

EO Sensors : ISRO

Past, Current & Future

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***International Regional Science Meeting on
Land Cover and Land Use Change Dynamics and Impacts in South Asia
Karunya University, Coimbatore, 10 Jan 2013***

Historical Development

- **Aryabhata**
 - **First Satellite (Not EO) built by ISRO & launched from Russia**
- **Bhaskara I (1979) & Bhaskara II (1981)**
 - **First series of experimental Earth Observation satellites,**
- **Geostationary for Weather Studies**
- **Experimental & Technology Satellites**
 - **SROSS , TES (High Resolution), IMS (Microsatellite)**
- **Operational IRS Series**
 - **IRS 1A, IRS 1B, IRS 1C, IRS 1D**
- **Thematic Series**

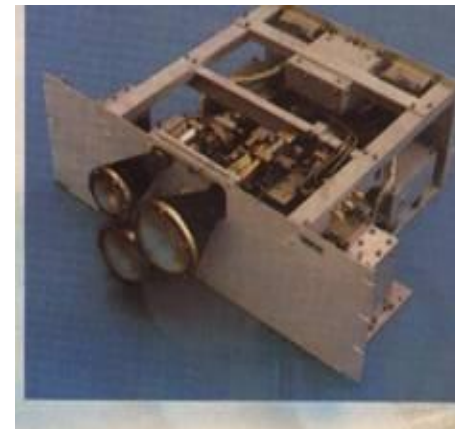
Bhaskara satellite

- **Bhaskara I**
 - Launched : June 7, 1979 by Intercosmos (USSR)
 - Optical : TV Camera, 1 km, 2 band (Red, NIR)
 - Microwave Radiometer : SAMIR (19.24, 22.235, 31.4 GHz)
- **Bhaskara II**
 - Launched : Nov 20, 1981 by Intercosmos (USSR)
 - Optical : TV Camera, 1 km, 2 band (Red, NIR)
 - Microwave Radiometer : SAMIR

SAMIR
Dicke Radiometer
3 frequencies
19.35, 22.35 and 31
GHz
150-250 Km GSD
1500 Km swath



TV Payload
Frame imager
341*341 Sq M
1Km GSD
Intensifier coupled
SUPER Vidicon
Refractive optics



Operational IRS Satellites - Initiation

Mission	IRS-1A	IRS-1B	IRS-1C	IRS-1D
Weight	975 kg	975 kg	1250 kg	1250 kg
Onboard power (Solar Panel, sq m)	600 Watts		809 Watts/(9.6 sqm)	
Communication	S-band, X-band, VHF		S-band, X-band	
Payloads, (Solid State Push Broom Camera)	LISS-1 (72.5 m) LISS-2A , 2B (36.25 m)		WiFS (189 m) LISS-3 (23.6m) PAN (<6m)	
Onboard Tape Recorder			62 Gb	62 Gb
Launch / Mission Completion	Mar 17, 1988/ Jul 1996	Aug 29, 1991/ Dec 20, 2003	Dec 28, 1995/ Sep 21, 2007	27 Sep 1997/ Jan 2010
Launch Vehicle/ Site	Vostok/ Baikanur, Kazakhstan		Molniya/ Baikanur, Kazakhstan	PSLV – C1, SHAR
,Orbit # (ht km)	904 km	904 km	817 km	740 x 817 km
Inclination	99.08°	99.08°	98.69°	98.69
Repetivity/ (Orbits)	22 days / (307 orbits)		24 days	
Local time &	10.30 a.m.	10.30 a.m.	10.30 a.m	10.30 a.m.

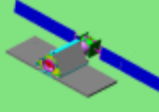
Orbit : Polar Sun Synchronous ; & Local Time : Descending Node

Indian Earth Observation Satellites

2009
RISAT-2
X-SAR



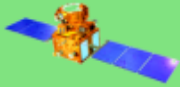
2012
RISAT-1
C-SAR



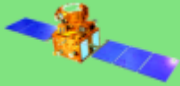
2007/ 2008/ 2010
CARTOSAT-2/2A/2B
PAN



2011
RESOURCESAT-2
LISS 3; LISS 4; AWiFS



2003
RESOURCESAT-1
LISS 3; LISS 4; AWiFS



2008
IMS-1
MX HySI-T



Land & Water

2005
CARTOSAT-1
Stereo PAN, F/A



2001
TES
Step & Stare PAN



Cartographic

2009
OCEANSAT-2
OCM, SCAT
ROSA



2003
INSAT- 3A
VHRR, CCD



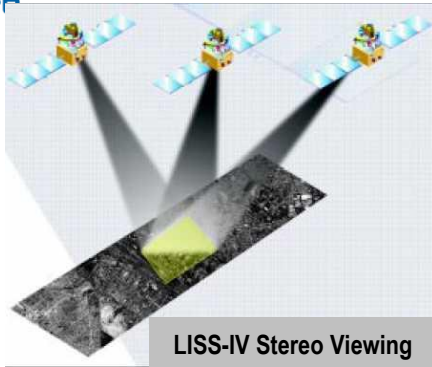
2011
Megha Tropiques
MADRAS, SAPHIR
SCaRaB



2002
KALPANA-1
VHRR



Resourcesat-1 (IRS-P6)

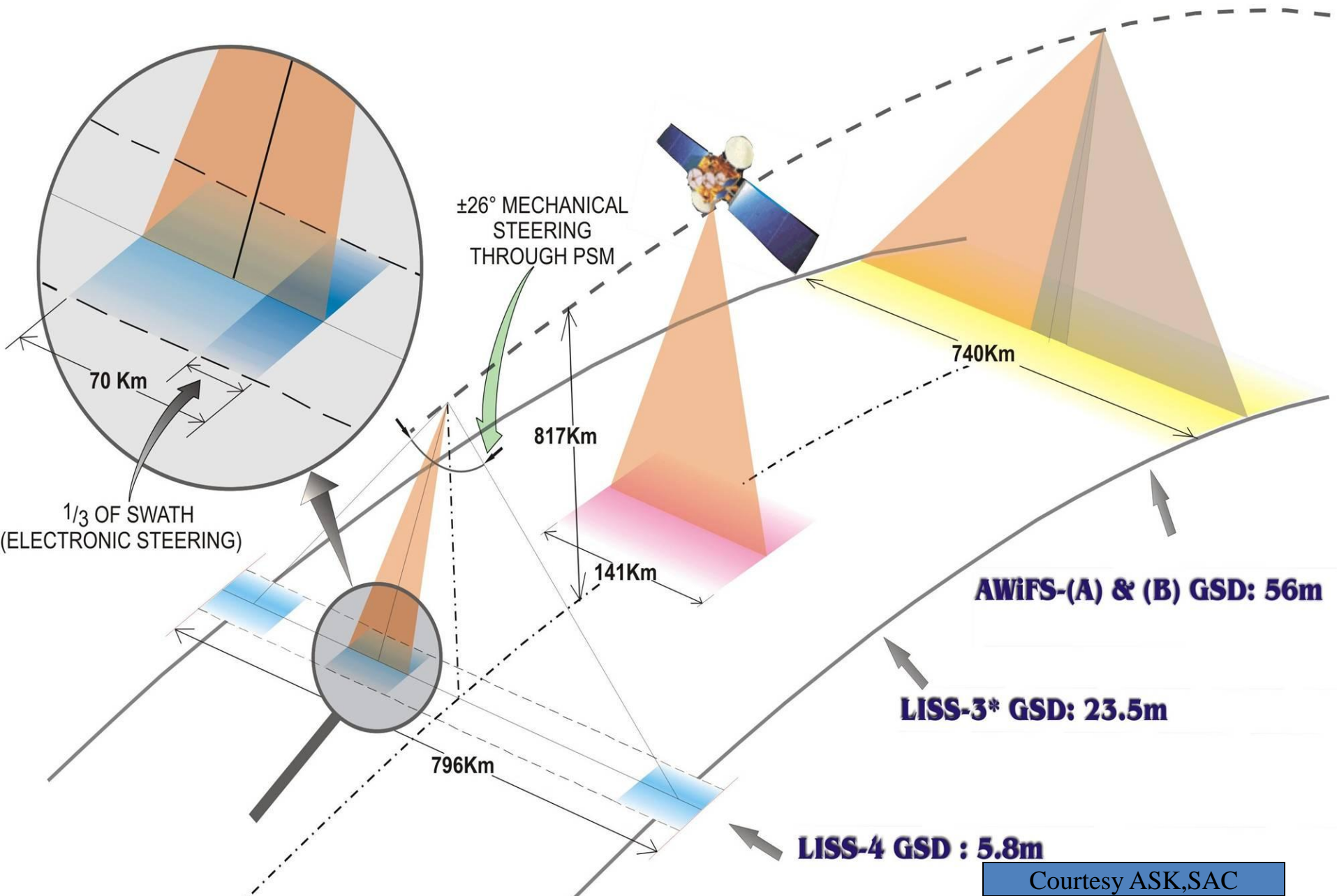


Specifications	LISS-4	LISS-3	AWiFS
Spatial Resolution (m)	5.8 m	23.5 m	56 m
Swath (km)	23.9 (MX)/ 70 (Mono)	141	370 x 2
Spectral Bands (μm)	B2 - 0.52 to 0.59 B3 - 0.62 to 0.68 B4 - 0.77 to 0.86	B2 - 0.52 to 0.59 B3 - 0.62 to 0.68 B4 - 0.77 to 0.86 B5 - 1.55 to 1.70	B2 - 0.52 to 0.59 B3 - 0.62 to 0.68 B4 - 0.77 to 0.86 B5 - 1.55 to 1.70
Quantization (Bits)	Best 7 of 10	7	10
Revisit / Cycle (Days)	5 / 24	24 / 24	5 / 24

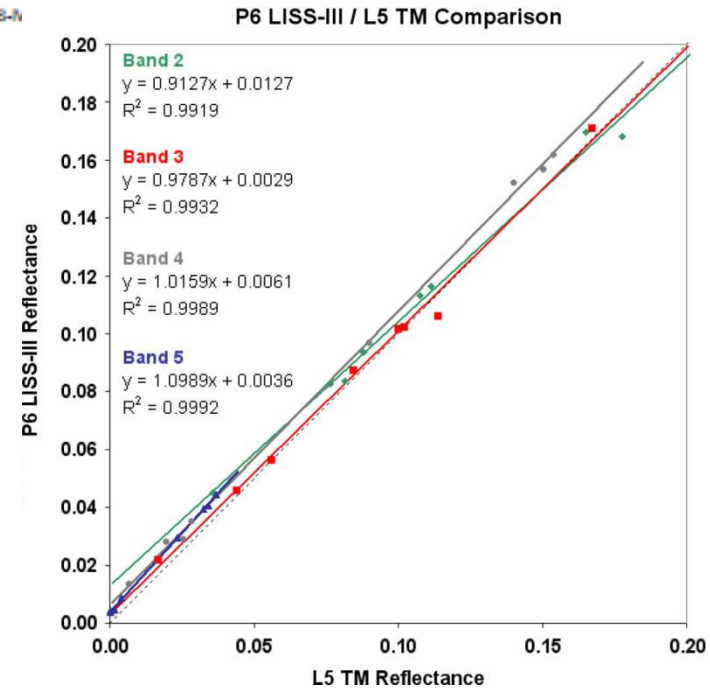
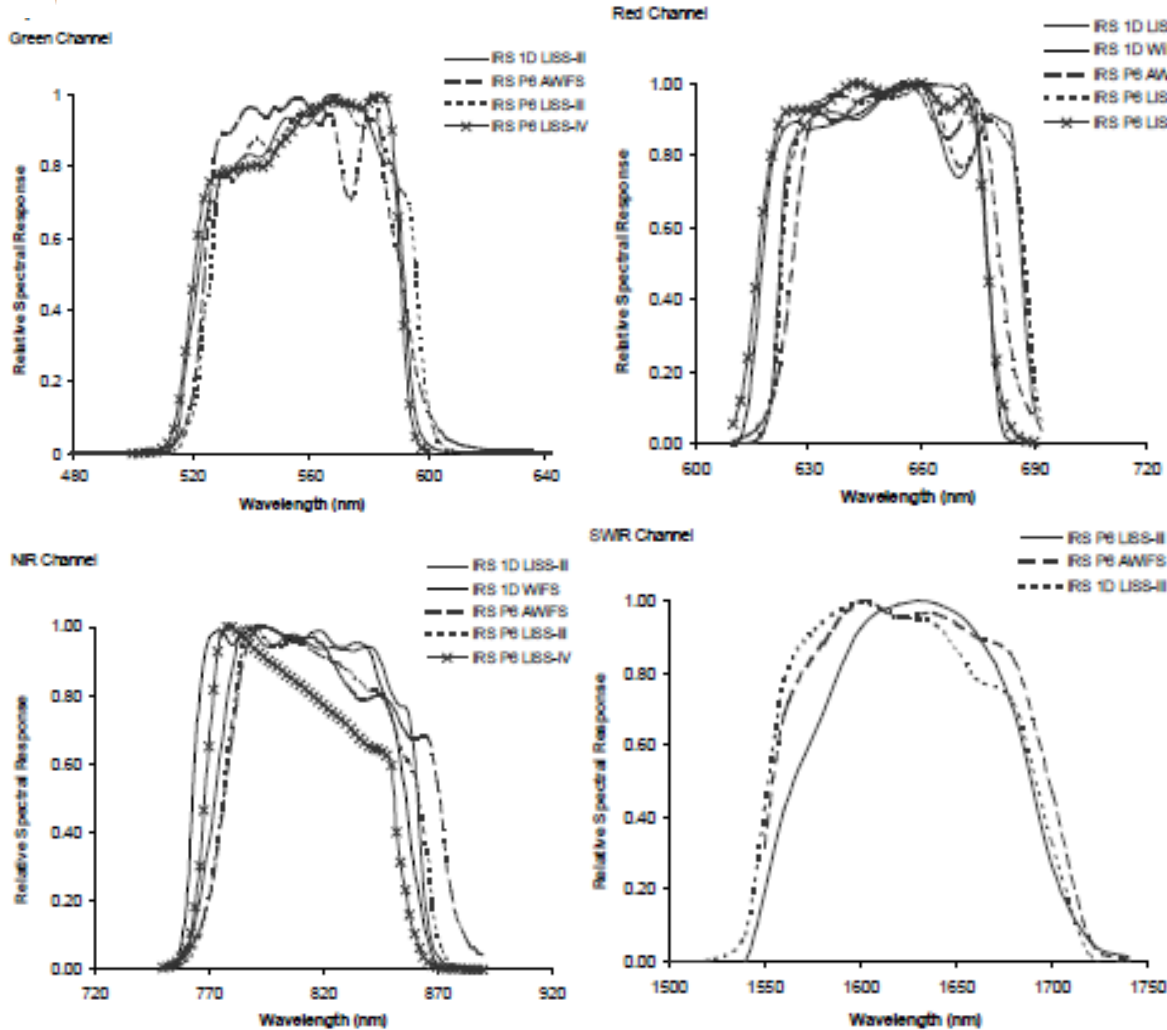
Improved capability in radiometric, spatial and temporal resolutions

Simultaneous data acquisition at different spatial resolutions for micro to macro level applications

IRS-P6 THREE TIER IMAGING



RSR : Across sensors & missions



Chander et al., 2007, Trans IEEE

Pandya Et al., 2007, J.Ind Soc. Rem Sens, 35, 333

IRS-P3 and P4: Ocean Observations

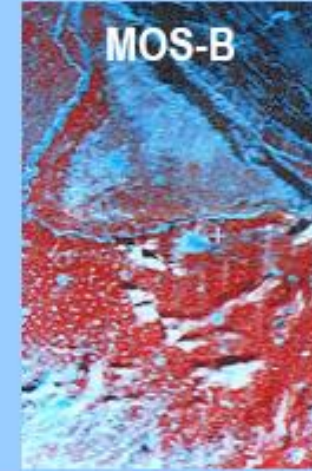
IRS-P3 (1996)

MOS-A/B/C Spectrometer

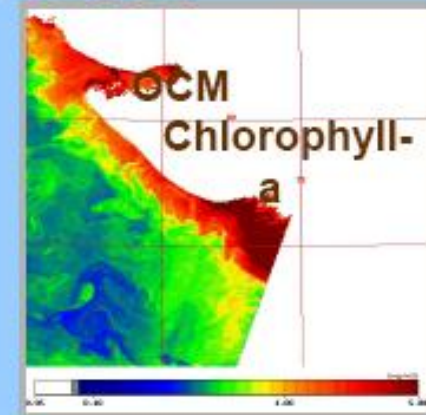
- 500m resolution, 200 km Swath
- 18 Bands (0.408-1.6 μm)

WiFS Sensor

- 188m resolution, 810 km swath



OCM



IRS-P4 (1999)

OCM Sensor

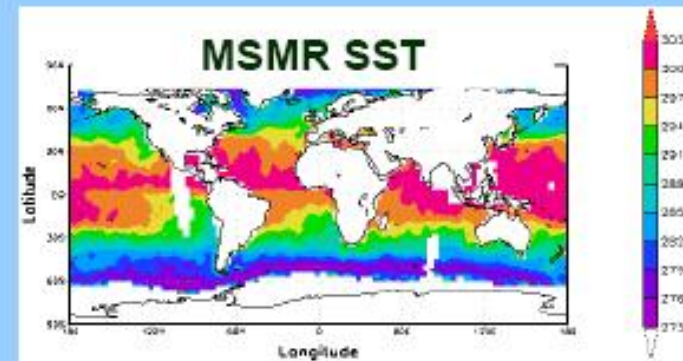
- 360m resolution, 1420 km Swath
- 8 Bands (0.402-885 μm)

MSMR Sensor

- Microwave passive Radiometer
- 6.6, 10.65, 18, 21 GHz
- 150, 75, 50, 50 km resolution



MSMR



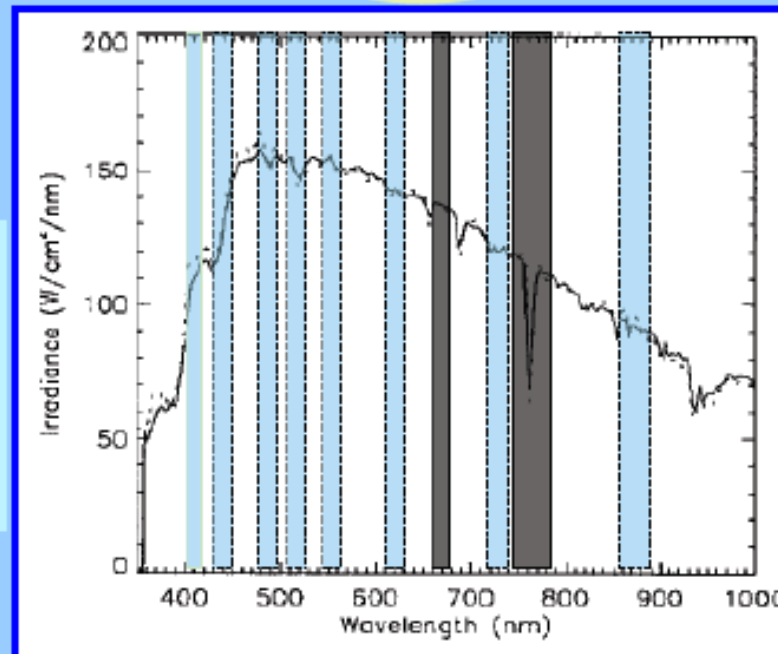
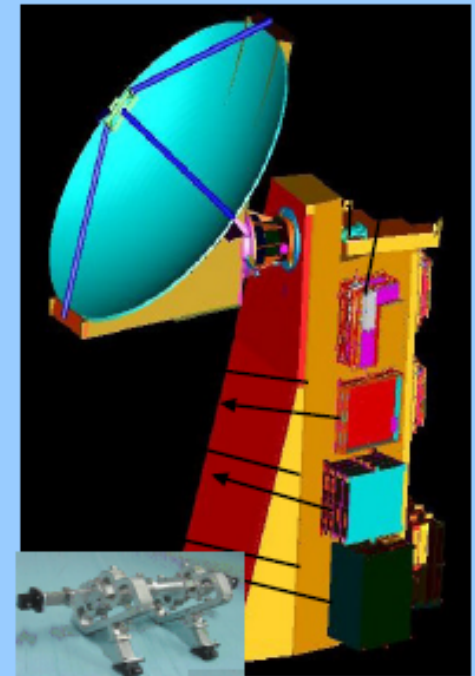
Oceansat-2: Payloads

Ocean Color Monitor -2



Oceansat-2 is continuity of Oceansat-1 with modification in OCM channels and availability of Scatterometer

Pencil Beam Scanning Scatterometer



Band 765 nm → 740 nm to avoid O₂ absorption

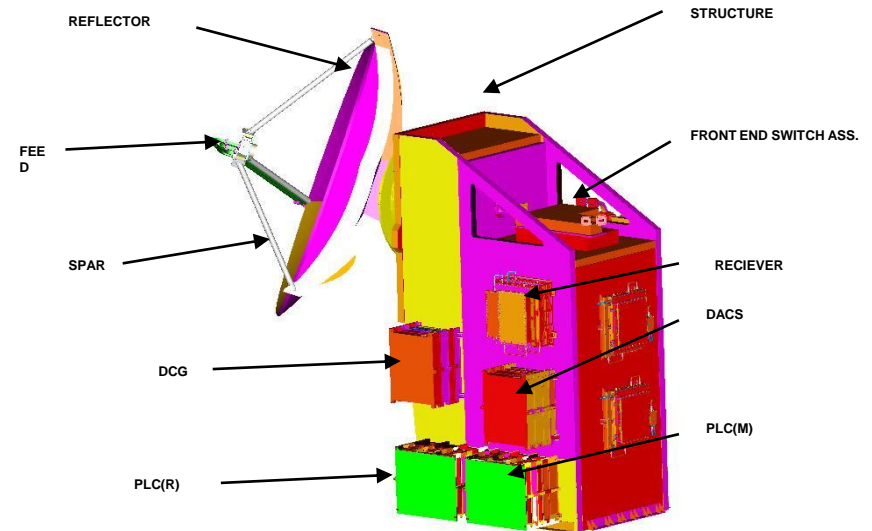
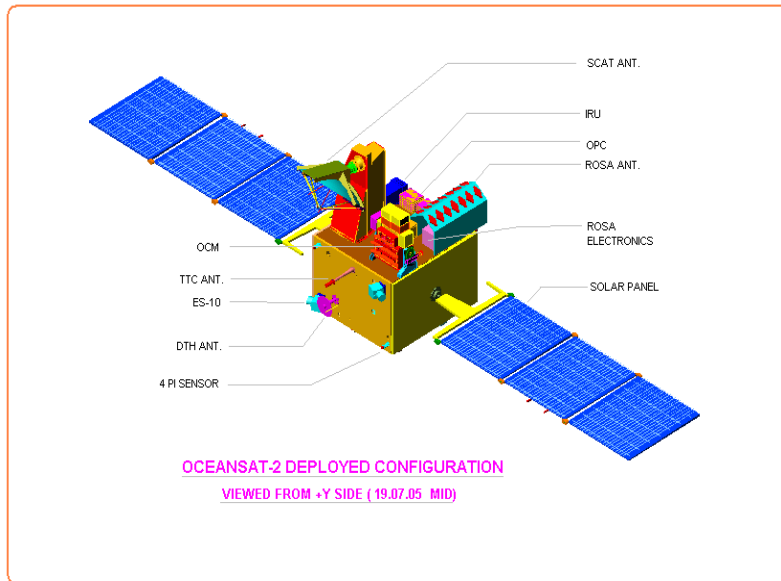
Band 670 nm → 620 nm for better quantification of suspended sediments

- Ku-band 13.515 GHz
- Spatial res., 50 km
- Ocean surface wind speed from 4 m/sec to 24 m/sec

OCEANSAT-2 : SCATTEROMETER

2009 Launch

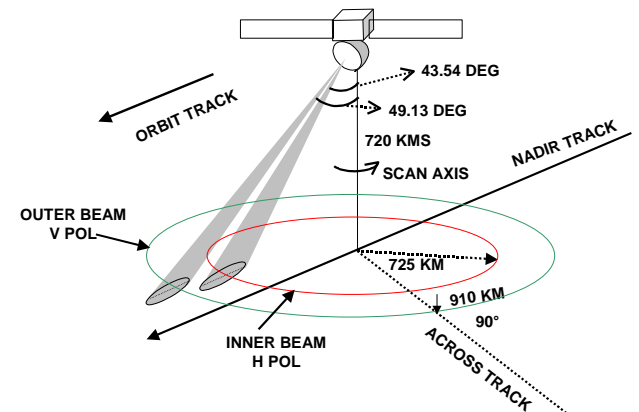
Scatterometer



Scatterometer Specifications

PARAMETER	VALUE
Altitude	720 Km
Frequency	13.5156 GHz
Resolution	50 km X 50 km
Polarisation	HH (Inner) and VV (Outer)
Antenna	Parabola of 1.0 m Dia
Scanning Rate	20.5 rpm
Data Rate	13.11 Mbit/sec (Raw) 74.4 Kbit/Sec (Processed)
Transmit Power	100 W Peak
Swath	1400 km
Wind Speed Range	4 to 24 m/s
Wind Speed Accuracy	2 m/sec or 10% (Whichever is higher)
Wind Direction Accuracy	20 deg RMS

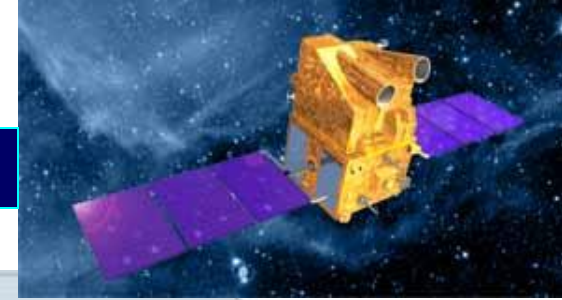
Scatterometer Geometry



GEOMETRY OF THE PENCIL-BEAM SCATTEROMETER FOR OCEANSAT-II

CARTOSAT-1

Launch : PSLV-C6: May 05, 2005

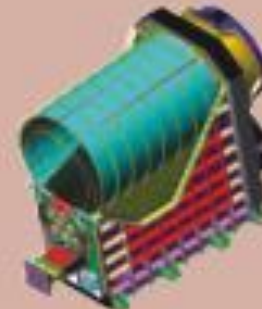


CARTOSAT-1 Specifications

Orbit	: 618 km high, circular Polar Sun Synchronous
Orbit inclination	: 98.87 deg
Orbit period	: 97 min
Number of orbits per day	: 14
Local time of equator crossing	: 10.30 AM
Repetivity	: 126 days
Revisit	: 5 days
Lift-off mass	: 1560 kg
Attitude and orbit control	: 3-axis body stabilised using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters
Electrical power	: 15 sq m Solar Array generating 1100 W, Two 24 Ah Ni-Cd batteries
Mission life	: 5 years



Payloads	: Two PAN Cameras (PAN fore mounted with a tilt of +26 deg and PAN aft mounted with a tilt of - 5 deg from the yaw axis to generate stereoscopic imagery)
Instantaneous Geometric Field of View (IGFOV)	: < 2.5 m
Swath	: 30 km
Spectral Band	: 0.50-0.85 Micron
Data rate	: 105 Mbps for each camera
Solid State Recorder	: 120 GB capacity for image data storage



CARTOSAT-1
PAN camera

CARTOSAT – 2 / 2A



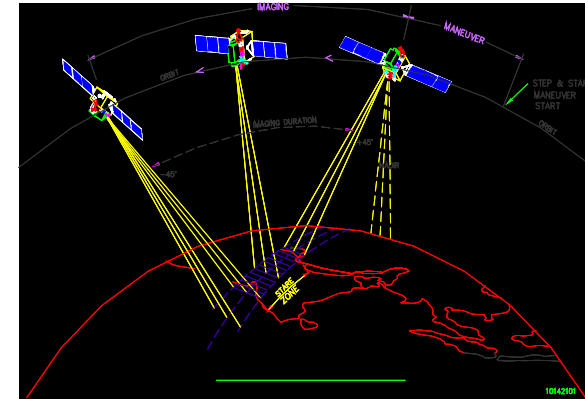
- Altitude : 630 km / **638 km***
- Inclination : 97.91 deg / **97.94 deg***
- Period : 97.4 minutes
- Local time (D) : 9.30 am
- Orbits.day : 14
- Revisit / Repetivity : 4 days / 310 days
- Lift-off mass : 680 kg
- Payload : Panchromatic Camera
- Operational Life : 5 Years

- **CARTOSAT 2/2A PAN SENSOR**

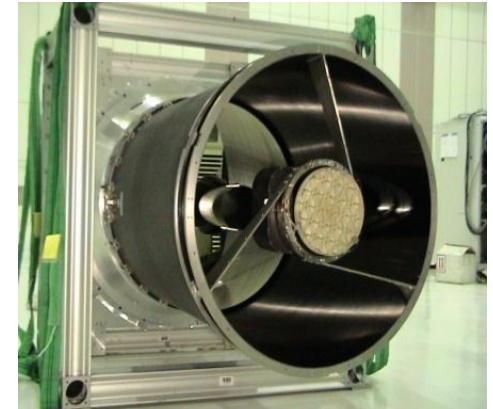
- Spectral Range : 0.5 – 0.85
- Spatial Res. : <1m (81cm nom.)
- Swath : 9.6 km
- SSR : 64 GB
- Data Rate : 336 MBPS
- On-board Comp. : 3.2:1
- Transmission : 105 MBPS

CARTOSAT - 2

- High Resolution PAN imaging
 - SWATH (km) : 10
 - SNR : ≥ 180
 - IGFOV (m) : 0.8
 - SWR (%) : ≥ 10



Step and Stare imaging



Cartosat 2-A PAN & P6 LISS-IV

CARTOSAT - 2A ; Launch PSLV C9 28 Apr 2008

RISAT

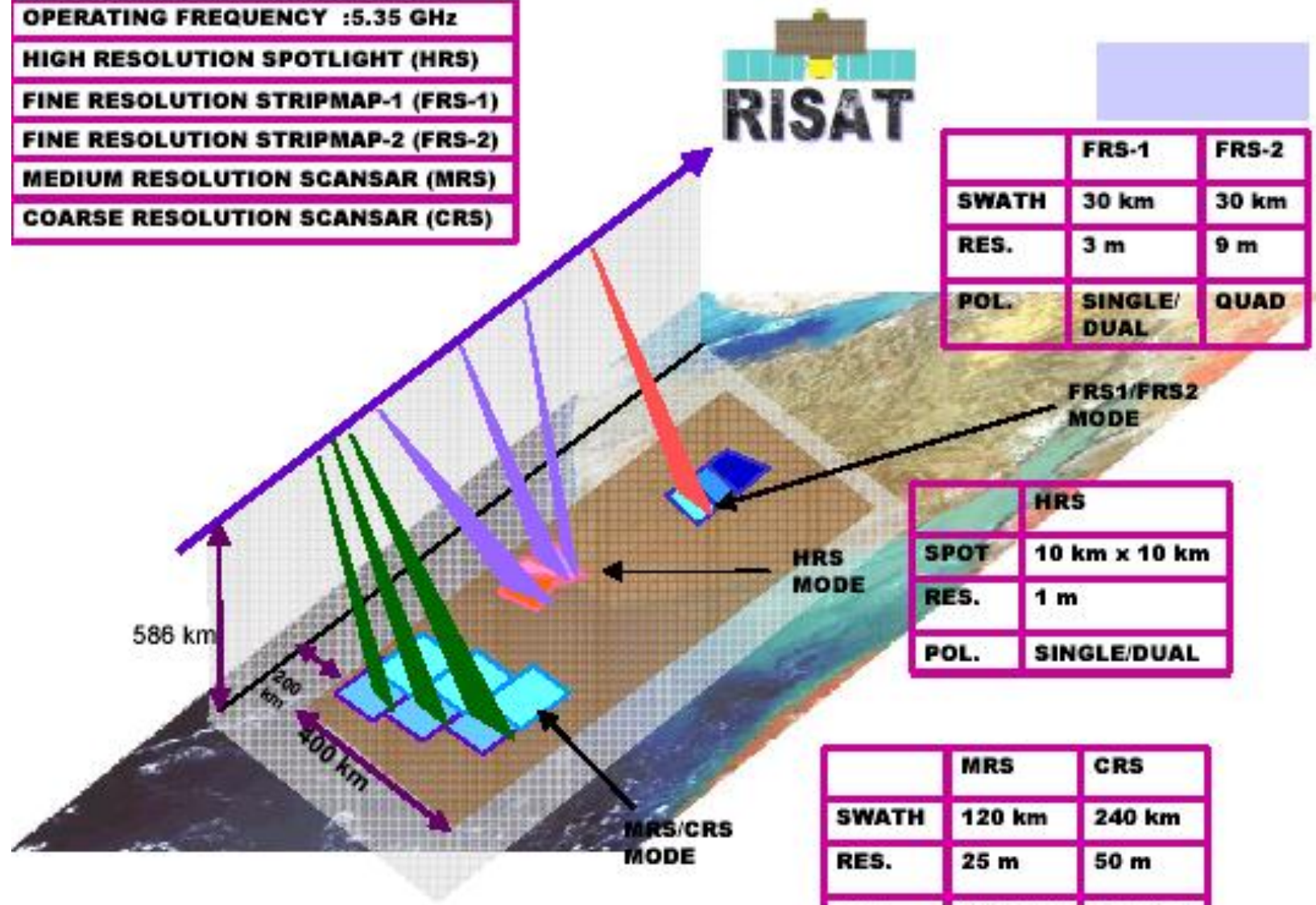
ALTITUDE	586.87 KM				
FREQUENCY	5.35 Ghz				
ORBIT	SUN SYNCHRONOUS				
POLARISATION	SINGLE / DUAL/ QUAD POLARISATION				
RESOLUTION (IN METER)	SINGLE POL HH / HV / VV / VH.		DUAL POL HH+HV / VV+VH		QUAD POL HH+HV+VV+VH
High Resolution Spotlight HRS	Azimuth	1 m	Azimuth	1 m	
	Sl. Range	0.7 m	Sl. Rang	0.7 m	
Fine Resolution Strip map FRS	Azimuth	3 m	Azimuth	3 m	Azimuth 9 m
	Sl. Range	2 m	Sl. Range	2 m	Sl. Range 4 m
Medium Resolution SCANSAR MRS	Azimuth	24 m	Azimuth	24 m	
	Sl. Range	8 m	Sl. Range	8 m	
Coarse Resolution SCANSAR CRS	Azimuth	50 m	Azimuth	50 m	
	Sl. Range	8 m	Sl. Range	8 m	
SWATH (IN km)	10 km x 10 km		SPOT (HRS)		
	30 km		STRIP (FRS)		
	120 km		STRIP (MRS)		
	240 km		STRIP (CRS)		
LOOK ANGLE COVERAGE	18.7 degrees to 44.3 degrees				
INCIDENCE ANGLE COVERAGE	20.5 degrees to 49.7 degrees				
SWATH SELECTABILITY	EITHER SIDE OF FLIGHT DIRECTION FROM 200 km TO 600 km FROM THE SUBSATELLITE TRACK				
TOTAL NO. OF BEAMS	41			39	
ON BOARD STORAGE	240 Gbits				

Imaging SAR : RISAT

- OPERATING FREQUENCY :5.35 GHz**
- HIGH RESOLUTION SPOTLIGHT (HRS)**
- FINE RESOLUTION STRIPMAP-1 (FRS-1)**
- FINE RESOLUTION STRIPMAP-2 (FRS-2)**
- MEDIUM RESOLUTION SCANSAR (MRS)**
- COARSE RESOLUTION SCANSAR (CRS)**



	FRS-1	FRS-2
SWATH	30 km	30 km
RES.	3 m	9 m
POL.	SINGLE/ DUAL	QUAD



	HRS
SPOT	10 km x 10 km
RES.	1 m
POL.	SINGLE/DUAL

	MRS	CRS
SWATH	120 km	240 km
RES.	25 m	50 m
POL.	SINGLE/ DUAL	SINGLE/ ₄ DUAL



Geostationary Operational Met. Satellites

- **INSAT – 1 Series 1982-90 (1A/ 1B/ 1C/ 1D); INSAT – 2 Series 1991-95 (2A/ 2B/ 2C/ 2D); VHRR**
 - **Visible 2.75 km**
 - **IR 11 km**
- **INSAT – 2E ; INSAT – 3A ; VHRR + CCD**
 - **VHRR : Visible 2 km, IR 8 km**
 - **CCD : Multispectral 3band, 1 km**
- **KALPANA (Met only payload), 2002, VHRR**

Megha-Tropiques - A Joint ISRO-CNES Mission



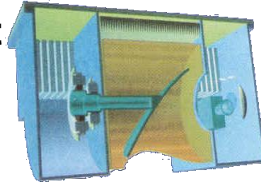
For studying water cycle and energy exchanges in tropical regions

Launch: 12 Oct 2011

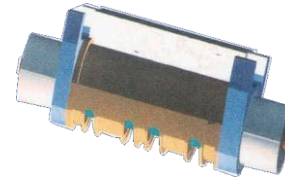
Low inclination (20°) for frequent simultaneous observations of tropics

- Water vapour, Clouds
- Cloud condensed water,
- Precipitation, Evaporation

SAPHIR



SCARAB



MADRAS



ROSA

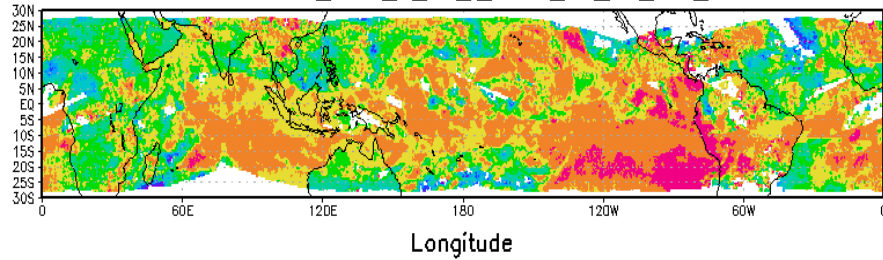


Contributing to Global Precipitation Mission (GPM)

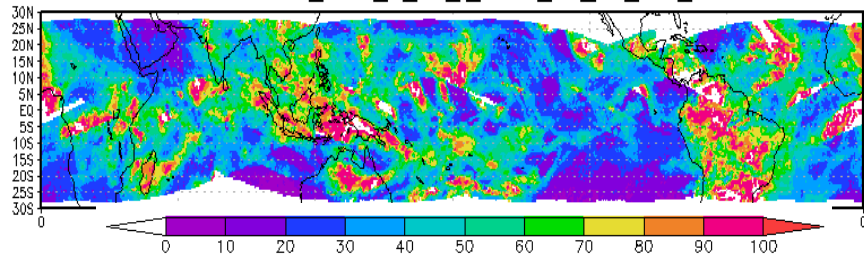
Payload	Type	Characteristic	Data Type
MADRAS	Microwave imager	Five Frequency, 9-channel Microwave imager 18, 23, 36, 89 and 157 Ghz All in V and H Polarisations except for 23 GHz (V only)	Surface wind speed, total water vapour, cloud liquid water, rainfall, cloud ice
SAPHIR	Sounder	Six-channel millimetre wave Humidity sounder at 183 Ghz (Water vapour Resonance Frequency)	Vertical humidity profiling at 6 altitudes with good horizontal resolution
SCARAB	Scanner	Four-channel Earth radiation budget instrument 0.5-0.7 μm, 0.2-4 μm, 10.5-12.5 μm, 0.2-200 μm, with a spatial resolution of 40 km	Long-wave radiation fluxes
ROSA	Sounder	Radio Occultation System to obtain vertical profiles of humidity, temperature, Aerosol contents, etc., GPS receivers at L1 and L2 channels	Vertical profiles of humidity, temperature, and aerosol contents with good vertical resolution

Initial Megha-Tropiques data products

LAYER AVERAGE RELATIVE HUMIDITY (1000-850)mb
MT1SAPSL1A_1.00_9_01_I_2011_10_15_asc_larh

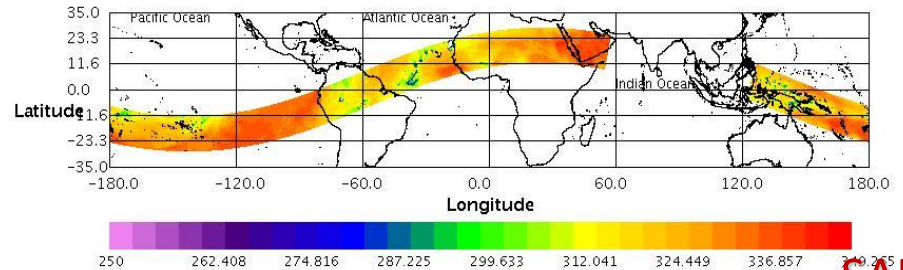


LAYER AVERAGE RELATIVE HUMIDITY (550-400)mb
MT1SAPSL1A_1.00_9_01_I_2011_10_15_asc_larh



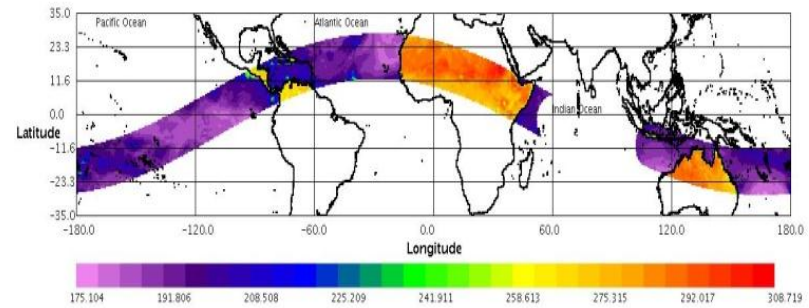
**SAPHIR Relative Humidity –
Two Layers**

SAPHIR_CHANNEL_4_ORB_15_16_DOP_13OCT2011_BRIGHTNESS_TEMPERATURE_DEG_K



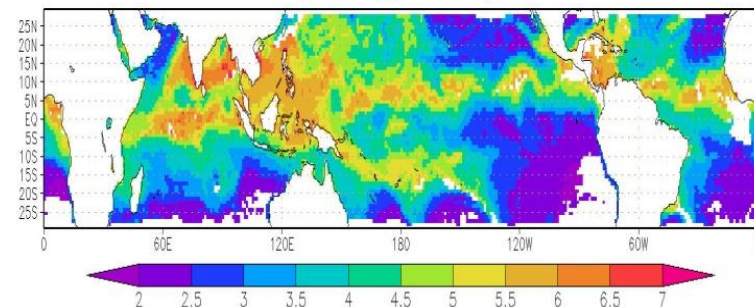
**SAPHIR
BT Data**

MADRAS_18.7GHZ_V_ORB_17_18_DOP_13OCT2011_BRIGHTNESS_TEMPERATURE_DEG_K



**MADRAS
BT Data**

MT-MADRAS Water Vapour (g/cm**2) - Oct. 14-15 2011



**MADRAS
GP Data**

FUTURE EO SATELLITES & SENSORS

SARAL (2013)

INSAT 3D (2013)

**Resourcesat – 2A, GISAT, Oceansat – 3,
RISAT – 1A, Cartosat – 2C**

EO – Near Future Satellites

SARAL

Satellite with ARgos and ALtika
- Joint ISRO-CNES Mission



Payloads

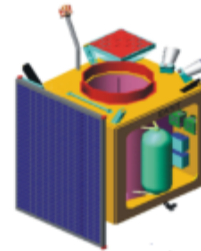
- Ka-band Altimeter (~35.5GHz)
- Dual freq Radiometer (23.8/36.8 GHz)

Status

- Launch by PSLV in early 2013

GISAT

Multiple acquisition capability
from a Geosynchronous Orbit



Payloads

- High resolution multi-spectral VNIR (HRMX-VNIR): 50m Res.
- Hyper spectral VNIR & SWIR: 320m and 192m Res.
- High resolution Multi-spectral (HRMX-TIR): 1.5km Res.

Status

- Launch by PSLV during 2016-17

INSAT - 3D

For improved understanding
of weather systems



Payloads

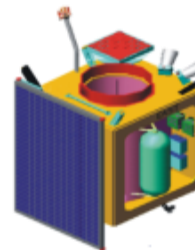
- 19 channel Sounder
- 6 Channel Imager

Status

- Launch by 2013

Resourcesat-2A

Land and Water Resources
Applications – Continuity Mission



Payloads

- LISS IV Mx, LISS III and AWiFS

Status

- Launch by PSLV during 2015-16

ISRO contribution: CEOS Virtual Constellations

- Land Surface Imaging (LSI) – Resourcesat-2
- Ocean Colour Radiometry (OCR) – Oceansat-2 OCM
- Ocean Surface Vector Wind (OSVW) - Oceansat-2 Scatterometer
- Precipitation (PC) – Megha-Tropiques
- Ocean Surface Topography (OST) – SARAL
- Sea Surface Temperature (SST-VC) - (*under discussion*)
- Atmospheric Composition (ACC)



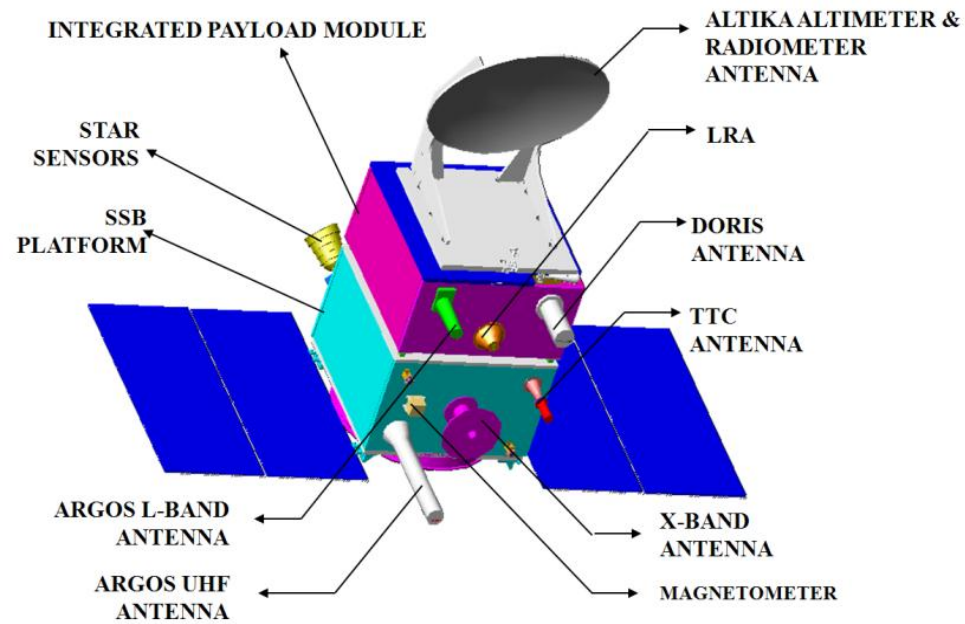
Thank You

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<http://www.nrsc.gov.in>

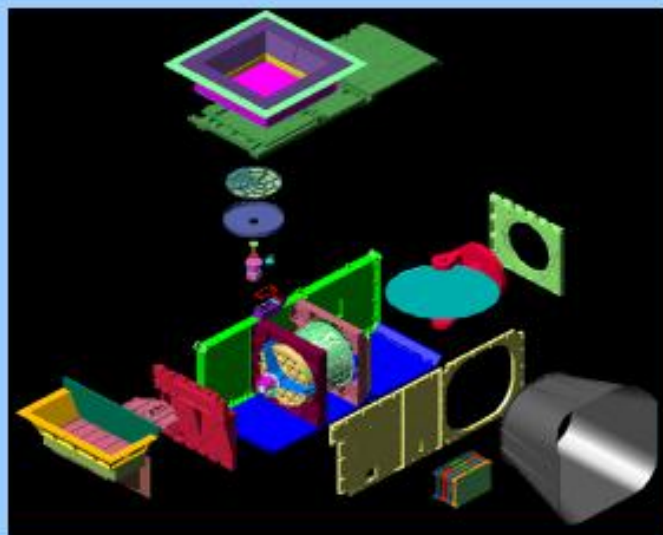
SARAL : Satellite for ARGOS & ALTIKA



INSAT 3D

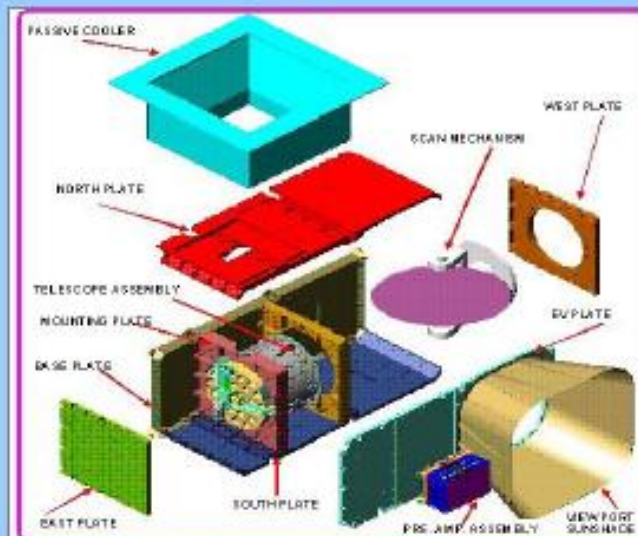


Sounder



19 channel Sounder

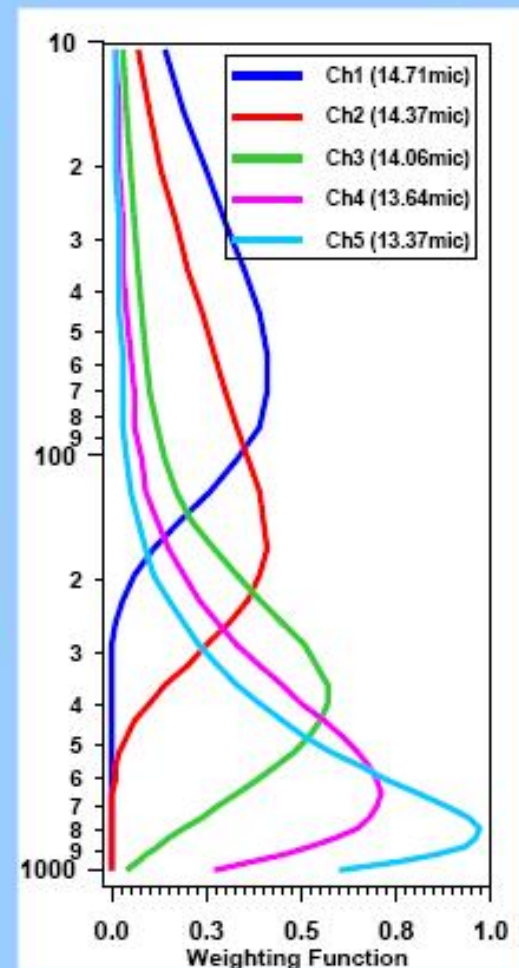
Imager



Advanced 6-channel imager

Sounder: 19 channels with spatial resolution of 10 km
Imager: 6 channel with spatial resolution of 1 km to 8 km

Applications: Improved estimation of water vapour content, cloud, wind vector, upper tropospheric humidity, sea surface temperature and surface insolation



INSAT-3D Weighting Function over Indian Region (July)

INSAT 3D: IMAGER: 6 Band

Band No.	Spectrum (mm)	IGFOV (km)	S/N/ Or NEDT (K)	Scene Condition
1	0.55-0.75	1	150:1	100% albedo
2	1.55-1.70	1	150:1	100% albedo
3	3.80-4.00	4	1.40 K	300 K
4	6.50-7.00	8	1.00 K	230 K
5	10.2-11.3	4	0.35 K	300 K
6	11.5-12.5	4	0.35 K	300 K

