filter, an APS area array and the associated electronics. The optical design consists of a single lens assembly. This optical design utilizes eight lenses, consisting of four types of Schott glasses. A telecentric design, in which the principal ray at all the field angles, is parallel to the optical axis, ensures that the angle of incidence on the band pass filter is nearly the same for all the wavelengths. Keeping the angle of incidence close to normal to the filter reduces the complexity of filter coating.

Detector head Assembly: LiVHySI DHA (Limb Viewing Detector Head Assembly) of Youthsat consists of512*256 elements Silicon based Area array Active Pixel Sensor (improved version of the sensor used in Chandrayaan-1 and IMS-1). Desired system sensitivity is achieved by fast optics and integrating the sensor for long duration. The sensor temperature is maintained with tight tolerance (21 ± 0.1°C) using heater and thermistor in close loop to minimize dark signal variation. The DHA responds to optical radiation covering spectral region from 450nm to 950 nm. Wedge filter is placed very close to the sensor array for obtaining spectral separation (512 spectral bands) along the row direction.

Thermal: The sensor temperature is maintained with tight tolerance (21 ± 0.1°C) using heater and thermistor in close loop. The temperature control system consists of two number of thermo foil heaters (type: MINCO HK5537R26.1L12E, 26.1ohm, 20W/inch, 12.7mm dia. Circular patch) and two numbers of thermistors (type: YSI44906/44907,one for the control loop and one for temperature monitoring). These components are mounted directly on back surface of the APS.

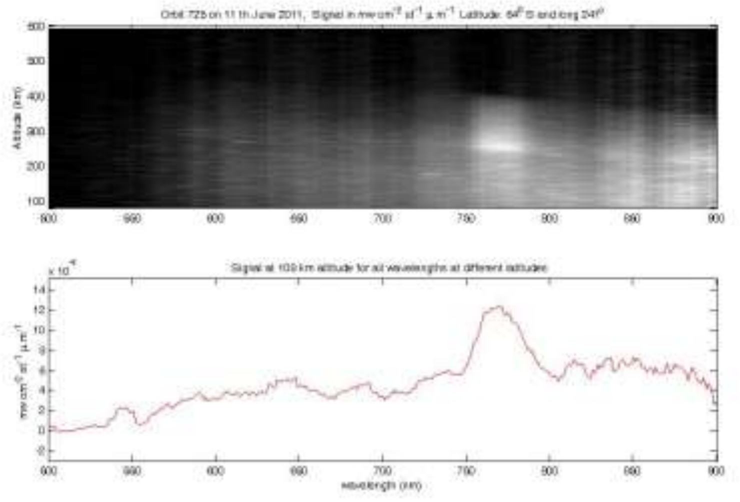
Camera Electronics - Limb viewing hyper-spectral imager (LiVHySI) consists oftwo trays stacked together.

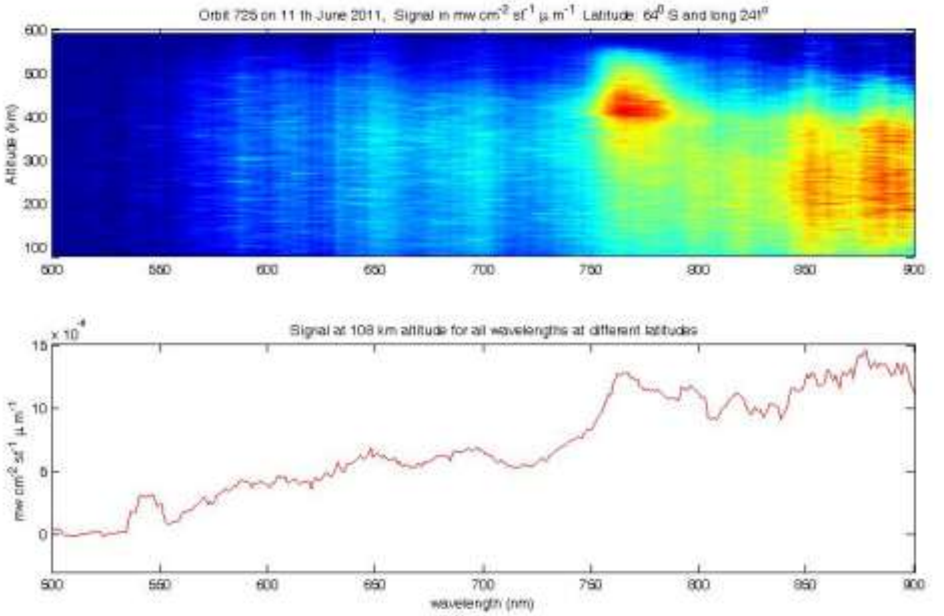
1. Camera Electronics Main tray (PLE21)
2. Temperature Controller tray (PLE22)

CE configuration is similar to IMS-1-HySI with changes carried out in FPGA logic design to meet LiVHySI configuration requirements. In addition, a temperature controller is added as a part of CE to minimize dark signal accumulated due to large integration time.

Following are the main changes in Youthsat-LiVHySI CE w.r.to IMS-1 Camera Electronics.

- All 512 bands data is transmitted as compared to 64 bands in IMS-1
- WLS from BDH is with minimum 8 skips as compared to IMS-1
- No TC/TM interface
- All dark pixels included in the data format from CE to BDH without change in data rate
- 12 LSB's out of 16 bit output data represent valid data with 4 MSB's stuffed to logic "1"


Orbit 725 on 11 th June 2011, Signal in mw cm^{-2} sr^{-1} μ m^{-1} Latitude: 64^0 S and long 24^0
Altitude (km)
Signal at 108 km altitude for all wavelengths at different latitudes
mw cm^{-2} sr^{-1} μ m^{-1}
wavelength (nm)


Orbit 725 on 11 th June 2011, Signal in mw cm^{-2} sr^{-1} μ m^{-1} Latitude: 64^0 S and long 24^0
Altitude (km)
Signal at 108 km altitude for all wavelengths at different latitudes
x 10^{-4}
mw cm^{-2} sr^{-1} μ m^{-1}
wavelength (nm)

19 MEGHA-TROPIQUES

19.1 Introduction

Megha-Tropiques is an Indo-French Joint Satellite Mission for studying the water cycle and energy exchanges in the tropics. In the early 1990s, France wanted a ‘Tropiques' satellite while India wanted a ‘Climatsat' satellite. They merged the two ideas, resulting in a joint venture Megha-Tropiques. The name chosen for the satellite, Megha-Tropiques, reflected the mission's goals. ‘Megha,' the Sanskrit word for clouds, underscoring a key focus of the satellite, and the French word ‘Tropiques' denoting its concentration on the tropical region.

The main objective of this mission is to understand the life cycle of convective systems that influence the tropical weather and climate and their role in associated energy and moisture budget of the atmosphere in tropical regions. Megha-Tropiques provides scientific data on the contribution of the water cycle to the tropical atmosphere, with information on condensed water in clouds, water vapour in the atmosphere, precipitation, and evaporation.

The scientific goal of the mission is to study the impact of this water cycle on the atmosphere, the oceans and climate variability.

19.2 Mission Objective

The main objective of the Megha-Tropiques mission is to study the convective systems that influence the tropical weather and climate. The tropical region is the domain of monsoons, tropical cyclones. It is also characterized by large intra seasonal inter annual variations, which may lead to catastrophic events such as droughts or floods. Any change in the energy and water budget of the land-ocean-atmosphere system in the tropics has an influence on global climate.

Objectives can be stated briefly as given below.

- *To provide simultaneous measurements of several elements of the atmosphere water cycle, water vapour, clouds, condensed water in clouds, precipitation and evaporation.*
- *To measure the corresponding radiative budget at the top of the atmosphere*
- *To ensure high temporal sampling in order to characterize the life cycle of the convective systems and to obtain significant statistics*

19.3 Orbital Parameters

Table 19.1: Orbital Parameters of Megha trophique

Orbit	Near circular/ equator
Altitude (km)	865.5.Km
Inclination (deg)	20 Deg
Orbit Plane regression	6.01 deg/day
Apparent Sun Angle	52 days/Cycle
Orbit perigee	within +/- 10 km
Distance between successive orbit (km)	2892
Orbital Period(min)	101.91
Number of period/day	14.13
Launch vehicle	PSLV-C18

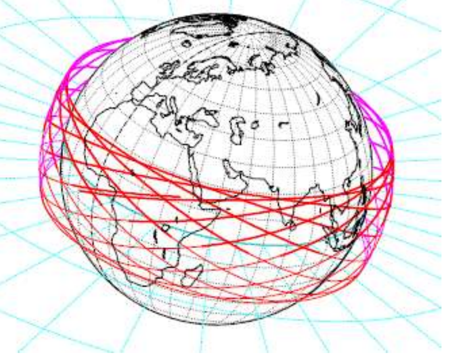


Figure 19.1 One day orbit pattern of Megha tropiques

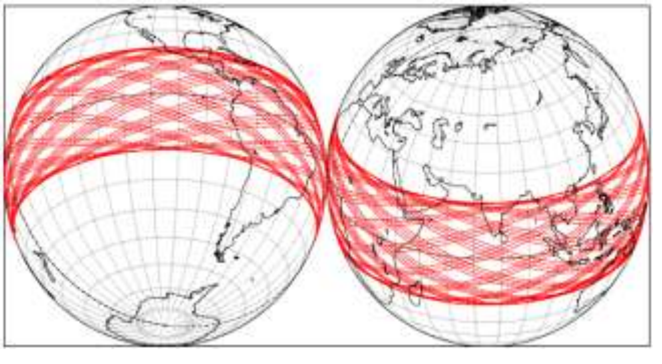


Figure 19.2: 3.5 day Orbit patterns of Megha tropiques

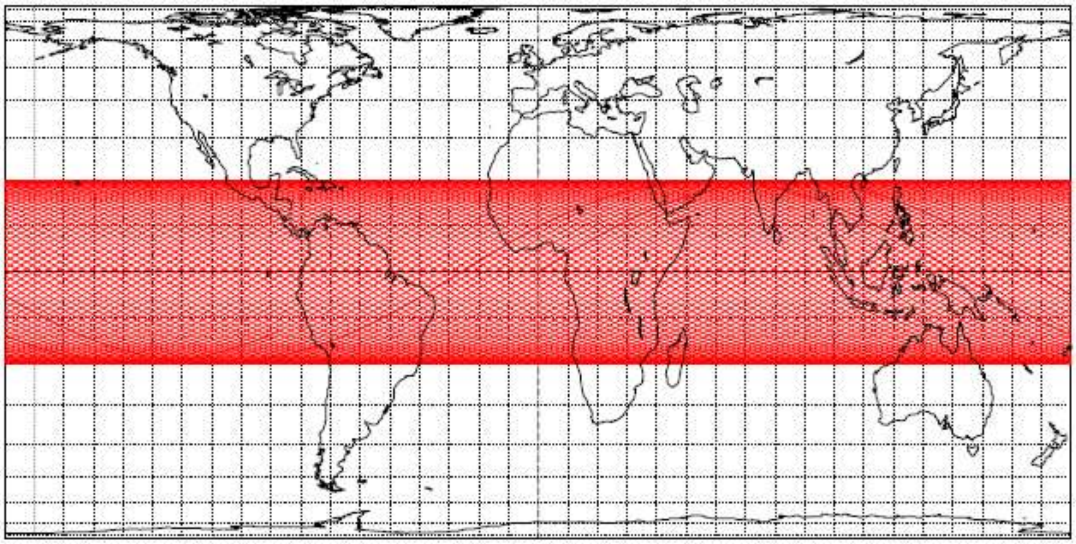
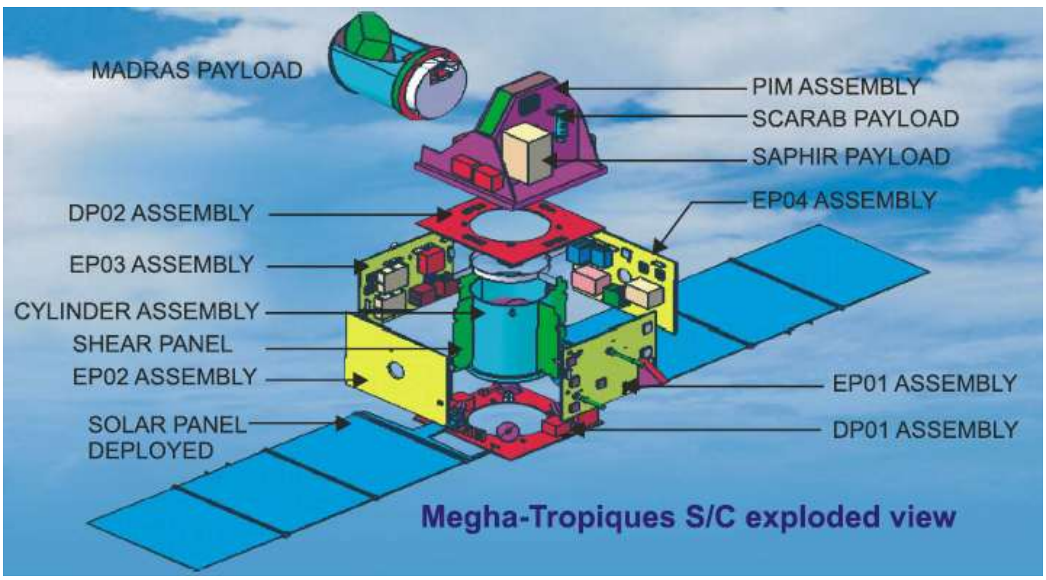


Figure 19.3 Orbital pattern of Megha Trophiques

The Megha Tropiques satellite can be divided into two main parts 1. Main Bus and 2 PIM(Payload Interface Module.



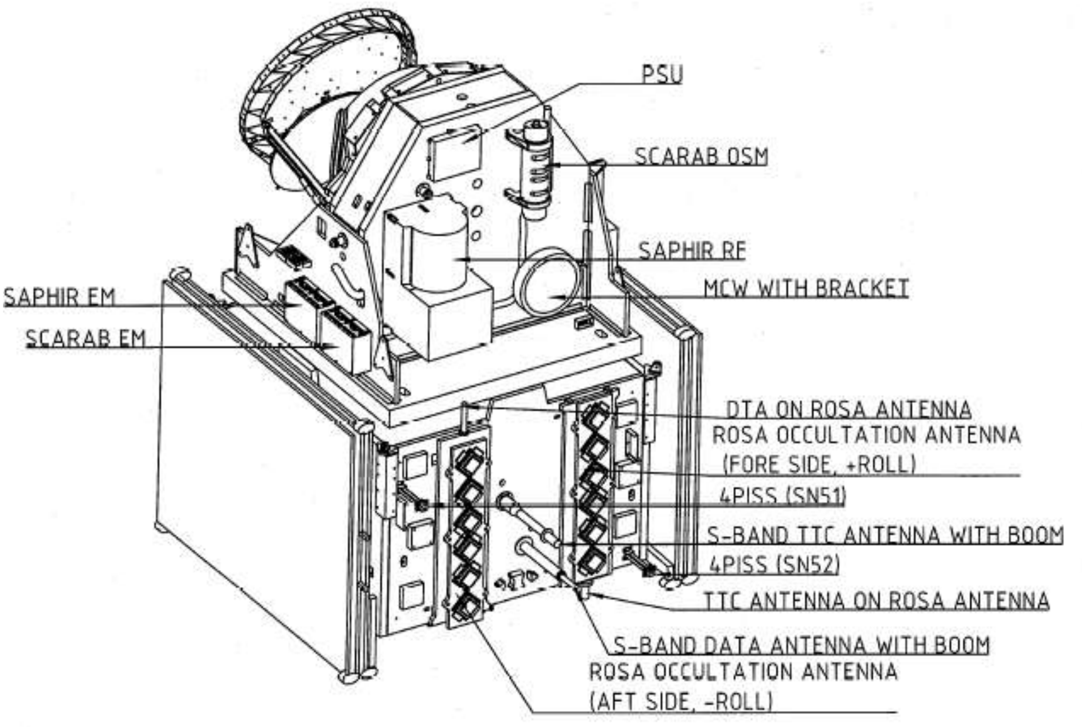


Figure 19.4 Stowed configuration of Megha tropiques

19.4 Payloads

Megha-Tropiques satellite carried 4 scientific passive instruments, ie :

MADRAS: (Microwave Analysis and Detection of Rain and Atmospheric Structures) A multi–channel self-calibrating microwave imager mainly aimed at studying precipitation and cloud properties.

SAPHIR: (Soundeur Atmospherique du profil d'Humidite Interopicale par Radiometric) A microwave instrument used to retrieve water vapour vertical profiles.

SCARAB: (Scanner for Radiation Budget) An optical radiometer devoted to the measurement of outgoing radiative fluxes at the top of the atmosphere.

ROSA: (Radio Occultation Sounder for Atmosphere Payload) A GPS Receiver specifically conceived for atmospheric sounding by radio occultation, which is able to determine position, velocity, and time using GPS signals.

Combining the information from these different payloads, the following parameters can be derived: size of convective cells, cloud cover, water vapour profiles, deep cloud water content, rain rate, cloud ice content and radiative fluxes, humidity content at the top of the atmosphere.

19.4.1 Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS)

The MADRAS instrument is a 9 channel self-calibrating microwave imager. The payload is jointly developed by ISRO and CNES. The payload scans the Earth +/65 deg, with onboard angle of +45.05 deg in the along track direction. The rotating part of MADRAS has a mass of about 100 kg. MADRAS is nominally a scanning payload. A **stationary mode** is defined for the payload, where the MADRAS is pointed a specific angle (within +/- 65 deg) continuously. IISU, SAC and ISAC have developed the MSM/MCE, MBE-R/MBE-S and HDRM components of MADRAS respectively, whereas MARFEQ-A & B have been developed by CNES.

The MADRAS RF front-end consisting of the entire RF units from 18 GHz – 157 GHz including the antenna, feed cluster, and on-board calibration is designated as MARFEQ (MADRAS RF Equipment).

MARFEQ-A is the mobile part of MADRAS. It includes a structure supporting the main reflector associated to the horns located at the focal point of the parabola. Behind each horn one or several receivers allows the detection of the RF signals

- Main Reflector made from a CFRP dish (projected diameter 650 mm),
- Feed Cluster and Front Ends Assembly constituted by aluminum RF elements with their supporting structure and thermal hardware
- Back Ends, Low Frequency Receivers and Interface Electronic Unit,
- Related waveguides, coaxial cables and harness,
- CFRP structure which supports the above elements and their thermal hardware and which interfaces with the Scan Mechanism Rotating part through a titanium cylinder and with the Hold Down and Release Mechanism through 6 titanium integrated fittings.
- MBE(R) will be accommodated on the lower part of MARFEQ-A Deck.

MARFEQ B is mounted on the fixed part of the instrument. It allows the calibration of the receivers at each rotation. It is constituted of a mirror allowing a cold calibration and a black body allowing the hot calibration. This equipment contains only accurate thermistors to measure the physical temperature of the black-body.

The MARFEQ fixed part (MARFEQ-B) consists of:

- Cold Calibration Reflector made from a CFRP dish (projected diameter 285mm),
- Hot Calibration Target
- Aluminum structure which supports the above elements and interfaces with the Scan Mechanism fixed part.

Hold Down and Release Mechanism (HDRM)

This is necessary to protect MSM bearings from launch loads, since the rotating elements of MADRAS high. The mechanism will rigidly hold the MARFEQ at six locations. Once the spacecraft is in orbit, the mechanism will release the MARFEQ, to enable scanning. MSM, MCW and MCE form MADRAS Mechanism and Momentum Compensation System (MMCS). MMCS has four modes of operation, viz.

- Run-up mode
- Scanning mode
- Pointing mode
- Run down mode.

MADRAS Momentum Compensation System (MMCS)

MMCS as a part of MADRAS payload consists of three elements such as;

MADRAS Scan Mechanism (MSM) : Scan Mechanism consisting of precision angular contact ball bearing assembly, Diaphragm assembly for hold down compliance, drive motor, optical encoder, PSTD for transfer of power and signal from and to Marfeq A/MBE(R) and MBE (S). The nominal speed of the mechanism is 24.14 rpm with scan stability of +/- 0.1%.

Momentum Compensating Wheel (MCW): Momentum Compensating Wheel MCW consists of precision ball bearing assembly, flywheel, brushless iron less DC motor in a hermetically sealed casing. The MCW (Momentum Compensative Wheel) generates counter momentum such that the residual momentum is very small and tolerable by the spacecraft. MCW consists of a wheel with a low mass but high rotational speed to generated compensative momentum.

MADRAS Control Electronics (MCE): The MADRAS Control Electronics (MCE) containing all the electronic functions as management of the MSM, MCW, commutation electronics, power supply, mechanisms command and control, interface with MBE.

MCE (MSM and Momentum Compensating Electronics) is an integrated control electronics package for MSM. Rotating mass of the payload (100kg) generates a large momentum about its axis of rotation, which can destabilize the platform.

Payload Characteristics

MADRAS channel definitions

Channel No.	Frequency	Polarization	Pixel size	*Bandwidth*	Science Parameters
M1	18.7 GHz	H+V	40 km	±100 MHz	Rain above oceans
M2	23.8 GHz	V	40 km	±200 MHz	Integrated water vapour
M3	36.5 GHz	H+V	40 km	±500 MHz	Liquid water in clouds, rain above sea
M4	89 GHz	H+V	10 km	±1350 MHz	Convective rain areas over land and sea
M5	157 GHz	H+V	6 km	±1350 MHz	Ice at cloud tops

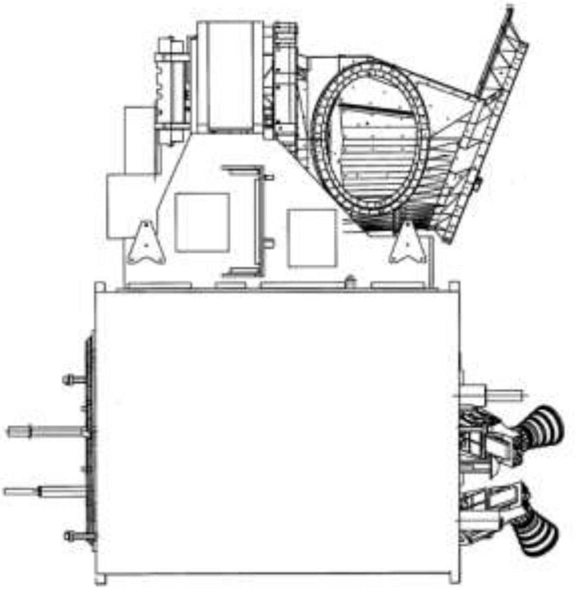


Figure 19.5: View from –ve pitch

Scan type	:	Conical scanning at constant speed
Onboard look angle (w.r.t. Nadir)	:	45.05°
Incidence angle	:	53.5°
Maximum scan angle (cross track)	:	±65°
Scan mechanism speed	:	24.14 rpm

⇔ 144.84 °/sec
⇔ 2.4855 sec/revolution
⇔ 0.4023 cycles/sec = 0.4023 Hz.

Dwell time (Channel wise) : 16.8 millisec (18.7, 23.8, 36.5 GHz)
: 4.2 millsec (89 GHz)
: 2.5 millisec (157 GHz)

Swath : 1700 km

Dynamic range of radiometer
Brightness temperature : 3 °K to 320 °K

Scan mechanism stability : 0.1% of the rate

Data rate: **The total data rate of MADRAS is 33.858 Kbps.**

Type of data	Size	Rate
Science TM	5248 words	2.48sec

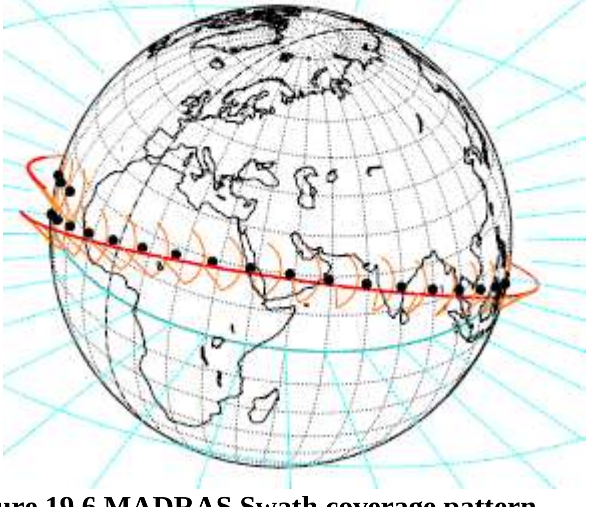


Figure 19.6 MADRAS Swath coverage pattern

19.4.2 SAPHIR (Soundeur Atmospherique du Profil d'Humidite Intertropicale par Radiometrie) Payload

SAPHIR is a Microwave instrument for the retrieval of water vapour vertical profiles and scanning millimeter wave humidity sounder. It scans the Earth in a nadir plane symmetrically with respect to the local vertical with a scan angle of ±42.96 deg. It uses narrow channels close to a water vapour absorption band at a frequency of 183 GHz. Six channels would allow to retrieve information about six atmospheric layers from the Earth surface up to 12 km height. The horizontal resolution is 10 km. The 6 channels are in the range of 183.31 ±0.2, ±1.1, ±2.8, ±4.2, ±6.8, ±11.0 (GHz).

The instrument is composed of two packages linked by a dedicated harness.
The packages are
The **RF Unit** (6 Passive microwave channels) contains the antenna, the frontend, IF processor, the scanning with the shroud and the calibration target.
The **Electronic unit** (EU) containing all the electronic functions as management of the equipment, power supply, mechanisms command and control interface with satellite processor.
Following are highlights of its operation. Scans Earth's atmosphere and switches between the calibration sources of cold sky and hot target

- During each scan period the antenna performs one complete rotation in order to scan the Earth over an angle of +/- 42.96 deg and performs hot and cold calibration
- During Earth scanning of +/- 42.96 deg, in nominal mode the angular speed is constant and equal to 103.5 degree/sec.
- During the rest of scan period, in order to optimize the time dedicated to Earth's atmosphere measurements, the motor will produce half part of the time a constant and maximum acceleration and on the other half part of the time a constant maximum deceleration. The current values of acceleration and deceleration [20] are 1666 deg/sec^2 and 1666 deg/sec^2.

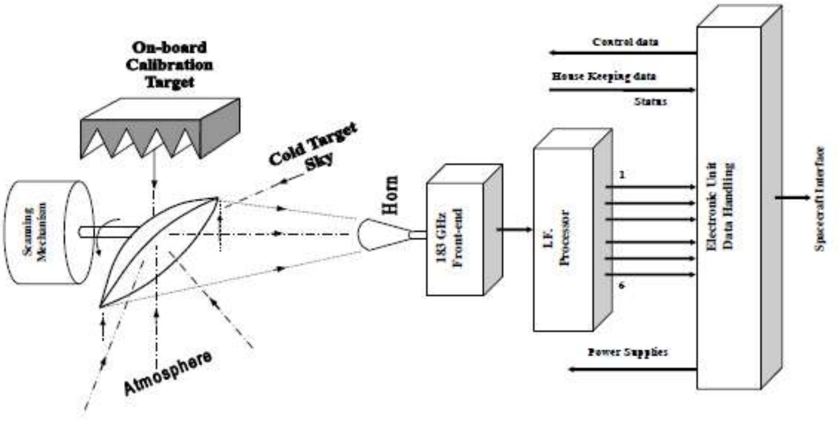


Figure 19.7 Schematic of SAPHIR Payload

SAPHIR channel definitions and characteristics

Channels	Central nominal frequencies (GHz)	Nominal Bandwidth (MHz)	□T (Sensitivity)	
			Req.	Goal
S1	183.31 ± 0.2	200	2 °K	**1 °K**
S2	183.31 ± 1.1	350	1.5 °K	**0.7 °K**

S3	183.31 ± 2.8	500	1.5 °K	**0.7 °K**
S4	183.31 ± 4.2	700	1.3 °K	**0.6 °K**
S5	183.31 ± 6.8	1200	1.3 °K	**0.6 °K**
S6	**183.31 ± 11**	**2000**	**1.0 °K**	**0.5 °K**

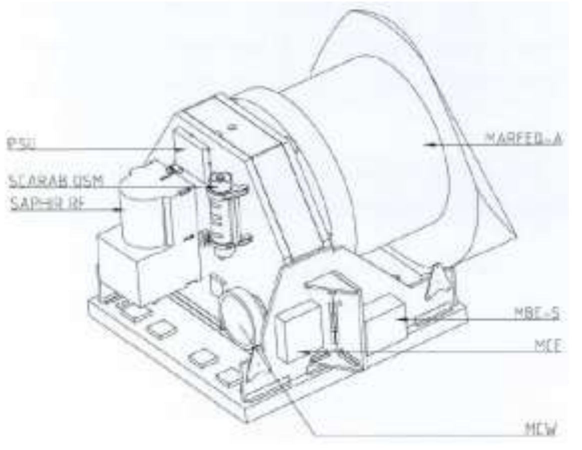


Figure 19.8 Payload Interface Module

Scan type : Cross track scanning at constant speed
Polarisation : Variable along swath
Incidence angle : Variable along swath
Maximum scan angle
(cross track) : ± 42.96°
Scan mechanism speed : 36.63 rpm ⇔ 219.78 °/sec
⇔1.638 sec/revolution
⇔ 0.6105 Hz
Scan rate during
Earth viewing phase : 103.5 °/sec
Dwell time : 6.406 msec
Swath : 1705 km
Nadir spatial resolution : 10 km
Brightness temperature Range: 4 °K to 313 °K

Data rate:

The total data rate of SAPHIR is 12.487 Kbps. The different kinds of data coming to BDH from SAPHIR instrument are given in the table below.

Type of data	Size	Rate
Science TM	**1216 words**	**1.64 sec**
Aux data	**64 words**	19.6 sec

19.4.3 ScaRaB (Scanner for Radiation Budget) Payload

Radiometer devoted to the measurement of outgoing radiative fluxes at the top of the atmosphere. Measures radiation fluxes in four channels in the range of 0.5 to 0.7μm, 0.2 to 4 μm, 0.2 to 50 μm and 10.5 to 12.5 μm spectral bands; in Visible, Solar, Total and IR Windows. It consists of (a) Optical Sensor Module (including scanner and calibration devices) and (b) Electronic Module.

The optical sensor module (OSM) can be divided in two parts

- A rotating part with mechanism, four detectors, two choppers, an internal electronics and a filter wheel.
- The external structure, with the casing, the two feet and the calibration module (CalM) formed by three black body simulators and a lamp.

The Electronic Module (EM) containing all the electronic functions as management of the equipment, power supply, mechanisms command and control interface with satellite processor.

Following are the highlights of its operation.

- During each scan period the rotor performs one complete rotation in order to scan the Earth over an angle of +/- 48.91° and performs calibration on cold space.
- Produce part of time some acceleration and part of time some deceleration. The total duration for one full scan is 6 sec.

19.4.3.1 Scanning sequence in nominal mode

Function	Angle	Typical Duration	Type of movement
Earth/Atmosphere Scanning	-48.91° to +48.91°	51Xte = 3.1875 sec	**Constant speed**
Switching period	+48.91° to -74.35°	30Xte = 1.875 sec	**Acceleration/ Deceleration**
Stop on space view	-74.35°	6Xte = 0.375 sec	**Stop(fixed**

			position)
Switching period	-74.35° to -48.91°	9Xte = 0.5625 sec	**Acceleration/ Deceleration**
Total Period		96*te = 6 sec	

In the background of the discussion above on the working of payloads, it is evident that the payloads' scanning are asynchronous. Further SAPHIR has acceleration and deceleration before it scans the Earth portion. Similarly in case of SCARAB, in addition to acceleration and deceleration, it stops to view deep space for a finite amount of time. This is likely to cause disturbance on the platform with impact on spacecraft control and eventually Data Products Generation. During this exercises, it emerged that platform rates achievable are of the order 10^{-2}deg/sec.

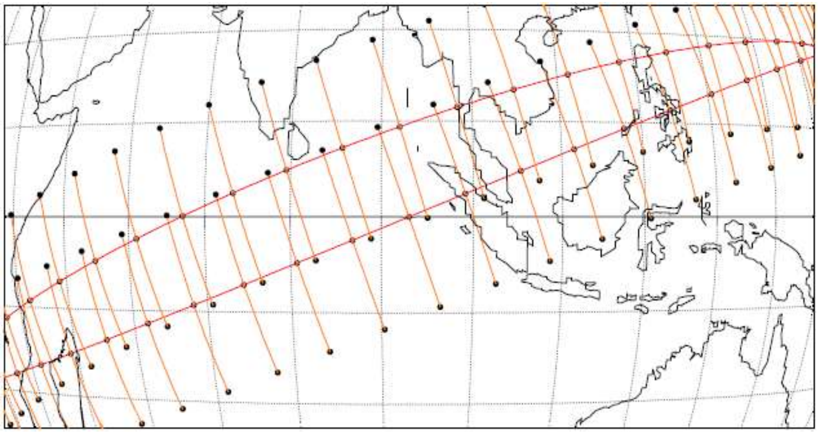


Figure 19.9: Scarab Scanning lines and Overlap

ScaRaB channel definitions and characteristics

Channels	Wavelength	*Radiometric Resolution (Noise)*	Signal Dynamics (Max.)
Sc_1 – Visible	0.5 to 0.7 µm	< 1 $W.m^{-2}.sr^{-1}$	**120 $W.m^{-2}.sr^{-1}$**
Sc_2 – Solar	0.2 to 4 µm	< 0.5 $W.m^{-2}.sr^{-1}$	**425 $W.m^{-2}.sr^{-1}$**
Sc_3 – Total	0.2 to 50 µm	< 0.5 $W.m^{-2}.sr^{-1}$	**500 $W.m^{-2}.sr^{-1}$**
Sc_4 – IR Window	**10.5 to 12.5 µm**	**< 0.5 $W.m^{-2}.sr^{-1}$**	**30 $W.m^{-2}.sr^{-1}$**

Scan type : Cross track scanning at constant speed

Scan Angle (across track) : ± 48.91°

Scan mechanism speed : 10 rpm ⇔ 60 °/sec
⇔ 6 sec/revolution
⇔ 0.17 Hz

Dwell time : 62.5 msec

Swath : 2242 km

Nominal nadir spatial resolution : 40 km

Data rate:

The total data rate of SCARAB is 853.333 Kbps. The different kinds of SCARAB data coming to BDH are given in the table below.

Type of data	Size	Rate
Science TM	**256 words**	**6 sec**
Aux data	**64 words**	**6 sec**

19.4.4 ROSA

The ROSA is a 16-channel dual-frequency GPS (Global Positioning System) receiver for space borne applications, specifically used for atmospheric sounding by radio occultation and determines position, velocity and time using GPS signals. The ROSA processes the received GPS signals in both the L1 and L2 frequency bands, allowing compensation of ionospheric delays. A codeless tracking scheme is included, in order to process the encrypted P(Y) signals transmitted in the L2 frequency band.

The ROSA, besides providing real-time navigation data, is able to accurately measure pseudo-ranges and integrated carrier phase (raw data), to be later processed on ground for the scientific purposes of retrieval of atmospheric parameters such as Humidity, Pressure and Temperature profiles between 0 and 100 km height above the Earth surface. These profiles can be used in meteorological and climatologic forecast with a vertical resolution much higher than that obtainable with measurement based upon microwaves or infrared techniques.

ROSA payload on Megha-Tropiques will supplement / complement the mission objectives for the atmospheric studies. ROSA on Megha-Tropiques spacecraft has a fore and an aft antenna facilitating occultation measurements in both velocity and anti-velocity directions of the spacecraft thus allowing a large number of observations. The Navigation antenna looking along the spacecraft's zenith direction facilitates the precise orbit determination (POD).

GPS ROSA, raw data and the products are generated at ISSDC Bangalore and are also archived for further use by application scientists.

ROSA Specifications

Features	Specification
Dual Frequency operation:	Receiving Frequencies: L1 [1575.42 MHz] C/A-Code signal L1 [1575.42 MHz] P-Code signal L2 [1227.60 MHz] P-Code signal
Bandwidth:	±10 MHz nominal
Number of Dual-Frequency Channels:	16 Dual-Frequency channels. Allocating channels to POD or Occultation is managed automatically only by onboard software in order to optimally share the hardware resources (channels).
Measurement rate:	Navigation/POD: 1 Hz sampling data rate (for both code phase and carrier phase) Carrier Phase measurements for Occultation/space weather channels: (a) Observation (Close loop): 1 Hz, 10 Hz and 50 Hz sampling data rate depending on altitude of the tangent point. (b) Occultation (open loop): 100 Hz sampling data rate only in lower troposphere.
Measurement accuracy:	Pseudo range: < 50 cm Carrier phase: < 5 mm Bending angle: Better than 1 µrad
On-board POD software with Satellite positioning accuracy:	< 30 metre (Real-time 3D-3σ solution)
Receiver Power consumption:	45 Watts (Operating Mode)
Receiver operating voltage:	+28V to +42V DC (37 V nominal)
Navigation input signal levels:	L1-CA: -127 dBm (minimum) L1-P: -130 dBm (minimum) L2-P: -133 dBm (minimum)
Radio Occultation input signal range:	L1-CA: -130 dBm to -142 dBm, -132 dBm (nominal) L1-P: -133 dBm to -145 dBm, -135 dBm (nominal) L2-P: -136 dBm to -148 dBm, -138 dBm (nominal)
Interfaces with satellite platform:	**House-Keeping Telemetry, Telecommand and Science Telemetry interface:** Mil-Std-1553B **Science Telemetry format:** Space Packet as per CCSDS 133.0-B-1 **Pulse Per Second (PPS) signal interface:** RS-422 **Number of PPS output signals:** 2

Receiver Mass:	9.2 kg
Receiver Dimension:	290.6 mm x 334.6 mm x 207.7 mm
Receiver operating temperature:	-10 °C to +45 °C

The total data rate of ROSA varies from 11.264 Kbps to 113.664 Kbps.

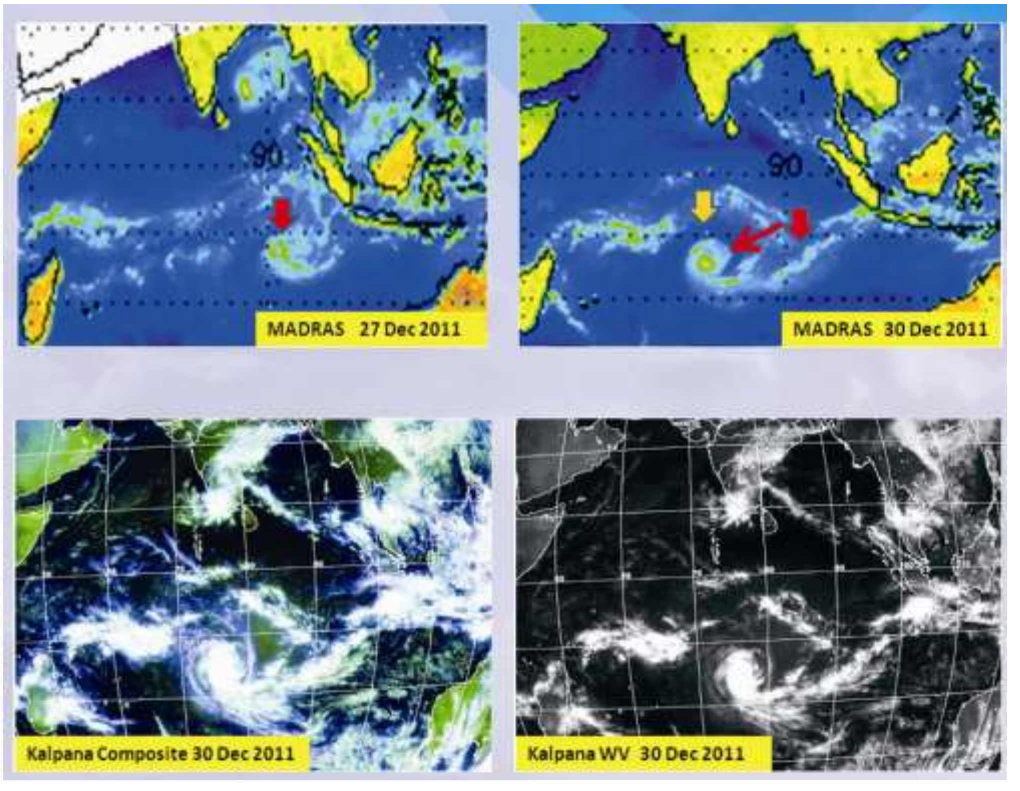
Type of data	Size	Rate
Navigation and Observation data	**704 to 7104 words**	**1 sec**

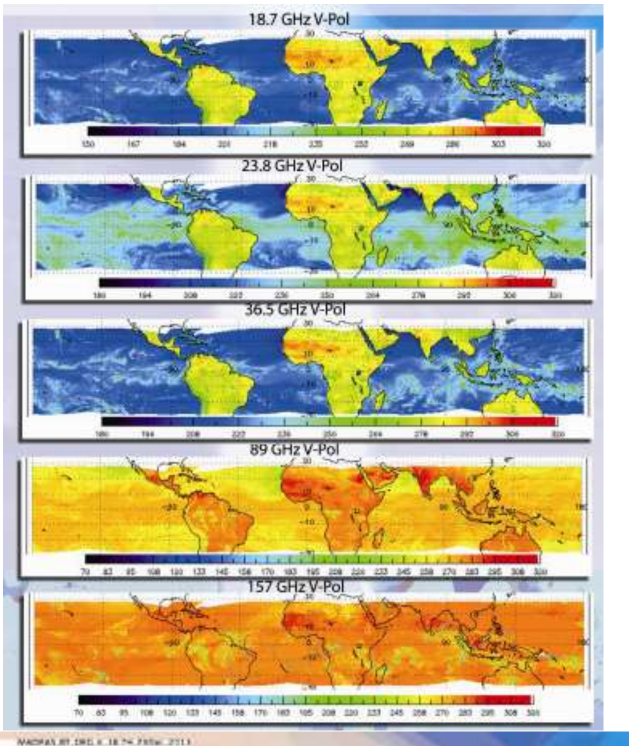
Dual-Frequency ROSA antenna specifications

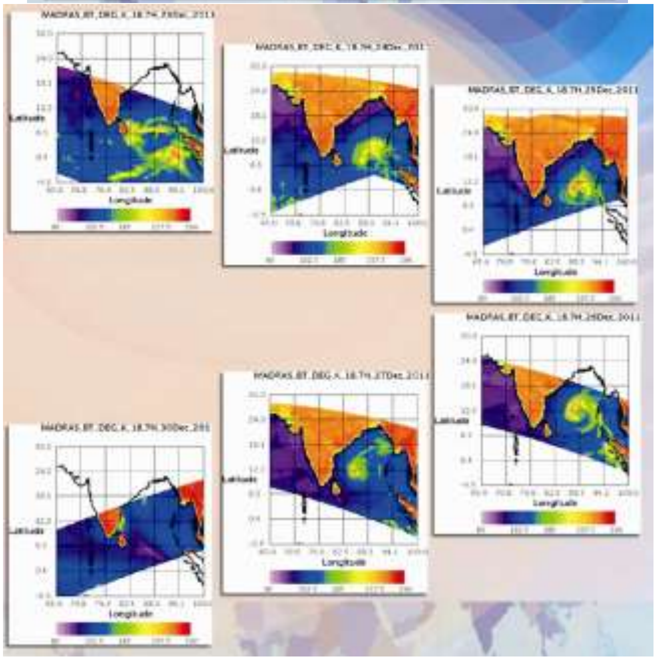
Features	Specification
FOV (Field of View):	Azimuth FOV (referred to orbital plane): ± 30° Elevation FOV (referred to local zenith) • Baseline coverage region: 116.7° to 118.3° • Extended coverage region: 90° to 116.7°
Antenna Gain:	Gain inside the coverage region: ≥ 12 dBi for both L1 and L2 band Gain inside the extended coverage region: ≥ -3 dBi for both the L1 and L2 band
Polarization:	Right Hand Circular Polarization (RHCP)
VSWR:	1.4:1
Mass:	2.5 kg
Dimensions:	1050 mm x 280 mm x 80mm (Single panel patch array)
Operating temperature:	-80 °C to +100 °C

Dual-Frequency Navigation/POD antenna specifications

Features	Specification
FOV (Field of View):	± 75° (referred to local zenith)
Antenna Gain:	5 dBi (at zenith) 4 dBi (at 5° elevation above the horizon)
Polarization:	Right Hand Circular Polarization (RHCP)
VSWR:	1.5:1
Mass:	0.138 kg
Dimensions:	127 mm x 49 mm
Operating temperature:	-70 °C to +80 °C


90
MADRAS 27 Dec 2011
90
MADRAS 30 Dec 2011
Kalpana Composite 30 Dec 2011
Kalpana WV 30 Dec 2011


18.7 GHz V-Pol
23.8 GHz V-Pol
36.5 GHz V-Pol
89 GHz V-Pol
157 GHz V-Pol


Latitude
Longitude

20 RISAT-1

20.1 Introduction

RISAT is the first microwave satellite designed and fabricated by ISRO. This mission will facilitate data collection in day/night and in all weather conditions.

20.2 Mission Objective

- *To Develop a multimode, agile SAR payload operating in ScanSAR, Strip and spot modes to provide images with coarse, fine and high spatial resolutions respectively*
- *To develop and operate a compatible satellite to meet the mission requirements operating in three axis stabilized mode in 536.38 km circular sun synchronous orbit.*
- *To establish ground segment to receive and process SAR data.*
- *To develop related algorithms and data products to serve in well established application area and also to enhance the mission utility.*

20.3 Orbital Parameters

The guiding parameter for the orbit selection for RISAT is achieving a global coverage in a systematic way for a given swath. In interferometric applications modes, the presence of atomic oxygen and atmospheric drag has also been kept in view.

Sl.No	Parameters	ScanSAR Mode	Medium Resolution Mode	STRIP MAP Mode	Interferometer Mode
1	Altitude(Km)	536.38	536.38	536.65	526.9
2	Inclination	97.554^{o}	97.554^{o}	97.555^{o}	97.52^{o}
3	Repeat cycle	377 orbits in 25 Days	377 orbits in 25 Days	2096 orbits in 139 Days	136 orbits in 13 Days
4	Orbit Period (Minutes)	95.4907	95.4907	95.542	95.294

5	Path-to-path Distance(Km)	212.6	106.3	19.12	294.7
6	Swath (Km)	223	115	25	25
7	Local Time: 6.00- Hrs +/- 5 min (Descending)				

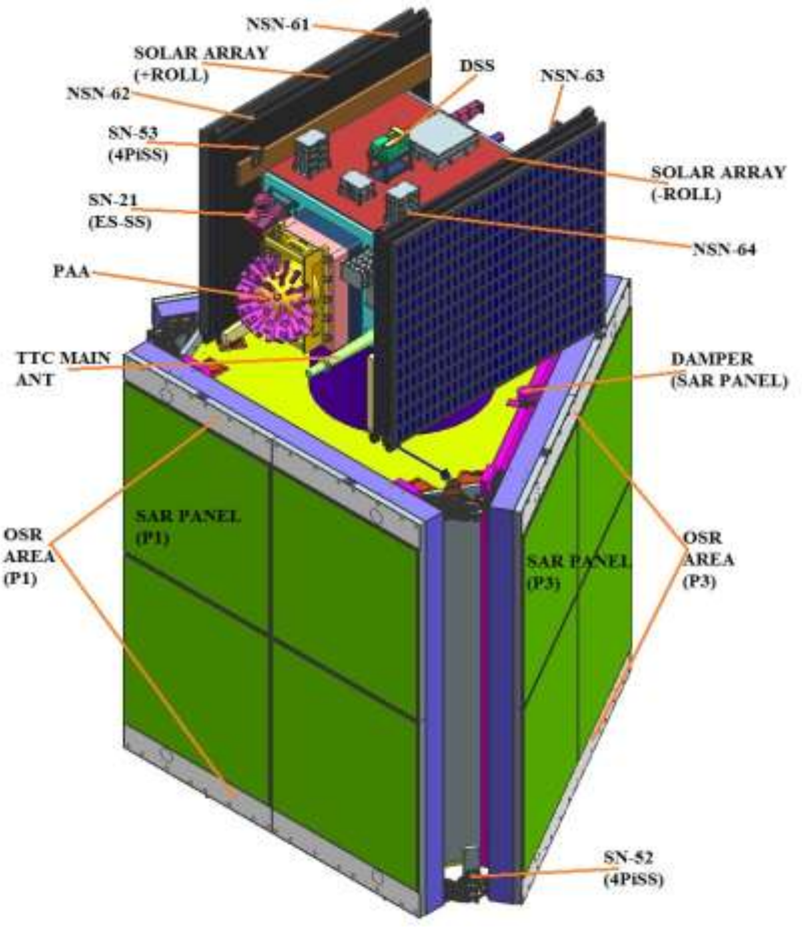


Figure 20.1 Stowed view of RISAT

20.4 Payload

20.4.1 SAR Payload

The C-Band Synthetic Aperture Radar (SAR) is the payload of RISAT. Radar backscattering depends upon the sensor parameters such as frequency, polarization and incidence angle, dielectric constant roughness and geometry of the target. In RISAT, SAR Payload will be operating in C-band (5.35 GHz) with both co-and cross- polarization, which will meet most of the resource applications and also enable achieving high resolution capability. The SAR payload is based on active phased array antenna technology, which will provide multimode capability.

20.4.1.1 Modes of Operation

The proposed SAR will operate in the following basic modes:

Fine Resolution strip map Mode-1 (FRS-1): This is the conventional mode of SAR. In this the orientation of the antenna beam is fixed with respect to flight path so that a strip of constant swath (25 Km) is illuminated along the flight direction. The indented resolution is 3m for FRS-1 mode.

Coarse Resolution ScanSAR Mode (CRS): The scanSAR mode allows increasing the swath. This is achieved by periodically stepping the antenna beam to the neighboring subswaths(in range direction). In the CRS mode of RISAT there will be 12 beams. These results, total swath in CRS mode would be 223 km. the resolution offered in this mode will be 50 m.

Medium Resolution Stripmap Mode-2 (FRS-2): This is a 6 beam scanSAR mode, similar to the CRS mode, providing a resolution of 25 m over a swath of 115 km.

Fine resolution Stripmap Mode-2(FRS-2): This mode has quad polarization capability. Philosophically, this mode is a hybrid strip map and scanSAR. In this case the beam orientation is kept fixed with respect to the flight path and a strip of constant swath width is covered. Part of the aperture time the beam polarisation is switched from V-transmit to H-transmit, and vice-versa. Hence, this mode would be used for polarimetry, as we can have all the four combinations of polarization viz. VV, VH, HH,HV.

High Resolution Spotlight Mode (HRS): In the spotlight mode, the antenna beam is oriented continuously to illuminate a particular spot on the ground. This method increases the target aperture time which results in improved azimuth resolution (1m) The improved resolution is obtained at the cost of azimuth coverage.

Circular Polarimetric Modes (C-HRS, C-FRS-1, C-FRS-2, C-MRS, C-CRS): All the modes mentioned above can be operated in hybrid-circular polarization. This is achieved by transmitting H & V polarized signals simultaneously but with a relative phase-shift of 90^o. Hence, the transmit signal is in circular polarization and the receive signal is in linear (Dual-pol) – this makes it a hybrid-circular polarisation operation. To keep the average power-requirements same as the original specifications, the pulse-width is reduced to half.

Major Mission Parameters for Space borne High Resolution SAR

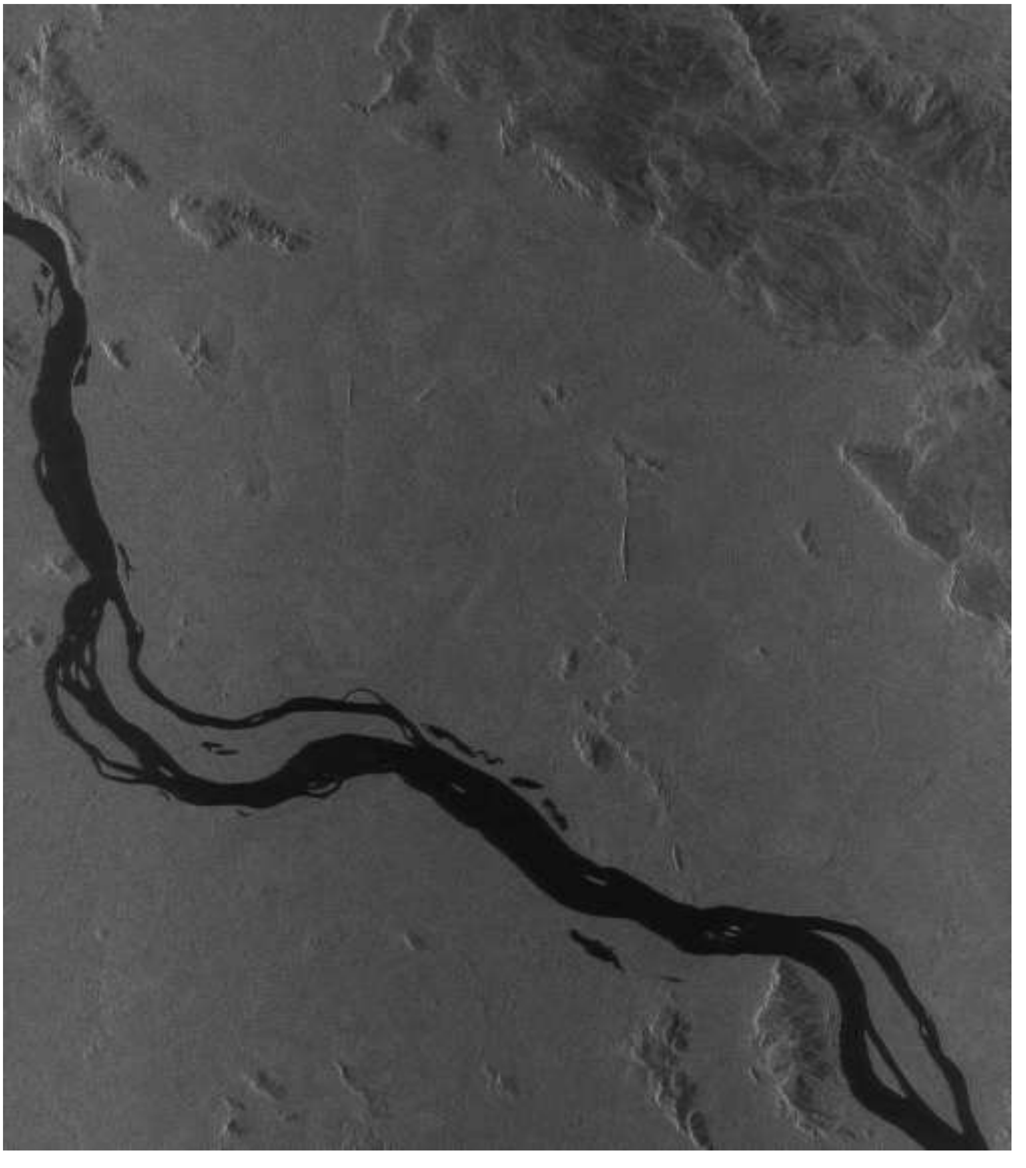
Altitude	**536 Km**	
Orbit	Sun Synchronous (6 A.M/6 PM equatorial crossing)	
P/L operating frequency	C-Band	
Polarisation	Single/Dual/Quad-polarisation Hybrid circular polarimetry (Transmit circular, receive linear)	
Antenna	Microstrip Active antenna 6m x 2m	
Peak Gain	43.1 dBi	
Total no. Beams	64 on each side of the flight track (Total 128)	
On board storage	SSR with 240 GBits	
No. of TR Modules	288 pairs	
Transmitter power per TRM	10 W (Ave.)	
Antenna peak power	2.88 kW	
Average DC Input Power	3.92 kW	
Range Compression	On Ground	
Pulse Width	20 micro sec/10 microsec (10 microsec for circular polarization)	
Antenna Roll Bias(deg)	36	
Range Coverage(Km)	107 - 659	
Look Angle (Deg	11.28 – 49.09	
Incidence Angle	12.25 – 55.02	
Doppler BW (Hz)	2532.23	
	FRS-1/FRS-2/ MRS/CRS	HRS
PRF(Hz)	2800-3200	3000-7000
Worst σ_0 (dB) Considering both qualified and unqualified regions (100 km – 700km)	-16.81 @ 25 Km	-15.82
Swath	25/25/115/223	10
Slant range resolution(m)	2/4/8/8	0.7
Ground range resolution(m)	FRS1: 9.4 – 2.4 FRS2: 18.8 – 4.9 MRS: 37.7-9.8 CRS: 37.7.9.8	3.3-0.85
Azimuth Resolution(m)	3/9/21-23/41-55	1
Chirp bandwidth(MHz)	75/37.5/18.75/18.75	225

Sampling frequency(MHz)	83.3/41.67/20.83/20.83	250
Data Window (micros)@ nominal earth radius of 6371 km	63-184 (@30km Swath)	80-165(@10km Swath
No. Of complex samples	4864-21504/2560-12288/1280-6144/1280-6144	19072-41344
Data Compression	Onboard BAQ(6/5/4/3/2 bits)	3 – bit BAQ
Data Rate (Mbps)	6 BAQ	3 BAQ(For 100km azimuth)
Single pol.	176-744/-/44-213/44-213	490 – 744
Dual Pol.	352-1488/-/88-426/88-426	980-1488
Quad pol.	-/1756-744/-/-	
Worst-case Range Ambiguity(in dB) @ nominal PRF	-16.94@22 Km -15.6@25 km -13.4@30 Km	-16.0@10Km
Worst case Azimuth Ambiguity (in dB) @ Nominal PRF	-21.47	-25.20

Active Antenna specifications of C- Band SAR

Frequency	**C-band**	
Antenna Type	Printed Antenna	
Antenna Size	6m (Along Flight) x 2m (Cross Flight)	
Antenna Gain	43.1 dBi	
Antenna Bandwidth	0.5 dB over 225 MHz bandwidth around center frequency	
Side Lobe Level	Azimuth	Elevation
	- 15 dB	- 18 dB
Cross polarization level	Better than – 23 dB	
Relative gain and phase tracking between radiating arrays of 24 elements	Gain Tracking	Phase Tracking
	0.5 dB rms	6 deg rms
No. of TR Modules	288, each with 10 W peak power	
Peak Power	2.88 kW	

Avg. Output power	213 W (with duty cycle of 7 %)			
Average DC Input Power (to Active antenna)	3.672 kW			
TR Module Output tracking	O/P Power Tracking		Phase Tracking	
	0.5 dB rms		6 deg rms	
TR Module Receive path Tracking	Gain		Phase	
	0.5 dB rms		6 deg rms	
Gain/Phase	Gain		Phase	
Quantisation	6 bits		6 Bits	
TR Module Bandwidth	0.5 dB over 225 MHz bandwidth around centre frequency			
Loss/Noise Figure	Tx loss	Rx loss	Mismatch Loss	Noise Figure
	0.3 dB	0.3 dB	0.6 dB	3.5 dB
No. of Antenna Beams	128			



Glossary

Absorption: The process by which radiant energy is absorbed and converted into other forms of energy. This occurs when radiation impinging on a molecule excites its internal energy and causes changes in its electronic, vibrational, and/or rotational states.

Across-track scanner : A remote-sensing tool with an oscillating mirror that moves back and forth across a satellite's direction of travel, creating scan line strips that are contiguous or that overlap slightly, thereby producing an image.

Active Sensor: A sensor that generates its own electromagnetic energy to illuminate the target, usually within the microwave wavebands. RADAR is an example of such a system.

Additive primary colors: Blue, green and Red.

Aerosol - A mixture of fine liquid or solid particles suspended in a gas or air. Or suspended particles like dust in atmosphere

Airglow: A nighttime glow from the upper atmosphere, occurring over middle and low altitudes, due to the emission of light from various atoms, molecules and ions.

Albedo: The ratio of the light reflected by a planet to that received by it

Altimeter: Instrument for measuring altitudes or elevations with respect to a reference level, usually mean sea level.

Altitude: The height or vertical elevation of a point above a reference surface. Altitude measurements are usually based on a given reference datum, such as mean sea level.

Angle of ascending node The angle between the ascending node and the x axis. Also referred to as the right ascension of the ascending node.

Angular Field of View: Angle subtended by remote sensing system/detector.

Angular resolving power: Minimum separation between two resolvable targets, expressed as angular separation.

Antenna: Device that transmits and receives microwave energy.

Aperture: Opening in the remote sensing system that admits electromagnetic radiation to the film/detector

Apogee: The point in an orbit farthest from the Earth.

Argument of Perigee: The angular distance between the ascending node and the point of perigee.

Artefact: A feature on an image which is produced by the optics of the system or by digital image processing.

Ascending node The point where the satellite crosses the equatorial plane going north.

Aspect ratio: The ratio of horizontal scale to vertical scale for printing or display.

Atmospheric windows: Wavelength interval within which the atmosphere readily transmits electromagnetic radiation.

Attitude: Angular orientation of a remote sensing system with respect to a geographic reference system.

Azimuth: Geographic orientation of the line given as an angle measured in degrees clockwise from north.

Band: A sub division within an electromagnetic region.

Binning: is the combination of intensities of adjacent pixels into in image with a resulting lower spatial resolution.

Bitmap: An image format in which one or more bits represent each pixel on the screen. The number of bits per pixel determines the shades of gray or number of colors that a bitmap can represent. Bitmap files generally have the extension .bmp.

Blackbody : Hypothetical body that absorbs and emits electromagnetic radiation in all parts of the electromagnetic spectrum so that

1) all incident radiation is completely absorbed;

2) The maximum possible emission takes place in all wavelengths of the EM spectrum.

Brightness temperature: is a measure of the intensity of radiation thermally emitted by an object, given in units of temperature because there is a correlation between the intensity of the radiation emitted and physical temperature of the radiating body which is given by the Stefan-Boltzmann law.

Calibration: The process of comparing measurements, made by an instrument, with a standard.

Cartography: The organization, design, collection and reproduction of geographic information on various formats to generate maps.

CCD (Charge Coupled Devices): A light sensitive solid-state detector sensitive solid-state detector that generates a voltage which is proportional to the intensity of illumination. Arrays of CCDs make up pushbroom scanners.

Chromatic aberration - Aberration caused by the dispersive effects of refracting optical systems. Because light rays of different wavelengths (colors) bend by different amounts as they pass through dielectric media, each wavelength will converge to a slightly different focal point. This means that it is impossible to focus rays from a polychromatic source accurately. This prove problematic in large refracting telescopes.

Contrast: good image contrast is desirable for viewing low contrast objects such as the lunar surface and planets. newtonian and catadioptric telescopes have secondary (or diagonal) mirrors that obstruct a small percentage of light from the primary mirror. light scattering and diffraction from such obstructions can cause a reduction in image contrast. it is commonly believed that image contrast is severely reduced with newtonians or catadioptrics because of this obstruction, but this is not the case. this would only be true if more than 25% of the primary mirror's surface area was obstructed by the secondary.

DEM (Digital Elevation Model): Represents a topographic surface using a continuous array of elevation values, referenced to a common datum. DEMs are used typically to represent terrain relief.

Detector: Component of a remote sensing system that converts electromagnetic radiation into a electrical signal.

Dichroic Mirror: A special type of interference filter, which reflects a specific part of the color spectrum.

Digital Image processing: Computer manipulation of digital images.

Digital Number(DN): Value assigned to a pixel in a digital image

Digitisation: Process of converting an analog display into a digital display

Dispersion: Is the phenomenon by which light the bending or refraction of light is dependent on its wavelength or frequency in a certain medium. This occurs because some frequencies are closer to the resonant frequencies of atoms in the medium, causing them to be propagated more effectively. This accounts for the dispersion of white light into a spectrum as it passes through a prism.

Distortion: On an image, changes in shape and position of objects with respect to their true shape and position.

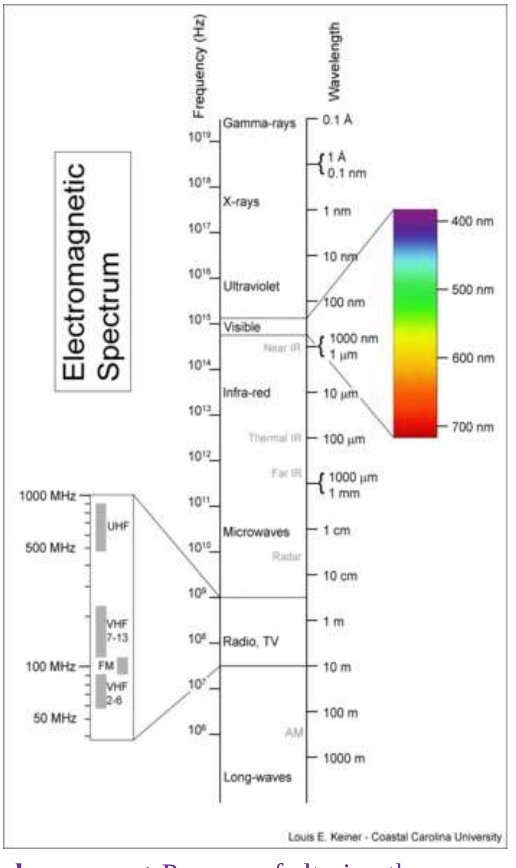
Doppler effect: The phenomenon of apparent change in frequency, with the relative motion of the source and the observer.

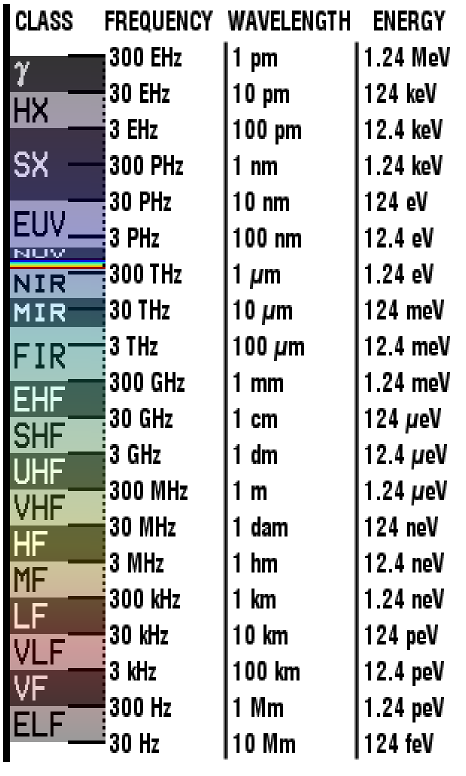
Dwell time: Time required in an image between areas with different tones.

Dynamic range: of the CCD is defined as the ratio of the full well capacity to the signal to noise ratio SNR.

Effective focal length: Distance between principal plane and the focal plane

Electromagnetic spectrum: The electromagnetic spectrum is the range of all possible electromagnetic radiation.





CLASS	FREQUENCY	WAVELENGTH	ENERGY
γ	300 EHz	1 pm	1.24 MeV
HX	30 EHz	10 pm	124 keV
SX	3 EHz	100 pm	12.4 keV
EUV	300 PHz	1 nm	1.24 keV
NUV	30 PHz	10 nm	124 eV
NIR	3 PHz	100 nm	12.4 eV
MIR	300 THz	1 µm	1.24 eV
FIR	30 THz	10 µm	124 meV
EHF	3 THz	100 µm	12.4 meV
SHF	300 GHz	1 mm	1.24 meV
UHF	30 GHz	1 cm	124 µeV
VHF	3 GHz	1 dm	12.4 µeV
HF	300 MHz	1 m	1.24 µeV
MF	30 MHz	1 dam	124 neV
LF	3 MHz	1 hm	12.4 neV
VLF	300 kHz	1 km	1.24 neV
VF	30 kHz	10 km	124 peV
ELF	3 kHz	100 km	12.4 peV
	300 Hz	1 Mm	1.24 peV
	30 Hz	10 Mm	124 feV

Enhancement-Process of altering the appearance of an image so that the interpreter can extract more information.

Equatorial Orbit: An orbit that lies at any altitude above the Equator, i.e. has an inclination of 0 degrees

False color composition (FCC): The selection of set of image bands whereby terrestrial features are not portrayed in their natural colors

Field Of View: the range of angle that is scanned or sensed by a system in degrees

Fill factor: Fill factor of Pixel is the active area for the conversion of incoming photons.

F-number: Representation of the speed of a lens determined by the focal length divided by diameter of the lens. Smaller numbers indicate faster lenses.

Full well capacity: Is the maximum number of electrons which one pixel can contain before its saturation.

GCP (Ground Control Point)

Ground control: Refers to points on the surface of the earth with known coordinates as represented by some geographic grid reference system. The location of ground control points can be represented on maps and other cartographic products, and can serve as reference points with which to rectify the scale and accuracy of cartographic products to the actual area on the ground that is represented. Ground control points are classified according to their horizontal and vertical accuracy

Geographical information system (GIS): a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data (such as geocoded images) which are spatially referenced to the earth

Geoid : The figure that represents the irregular spheroidal shape of the earth is called the geoid.

Geostationary Orbit: A Geosynchronous Orbit having zero inclination so that the spacecraft hangs motionless with respect to a point on the planet below.

Geosynchronous Orbit: A direct, circular, low-inclination orbit around Earth having a period of 23 hours 56 minutes 4 seconds and a corresponding altitude of 35,784 km (22,240 miles, or 5.6 Earth radii).

Geosynchronous orbit: An orbit in which the satellite's orbital period is identical to the orbital period of the Earth.

Grey Scale: A calibrated sequence of grey tones ranging from black to white.

Ground sampling distance (GSD): GSD is defined as the distance moved on the ground during the integration period of the detector line array of an imaging instrument.

Ground Segment : The part of an earth observation mission comprising data reception processing archiving and distribution facilities

Ground track: Refers to the vertical projection of the actual flight path of a satellite onto the surface of the Earth.

Histogram: A graph showing the distribution of values in a set of data. Individual values are displayed along a horizontal axis, and the frequency of their occurrence is displayed along a vertical axis.

Hyper spectral: More spectral bands (Minimum 20 Spectral band)

Image Processing: Encompasses all the various operations which can be applied to photographic or image data. These include, but are not limited to image compression, image restoration, image enhancement, preprocessing, quantization, spatial filtering and other image pattern recognition techniques.

Image: pictorial representation of a scene recorded by a remote sensing system.

Inclination: The angular distance of the orbital plane from the equatorial plane of the planet, stated in degrees.

Instantaneous Field of View (IFOV): A term denoting the angular resolution of a single detector element.

Instantaneous Geometrical Field of View (IGFOV): The projection size of a pixel on ground specified in length.

Integration Time: The time period allocated for the radiative measurement of the instantaneous area of observation by the detector of a sensor.

Interpretation: The process in which a person extracts information from an image.

Irradiance: The radiative energy per unit time(power) impinging on a surface normalized by the surface area, and is specified in watt per square meter(W/m^2)

Isotherm: Contour line connecting points of equal temperature.

Isotropy (the opposite of anisotropy) is the property of being independent of direction. Isotropic radiation has the same intensity regardless of the direction of measurement, and an isotropic field exerts the same action regardless of how the test particle is oriented.

JPEG2000 (Joint Photographic Experts Group): An updated version of JPEG which offers more efficient compression of images and can use both lossless and lossy compression algorithms. The lossless compression method makes JPEG2000 images very useful in GIS applications.

Langmuir probe: An instrument employed to measure the current-voltage characteristics of plasma in order to determine plasma density.

Lens: A lens is any refracting device (corresponding to a discontinuity in a medium) that rearranges the distribution of transmitted energy. Lens do not have to be transparent to light, but can instead be used to redirect X-rays or microwaves. The most useful lenses have spherical surfaces and act to focus light rays to a point near the lens

Limb Occultation sounding: A horizon-looking observation technique that uses a distant object sun, Star, or a sensor on another satellite in a different earth orbit as a source to observe the signal on its path through the atmosphere that is essentially tangential to the Earth's Surface

Low Earth Orbit: The lowest altitude a spacecraft must achieve to orbit the Earth.

Map Base: A map depicting background reference information such as landforms, roads, landmarks, and political boundaries, onto which other, thematic information is placed. A basemap is used for locational reference and often includes a geodetic control network as part of its structure.

Map Cadastral: is a comprehensive register of the metes-and-bounds real property of a country. A cadastre commonly includes details of the ownership, the tenure, the precise location, the dimensions and the value of individual parcel of land

Map Contour: A topographic map that uses contour lines to portray relief. Contour lines join points of equal elevation or simply lines on any other isomorphic map (such as temperature isolines on a weather map) that identify levels of a parameter at specified, discrete intervals.

Map Thematic: The application specific maps. Example: road ways, pipelines, soil types, vegetation types and water distributions

Map Units: The coordinate units in which the geographic data are presented, such as inches, feet, or meters or degrees, minutes and seconds.

Map, Isopleth (isoline): A map displaying the distribution of an attribute in terms of lines connecting points of equal value. Examples include contour maps and weather maps depicting lines of temperature or precipitation changes.

Metrology: is the interdisciplinary scientific study of the atmosphere

Microwave: Region of the electromagnetic spectrum in the wavelength range from 0.1 to 30 cm.

MID-INFRARED (MIR): The range of wavelengths from 8 to 14 micrometres dominated by emission of thermally generated radiation from materials; also known as thermal infrared.

Modulation Transfer Function(MTF): A function measuring the reduction in contrast from object

Mosaic: A technique whereby multiple satellite images are digitally joined, while correcting for systematic changes in radiometry and geometry thus creating a 'seamless' image product.

Nadir: Point on the ground directly in line with the remote sensing system and the center of the earth.

Nodal period: The time required to make a complete orbit. For a polar orbiting sun synchronous satellite the nodal period is 102 minutes.

Occultation : An alignment of two bodies with the observer such that the nearer body prevents the light form the farther body from reaching the observer

Optical axis: is an imaginary line that defines the path along which light propagates through the system

Orbit: Path of a satellite around a body such as the earth, under the influence of gravity.

Orthoimage : An image derived from a conventional perspective image by simple or differential rectification so that image displacements caused by sensor tilt and relief of terrain are removed.

Panchromatic channel: A channel of a sensor detector system covering the entire visible part of the electromagnetic spectrum

Parallax: A change in position of the object, as viewed through an instrument, if the viewing eye is moved. Parallax correction is especially important for a riflescope.

Passive remote sensing: Remote sensing of energy naturally reflected or radiated by the target (Terrain)

Period: The length of time required for a satellite to complete one orbit.

Photogrammetry: Science or art of obtaining reliable measurements or information from photographs or other sensing systems.

Pitch: Rotation of a satellite/aircraft about the horizontal axis normal to its longitudinal axis that causes a nose-up r nose down attitude.

Polar Orbit: An orbit that passes close to the poles, thereby enabling a satellite to pass over most of the surface of the earth, except the immediate vicinity of the poles themselves.

Pre-processing: it a process of radiometric correction and geometric correction

Prism: is a transparent optical element with flat, polished surfaces that refract light. The exact angles between the surfaces depend on the application. The traditional geometrical shape is that of a triangular prism with a triangular base and rectangular sides, and in colloquial use "prism" usually refers to this type.

Quantum efficiency: QE is defined as the percentage of the generated electronic charges by the incoming photos.

Radiometric resolution: capability of the sensor to differentiate the smallest change in the spectral reflectance/emittance between various targets

Raster Data: Machine-readable data that represent values usually stored for maps or images and organized sequentially by rows and columns. Each "cell" must be rectangular but not necessarily square, as with grid data.

Reflection: When a light ray is incident on an interface between two media, some portion of the light ray will usually remain in the incident medium, tracing a path such that the angle of the incident ray with respect to the normal is equal to the angle of the reflected ray with respect to the normal. Moreover, the incident and reflected rays, as well as the normal to the surface, all lie in the same plane.

Refraction: When a light ray is incident on an interface between two media, some portion of the light ray will usually be transmitted into the second medium. If the speed of light in the transmitting medium is different to the incident medium, this causes the light ray to change direction. This phenomenon is called refraction. The amount of refraction is determined by the ratio is the speed of lights in the two media, and the angle of the incident ray as given by Snell's Law.

Remote sensing: sensing of earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed object *or* Technique of acquiring information about an area or an object from a distance without being in physical contact with the object.

Repetivity: The frequency with which given scene can be imaged. Depends on orbit characteristics and swath.

Roll: Rotation of an Aircraft/satellite that causes a wing-up or wing-down attitude

Scale: The relationship between a distance on a map and the corresponding distance on the earth. Often used in the form 1:24,000, which means that one unit of measurement on the map equals 24,000 of the same units on the earth's surface.

Sensor: An instrument, usually consisting of optics, detectors, and electronics, that collects radiation and converts it into some other form suitable for obtaining information.

Spatial resolution: the capability of sensor to discriminate the smallest object on the ground. The ability of the sensors to image closely spaced objects so that they are distinguishable as separate objects.

Spectral Band: An interval in the electromagnetic spectrum defined by two wavelengths, two frequencies, or two wave numbers.

Spectral resolution: the spectral band width with which the data is collected

Spectrometer: Device for measuring intensity of radiation radiated or reflected by a material as a function of wavelength.

Stefan-Boltzmann law-States that radiant flux of a blackbody is equal to the temperature to the fourth power times the Stefan-Boltzmann constant.

Step and stare: Step is to impart the initial bias to spacecraft to make the camera look ahead of the sub-satellite point.

Sun Synchronous Orbit: An Earth satellite orbit in which the orbital plane is near polar and the altitude is such that a satellite will always pass over a specific place on earth at the same local sun time and at fixed time intervals

Telescope (from the Greek *tele* = 'far' and *skopein* = 'to look or see'; *teleskopos* = 'far-seeing') is an instrument designed for the observation of remote objects.

Temporal resolution: The capability to view the same target, under similar conditions at regular intervals.

UV: Ultraviolet region of the electromagnetic spectrum, ranging in wavelength from 0.01 to 0.4 microns.

Wien's displacement law-Describes the shift of the radiant power peak to shorter wavelengths as temperature increases.

Yaw: Rotation of an aircraft /satellite about its vertical axis (Nadir)

Acronyms

4 Pi SS	4 Pi Sun Sensor
ADC	Analog to Digital Converter
ADCS	Attitude Determination and Control Subsystem
AH	Ampere Hour
AIT	Assembly Integration & Testing
Al	Aluminium alloy
AOCE	Attitude and Orbit Control Electronics
AOCS	Attitude and Orbit Control System
APD	Avalanche Photo Detector
APS	Active Pixel Sensor
ASIC	Application Specific Integrated Circuit
ASLV	Augmented Satellite Launch Vehicle
ATC	Auto Temperature Control
ATE	Automated Test Equipment
ATJ	Advanced Triple Junction
AWiFS	Advanced Wide Field Sensor
BAPTA	Bearing and Power Transfer Assembly
BBR	Band-To-Band Registration
BCD	Binary Coded Decimal
BDH	Baseband Data Handling
BDR	Base-line Design Review
Be	Beryllium
BER	Bit Error Rate
BFL	Back Focal Length
BMU	Bus Management Unit
BOL	Beginning of Life

BPSK	Binary Phase Shift Keying
BRC	Bit Rate Clock
CAN	Controller Area Network
CARTOSAT	Cartographic Satellite
CBT	C-Band Transponder
CCD	Charge Coupled Device
CCGA	Ceramic Column Grid Array
CCL	Closed Control Loop
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFRP	Carbon Fibre Reinforced Plastic
CGP	Central Grounding Point
CIP	Command Interface Port
CMG	Control Moment Gyro
CMOS	Complementary Metal Oxide Semiconductor
CMRB	Configuration Management Review Board
CNES	Centre National d'Etudes des Spatiales
COTS	Commercial - Off –The- Shelf
CP	Circular Polarized (RCP, LCP)
CPM	Charge Particle Monitor
CPSK	Coherent Phase Shift Keying
CRC	Cyclic Redundancy Code
CTE	Coefficient of Thermal Expansion
CTF	Contrast Transfer Function
CVD	Chemical Vapor Deposition
CZT	Cadmium Zink Telluride
dB	Decibel

DCU	Data Compression Unit
DDR	Detailed Design Review
DE	Detector Electronics
DEC	Decoder
DFT	Discrete Fourier Transform
DFU	Data Formatting Unit
DGA	Dual Gimbal Antenna (DGA)
DH	Data handling
DIP	Dual Inline Package/Data Interface Package
DMA	Direct Memory Access
DMSS	Dynamic Multi Star Simulator
DN	Digital Number
DP	Data Products
DPCM	Differential Pulse Code Modulation
DPSK	Differential Phase Shifting Keying
DQE	Data Quality Evaluation
DRAM	Dynamic Random Access Memory
DSER	Deserializer
DSN	Deep Space Network
DSP	Digital Signal Processing
DSS	Digital Sun Sensor
DTG	Dynamically Tuned Gyroscope
EDAC	Error Detection and Correction
EED	Electro Explosive Device
EFL	Effective Focal Length
EID	Electrical Interface Document
EIRP	Effective Isotropic Radiated Power
EM	Engineering Model

EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
EOM	Electro-Optical Module
EOS	Earth Observation System
ESD	Electro Static Discharge
FCC	False Color Composite
FD	Flange Distance
FM	Frequency Modulation
FM	Flight Model
FOG	Fiber Optic Gyro
FOV	Field of View
FPA	Focal Plane Arrays
FPGA	Field Programmable Gate Array
FRR	Flight Readiness Review
FSK	Frequency Shift Keying
G/T	Gain/Temperature
Gbps	Giga Bits Per Second
GCP	Ground Control Point
GMT	Greenwich Mean Time
GPS	Global Positioning System
GSLV	Geo-Synchronous Satellite Launch Vehicle
HEX	High Energy X-ray Payload
HILS	Hardware In-Loop Simulation
HK	House Keeping
HMC	Hybrid Microwave Circuit
HR	High Resolution
HRMX	High Resolution Multispectral
HySI	Hyper spectral imaging instrument
IC	Integrated Circuit

IFOV	Instantaneous Field Of View
IGFOV	Instantaneous Geometric Field Of View
IIMS	Integrated Information Management System
IISU	ISRO Inertial Systems Unit
IMS	Information Management System
IMS	Indian Micro Satellite
INCOIS	Indian National Committee for Ocean Information Services
InGaAs	Indium Gallium Arsenic
IOC	Integrated Optic Chip
IR	Infra-Red
IRS	Indian Remote Sensing Satellites
IRU	Inertial Reference Unit
ISPRS	International Society for Photogrammetry and Remote Sensing
ISRO	Indian Space Research Organisation
ISS	International Space Station
ISSDC	Indian Space Science Data Centre
ISSP	Indian Scientific Satellite Project
IST	Integrated Spacecraft Testing
ISTRAC	ISRO Telemetry Tracking and Command Network
ITT	International Telephone & Telegraph
JPEG	Joint Photographic experts group
K	Kelvin
LAXPC	Large area Xenon Filled Proportional counter

LCD	Liquid Crystal Display
LED	Light Emitting Diodes
LENA	Low Energy Neutral Atom
LEO	Low Earth Orbit
LEOS	Laboratory for Electro Optics Systems
LHCP	Left Hand Circular Polarisation
Li-ion	Lithium ion
LISS	Linear Imaging Self-Scanning Sensor
LLRI	Lunar Laser Ranging Instrument
LNA	Low Noise Amplifier
LO	Local Oscillator
LOCO	Low Complexity Lossless Compression
LPSC	Liquid Propulsion Systems Centre
LTC	Light Transfer Characteristics
LVDS	Low Voltage Differential Signaling
LWIR	Long Wave Infrared
M3	Moon Mineralogy Mapper
MADRAS	Microwave Analysis and Detection of Rain and Atmospheric Structures
Mbps	Mega Bits Per Second
MCT	Mercury Cadmium Telluride
MEO	Medium Earth Orbit
MEOSS	Monocular Electro-Optical Stereo Scanner
MHDMSS	Multiple Head Dynamic multi star simulator
MI	Moment of Inertia

MID	Mechanical Interface Document
MIL-STD	Military Standard
MIP	Moon Impact Probe
MIR	Medium wave Infra-Red
MLI	Multi-Layer Insulation
MMU	Mission Management Unit
MOS	Multispectral Opto-electronic Scanner
MRB	Material Review Board
MRR	Mission Readiness Review
MSMR	Multi-frequency Scanning Microwave Radiometer
MTC	Magnetic Torquer Coil
MTF	Modulation Transfer Function
MX	Multispectral
NDC	NRSC Data Centre
NI-Cd	Nickel Cadmium Batteries
NIR	Near Infra Red
Nm	Newton Metre
NMS	Newton Metre Second
NRSC	National Remote Sensing Centre
OBC	On-Board Controller/Computer
OBT	On-Board Time
OCM	Ocean Colour Monitor
OCP	Over Current Protection
OILS	Onboard Software In Loop Simulation
OSR	Optical Solar Reflector
P	Pitch axis
PAA	Phased Array Antenna

PAN	Panchromatic
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PEB	Project Executive Board
PFZ	Potential Fishing Zone
PID	Parameter Identification
PINFET	Positive Intrinsic Field effect Transistor
PIU	Payload Interface Unit
PLE	Payload Electronics
PLL	Phased lock loop
PM	Phase Modulation
PMB	Project Management Board
PMO	Programme Management Office
PMT	Photo Multiplier Tube
PPC	Payload Power Converter
PPC	Pointed Proportional Counter
PPR	Payload Power Regulator
PrEB	Programme Executive Board
PrMB	Programme Management Board
PRNU	Photo Response Non-Uniformity
PROM	Programmable Read Only Memory
PSK	Phase shift keying
PSLV	Polar Satellite Launch Vehicle
PSR	Pre-Shipment Review
QPSK	Quadrature Phase shift keying
R	Roll axis
RADOM	Radiation Dose Monitor

RAM	Random Access Memory
RCS	Reaction Control System
RF	Radio Frequency
RHCP	Right Hand Circular Polarization
RISAT	Radar Imaging Satellite
RISC	Reduced Instruction Set Computing
ROM	Read Only Memory
ROSA	Radio Occultation for Sounding of Atmosphere
RS	Reed-Solomon, Receive/send
RTO	Regenerative Thermal Oxidizer
RTX	Receive/Transmit
RW	Reaction Wheel
Rx	Receiver
S/N	Signal-to-Noise Ratio
SAA	Sun Aspect Angle
SAC	Space Application Centre
SADA	Solar Array Drive Assembly
SAMIR	Satellite Microwave Radiometer
SAR	Synthetic Aperture Radar
SARA	Sub KeV Atom Reflective Analyzer
SARA L	Satellite for Argos and Altika
SCC	Spacecraft Control Centre
SCD	Swept Charge Device
SEO	Satellite for Earth Observation
SER	Serializer
SGCM G	Single Gimbal Control Moment Gyro

SiC	Silicon Carbide
SLV	Satellite Launch Vehicle
SNR	Signal to Noise Ratio
SOC	System On Chip
SPS	Satellite Positioning System
SPSS	Solar Panel Sun Sensor
SRC	Standing Review Committee
SROSS	Stretched Rohini Satellite Series
SS	Star Sensor
SSM	Scanning Sky Monitor
SSPA	Solid State Power Amplifier
SSPO	Sun Synchronous Polar Orbit
SSR	Solid State Recorder
SSRB	Subsystem Review Board
SST	Sea Surface Temperature
SWIR	Short Wave Infrared
SWR	Square Wave Response
SXT	Soft X-ray imaging Telescope
TC	Telecommand
TCXO	Temperature Controlled Crystal Oscillator
TDI	Time Delay Integration
TES	Technology Experimental Satellite
TIFR	Tata Institute of Fundamental Research
TM	Telemetry
TMC	Terrain Mapping Camera
TSG	Thermal Systems Group
TTC	Telemetry Tracking and Command
TWTA	Traveling Wave Tube Amplifier
Tx	Transmitter

UHF	Ultra high Frequency
USB	Universal Serial Bus
UTMC	United Technologies Microelectronics Center
UV	Ultra Violet
UVIT	Ultra Violet Imaging Telescope
VHDL	Very high speed Hardware Description Language
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VNIR	Visible and Near InfraRed
VSSC	Vikram Sarabhai Space Centre
VSSG CMG	Variable Speed Single Gimbal Control Moment Gyro
WDE	Wheel Drive Electronics
WiFS	Wide Field Sensor
XSM	X-ray Sky Monitor
Y	Yaw Axis

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