January-March 2000

SPACE india

INDIAN SPACE RESEARCH ORGANISATION

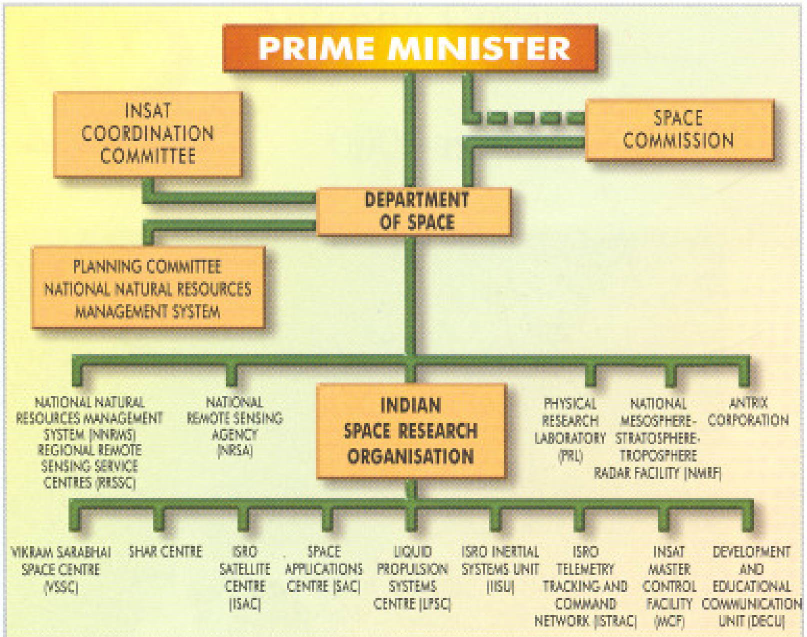
The Indian Space Programme

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

Front Cover
Insat-3B in Orbit - an artist's concept

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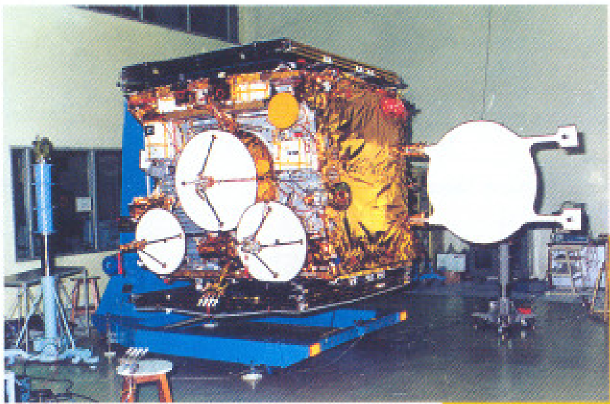
INSAT - 3B Launched

INSAT System Gets Further Boost

ISRO achieved yet another important milestone with the launch of Indian National Satellite, INSAT-3B, on March 22, 2000. It is the tenth satellite in the INSAT series.

The European launch vehicle, Ariane-505 that lifted off from Kourou in French Guyana at 4:58 am (IST) on March 22, 2000 placed INSAT-3B into a highly elliptical Geosynchronous Transfer orbit with a perigee of 560 km and an apogee of 35,770 km with an inclination of 7 degree with respect to the equator. Soon after its injection into orbit, the INSAT Master Control Facility (MCF) at Hassan in Karnataka took control of INSAT-3B and carried out the health checks. Since then, critical orbital maneuvers to boost the satellite from its Geostationary Transfer Orbit to its near Geostationary circular orbit of 35,786 km were successfully carried out by firing the 440 Newton liquid propulsion apogee boost motor that is incorporated in the satellite.



INSAT-3B Spacecraft with antenna deployed

Once the satellite was successfully placed in the Geostationary orbit, the two solar arrays, one on the south and the other on the north side, were opened up along with the two antennas on the east and west side of the satellite. INSAT-3B has since been collocated with INSAT-2E satellite at 83 degree east longitude over the equator.

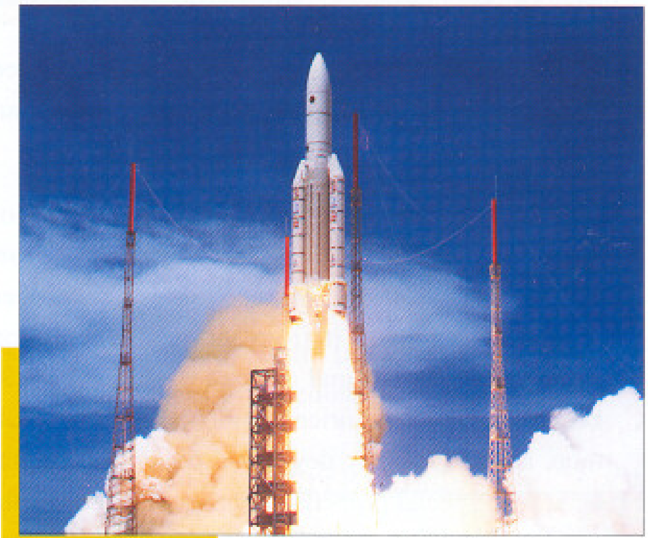
INSAT-3B, designed for 10 years life, is primarily intended for business communication, developmental communication and mobile communication. It carries twelve 15 W extended C-band transponders each having a bandwidth of 36 MHz, three 55 W Ku-band transponders each having a bandwidth of 72 to 77 MHz and a Mobile Satellite Service transponder operating in C-band and S-band frequencies. The satellite will provide further fillip to business communications, especially, through Very Small Aperture Terminals (VSATs). The VSAT services which started less than five years ago have seen a rapid growth in the

Prime Minister Congratulates Scientists

The Prime Minister Mr Atal Behari Vajpayee congratulated the Indian Scientists associated with the launch of INSAT-3B. In a message addressed to Dr K Kasturirangan, Chairman, ISRO, he said "India has crossed yet another significant milestone today with the launch of INSAT-3B. The ISRO built INSAT-3B will open more doors for business communications, developmental communications and mobile communications. It is the dedication and team work of all the persons involved that has enabled us to reach this significant milestone. I join the nation in congratulating you and your excellent team. I wish the Scientists success in all the orbit raising and other operations of the satellite, leading to its commissioning".

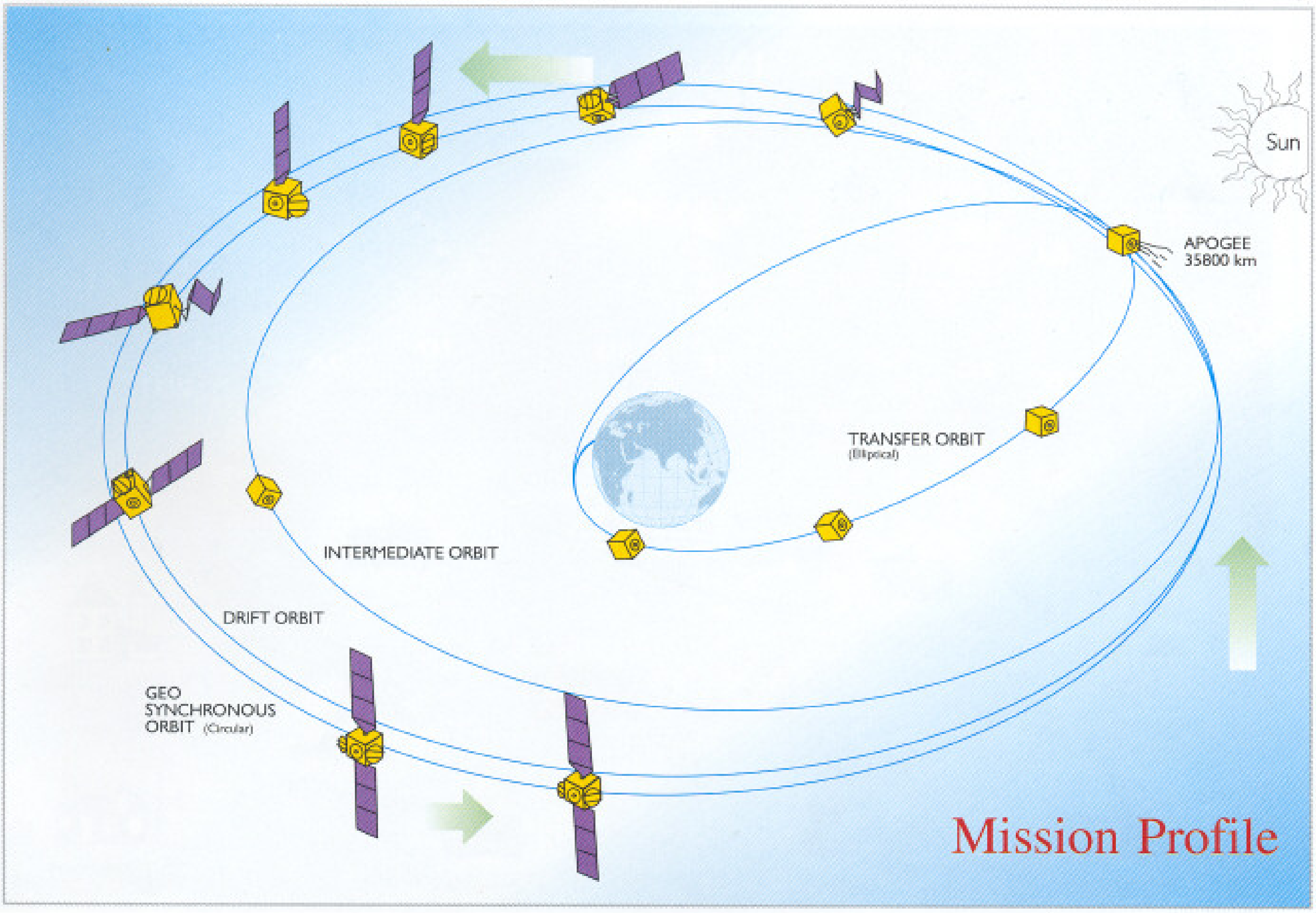
country. Today, there are about 7,500 VSATs, serving about 300 corporates in about 400 locations. The major VSAT users include banking and financial institutions, stock markets, white goods sector, fast moving consumer goods sector and medium to heavy engineering companies. Several public and private sector units have established dedicated closed-user group networks for their in-house applications. At present seven transponders from INSAT-2B and INSAT-2C are being used for these applications and INSAT-3B will almost double the transponder capacity for these services. Also, for the first time in the country, Ku-band frequencies will also be used for VSAT services, which enables use of smaller ground terminals.

Another important application of INSAT-3B will be the Swaran Jayanti Vidya Vikas Antariksh Upagraha Yojana, that was announced by the Prime Minister on the occasion of Golden Jubilee of India's independence. A few transponders on INSAT-3B will be reserved exclusively for this Yojana to be used for interactive training and developmental communications. New demonstrations and applications like tele-medicine that will enable take super special hospital treatment to rural population, are also planned. The mobile satellite service that was started on an experimental



Ariance-5 lifts off with INSAT-3B on board

basis with the launch of INSAT-2C in 1995 will also become operational with the commissioning



Mission Profile

MCF ground station at Hassan

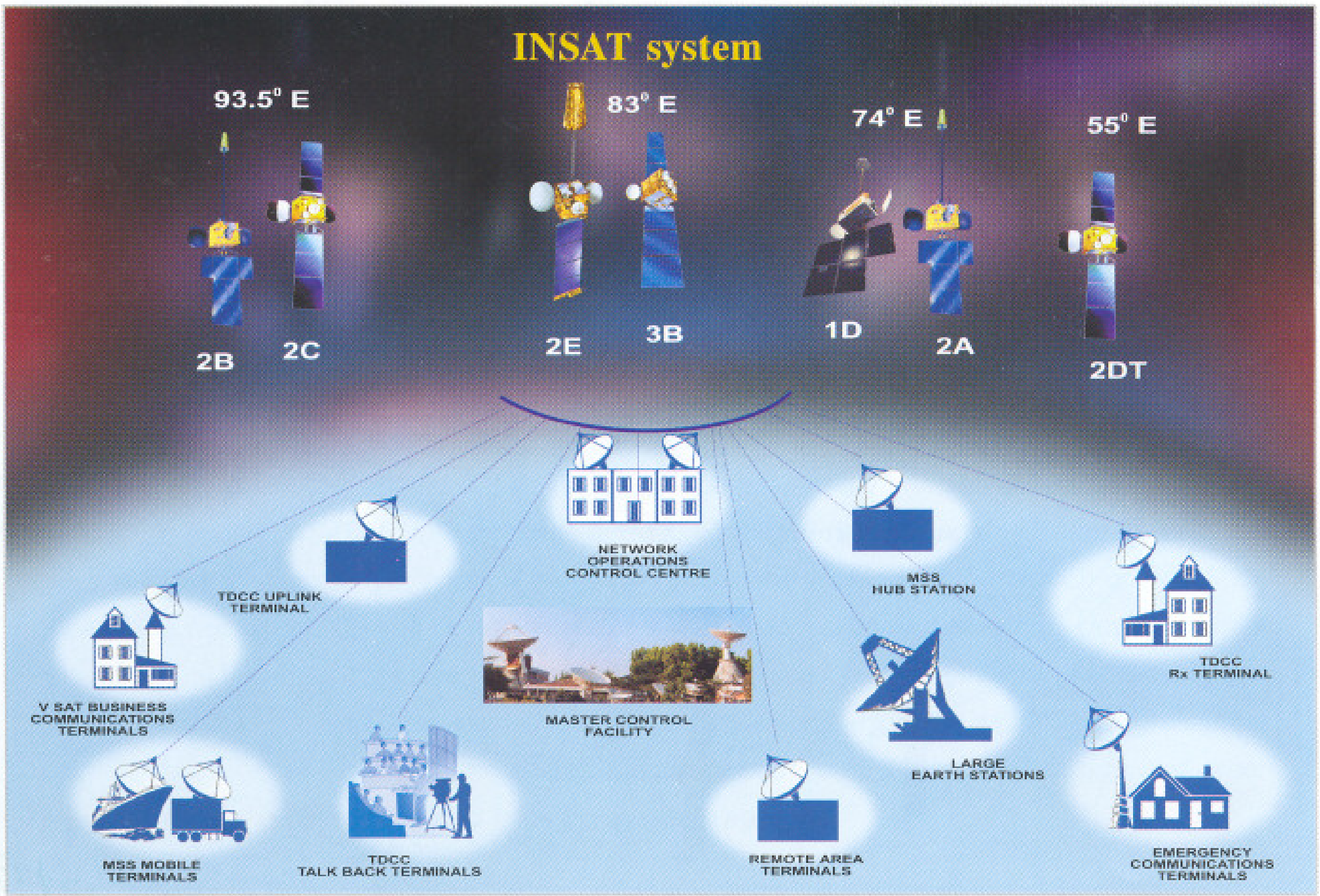
of INSAT-3B thus helping communication between fixed and mobile platforms like road, rail, air and sea transport systems.

INSAT-3B weighed 2,070 kg at lift-off including about 1100 kg of propellant (Mono Methyl Hydrazine and Mixed Oxides of Nitrogen) required for raising it from the geo-synchronous transfer orbit to its final orbit as well as for station keeping and in-orbit orientation control. For the first time, an indigenously developed titanium propellant tank, with special propellant management device that ensures bubble-free propellant supply under zero-gravity environment, has been employed.

The main body of INSAT-3B is in the form of a cuboid that measures 1.90 m in height, 1.7 m in length and 1.65 m in breadth. With two solar panels fully opened out after it is placed in orbit, the satellite measures 14.7 m in length. The two solar panels, one on the south and the other on north side have a total area of 23 sq m and generate 1.7 kW of electrical power required by the satellite. A 24 Ampere hour Nickel-Cadmium battery supports the payload operations when the satellite is under earth's shadow. INSAT-3B is stabilised about all its three axes using momentum wheels that rotate at high speeds of about 3,500 revolutions per minute along with reaction wheels, magnetic torquers and reaction control micro-thrusters. It uses earth sensors, sun sensors and inertial reference units to measure its orientation. The 440 Newton liquid propulsion motor is used for orbit raising. The satellite uses passive thermal control system.

The satellite has two antennas that are opened out in orbit and three fixed antennas with very high pointing accuracies to carry out various transmit and receive functions for communications.

With ISRO Satellite Centre (ISAC) at Bangalore as lead centre, INSAT-3B was realised with major



contributions from Space Applications Centre (SAC) at Ahmedabad, Liquid Propulsion Systems Centre at Thiruvananthapuram and Bangalore, Vikram Sarabhai Space Centre at Thiruvananthapuram and ISRO Inertial Systems Unit also at Thiruvananthapuram. Besides, several industries in both public and private sectors have contributed to the realization of INSAT-3B.

The INSAT Master Control Facility (MCF) at Hassan in Karnataka is responsible for monitoring and controlling INSAT-3B. During the orbit raising phase of INSAT-3B, Telemetry, Tracking and Command stations located at Perth in Australia, Fucino in Italy and Lake Cowichan in Canada also supported the Telemetry, Tracking and Command operations.

India has one of the largest domestic communication satellite system in the world today. INSAT satellites occupy four orbital slots — INSAT-2B and INSAT-2C are collocated at 93.5 degree east longitude, INSAT-1D and INSAT-2A are collocated at 74 degree east longitude and INSAT-2DT is located at 55 degree. The collocation of satellites in a single orbital location helps in more efficient use of the limited frequency spectrum available for operating communication satellites. INSAT-3B will be commissioned into service in May after testing all its communication transponders. INSAT-3B will further augment the system capacity. Another four satellites, INSAT-3A and INSAT-3C through INSAT-3E are planned to be launched in the coming years not only to replace the present satellites at the end of their life but also to augment continuously the space segment capacity in tune with the growth of satellite communications in the country.

Salient Features

Orbit	Geo-stationary
Location	83 degree East
Mass at Lift off	2070 kg
Dry Mass	970 kg
Body size	1.93m x 1.7m x 1.65m
Length	14.7 m
Power	Transfer Orbit: 346W On-orbit: 1712W
Life	10 years

Payloads

Extended C-band	
No. of channels	12
Channel bandwidth (MHz)	36
Up-link frequency (MHz)	6735-6975
Down-link frequency (MHz)	4510-4750
Ku-band	
No. of channels	3
Channel bandwidth (MHz)	77/72
Up-link frequency (GHz)	14.25-14.5
Down-link frequency (GHz)	11.45-11.70
Beacon frequency (GHz)	11.6995
Mobile Satellite Service (MSS)	
Up-link -Forward (MHz)	6450-6470
Return (MHz)	2670-2690
Down-link - Forward	2500-2520
Return (MHz)	3680-3700

Spacecraft Bus

- Two-sided sun-tracking solar arrays with 23 sq m area generating 1.7 kW of power
- 24 Ah Ni-Cd battery supporting 750 W load during eclipse
- 3-axis body-stabilised, biased momentum control system using earth sensors, sun sensors, inertial reference unit, momentum/reaction wheels, magnetic torquers and unified bi-propellant thrusters
- Antenna pointing accuracy ±0.2 deg in pitch & roll and ±0.4 deg in yaw
- Liquid Apogee Motor with fuel and oxidizer stored in separate titanium tanks and pressurant in kevlar wound titanium tank
- Thermal control system using passive devices as well as heaters
- Mechanisms to deploy two solar arrays and two reflectors that are stowed during launch phase
- Telemetry, Tracking and Command link is in C-band during all phases of the mission. Ku-band telemetry also available during on-orbit phase

Y2K Happy New Year for ISRO

The year 2000 has begun well for ISRO. All its satellites passed through the millennium transition with no anomalies observed on their functioning. The millennium transition occurred at 5.30 am IST on January 1, 2000, which is 00 hour Universal Time. ISRO had five INSAT satellites (INSAT-1D, INSAT-2B, INSAT-2C, INSAT-2DT and INSAT-2E), five Remote Sensing Satellites (IRS-1B, IRS-1C, IRS-1D, IRS-P3 and IRS-P4) and a scientific satellite (SROSS-C2) in operation and faced the risk of Year 2000 (Y2K) bugs.

However, ISRO had prepared well for the transition. It had initiated Y2K compliance activities as far back as June 1998 and had closely monitored and reviewed the Y2K activities through a three-tier task team. INSAT and IRS satellites had already been assessed to be "Y2K indifferent" since they operate by referencing the sun and do not contemplate time and dates. They were not expected to face any problem during the transition. The mission operations ground systems had been analysed and necessary modifications had been incorporated to make them Y2K compliant. A detailed mission simulation with real data sets was also carried out to ensure compliance in an operational environment. Further, contingency plans to take care of any unforeseen problems during the actual Y2K transition were also in place.

Expert teams of designers and software specialists were present at the Spacecraft Control Centres at INSAT Master Control Facility, Hassan and ISRO Telemetry, Tracking and Command Network at Bangalore during the Y2K transition on the night of December 31, 1999 and eagerly awaited the transition that occurred early in morning of New Year's day. As expected, all the Y2K certified systems performed normally.

(Why)2K Problem

The essence of the year 2000 (Y2K) problem is the representation of the year as a two-digit number in hardware, software (both system and application) and data elements of computer systems and other technologies. This representation may, for example, cause hardware or software malfunctions or data corruption to occur when the date crosses the year 2000 or an application refers to a range of dates that spans the year 2000 boundary. These malfunctions can include:

- Incorrect arithmetic calculation, comparison, sorting, or sequencing involving dates and time that result in the failure of logical, relational, and set-membership operations;
- Incorrect display of date or time;
- Failure to recognise the year 2000 as a leap year;
- Conflict with values in date fields used for non-date purposes, e.g. no date provided, or never expires;
- Overflow of fields or registers containing dates

ITU Task Group Meets in Bangalore

Dr K Kasturirangan, Chairman ISRO delivering the inaugural address

The Task Group (task group-1/5) meeting of the International Telecommunication Union (ITU), that deals with Radio Communications (ITU-R), was hosted by Department of Space at Bangalore during January 6-14, 2000. The task group is mandated to study issues related to unwanted emission from radio transmitters and protection to sensitive services. The recommendations of this task group will be further reviewed at high levels of ITU before integration in the international radio regulations. Inaugurating the task group meeting Dr K Kasturirangan, Secretary, Department of Space and Chairman, Indian Space Research Organisation, recounted the growth in telecommunications converting the world into a global village. He said that, with the increased demand for communication services, it is imperative to judiciously use the spectrum resource which is limited. "There is no scope for wasting this precious natural resource and the allocation of frequency band and its use must become even more efficient" he said. While recognising the pressure for more spectrum allocation for commercial services, Dr Kasturirangan said that such allocations are equally important for scientific missions.

Presiding over the inaugural function, Mr R N Agarwal, Wireless Adviser to the Government of India said that scientific features and physical laws of nature predominantly govern the management and regulation of frequency management. He also said that while spectrum can neither be created, nor destroyed, it is the use of spectrum that can be regulated so as to multiply its usage by technological means. "The new millennium is going to witness more new technologies at a much faster rate and there is going to be convergence of technologies wherein public telecommunication, broadcasting and IT are going to merge together. Spectrum sharing and co-existence are the key themes for the futuristic utilisation of space spectrum" he said. Keeping in view the harmful interference from unwanted emissions to safety services, radio astronomy and space services, he stressed the need for stringent regulations to be adopted to curtail spurious and out-of-band emissions.

International Telecommunication Union

The International Telecommunication Union (ITU) provides a forum in which its 189 Member States (September 1999) and some 580 Sector Members co-operate for the improvement and rational use of telecommunications world-wide. The main objectives of ITU are:

- to promote the development, efficient operation, usefulness and general availability of telecommunications facilities and services;
- to promote the development of telecommunications in developing countries and the extension of the benefits of telecommunications to all people everywhere; and
- to promote the adoption of a broader approach to telecommunications issues in the global information economy and society.

The work of ITU is organised around three Sectors: the Radio-communication Sector (ITU-R); the Telecommunication Standardisation Sector (ITU-T); and the Telecommunication Development Sector (ITU-D).

The ITU work in the field of radio-communications is consolidated in the Radio-communication Sector (ITU-R), which is charged with reaching consensus on the coherent use of growing range of wireless services, including the popular mobile communications technologies. The ITU-R Sector also plays a vital role in the management of radio frequency spectrum and satellite orbits. It is important to note that these are finite natural resources but are increasingly in demand for a large number of services like fixed, mobile, broadcasting, amateur, space research, meteorology, global positioning systems, environmental monitoring and those communications services that ensure safety of life at sea and in the skies.

The aim of the Radio-communication Sector is to ensure rational, equitable, efficient and economical use of the radio-frequency spectrum and satellite orbits. ITU-R holds World and Regional Radio-communication Conferences to develop and adopt Radio Regulations and Regional Agreements covering the use of radio-frequency spectrum. It makes recommendations on the technical characteristics and operational procedures for radio-communications services and systems and coordinates efforts to eliminate harmful interference between radio stations of different countries. It also maintains the Master International Frequency Register, and provides tools and information to assist national radio-frequency spectrum management. The Radio Regulations constitute an international treaty on radio-communications covering the use of the radio-frequency spectrum by radio-communication services.

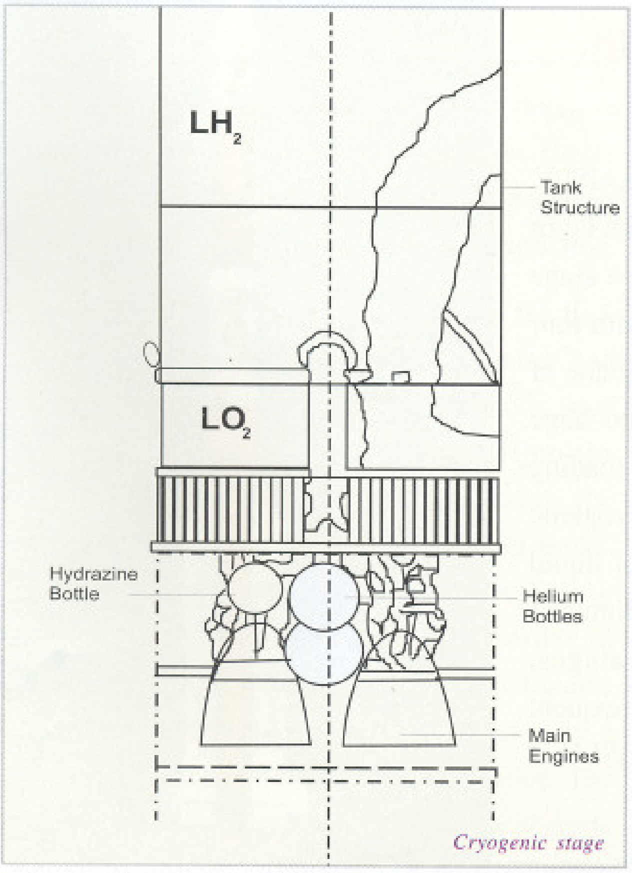
Indigenous Cryogenic Stage for GSLV

ISRO achieved an important milestone on February 16, 2000 in the development of its Cryogenic Stage when the first engine, employing liquid hydrogen and liquid oxygen, which was ignited at Liquid Propulsion Systems Centre test complex at Mahendragiri in Tamil Nadu. ISRO is developing the stage for use as the upper stage of its Geo-synchronous Satellite Launch Vehicle (GSLV). Though the test had to be aborted at 15 seconds instead of planned 30 seconds, a good amount of useful data has been obtained from the test by the elaborate instrumentation that had been employed. ISRO is now analysing the test data to evaluate the performance and to pinpoint the anomaly that caused the premature abortion and to take the corrective actions for subsequent tests.

This first Cryogenic Engine test had several accomplishments — fabrication, assembly and integration of the complete cryogenic engine; validation and commissioning of the test stand; chill down trials of the engine and associated system; production of cryogenic propellants to required specifications and; validation of appropriate safety procedures, besides collection of data during the 15 second test. After detailed analysis of the result, further tests in the series of ground qualification trials of the engine, will be taken up.

Cryogenic Propulsion for Improved Payload Capability

Even though the development of cryogenic propulsion for launch vehicles to boost their payload capability was initiated during 1930's, the real momentum picked up only after the second world war when both, USA and erstwhile USSR embarked on the development of this complex technology. Today, cryogenic engines are used by most of the international launchers for delivering heavier payloads into geo-stationary transfer orbits. While India's Polar Satellite Launch Vehicle, PSLV, uses both solid and liquid propulsion stages, the Geo-synchronous Satellite Launch Vehicle (GSLV), will employ a cryogenic upper stage; the lower stages employ propulsion modules derived from PSLV. This will enable GSLV to place a payload of 2 tonne in Geo-synchronous Transfer Orbit (GTO).



Cryogenic stage

Cryogenic engines also come under the broad category of liquid propulsion engines. The liquid propulsion engines have better performance in terms of its specific impulse (the parameter that indicates the efficiency of the propulsion system) compared to solid propellants. Also, they have stop and start capability, better reusability and their burning duration and thrust can be made variable.

A cryogenic engine is a liquid propulsion engine that employs cryogenic propellants — liquid oxygen (LOX) as oxidiser and liquid hydrogen (LH_2) as fuel. Though complex, mainly because of the low temperatures involved (liquid oxygen at 80 degree Kelvin and liquid hydrogen at 20 degree Kelvin), cryogenic propulsion has superior performance in terms of its high specific impulse, excellent cooling properties of LH_2 and non-corrosive and non-polluting nature of the combustibles. The specific impulse of cryogenic propulsion is as high as 473 seconds compared to about 280 and about 320 seconds of solid and liquid propulsion systems, respectively.

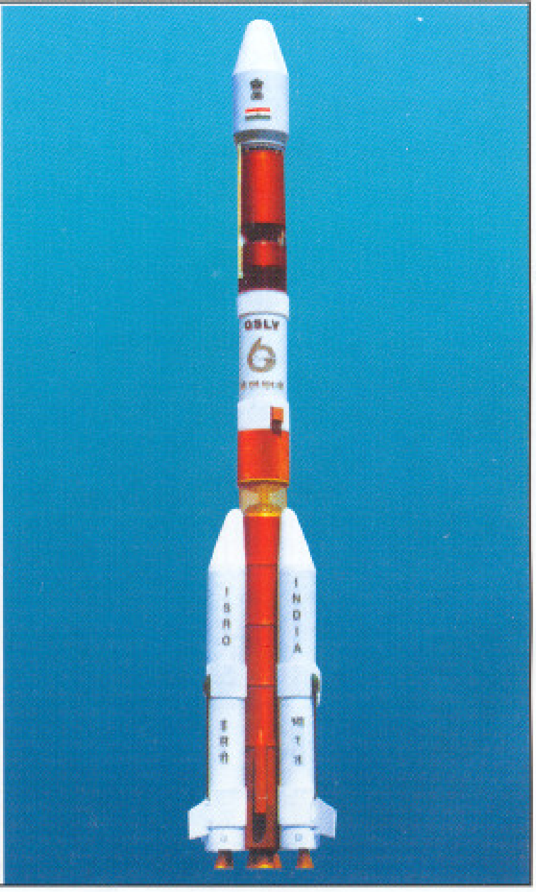
For a typical three-stage launch vehicle that is commonly used for GTO mission, the terminal stage imparts about 45 percent of the required orbital velocity. With a very high specific impulse and lower dry mass due to lesser fluid storage space required, the cryogenic propulsion enables to deliver a payload up to two times higher than that delivered by a vehicle with comparable take-off weight but without a non-cryogenic upper stage.

A cryogenic stage, mainly, comprises one or more tanks to store fuel and oxidiser, mechanism to feed liquids in right proportion into the thrust chamber, a power source for feed mechanism, suitable plumbing to transfer liquids, structure to transmit the thrust to the vehicle and, control devices to initiate and regulate propellant flow. Thermal insulation plays an important role due to very low temperatures involved. Instrumentation to monitor and control various elements is also required as part of the sub systems.

The thrust chamber is the powerhouse of the engine where combustion of fuel and oxidiser takes place. The burnt gases are ejected through a nozzle, converting the thermal energy of the combusted products into kinetic energy. The cryogenic engine thrust chambers need to be cooled to protect it from high temperatures. A regenerative cooling system is generally employed with one of the propellants (usually the hydrogen) through cooling jackets or special cooling passages to absorb the heat that is

Geo-synchronous Satellite Launch Vehicle - GSLV

ISRO's Geo-synchronous Satellite Launch Vehicle, GSLV, is aimed at placing 2 tonne class INSAT in geo-synchronous transfer orbit. GSLV is a three stage vehicle. The core first stage has a solid booster with four strap-on liquid propulsion motors, each with 40 tonne of liquid propellant stages attached to it. The second stage is a liquid propulsion system with a propellant loading of 37.5 tonne. The upper stage is a restartable cryogenic engine with a propellant loading of 12 tonne (of liquid oxygen and liquid hydrogen). While the initial flights of GSLV will use Russian-supplied cryogenic stages, indigenous cryogenic stage will be used in the subsequent flights. The first developmental test flight of GSLV is planned during 2000-2001.



Cryogenic Engine Test

Propulsion	*Specific Impulse - ISP (Sec)*
Solid	*260-280*
Storable Liquid	*290-320*
Semi Cryo	*340-360*
$LOX-LH_2$	*445-473*
Nuclear	*1250*

Some International Cryogenic Engines

PARAMETER	RL-10	HM-7	LE-5	ISRO-C12	HM-60	LE-7	SSME
Launcher	Centaur USA	Ariane-4 Europe	H-1 Japan	GSLV India	Ariane-5 Europe	H-II Japan	Space Shuttle USA
No.of engines	2	1	1	1	1	1	3
Vac.Thrust (T)	6.8	6	10.5	7.5	93	119	213
Sp.Impulse (sec)	444	442.4	447	461	444	444	455.2
Burn Time (sec)	450	563	400	800	291	300	480

transferred from the hot gases to the thrust chamber walls. The temperature inside the combustion chamber reaches about 3,500 degree Kelvin. Hence materials of high thermal conductivity, like copper and its alloys, are used for the chamber construction.

An injector introduces and regulates the flow of propellant into the combustion chamber and atomises and mixes them in a homogenous way. A turbo-pump that derives its power from the expansion of the hot gases pressurises the propellant. The propellants are stored in tanks. The design of propellant tank is complex since it needs special insulation like foam in order to minimise the heat leak into/from cryogenic liquids. The tanks are arranged in tandem, separated by a common bulkhead to provide thermal isolation. The cryogenic propellants are non-hypergolic and needs a source to initiate ignition. The most common ignition method is spark type system that provides for multiple restarts.

Cryogenic stage also requires ground support systems like propellant storage and fill systems, engine and stage test facilities, transportation and handling of the cryogenic fluids. Besides, several safety features are to be incorporated. Therefore, development of cryogenic engine is expensive; only a very few engines have so far been qualified and flown in the world.

The development of a cryogenic engine in ISRO was initiated in the 1980s by developing and testing a single element injector generating about 60 kg thrust. A one-tonne sub-scale engine was also realised and tested up to 600 seconds. With these hands-on experiences, development of cryogenic engine and stage development for use in Geosynchronous Satellite Launch Vehicle was initiated in the year 1994.

Asking For THE MOON!

Scientists Discuss on Indian Lunar Mission

Discussions have started under the auspices of Indian Academy of Sciences and Astronautical Society of India that have provided opportunities for scientists, engineers and mission planners to interact and study the feasibility of undertaking a Lunar Mission. These preliminary studies are primarily related to definition of possible scientific objectives, conceptualisation of mission including the spacecraft and the feasibility of using Indian launch vehicles to place a spacecraft into lunar orbit. A Lunar mission can provide impetus to science in India, challenge to technology and, possibly, a new dimension to the international cooperation. It can also serve as a test bed for future missions that could be undertaken by India to explore outer world in the new millennium. Several missions to Moon have been undertaken so far, especially, by the United States and the erstwhile Soviet Union. Some of them are:

- Lunar Mission by USSR comprising 24 missions between 1957 and 1976 to collect information about the Moon and its surroundings and data related to landing missions. Collected photographic and remote sensing data, operated Lunar rovers and collected Lunar soil samples.

- Ranger Programme of NASA, USA during 1961 to 1965 comprising 9 missions to design Lunar trajectories and collect scientific data. Three missions were designed to impact Moon and send high resolution pictures.

- Clementine mission of NASA in 1994 for mapping moon from polar orbit at a height of 350 km.

- Lunar Prospector of NASA in 1998 to collect very high resolution pictures from 96, 80 and 9.6 km height. Also, investigated water availability.

- Surveyor Programme consisting of 7 unmanned missions between 1966 and 1968 to demonstrate landing feasibility on Moon as precursor to Apollo missions.

- Apollo missions comprising a total of 17 missions, including manned missions, to collect Lunar samples and to install scientific instruments on the Moon's surface.

The international community is again focusing its attention on Moon based on some recent observations suggesting presence of water, which is the main supporter of life; but there is no conclusive evidence of that. The new millennium is expected to provide several exciting opportunities for expanding the horizons of knowledge through missions of explorations beyond Earth. India, as a

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Space Science in India

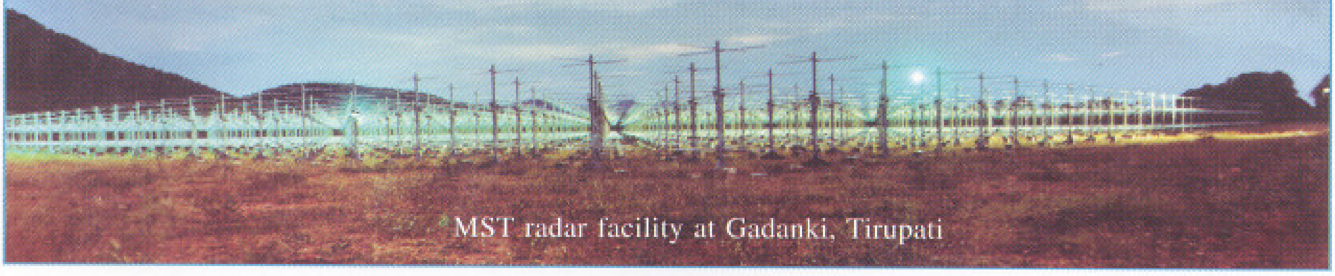
Even though, Indian space programme is primarily oriented towards practical application of space technology for direct benefit to common man, research in space science has also been pursued. India, has an array of space based and ground based systems to pursue space science studies through X-ray and Gamma ray detectors flown on Indian Remote Sensing satellites and SROSS satellites, Mesosphere-Stratosphere-Troposphere (MST) radar, Giant Metre Wave Radio telescope, infra-red and optical telescopes, balloon and rocket borne instruments.

MST radar is a major ground based national facility set up at Gadanki near Tirupathi in south India. It is used by a number of scientists from universities and research institutions to study the structure of atmospheric dynamics like winds, waves and turbulence. The Giant Metre Wave Radio Telescope (GMRT), operated by National Centre for Radio Astronomy, is located near Pune. It is one of the major telescopes for radio astronomy and is being used by large number of radio astronomers in the country. The infra-red telescope set up Physical Research Laboratory (PRL), at Gurushikar in Rajasthan is used for infra-red astronomy to understand the evolution of stellar systems and cosmic dust. Besides, PRL operates the Udaipur Solar Observatory that has a spatial resolution solar optical telescope for studying various dynamics of solar regions.

India has an array of Rohini sounding rockets (RH-200, RH-300 Mk-II, RH-560 Mk-II) which are used for conducting scientific and technological experiments. These rockets can carry 10 to 80 kg payloads to altitudes of 80 to 350 km. The Tata Institute of Fundamental Research and ISRO jointly operates the National Balloon Facility at Hyderabad for conducting experiments in high energy astronomy and middle atmosphere. These balloons can carry more than one tonne of scientific payloads to heights of 40 km.

India also participates in international science campaigns. ISRO Geosphere Biosphere Programme (IGBP) aims at a systematic study of global climate change with special reference and emphasis to Indian sub-continent in specific areas like atmospheric minor constituent and radiation, air-sea interaction and climate. The Solar Terrestrial Energy Programme (STEP) has the objective to achieve quantitative assessment of sun-earth relationship through better understanding of physical linkages between solar wind/radiation, inter-planetary space, magnetosphere and thermosphere/ionosphere system, middle atmosphere and troposphere. Indian Ocean Experiment (INDOEX) is an international field experiment. It is a coordinated scientific programme with participation from France, Germany, Maldives, The Netherlands and the USA, besides India, to study the interactive phenomenon of cloud heat-radiation-aerosol interaction and associated chemistry over the Indian Ocean. Two campaigns — February-March, 1998 and January-March, 1999 have already been completed under INDOEX. ISRO and the French Space Agency, CNES, signed a statement of intent in November, 1999 for a joint satellite mission, MEGHA TROPIQUES that aims at studying climatic variables in the tropical regions and modeling of climate systems.

With such a vibrant space science activity it is natural that Indian scientists are now looking for a more challenging scientific mission like mission to moon.



MST radar facility at Gadanki, Tirupati

space faring nation should not miss this excitement. In fact, India has carried out investigation of Lunar soil samples provided by the USA as well as data from planetary missions to Venus, Mars, etc.

There are several interesting scientific problems related to Moon that are yet to be solved. The distribution of the interplanetary asteroidal and meteoritic bodies of one to five metre size has not been determined so far since the imaging was in low resolution. Levitation of dust on Moon due to electro-static charging, a more detailed classification of rocks and confirmation of water availability and its quantity are interesting subjects for investigation. Transport of volatile materials on Moon which occur due to large temperature variation from +120 deg C to - 120 deg C between sun-lit and dark sides of Moon could be another interesting scientific study. Considering that most of the missions carried out so far were exploratory in nature and looked at all possible aspects such as imaging in various wavelengths, study of gravity variation, chemical composition and chronological changes, the scientific objectives for an Indian mission could be one or more of the following:

- Extensive investigation of particle and radiation environment in the vicinity of moon.
- Understanding distribution of rare elements through Gamma-ray spectrometry.
- Study of detailed aspects of surface composition and sub-groups of rocks.
- Study and analysis of cometary dust over moon's surface.
- Detailed Mapping with high resolution stereoscopic photography.

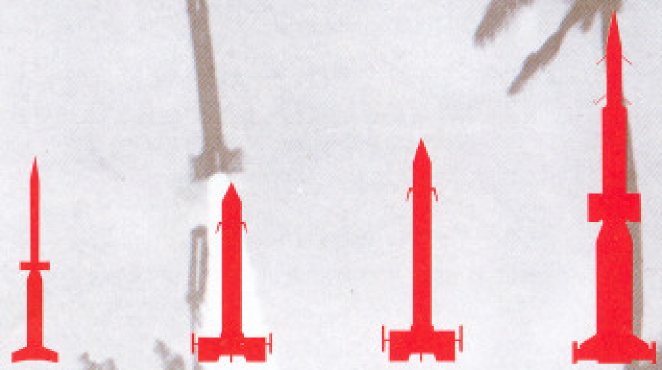
LUNAR DETAILS

Mass of Earth ÷ Mass of Moon	=	81.357
Gravitational Constant	=	4902.65 km^3/sec^2
Equatorial Radius	=	1738.57 km
Polar Radius	=	1737.58 km
Mean Distance from Earth	=	384400 km
Perigee Distance	=	363300 km
Apogee Distance	=	405500 km
Eccentricity of the orbit	=	0.0549 km
Geocentric Velocity	=	1.023 km/sec
Orbit Inclination to Ecliptic	=	5.145 deg
Siderial Month	=	27.322 days

Preliminary analysis shows that India's Polar Satellite Launch Vehicle (PSLV), is capable of sending a spacecraft to Moon. By modifying its upper stage into a Trans-Lunar Injection stage with about 2,200 kg propellant, it can send about 530 kg spacecraft as a fly-by mission or a 350 kg spacecraft which can orbit the Moon. Similarly, India's Geosynchronous Satellite Launch Vehicle (GSLV), which is now under development, can send a spacecraft of about 850 to 950 kg spacecraft as a fly-by mission to Moon or about 600 kg spacecraft to orbit the moon after incorporating a Trans Lunar Injection stage of 3,400 kg propellant.

If there is a wide ranging interest among the scientific community with well justified mission objective, ISRO could pursue further work towards realising a mission to Moon.

Sounding Rocket Launches to Study Atmospheric Waves



Features	RH-200	RH-300	RH-300 MK II	RH-560 MK II
No. of stages	2	1	1	2
Length (m)	3.6	4.8	4.9	7.7
Lift-off weight (kg)	108	370	510	1350
Payload Wt. (kg)	10	60	70	100
Altitude (km)	85	100	150	550
Application	Meteorology Atmosphere	Middle Atmosphere	Middle	Ionosphere

ISRO conducted an intensive scientific campaign, involving launch of 40 Rohini Sounding Rockets (RH 200) along with launches of high-altitude balloons from Sriharikota and low altitude balloons from Thiruvananthapuram to study gravity waves in the atmosphere. Ground-based observations using National Mesosphere Stratosphere Troposphere Radar Facility (NMRF) at Gadanki near Tirupati were also made under this scientific campaign which began on February 21, 2000 and continued till the first week of April 2000.

The instruments carried on board the Rohini sounding rockets and balloons measure the height structures of winds and waves in the atmosphere. The data will be used to determine the momentum fluxes associated with various types of waves that are present in the equatorial atmosphere such as the Kelvin waves (having periods of 10 to 20 days) and Rossby gravity waves (having periods of 4 to 5 days) in the troposphere (up to about 16 km height), stratosphere (16 to 50 km) and mesosphere (50 to 80 km). These waves are believed to be the major driving forces for the evolution of quasi-biennial oscillations in the atmosphere. The knowledge about these quasi biennial oscillations is important for understanding the interactions with meteorological phenomena at lower altitudes such as El-Nino and La-Nino.

The Rohini sounding rockets that reach an altitude of about 70 km, along with balloons that reach altitudes of 25 to 30 km, collected data for 40 consecutive days. Extended periods of observations by NMRF and Rayleigh Lidar that is collocated with NMRF were also undertaken to delineate shorter period gravity waves.

It is for the first time that such an elaborate scientific campaign was undertaken. Space Physics Laboratory of Vikram Sarabhai Space Centre, Kerala University, National Mesosphere-Stratosphere-Troposphere Radar Facility and Sri Venkateswara University besides several meteorologists are participating in the campaign.

20TH CENTURY

INTERNATIONAL

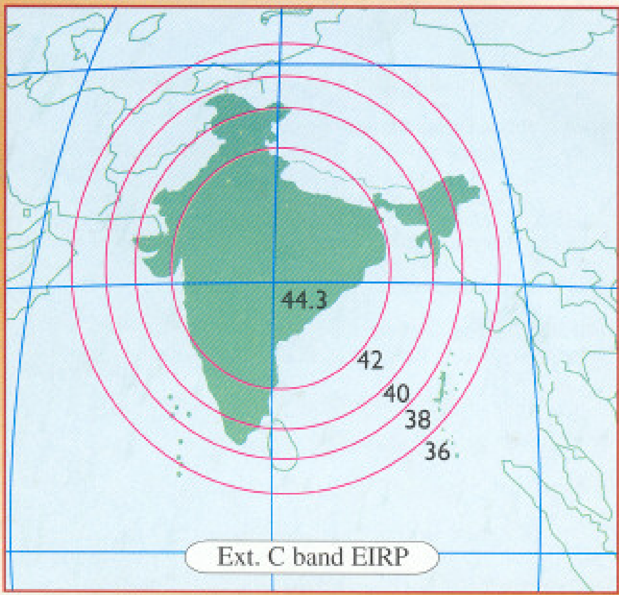
First scientific treatise on space travel by Konstantin Tsiolkovsky	1903
Albert Einstein proposes Special Theory of Relativity	1905
Annie Jump Cannon publishes the first fundamental catalogue of star spectra	1918
Robert H Goddard published 'method of reaching extreme altitudes'	1926
Edwin Powell Hubble discovers the linear relationship between galaxy distance and radial velocity, the Hubble constant, demonstrating that galaxies move away from each other	1929
Karl Jansky discovers cosmic radio waves	1930
Grote Reber constructs the first radio telescope	1937
The first artificial satellite, Sputnik, launched by the Russians. The Modern Space Age begins	1957
Launch of the first living entry 'Dog Laika' into Space	1957
First American Satellite launched	1958
The first man made object 'Lunar-2' hits the moon	1959
Yuri Gagarin, a Russian, is the first man in space	1961
Successful launch of first automatic spacecraft to planet Venus	1961
Valentina Tereshkova the first woman in space	1963
The first human space 'Walk' was by Alexei Leonov	1965
Arno Penzias and Robert Wilson discover the cosmic background radiation, providing direct evidence of the Big Bang	1965
Jodrell Bank radio telescope in northern England transmits the first photographs of the moon's surface, taken by the Soviet Luna 9 probe	1966
Americans Neil Armstrong and Buzz Aldrin become the first men on the moon	1969
Launch of world's first space station Salyut 1	1971
Reentry of the large American Space Station SKYLAB	1979
First launch of the Space Shuttle	1981
Seven astronauts killed when the space shuttle 'Challenger' explodes 73 seconds after take-off	1986
Mir Space Station Core Module launched	1986
Exploration of Halley Comet by 5 unmanned spacecraft	1986
Discovery of quasars (quasi-stellar objects) – believed to be very luminous galactic nuclei – at a distance of 17bn light years	19[illegible]
Launch of Soviet Space Shuttle	1988
12 tonnes Hubble Space Telescope launched	1990
COBE (Cosmic Background Explorer) satellite takes pictures of the early universe bathed in fluctuating background radiation	1991
Comet Shoemaker-Levy crashes into Jupiter, the most spectacular observed event in history	1994
Galileo probe reaches Jupiter	1995
Path finder lands on Mars	1997
Virgo Consortium makes its computer calculation for simulating universe	1998
First US and Russia modules of International Space Station launched	1998
SETI@home project is launched to help in search for life in other galaxies	1999
Lunar Prospector lands on moon	1999
23 tonnes Chandra Observatory launched	1999

MAJOR SPACE EVENTS

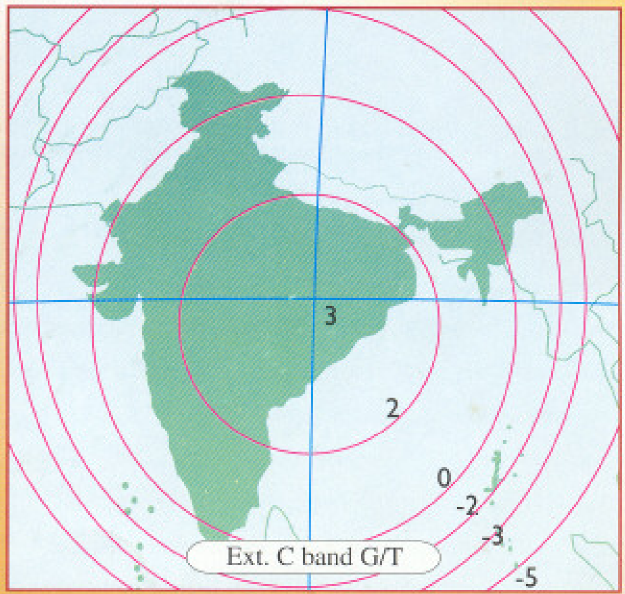
INDIAN

Indian National Committee for Space Research (INCOSPAR) formed by the Department of Atomic Energy and work on establishing Thumba Equatorial Rocket Launching Station (TERLS) started.	1962
First sounding rocket launched from TERLS.	1963
Satellite Telecommunication Earth Station set up at Ahmedabad.	1967
TERLS dedicated to the United Nations.	1968
Indian Space Research Organisation (ISRO) formed under Department of Atomic Energy.	1969
Space Commission and Department of Space set up. ISRO brought under DOS.	1972
First Indian Satellite, Aryabhata, launched.	1975
Satellite Instructional Television Experiment (SITE) conducted.	1975-1976
Satellite Telecommunication Experiments Project (STEP) carried out.	1977
Bhaskara-I, an experimental satellite for earth observations, launched.	1979
First Experimental launch of SLV-3 with Rohini Technology Payload on board.	1979
Second Experimental launch of SLV-3. Rohini satellite successfully placed in orbit.	1980
First developmental launch of SLV-3. RS-D1 placed in orbit.	1981
APPLE, an experimental geo-stationary communication satellite successfully launched.	1981
Bhaskara-II launched.	1981
INSAT-1A launched.	1982
Second developmental launch of SLV-3. RS-D2 placed in orbit.	1983
INSAT-1B, launched.	1983
Indo-Soviet manned space mission.	1984
First developmental launch of ASLV with SROSS-1 satellite on board.	1987
Launch of first operational Indian Remote Sensing Satellite, IRS-1A.	1988
INSAT-1C launched.	1988
Second developmental launch of ASLV with SROSS-2 on board.	1988
INSAT-1D launched.	1990
Launch of second operational Remote Sensing satellite, IRS-1B.	1991
Third developmental launch of ASLV with SROSS-C on board.	1992
INSAT-2A, the first satellite of the indigenously-built second-generation INSAT series, launched.	1992
INSAT-2B, the second satellite in the INSAT-2 series, launched.	1993
First developmental launch of PSLV with IRS-1E on board.	1993
Fourth developmental launch of ASLV with SROSS-C2 on board.	1994
Second developmental launch of PSLV with IRS-P2 on board.	1994
INSAT-2C, the third satellite in the INSAT-2 series, launched.	1995
Launch of third operational Indian Remote Sensing Satellite, IRS-1C.	1995
Third developmental launch of PSLV with IRS-P3 on board.	1996
INSAT-2D, fourth satellite in the INSAT series, launched.	1997
First operational launch of PSLV with IRS-1D on board.	1997
INSAT system capacity augmented with INSAT-2DT acquired from ARABSAT.	1998
INSAT-2E, the last satellite in the multipurpose INSAT-2 series, launched by Ariane from Kourou French Guyana.	1999
Indian Remote Sensing Satellite, IRS-P4 (OCEANSAT), launched by Polar Satellite Launch Vehicle (PSLV-C2) along with Korean KITSAT-3 and German DLR-TUBSAT from Sriharikota.	1999

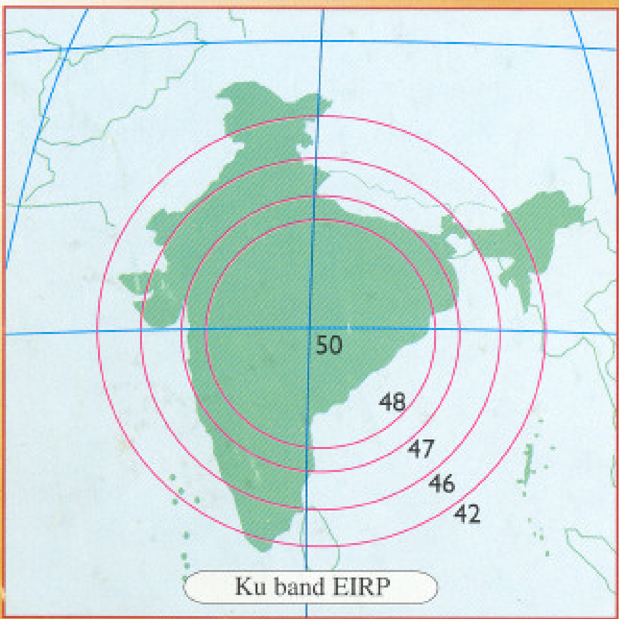
INSAT-3B Communication Antenna Coverage



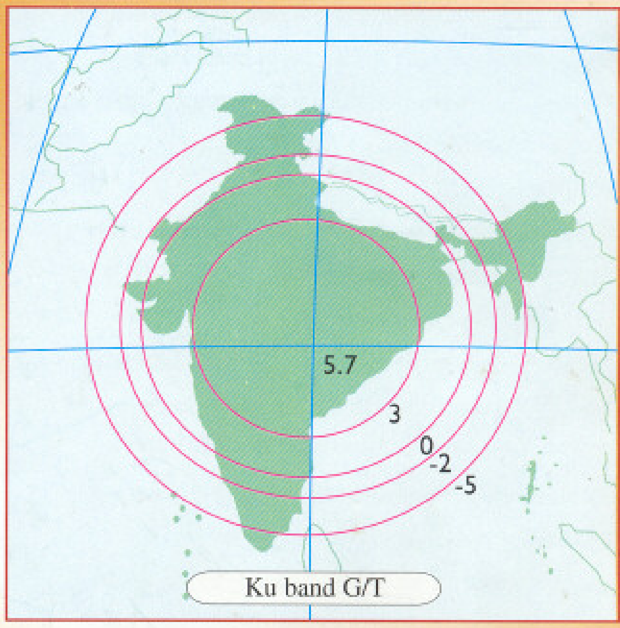
Ext. C band EIRP



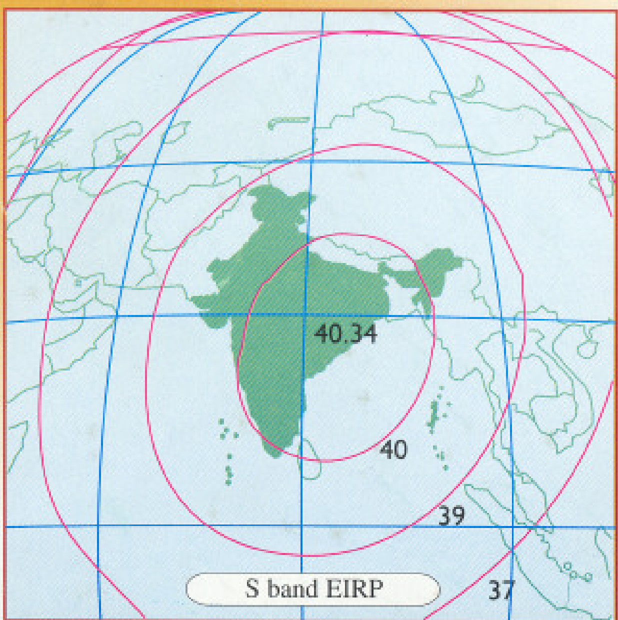
Ext. C band G/T



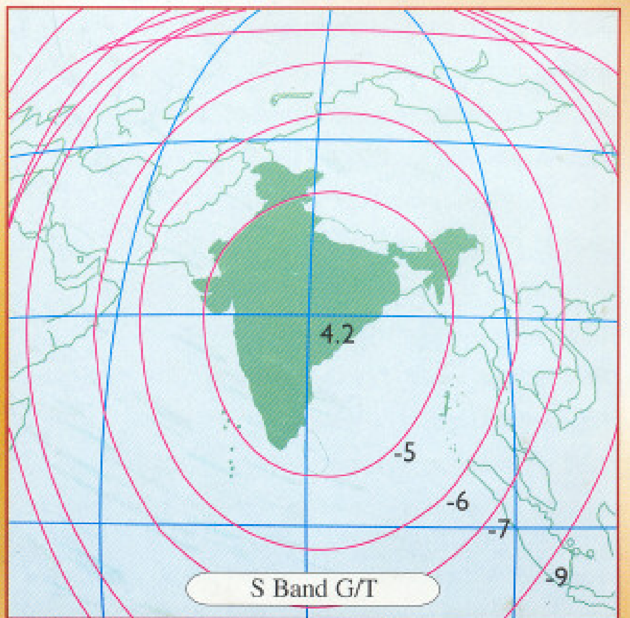
Ku band EIRP



Ku band G/T



S band EIRP



S Band G/T