January-June 1999

SPACE india

INDIAN SPACE RESEARCH ORGANISATION

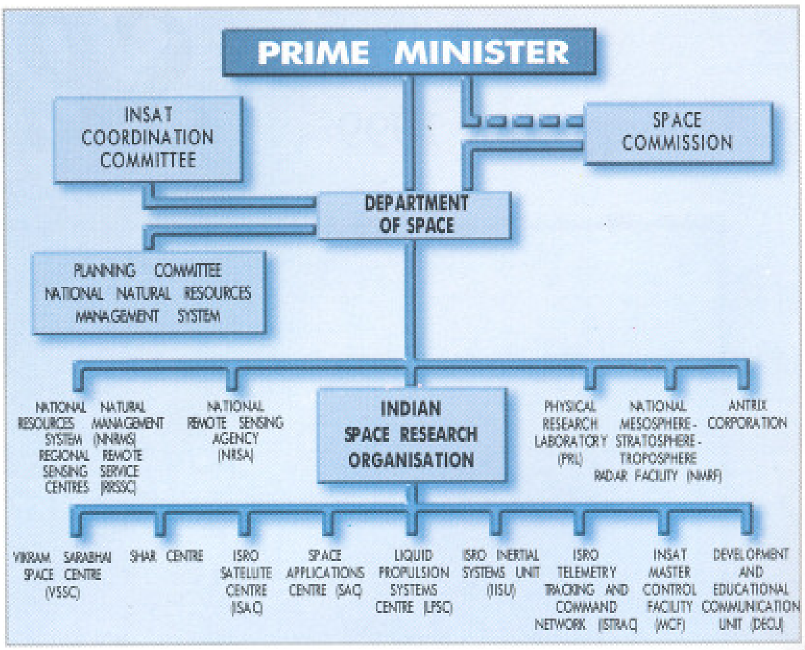
The Indian Space Programme

The setting up of the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 marked the beginning of the Indian Space Programme. The Space Commission and the Department of Space (DOS) were established by the Government of India in 1972 to promote unified development and application of space science and technology for identified national objectives.

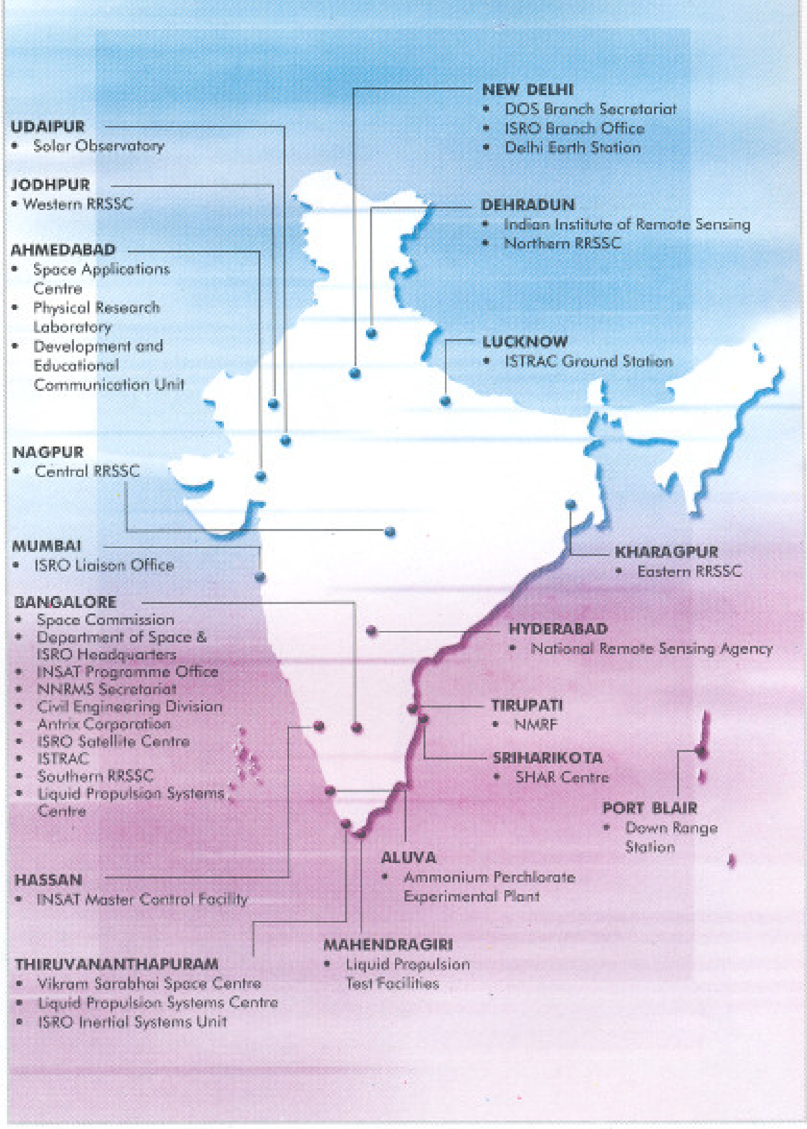
The Indian Space Programme is directed towards the goal of self reliant use of space technology for national development, its main thrusts being (a) satellite communications for various applications, (b) satellite remote sensing for resources survey and management, environmental monitoring and meteorological services and (c) development and operationalisation of indigenous satellite and launch vehicles for providing these space services.

The Indian Space Research Organisation (ISRO) is the research and development wing of DOS and is responsible for the execution of the national space programme. ISRO also provides support to universities and other academic institutions in the country for research and development projects relevant to the country's space programme.

Both the DOS and ISRO Headquarters are located at Bangalore. The development activities are carried out at the Centres and Units spread over the country.



SPACE CENTRES AND UNITS IN INDIA



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Editorial / Circulation Office

Publications & Public Relations Unit,
ISRO Headquarters,
Antariksh Bhavan, New BEL Road,
Bangalore - 560 094, India.

Printed at Sharadh Enterprises, Bangalore.

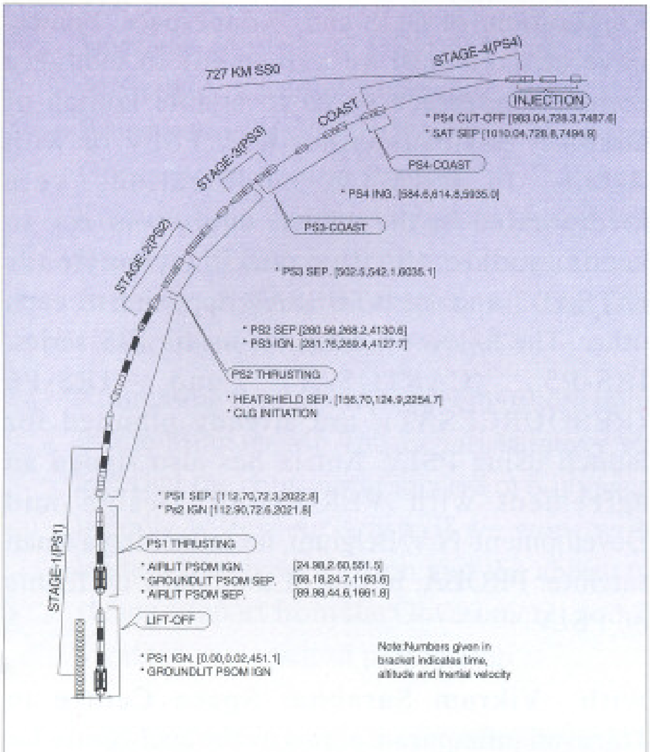
PSLV-C2 Launches Three Satellites

The national flags of Germany, India and Republic of Korea, flying high in front of Mission Control Centre at Sriharikota.

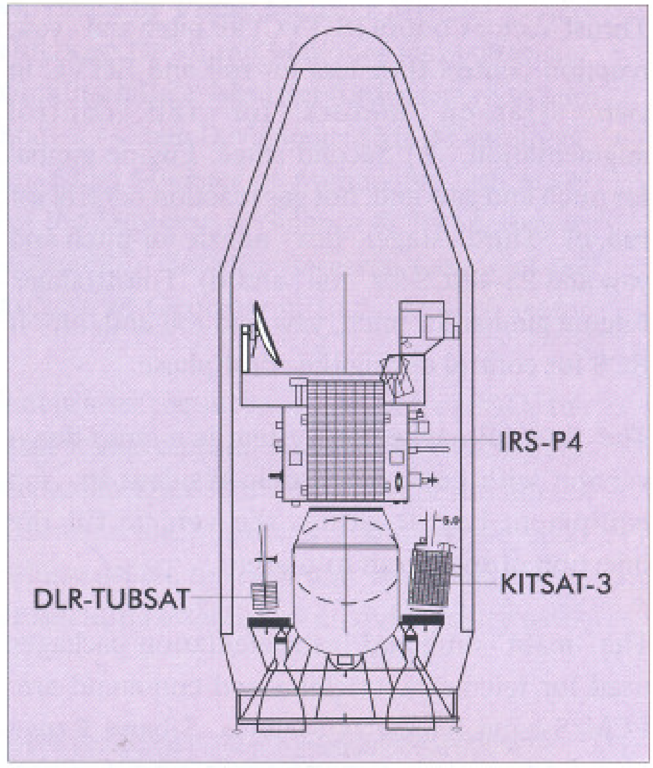
ISRO launched its Polar Satellite Launch Vehicle (PSLV-C2) on May 26, 1999 from SHAR Centre, Sriharikota, placing three satellites - Indian Remote Sensing Satellite, IRS-P4 (OCEANSAT) as the main payload and Korean KITSAT-3 and German DLR-TUBSAT as the auxiliary payloads in the predetermined polar orbit of 727 km.

It is for the first time that PSLV launched three satellites in a single flight. The two auxiliary payloads were flown under commercial agreements between the Antrix Corporation of the Department of Space and the concerned agencies — Satellite Technology Research Centre of the Republic of Korea and the German Aerospace Centre, DLR. While IRS-P4 (OCEANSAT) weighed about 1,050 kg, KITSAT-3 and DLR-TUBSAT weighed 110 kg and 45 kg, respectively. The two auxiliary payloads were mounted on the equipment bay of PSLV, diametrically opposite to each other, while the main payload, IRS-P4, was mounted on top of the equipment bay. In the flight sequence, IRS-P4 was injected first followed by KITSAT-3 and DLR-TUBSAT, respectively.

The 294 tonne, 44.4 m tall, PSLV-C2 lifted off at the opening of the launch window at 11:52 am with the ignition of first stage motor along with four strap-on motors. All the flight events passed off without a hitch and IRS-P4 was injected into



PSLV-C2 Flight Sequence.



Locations of the three satellites inside the PSLV heat-shield.

orbit about 1010 seconds after lift-off . This was followed by a 40 deg yaw manoeuvre of the fourth stage and separation of KITSAT-3 which was mounted on the equipment bay. Subsequently, the fourth stage was yaw-manoeuvred for another 40 deg and DLR-TUBSAT, mounted diagonally opposite to KITSAT-3 was injected into orbit. The sequence of separation was planned in such a way as to avoid any collision between the three satellites and the spent fourth stage.

The Polar Satellite Launch Vehicle (PSLV) project was initiated in 1982. In the present configuration, the 44.4 metre tall, 294 tonne PSLV, has four stages using solid and liquid propulsion systems alternately. The first stage is one of the largest solid propellant boosters in the world and carries 138 tonne of propellant. It has a diameter of 2.8metre. The motor case is made of maraging steel which is indigenously produced. The booster develops a maximum thrust of about 4,630 kN. The first stage thrust is augmented by six strap-on motors, four of which are ignited on the ground. Each of these solid propellant strap-on motors, carries nine tonne indigenously produced Hydroxyl Terminated Poly Butadiene (HTPB) fuel and Ammonium Perchlorate oxidiser. Each of these motors produces 662 kN thrust.

The second stage employs indigenously manufactured Vikas engine and carries 40.6 tonne of liquid propellant — Unsymmetrical Di-Methyl Hydrazine (UDMH) as fuel and Nitrogen tetroxide (N_2O_4) as oxidiser. It generates a maximum thrust of about 725 kN.

The third stage uses 7.2 tonne of HTPB-based solid propellant and produces a maximum thrust of 340 kN. Its motor case is made of polyaramide (Kevlar) fibre. The fourth and the terminal stage of PSLV has a twin engine configuration using liquid propellant. With a propellant loading of 2 tonne (Mono-methyl hydrazine + N_2O_4), each of these engines generates a maximum thrust of 7.4 kN.

The metallic bulbous heat-shield of PSLV, 3.2 m in diameter, is of isogrid construction and protects the spacecraft during the atmospheric regime of the flight. PSLV control system includes: a) First stage; Secondary Injection

Thrust Vector Control (SITVC) for pitch and yaw, reaction control thrusters for roll and SITVC in two strap-on motors for roll control augmentation, b) Second stage; Engine gimbal for pitch and yaw and, hot gas reaction control for roll, c) Third stage; flex nozzle for pitch and yaw and PS-4 RCS for roll and d) Fourth stage; Engine gimbal for pitch, yaw and roll and, on-off RCS for control during the coast phase.

The inertial navigation system is a strap-down version with guidance system resident in the equipment bay. It guides the vehicle till the injection of spacecraft into orbit.

The main on-board instrumentation packages used for telemetry, tracking and command are: PCM/S-band telemetry systems, S-band Range and Range rate transponders and C-band transponders, and a host of power and signal conditioning packages. PSLV employs a large number of stage auxiliary systems for stage separation, heat-shield separation and jettisoning, etc.

The first developmental test launch of PSLV (PSLV-D1), on September 20, 1993 could not inject IRS-1E satellite, on board, into orbit due to a software error in the pitch control loop of the on-board guidance and control processor. The second developmental flight, PSLV-D2, on October 15, 1994, was a complete success when the vehicle injected the 804 kg remote sensing satellite, IRS-P2, into the desired orbit. During the third developmental test flight, on March 21, 1996, PSLV could place a 922 kg IRS-P3 satellite, in the intended 817 km polar orbit. With these two consecutive successes, PSLV became an operational vehicle for launching Indian Remote Sensing satellites and in its first operational flight conducted on September 29, 1997, PSLV-C1, placed the 1,200 kg IRS-1D in polar orbit. Besides, the vehicle is also offered for launching satellites of other agencies either as auxiliary payloads or as main payloads depending upon the capacity of the vehicle. Antrix Corporation of DOS and Arianespace, France, have entered into an agreement to evolve a common interface so as to enable launch of auxiliary payloads either with PSLV or with Ariane. In PSLV-C2, modifications were incorporated in the vehicle equipment bay to accommodate the two auxiliary payloads KITSAT-3 and DLR-TUBSAT opposite to each other. The follow-on satellites in the IRS series, IRS-P5 (CARTOSAT) and IRS-P6 (RESOURCESAT), are already planned for launch using PSLV. Antrix has also signed an agreement with VERHAERT Design and Development N.V, Belgium, for launching a small satellite, PROBA, in one of the follow-on flights of PSLV.

With Vikram Sarabhai Space Centre in Thiruvananthapuram acting as the lead-centre for launch vehicle development, major responsibilities for design and development of all launch vehicles are shared by the Liquid Propulsion Systems Centre, also headquartered in Thiruvananthapuram and SHAR Centre in Sriharikota. The ISRO Inertial Systems Unit, Thiruvananthapuram is responsible for the development of inertial systems. The ISRO Telemetry, Tracking and Command Network (ISTRAC) with its TTC stations at Sriharikota, Thiruvananthapuram and Mauritius is responsible for the telemetry and tracking support to all missions. A host of institutions and over 150 industries are partners in the launch vehicle programme of ISRO. Both public and private sector industries are involved in the fabrication of a variety of hardware: light alloy structures for interstages, motor cases, electronic packages, heatshield, precision coherent radars, etc.

The launch of PSLV-C2, the fourth successive successful flight in the PSLV series, has demonstrated the maturity of ISRO to build operational launch vehicles to place Indian satellites in orbit from within the country. The flight also points to the ISRO entering into commercial launch services market having proved the capability to launch multiple satellites in a single flight.

Prime Minister Witnesses PSLV Launch

The PSLV-C2 launch from Sriharikota was witnessed by Prime Minister Mr Atal Behari Vajpayee, Minister of HRD and Science & Technology Dr Murali Manohar Joshi, Minister of State for External Affairs and Space Mrs Vasundhara Raje, Minister for Information and Broadcasting Mr Pramod Mahajan, Minister of State for Urban Development Mr B Dattatreya, Governor of Andhra Pradesh Mr C Rangarajan, Chief Minister of Andhra Pradesh Mr N Chandrababu Naidu, Director-General R&D of the Ministry of Science & Technology in Republic of Korea, Dr Yoon Chung, Director-General of Satellite Research Center of the Republic of Korea Prof Soon Dal Choi, Ambassador of Germany in India, besides senior Government officials and scientists.

Addressing the nation from Sriharikota immediately after the successful launch of PSLV the Prime Minister Mr Atal Behari Vajpayee said that it was a proud day for Indian scientists and that the continuing success of our space programme shows how reaching for the stars is literally within our grasp, if we work with dedication and team-spirit; if there are good leaders who have a vision and the ability to enthuse others to reach that vision; if there is strong support from the Government; and if our scientific establishment and industry work together in a spirit of partnership.

The Prime Minister Mr. Atal Behari Vajpayee (3rd from right) and other dignitaries pose for photograph in front of PSLV-C2. Seen in the picture from left are Dr. S. Vasantha, Director SHAR Center, Mr. Brajesh Mishra, Principal Secretary to PM (fourth), Mr. Pramod Mahajan, Minister for Information and Broadcasting (fifth), Dr. K. Kasturirangan Chairman ISRO (sixth), Mr. C. Rangarajan, Governor Andhra Pradesh (seventh), Mr. Chandrababu Naidu Chief Minister of Andhra Pradesh (eighth) and Mrs. Vasundhara Raje Minister of State for External Affairs and Space (extreme right).

PSLV-C2 ready for lift-off and the lift-off.

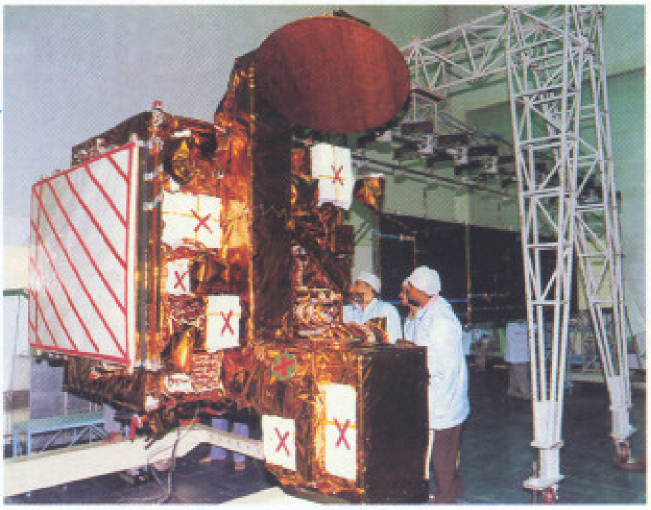
Indian Remote Sensing Satellite, IRS-P4 (Oceansat-1)

IRS-P4 (Oceansat-1) launched by ISRO's PSLV from Sriharikota Centre (SHAR), on May 26, 1999 in a polar sun-synchronous circular orbit of 727 km, carries two payloads on board, Ocean Colour Monitor (OCM) and a Multi-frequency Scanning Microwave Radiometer (MSMR).

OCM is a solid state camera operating in push-broom scanning mode, using linear array Charge Coupled Devices as detectors. The camera operates in 8 narrow spectral bands, in the visible and near-infrared, with a spatial resolution of 360 metre and swath of 1420 km. The spectral bands have been specifically chosen to observe the optical properties of phytoplankton pigments, inorganic suspended sediments, and yellow substance as well as to study aerosol characteristics and atmospheric corrections. The phytoplankton supports almost all marine life and serves as a biological pump in the oceans and is essentially responsible for the cycling of many biologically active substances. It also acts as a significant sink for atmospheric carbon dioxide. Estimation of ocean phytoplankton levels from OCM is based on changes in the optical properties of sea water caused by chlorophyll, the primary photosynthetic pigment. Thus, data from OCM, has applications in the following areas:

- Measurement of phytoplankton and assessment of their distribution both spatially and temporally; detection of algal blooms and their dynamism.
- Identification of potential fishery zones, as well as upwelling and other high productivity regions optimal for fish production.
- Delineation of ocean currents and eddies.
- Estimation of optical properties and phytoplankton abundance for marine resource and habitat assessment.
- Observation of pollution and sediment inputs to the coastal zone and their impact on the marine food.
- Sediment dynamics, dynamics of estuarine / tidal inlets, prediction of shoreline changes, coastal circulation and dispersion pattern etc.

MSMR is a highly sensitive instrument capable of measuring very low levels of microwave radiation.



IRS-P4 (Oceansat) undergoing tests at SHAR Centre.

SPACECRAFT FEATURES

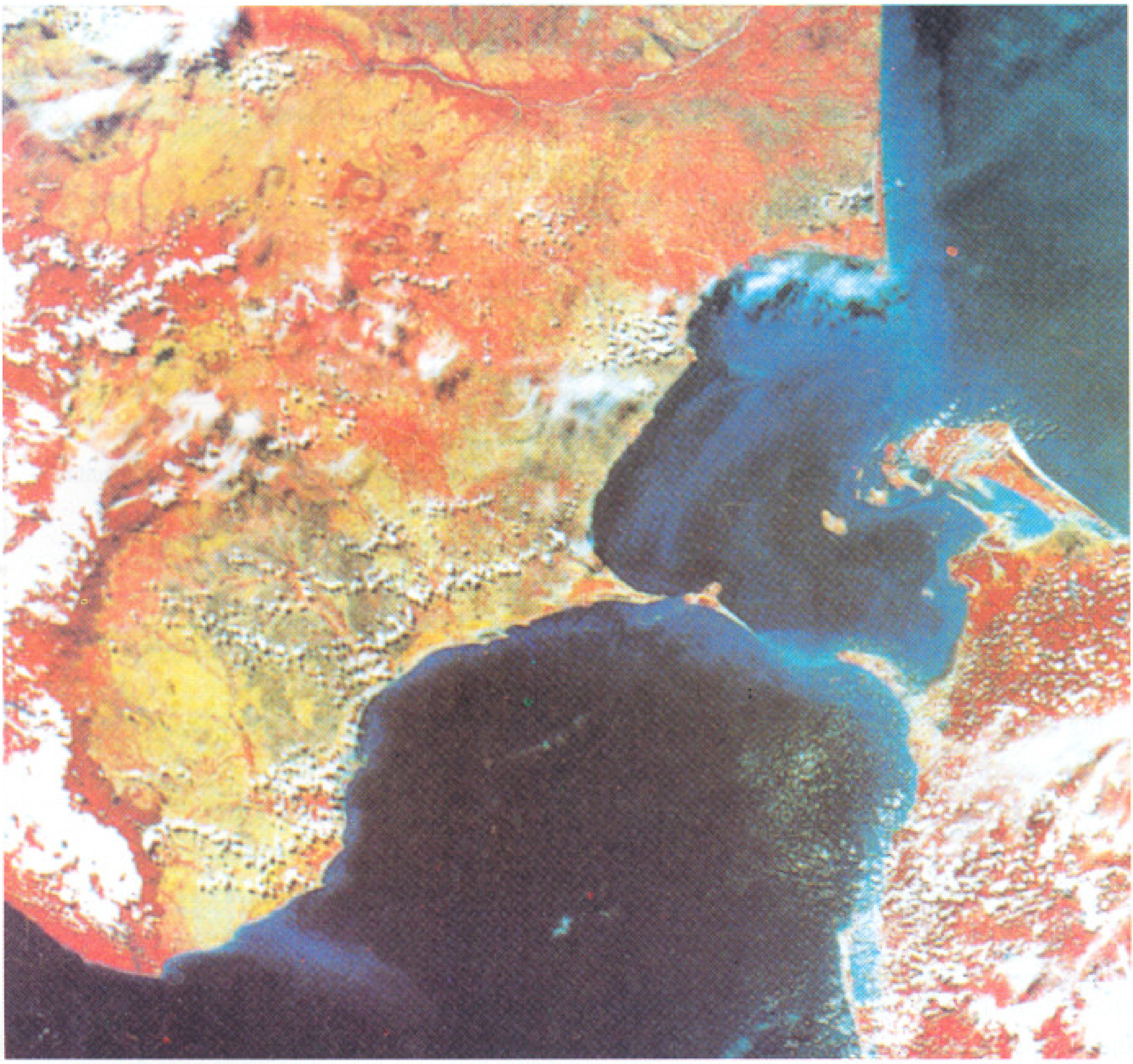
Orbit	:	Polar Sunsynchronous Circular
Altitude	:	727 km
Inclination	:	98.28 degree
Period	:	99.31 min
Local time of Eq. crossing	:	12 noon
Repetitivity cycle	:	2 days
Size	:	2.8 m x1.9 mx2.57 m
Mass at lift off	:	1050 kg
Length when fully deployed	:	11.67 m
Altitude and Orbit Control	:	3-axis body-stabilised using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters
Power	:	9.6 Sq.m solar array generating 750W. Two 21 Ah Ni-Cd battries
Mission Life	:	5 years

When a terrain is observed by a microwave radiometer (through its antenna beam), the radiation received by the radiometer is partly due to self-emission from the scene and partly due to reflected radiation originating from the atmosphere. Through proper choice of the radiometric parameters (such as wavelength, polarisation and viewing angles), it is possible to establish useful relations between the magnitude of the energy received by the radiometer and the specific terrestrial or atmospheric parameters of interest.

MSMR is a passive microwave radiometer, operating in 4 frequencies (6.6 GHz, 10.65 GHz, 18 GHz and 21 GHz) in both vertical and horizontal polarisations.Operating in the microwave domain, MSMR has the advantage of penetrating clouds and hence has all weather capability. The radiation emitted by the ocean surface passes through the earth's atmosphere, gets modified before detection by MSMR. Various

Ocean Remote Sensing in India

India's 7,500 km coastline supports vast marine resources. The oceanic processes are known to influence the climate and the weather, thus affecting the economy and day-to-day life of the people. The scientific studies of the Indian oceans have normally been carried out from the observations made from ships and buoys, which have several restrictions in terms of space and time. The advent of satellites with their capability to provide repetitive and wide area coverage has radically changed the nature of oceanographic applications in the recent years. India has also conducted a major programme known as Marine Satellite Information Services (MARSIS) over the last one decade in order to develop methodologies for retrieval of oceanographic parameters. One of the important applications has been in estimating Sea Surface Temperature using US NOAA satellite data. Mapping of coastal zone at different scales has also been carried out using Indian Remote Sensing satellites, IRS-1A through IRS-1D. Also, data from satellites like Nimbus-7, ERS 1 & 2, Topex/Poseidon etc, have been used to develop various methodologies. The advent of a dedicated, oceanographic satellites, IRS-P4 (Oceansat-1), is expected to give a great fillip to the application of space based ocean remote sensing.



First imagery from Ocean Monitor of IRS-P4 received on June 4, 1999. The imagery brings out features such as turbidity and suspended sediments in the Bay of Bengal / Indian Ocean.

constituents of the atmosphere have different and specific effect on a particular microwave frequency. The frequency and the polarisation combination for MSMR have been arrived at by taking into consideration various applications of relevance. Using the combination of these frequencies and polarisation, geo-physical parameters such as atmospheric water vapour, Sea Surface Temperature, precipitation over oceans, ocean surface winds, cloud liquid water etc., can be derived. Various applications using the geo-physical parameters derived from MSMR could be: Inputs to medium range weather forecasting; And studies related to mixed layer depth, air sea exchanges, ocean circulation models etc.

Soon after its launch into orbit, the two sun-tracking solar panels of IRS-P4, which generate electrical power for the satellite, were automatically deployed by an on-board sequencer The following day, the hold-down and tilt mechanisms, that enables OCM instrument to be directed in such a way as to avoid sun glint during data collection over the oceans, were released. Following this, in the satellites 16th orbit, MSMR was also tested and preliminary data collected by National Remote Sensing Agency (NRSA),

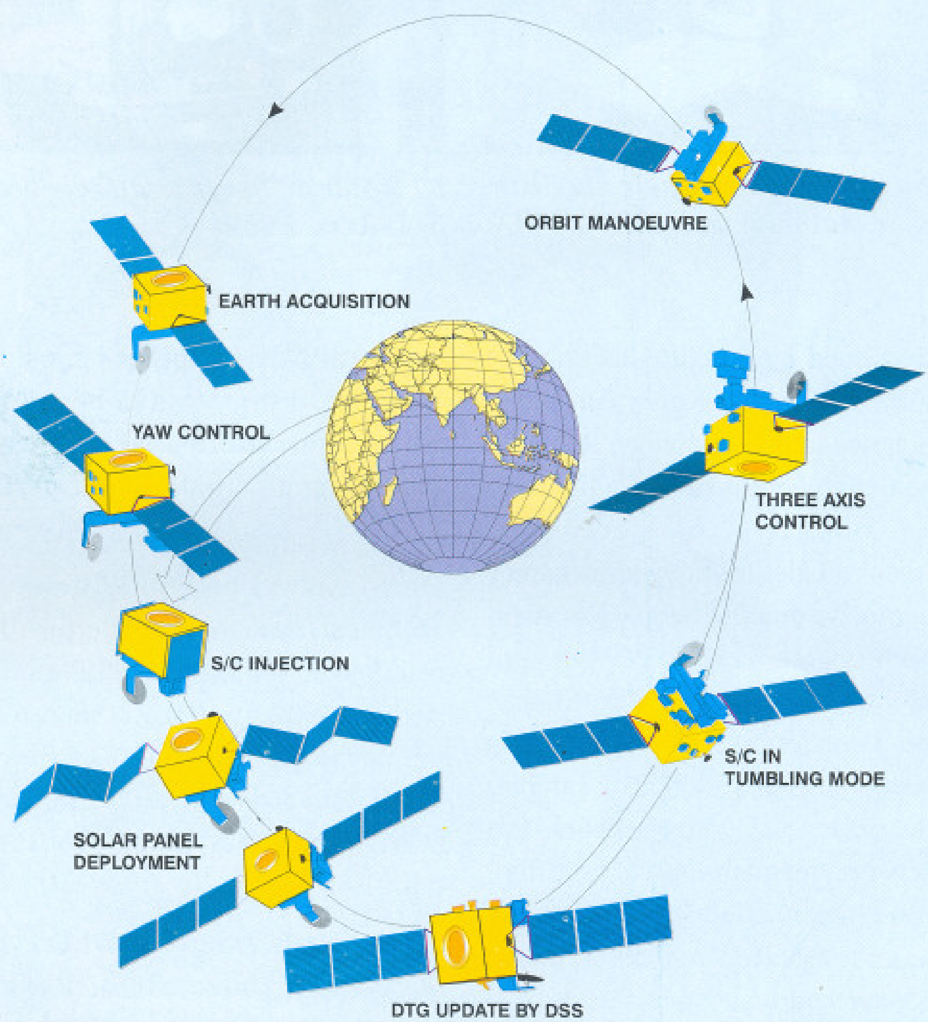
Applications of Data from MSMR		
Frequency	Parameters	Application Potential
21 with 18 & 10.6 GHz (V&H)	Atmospheric Water Vapour (WV)	- Input to medium range forecast system - Humidity corrections to other measurements
21 with 18 & 10.6 GHz (V&H)	Cloud Liquid Water(CLW)	- Input to medium range forecasting - Validation of numerical models
10.6 with 6.6, 18 & 21 GHz (V&H)	Sea Surface Wind (SSW)	- Sea Surface Wind (SSW) - Assimilation to medium & extended range weather forecasting - Cyclogensis studies - Mixed layer depth - Air sea exchanges and - In-put to ocean circulation models
6.6 with 10.6, 18 & 21 GHz	Sea Surface Temperature (SST)	- Monsoon convective systems - Tropical cyclone genesis - Extent/strength of El-Nino - Latent heat input to ocean models - Mixed layer depth - Antarctic ice-sheet dynamics

Hyderabad. The OCM was switched on during the satellite's 117th orbit on June 3, 1999 when the satellite was passing over Bihar, Orissa and Bay of Bengal off East coast of India over Sri Lanka. Data received at NRSA indicated normal performance of the payload.

IRS-P4 was designed and developed by ISRO Satellite Centre, the lead Centre for all Indian satellites. MSMR and OCM payloads were designed and developed by the Space Applications Centre (SAC), Ahmedabad. SAC is also responsible for developing various data processing and special software for deriving geo-physical parameters. The ISRO Inertial Systems Unit at Thiruvananthapuram supplied the inertial system like reaction wheel, power transfer assembly, Inertial Reference Units, etc, while Liquid Propulsion Systems Centre supplied the reaction control system. Vikram Sarabhai Space Centre Thiruvanantapuram has supplied the pyrotechnic devices and composite material systems. Many industries and institutions both in public and private sector have been involved in the realisation of IRS-P4.

Multi Frequency Scanning Microwave Radiometer (MSMR)				
Frequency (GHz)	6.6	10.6	18	21
Spatial Resolution (km)	120	80	40	40
Polarisation	V&H			
Swath (km)	1360			
Temp. Resolution	1.0 deg K			
Dynamic Temp. Range	330 deg K			

IRS-P4 Mission Sequence



Ocean Colour Monitor (OCM)

Sensor Parameters	Specifications
Spatial Resolution(m)	360
Swath (km)	1420
Repetitivity (days)	2
Local time of equator crossing (hrs)	12 noon
Scan Plane Tilt (deg.) (to avoid sun glint)	±20
Spectral Bands (nm)	402-422; 433-453; 480-500; 500-520; 545-565; 660-680; 745-785; 845-885.

ISRO Telemetry, Tracking and Command Network (ISTRAC) with its Spacecraft Control Centre at Bangalore monitors and controls the IRS-P4 satellite. ISTRAC network of ground stations located at Bangalore, Sriharikota, Lucknow, Mauritius, Bearslake and Biak in Indonesia support the IRS-P4 mission. During the initial phase of the mission the ground station at Weilheim in Germany also provided the network support.

The National Remote Sensing Agency, Hyderabad receives, processes and disseminates the data from IRS-P4. Many agencies/institutions will participate in the use of IRS-P4 data. The Indian National Centre for Ocean Information Services established under Department of Ocean

KITSAT-3 & DLR-TUBSAT

Korean scientists checking their satellite, KITSAT-3 before mating it with ISRO's PSLV.

DLR-Tubsat, the German satellite to be flown by ISRO's. PSLV.

KITSAT-3, developed by Satellite Technology Research Centre (SaTReC), Korea Advanced Institute of Science and Technology, Republic of Korea, is an engineering test satellite with the primary objective of developing fundamental technologies for high performance micro satellites and to qualify them in low earth orbit environment. It weighs 103 kg and measures 49.5 cm x 63 cm x 85.4 cm. It has one fixed and two deployable solar panels generating a maximum of 150 W. The satellite is three axis stabilised using star sensors, sun sensors, IR sensors, magnetometers and fibre optic gyros and attitude control actuators like magneto-torquers, reaction wheels. It also employs a GPS navigator.

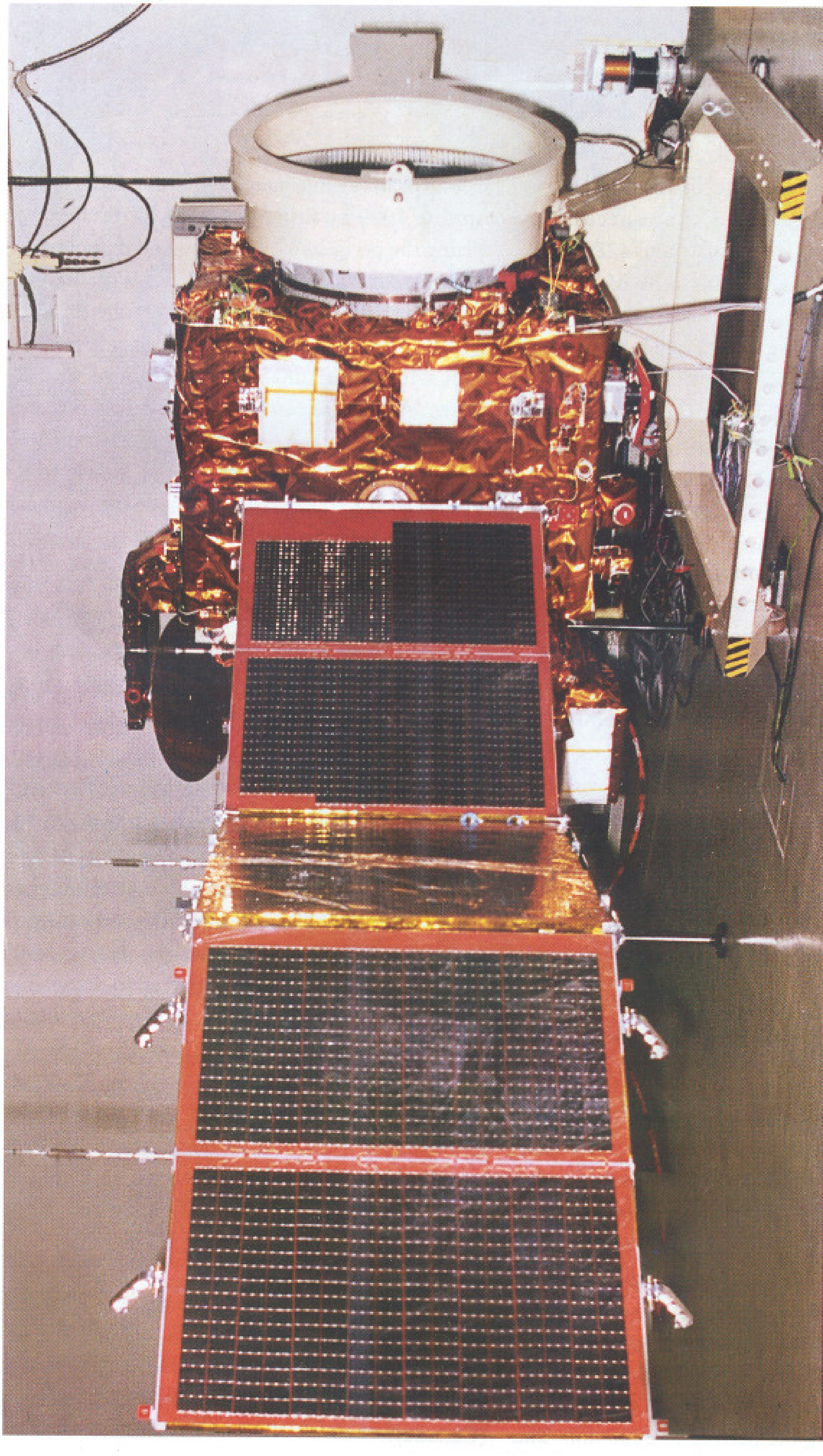
KITSAT-3 carries a Multispectral Earth Imaging System, MEIS, and a Space Environment Scientific Experiment (SENSE). MEIS will provide images of earth surface in three spectral bands. SENSE comprises High Energy Particle Telescope, instruments for measuring Radiation Effects on Micro-Electronics, Scientific Magnetometer and Electron Temperature Probe.

DLR-TUBSAT is jointly developed by the Technical University of Berlin (TUB) that is responsible for the satellite and the German Aerospace Centre (DLR) that is responsible for the payload. The 45 kg, 32 cm cuboid DLR-TUBSAT is an earth observation satellite having a high ground pixel resolution better than 10 m.

First signals from the DLR-TUBSAT were received by University of Berlin during its second orbit about 3 hours after its injection into orbit. The first signals from KITSAT-3 were acquired by the Korean Station during its fifth orbit as expected. Both the satellites are reported to be functioning normally.

Development will provide necessary interface with these users for carrying out various studies and applications.

With four satellites, IRS-1B, IRS-1C, IRS-P3 and IRS-1D providing a variety of data to the user community, India is one of the leading countries in the world today in satellite remote sensing. Under the umbrella of National Natural Resources Management System (NNRMS), India has carried out many remote sensing based operational projects in agriculture, geology, surface and ground water, forestry and environment, urban and rural development, watershed development etc. Data from IRS-1C and 1D are being received and used by several countries including USA, Japan, Germany, Korea, Thailand, Dubai etc. With the launch of IRS-P4, India is well poised to make its presence in the ocean applications as well.

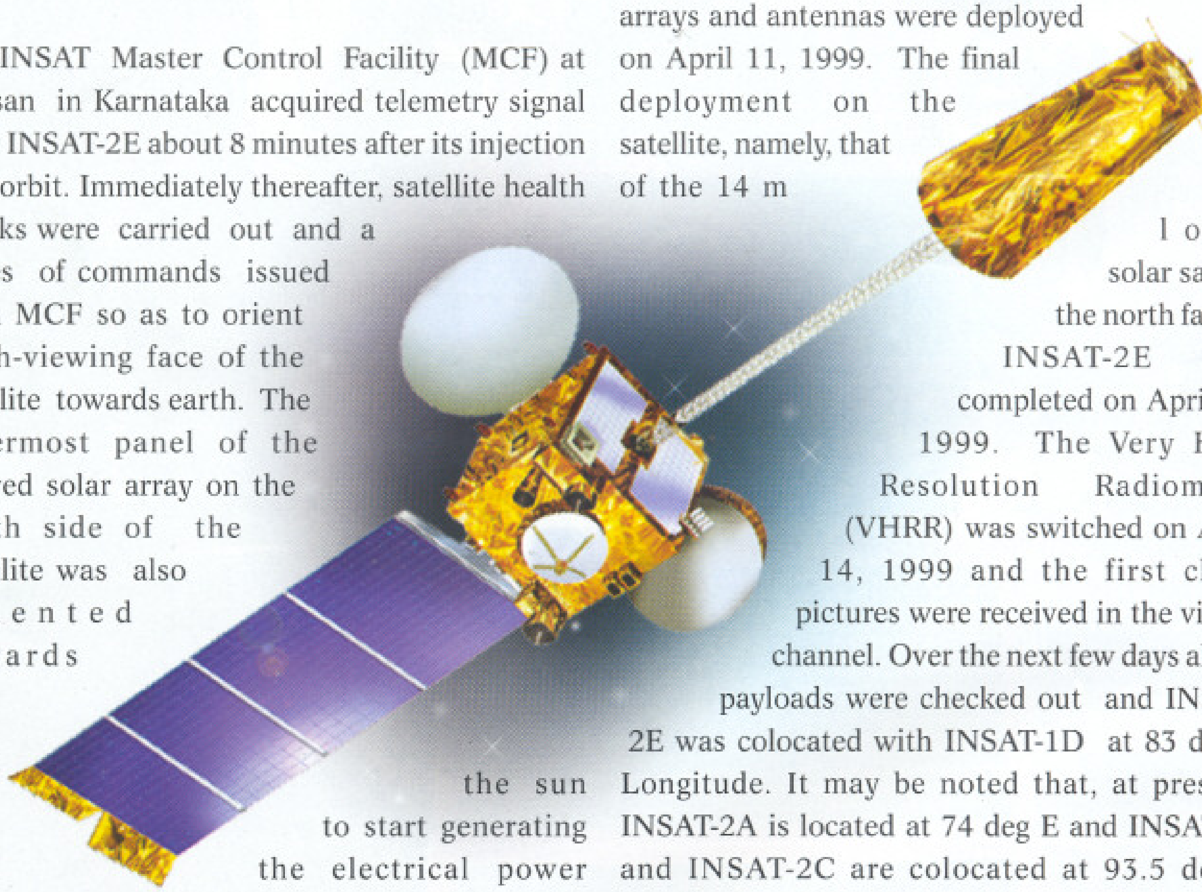


IRS-P4 Solar array deployment test.

INSAT-2E Launched

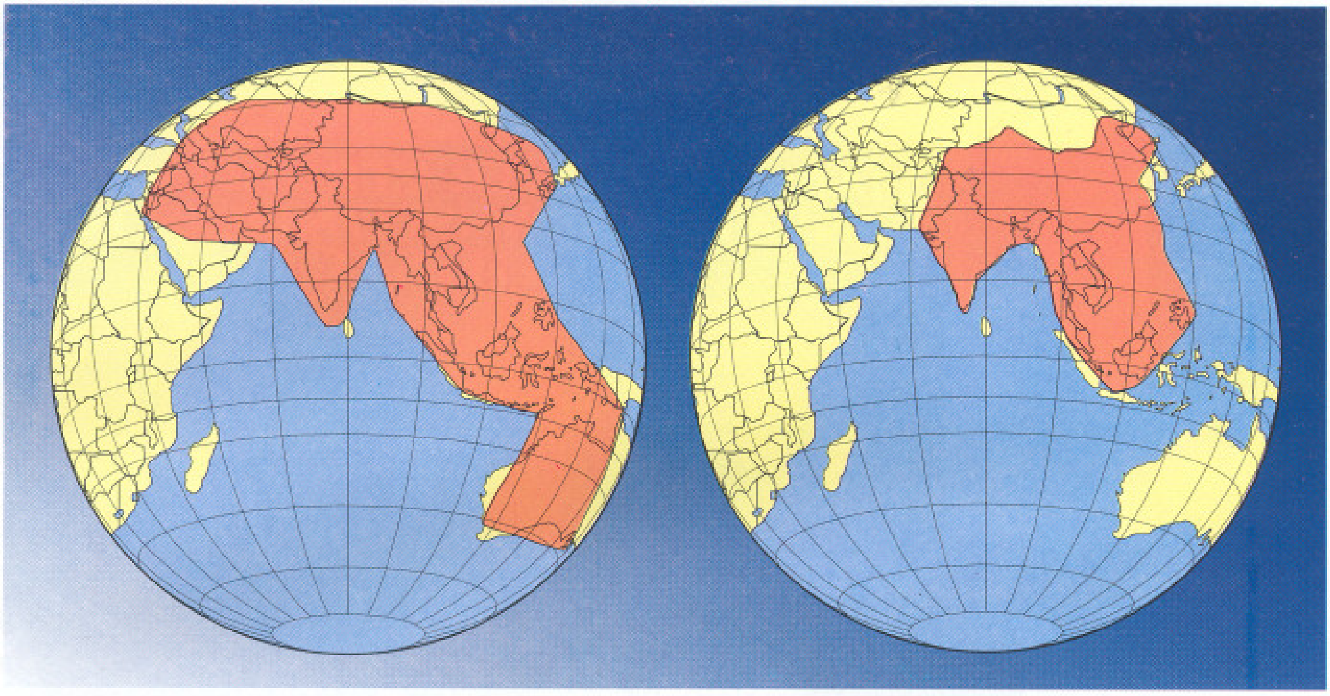
INSAT-2E, the last satellite in the ISRO-built INSAT-2 series of satellites, was successfully launched on April 3, 1999 by Ariane-42P vehicle of Arianespace. The 117th flight of Ariane, carrying INSAT-2E satellite, lifted off at 03.33 am IST from Kourou, French Guyana in South America and 21 minutes after lift-off, INSAT-2E was injected into Geosynchronous Transfer Orbit (GTO), with a perigee of 250 km and an apogee of 36,155 km with an orbital inclination of 4 degree.

The INSAT Master Control Facility (MCF) at Hassan in Karnataka acquired telemetry signal from INSAT-2E about 8 minutes after its injection into orbit. Immediately thereafter, satellite health checks were carried out and a series of commands issued from MCF so as to orient earth-viewing face of the satellite towards earth. The outermost panel of the stowed solar array on the south side of the satellite was also oriented towards the sun to start generating the electrical power required by the satellite during its transfer orbit phase. The calibration of the gyros on board the satellite were also carried out.



The following day the first orbit raising manoeuvre was conducted by firing for 16 minutes, the 440 Newton Liquid Apogee Motor (LAM) on board the satellite raising the perigee to 2000 km. The second orbit raising manoeuvre was conducted on April 6, 1999 by firing the LAM for 60 minutes raising the perigee to 14,600 km and reducing the orbital inclination to 1,027 degree. With another firing of LAM for a duration of 33 minutes on April 8, 1999, INSAT-2E entered a near geosynchronous orbit with the inclination also reduced to 0.15 degree. A trim manoeuvre was carried out on April 10, 1999 by firing the LAM for about 219 seconds. Even as the satellite started drifting slowly to its final home at 83 degree east longitude the two solar arrays and antennas were deployed on April 11, 1999. The final deployment on the satellite, namely, that of the 14 m long solar sail on the north face of INSAT-2E was completed on April 12, 1999. The Very High Resolution Radiometer (VHRR) was switched on April 14, 1999 and the first cloud pictures were received in the visible channel. Over the next few days all the payloads were checked out and INSAT-2E was colocated with INSAT-1D at 83 deg E Longitude. It may be noted that, at present, INSAT-2A is located at 74 deg E and INSAT-2B and INSAT-2C are colocated at 93.5 deg E longitude while INSAT-2DT, acquired from ARABSAT, is located at 55 deg E longitude.

In the initial phases of the mission, INSAT-2E was tracked, apart from MCF Hassan, by INTELSAT Organisation's ground stations at Perth (Australia), Fucino (Italy) and Lake Cowichan (Canada).



Wide-Beam Coverage and Zonal-Beam Coverage of INSAT-2E communication transponders.

INSAT-2E, weighing about 2,550 kg at lift-off, is the last of second generation satellites built by ISRO. It is the most advanced satellite built so far in terms of technologies used in the mechanical and electronic hardware and state-of-art payloads. The communication payload is designed with 17 C-band transponders, out of which five channels operate in lower extended C-band and 12 channels operate in normal C-band. Ten of the channels, including five lower extended C-band channels operate through a shaped zonal beam, whose coverage includes India, China, Middle East and major parts of South East Asia. The remaining channels operate through a shaped wide beam, whose coverage extends from Central Europe to Australia and includes China and southern parts of erstwhile USSR. The meteorological payload on board INSAT-2E includes an improved version of Very High Resolution Radiometer (VHRR) and a high resolution Charge Coupled Device (CCD) camera. The VHRR payload operates in three spectral bands, namely, visible, thermal infrared and water-vapour bands. This payload will be used for imaging cloud cover including cyclone formation and its movement, estimation of water vapour content in the clouds and rain forecast. The CCD camera also operates in three spectral bands, namely, visible, near infrared and short-wave infrared bands. The data from this payload supplements VHRR data to assist in cyclone analysis, local severe storm monitoring, heavy-rainfall forecast and estimation, snow detection and long term climatic studies.

INSAT-2E is configured with single-sided solar array consisting of four panels. This configuration is chosen to avoid any heat load on the IR detector cooler of VHRR, mounted on the spacecraft north side. To counteract the torque generated due to solar pressure on the array, a solar sail mounted on a boom is introduced on the northern side of the satellite. Inclusion of the solar flap at the tip of solar array helps to overcome seasonal variation in the solar radiation pressure torque. The Attitude and Orbit Control System (AOCS) provides three axis body stabilisation with a momentum-biased system by making use of momentum wheels, earth and sun sensors, magnetic torquer and reaction control thrusters.

The power system of INSAT-2E provides regulated

INSAT-2E Transponder

Dr. K. Kasturirangan, Chairman ISRO, handing over a model of INSAT-2E to Mr Conny Kullman, Director General of INTELSAT (right). Dr V S Ramamurthy, Secretary, Department of Science and Technology (Extreme left) and Dr S Rangarajan, Programme Director INSAT are also seen.

At a function held on April 27, 1999 at Bangalore, India's Department of Space (DOS) formally handed over an equivalent of eleven 36 MHz C-band transponders on board INSAT-2E to International Telecommunications Satellite Organisation (INTELSAT) in accordance with the lease arrangement between DOS and INTELSAT. Under the lease arrangement, DOS was required to build and provide a bulk capacity of nine transponders (two transponders with 72 MHz bandwidth and seven with 36 MHz bandwidth – thus adding to a total of eleven equivalent 36 MHz capacity) on an 'in-orbit lease' basis. The lease is for a period of ten years, with an option to extend by two more years. In turn, INTELSAT will provide lease charges periodically to DOS amounting to nearly US$ 10 million per year. INTELSAT will commence the services in the next few weeks after conducting necessary interface tests between the satellite and the various earth stations.

INTELSAT is an international, inter-governmental organisation of which India is also a member and is represented on its Board by Videsh Sanchar Nigam Limited

Leased to Intelsat

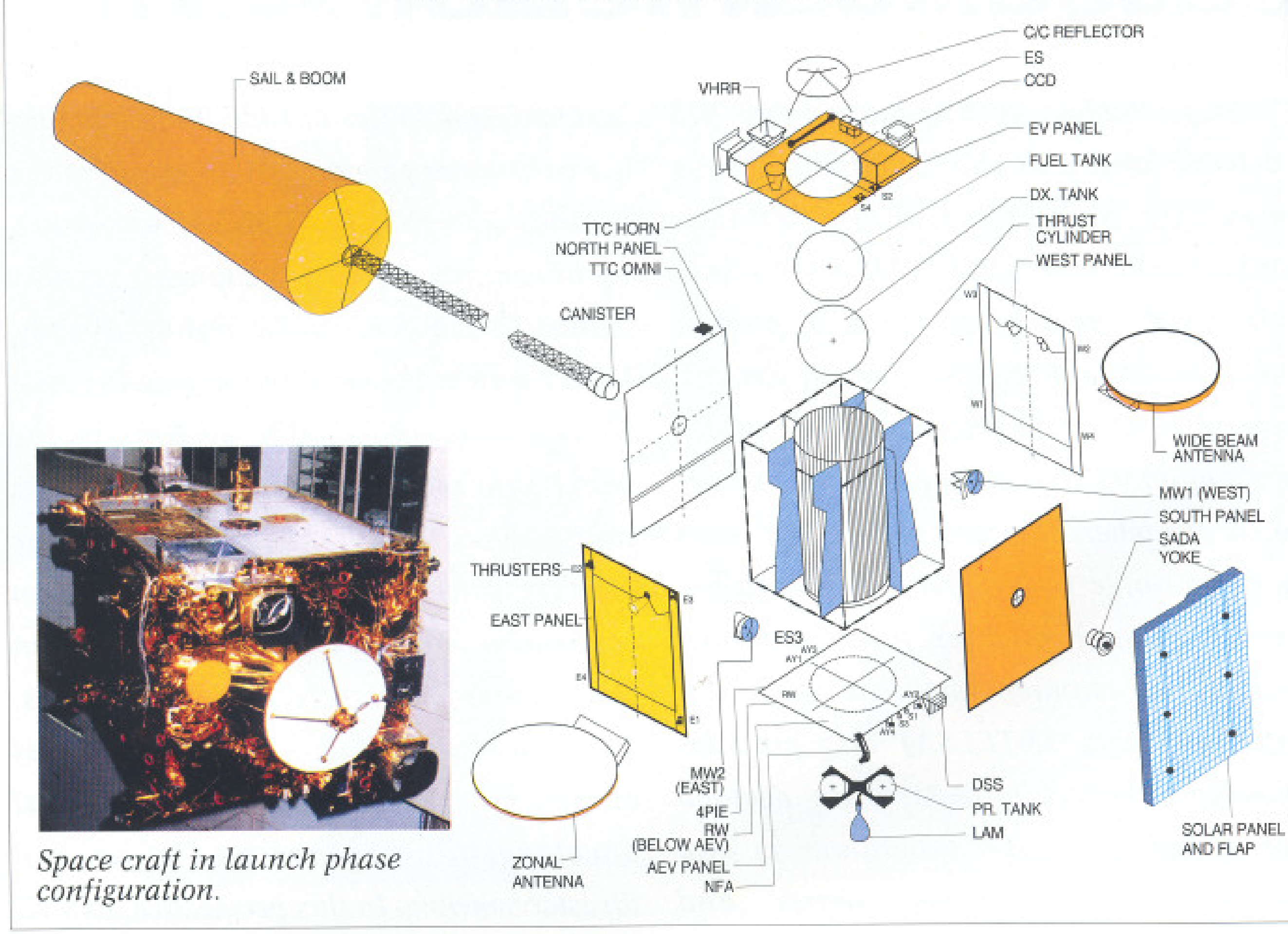
(VSNL). INTELSAT has more than 300 customer organisations operating in more than 200 countries and/or territories authorised to access the INTELSAT system. INTELSAT has a broad range of product lines like digital PSN, IDR channel services, private network business services, multi-application VSAT services etc, which it offers to its customers. Besides, INTELSAT offers a wide range of domestic and regional services to meet all types of national and transborder requirements on a very cost-effective basis. INTELSAT also provides broadcast services to cater to the demand for global television programming and several special news, sports and entertainment events.

The communications functions of INSAT-2E includes 17 high power transponders - ten of which are capable of providing a 'Zonal beam coverage' covering India, South East Asia and mainland China. The remaining seven transponders are capable of providing a 'Wide Beam Coverage' covering the continents of Australia, the entire Asia and eastern and central Europe. TV programmes beamed by the satellite will have an outreach covering nearly three continents.

The agreement between DOS and INTELSAT is for the mutual benefit of both INSAT and INTELSAT. As the leased transponders will become part of the INTELSAT Space Segment, companies outside India can also lease these transponders. With this strategic alliance with INTELSAT, INSAT will play a significant role in the fast changing satellite market in the Asia-Pacific region. Already, INSAT system is one of the largest domestic communications satellite systems in the world with more than 60 communications transponders. This infrastructure in space together with the meteorological observation component provides a variety of services in the areas of telecommunications, TV broadcasting, developmental communications, education, rural development, weather prediction and disaster warning. In this perspective, INSAT-2E represents the nation's resolve to use space capabilities for several of its developmental needs. In addition, with the arrangement with INTELSAT, INSAT assumes, for the first time, a new role in the international satellite communications arena.

Since its launch on April 3, 1999, INSAT-2E, has undergone successfully all orbit manoeuvre and deployment of all its appendages. After it reached its space home at 83 degrees East longitude around April 17, 1999, in-orbit testing of the communication and meteorological instruments was carried out. INTELSAT also participated in the acceptance testing of the leased transponders.

DISASSEMBLED VIEW OF INSAT-2E



Space craft in launch phase configuration.

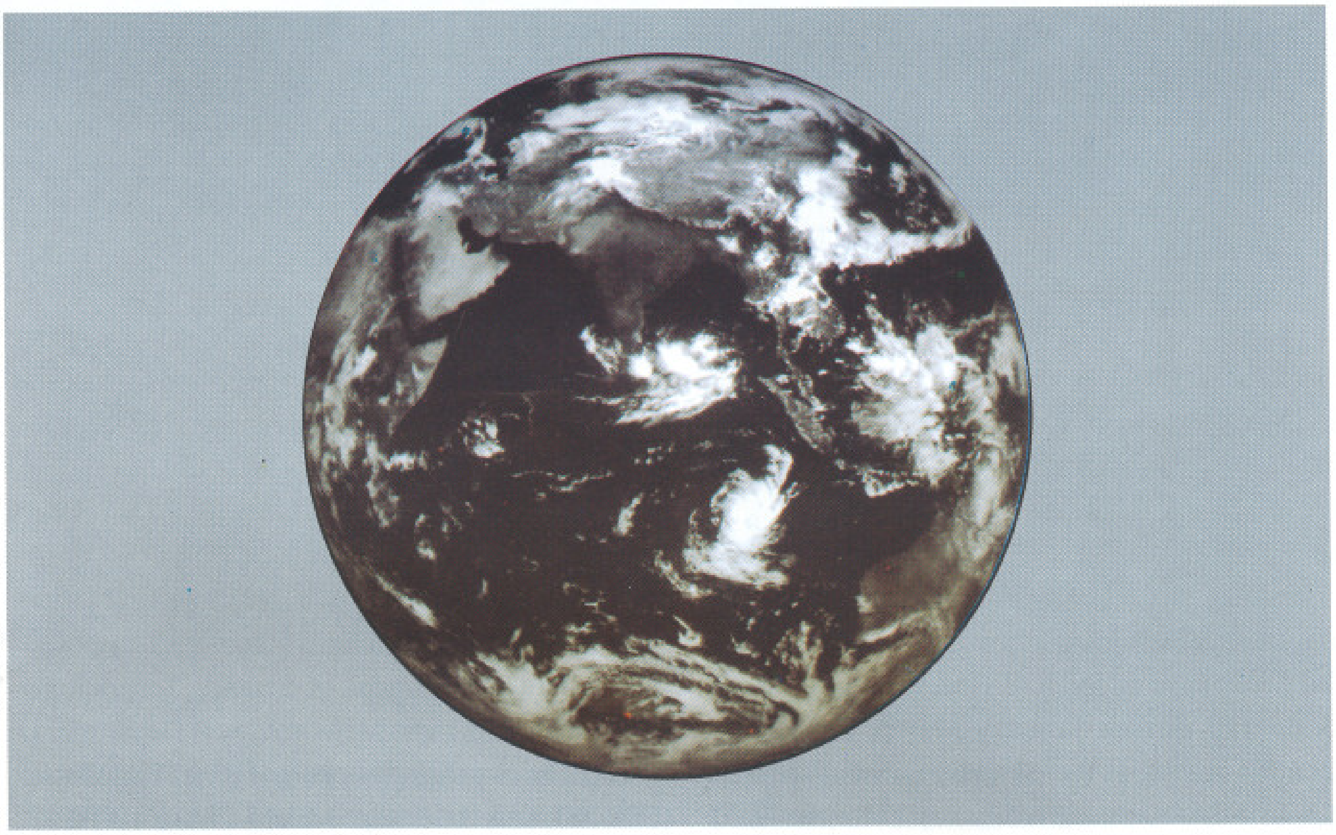
dual power bus. Critical subsystems can be connected to any of the bus by ground command. The solar panels use Ga-As/Ge (Gallium-Arsenic/ Germanium) cells and generate a net power of about 2,240 Watts. Two 60 Ah Nickel Hydrogen batteries provide eclipse period power support for full payload operations.

INSAT-2E uses many state-of-the-art technology elements such as embedded heat pipe panels for efficient thermal control, high efficiency Ga-As/ Ge solar cells in the solar array for obtaining a high power to area ratio, high capacity nickel-hydrogen batteries for full payload support during eclipses, ASICs (Application Specific Integrated Circuits) and HMCs (Hybrid Micro Circuits) to reduce volume and mass of electronics packages. The communication payloads use shaped beam dual-grid antenna for the first time, which provides land mass coverage. Again, for the first time, apart from Charge Coupled Device Camera (CCD), a water vapour channel has been introduced in the VHRR instrument of this satellite. CCD camera provides a resolution of 1 km from the geostationary altitude. The mechanism used for the operation of the solar flaps employs shape memory alloy.

INSAT-2E weigh about 2,550 kg at lift-off including 1404 kg of propellants required for orbit

SALIENT FEATURES

Mission payloads	:	Communication & Meteorological
Orbit	:	Geostationary
Location	:	83° E Longitude
Mass at lift-off	:	2550 kg
Dry mass	:	1146 kg
Size	:	Cuboid 1.93 x 1.77 x 2.37 m
Length when fully deployed	:	25.78 m
Power	:	Solar array generating 2,143W. Two 60 Ah Ni-H_2 batteries to support full payload operation during eclipse period
Mission life	:	12 years



INSAT-2E VHRR imagery in visible spectral band obtained on April 20, 1999.

PAYLOAD

Communication Payload

- 12 C-band transponders, seven of which have wide beam coverage and five zonal beam coverages.
- 5 lower extended C-band tranponders with zonal beam coverage
- All channels provide edge of coverage - effective isotropic radiated power (EOC-EIRP) of 36 dBW

Meteorological Payload

- Very high resolution radiometer (VHRR) with 2 km resolution in visible band and 8km resolution in infrared and water vapour band.
- Charge Coupled Device (CCD) camera operating in visible, near infrared and shortwave infrared band with 1km resolution.

raising and in-orbit control for the planned mission life of 12 years.

ISRO Satellite Centre, Bangalore, as the lead centre for INSAT-2 project, was responsible for the design, development and integration and testing of INSAT-2E. The communication and meteorological payloads were developed by Space Applications Centre, Ahmedabad. The Liquid Propulsion Systems Centre of ISRO developed the Liquid Apogee Motor and reaction control systems. The Vikram Sarabhai Space Centre supplied the various composite element subsystems such as CFRP antenna and the pyro system. ISRO Inertial Systems Unit, Thiruvananthapuram, was responsible for the design and development of the gyros, momentum/reaction wheels and the solar array drive and power transfer mechanisms. MCF, Hassan, is responsible for the on-orbit operations of the satellite.

Several industries and institutions both in public and private sector, have contributed for the realisation of the satellite.

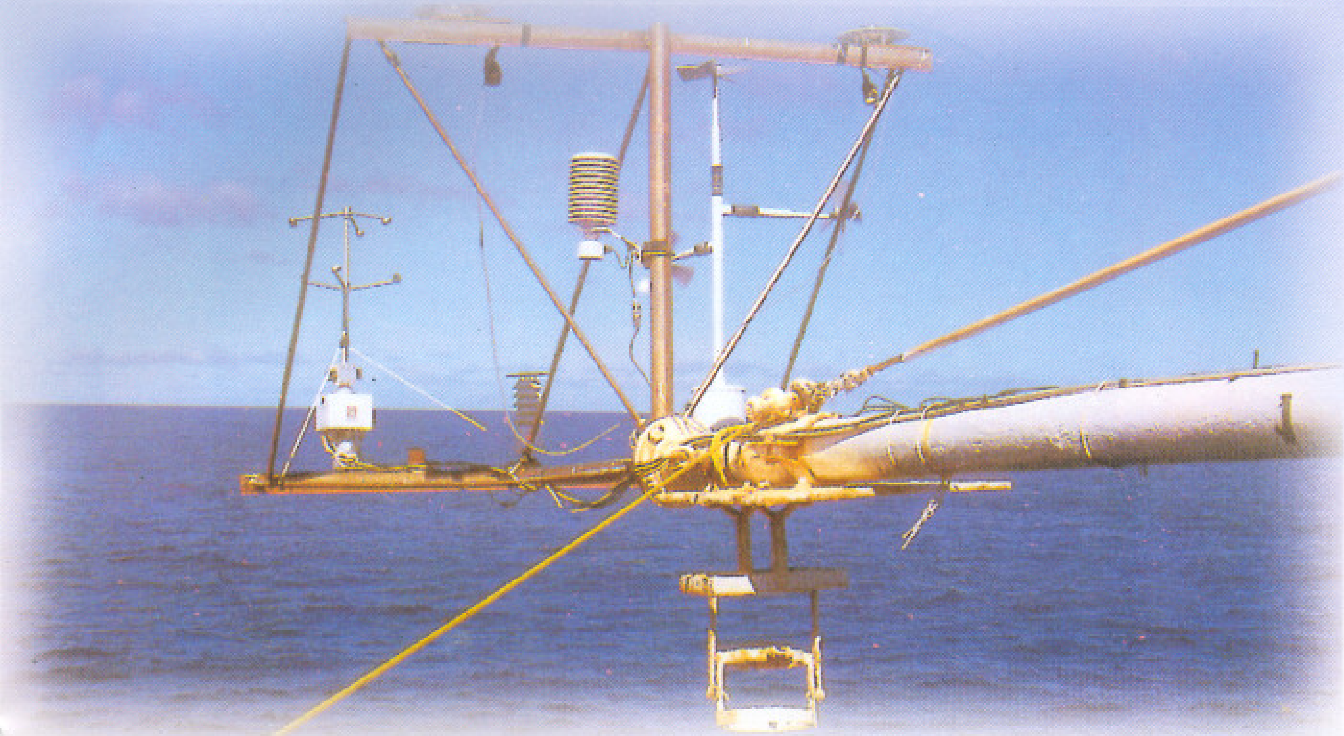
Second Phase of Indian Ocean Experiment Completed

The Second Phase of Indian Ocean Experiment (INDOEX) was conducted for three months using India's Ocean Research Vessel (ORV) Sagar Kanya that set sail from Goa on January 20, 1999. During the campaign that took the ship up to Mauritius, 25 Indian scientists on board carried out atmospheric measurements over the Indian ocean. The first phase of INDOEX campaign had been conducted during January-March 1998. The scientific results of the campaign were discussed at a two-day national workshop, Intense Field Phase (IFP-99) held on July 12, 1999 at Antariksh Bhavan, Bangalore, the headquarters of ISRO.

INDOEX is an internationally coordinated scientific observational programme to study the effect of aerosols and radiative forcing of the earth's atmosphere. The programme, which has the participation of France, Germany, Mauritius, Maldeves, The Netherlands, Sweden, United Kingdom and USA besides India, is vital to the understanding of the different factors affecting global change phenomenon, the other important factor being the effect of greenhouse gases. INDOEX is a multi agency programme coordinated in India (INDOEX-India) by Department of Space (DOS). It has active participation from Council of Scientific and Industrial Research (CSIR), Department of Ocean Development (DOD), Department of Electronics (DOE) and Department of Science Technology (DST) including India Meteorological Department (IMD). The two major campaigns First Field Phase (FFP-98) and the Intense Field Phase (IFP-99) under INDOEX-India involved coordinated measurements relating to atmospheric chemistry, radiation, meteorological parameters as well as analysis of air mass trajectories due to post North-East monsoon flow. The observational systems included ground based, shipborne, airborne (both balloon based or aircraft based) and space based systems using geosynchronous and low earth orbiting satellites.

Several important results were obtained on the composition, size and height distribution of the

Sagar Kanya.



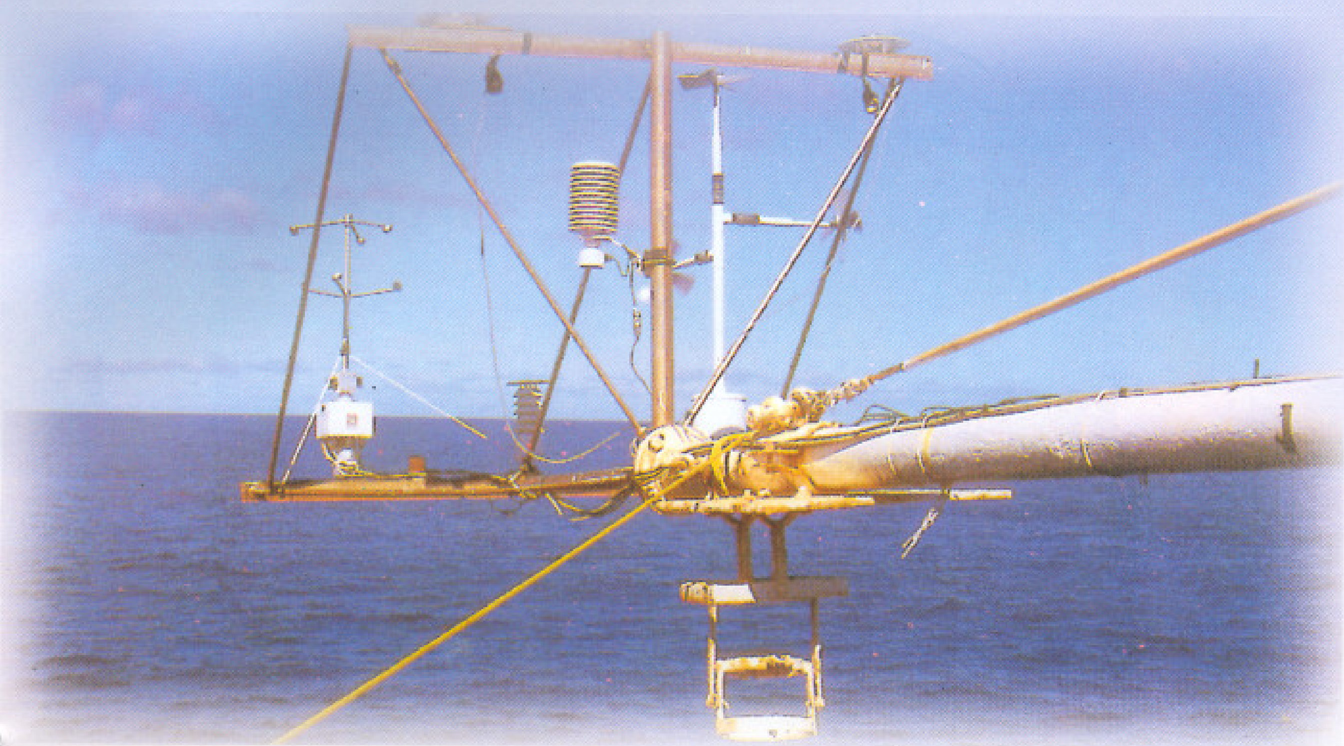
The Experimental arrangement on board Sagar Kanya for boundary layer measurements.

aerosols. The Indian Ocean region from 20°N to 20°S latitude was investigated using Lidars, radiometric-sondes and airborne instruments with the observational systems. Radiative flux was measured using sophisticated radiometers. Transport and flow measurements of air mass were conducted using constant altitude balloon launches from Goa in collaboration with the French Aerospace Agency, CNES. Ground-based measurements related to atmospheric chemistry were conducted at a coastal location at the Goa University and a continental site, namely, the Karnatak University, Dharwad. Effect of trace gases and minor constituents of atmosphere were investigated using ozone sondes on board ORV Sagar Kanya as well as satellite based measurements.

One of the important observations is the occurrence of large variability of the ozone with both high and very low values occurring on some areas of the oceans. A steady haze was observed over the entire observational area from aerosol particles of various kinds including soot carbon, hydrocarbons and mineral dust. These studies have shown an anti co-relation between the levels of water vapour and ozone.

Indian scientists have set up experiments at the University of Mauritius to observe the atmospheric radiative forcing in that pristine location in the southern Indian ocean. The Indian ship ORV Sagar Kanya belonging to the Department of Ocean Development played a major role as the ship-borne platform during pre-INDOEX as well as INDOEX IFP-98 and IFP-99 cruises. The field campaigns have revealed that the aerosol concentration observed in 1999 was higher than in previous year. When the observational data from the field campaigns were given as an input to the models used at National Centre for Medium Range Weather Forecasting (NCMRWF), the predictive capability of the model has shown considerable improvement. Hence, the importance of such observations in the future. A National Data Centre has been set up at National Physical Laboratory (NPL), New Delhi, to provide access to the data collected as part of the INDOEX programme to the participating Indian scientists from different national laboratories and academic institutions.

A large contingent of scientists drawn from the participating agencies, National laboratories and academic institutions participated in the workshop.



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Imagery obtained from the CCD camera of INSAT-2E on April 16, 1999.