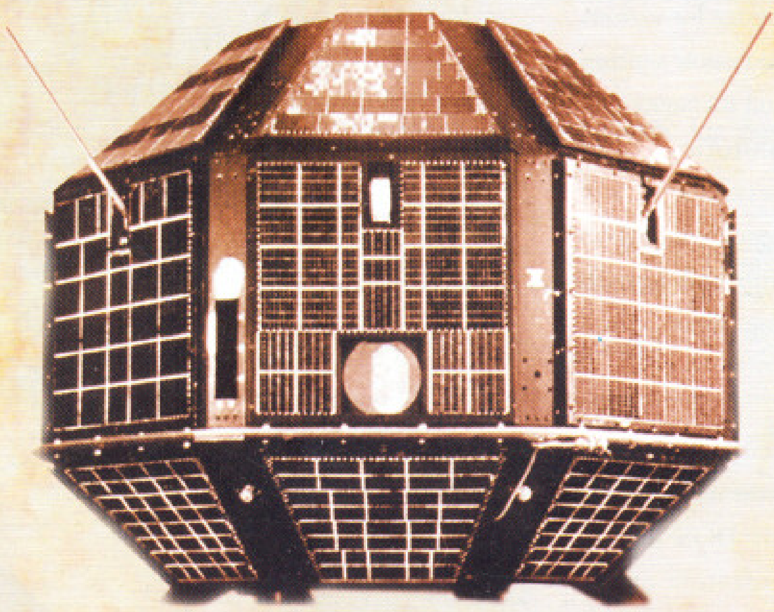
April-June 2000

SPACE india

ARYABHATA
India's first Satellite



Launched on April 19, 1975

INDIAN SPACE RESEARCH ORGANISATION

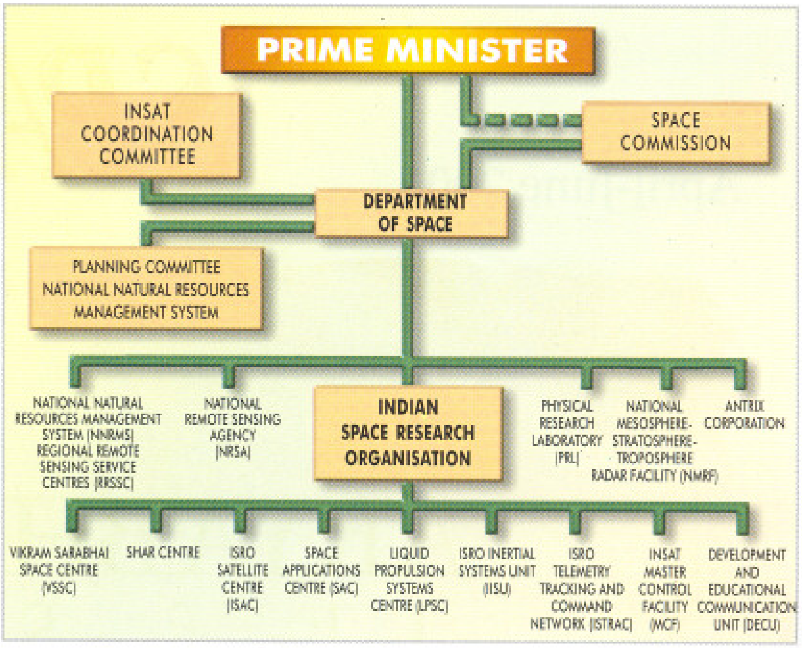
The Indian Space Programme

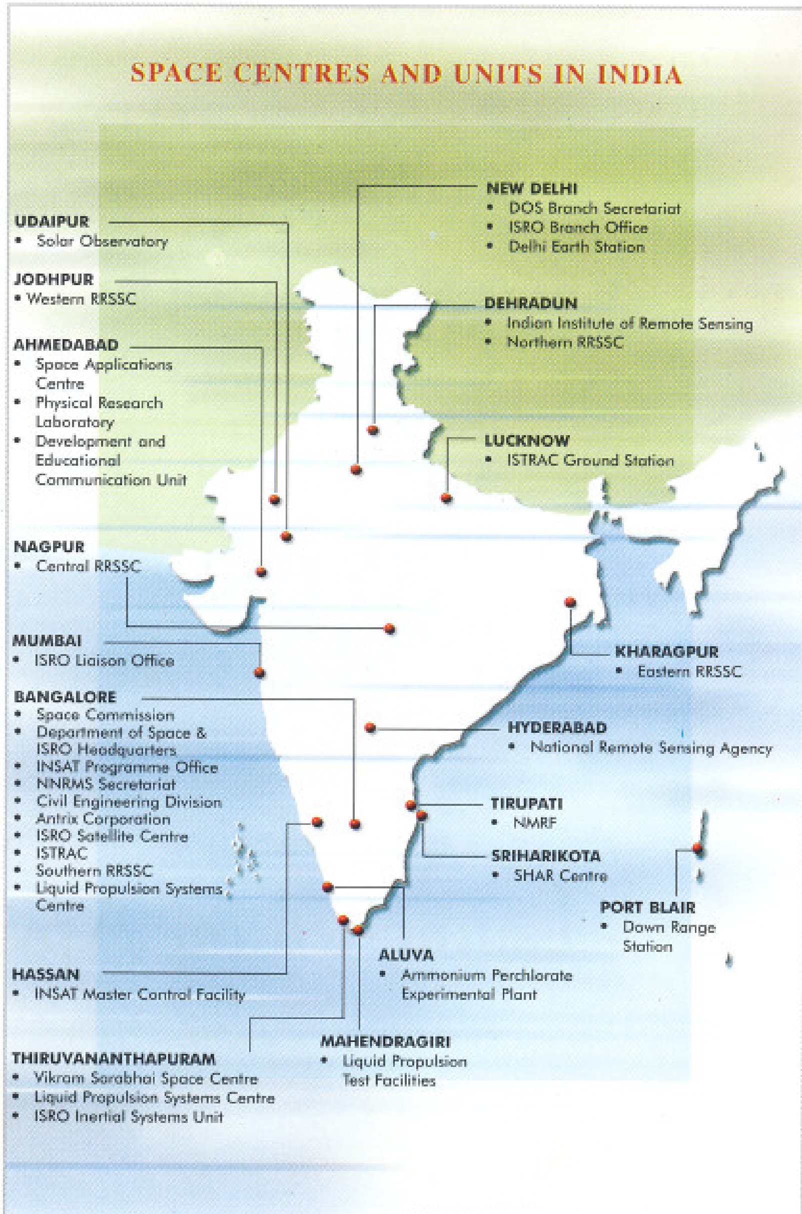
The setting up of the Thumba Equatorial Rocket launching Station (TERLS) in 1963 marked the beginning of the Indian Space Programme. The Space Commission and the Department of Space (DOS) were established by the Government of India in 1972 to promote unified development and application of space science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





Front Cover:
Aryabhata - the first Indian satellite

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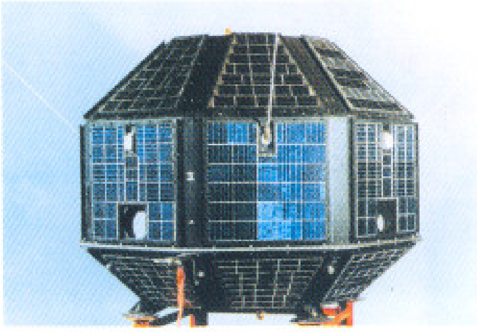
Remembering Aryabhata



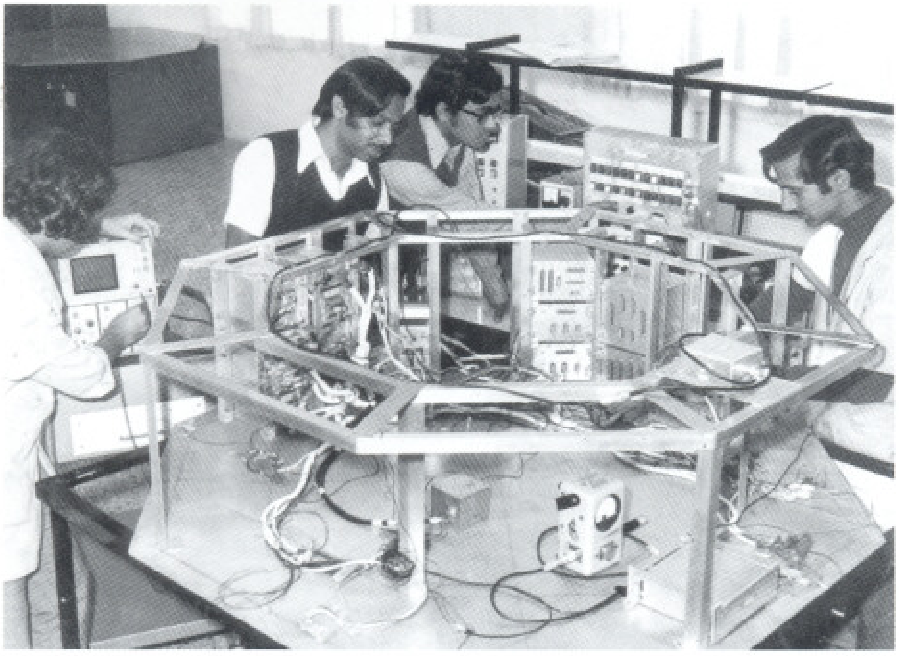
April 19, 2000 marked the 25th anniversary of the launch of India's first satellite Aryabhata. In fact, Aryabhata laid the foundation for India's satellite programme which has grown over the years and now include one of the largest domestic communication satellite system, INSAT, and the largest constellation of Indian remote sensing satellite series, IRS. Design, development, fabrication, testing and launch of Aryabhata with meagre infrastructure and human resources was a major challenge for ISRO in the early 70s.

The primary objectives of the Aryabhata mission were to indigenously design and fabricate spacecraft systems and evaluate their performance in orbit; evolve the methodology for conducting operations on the satellite; set up ground-based receiving, transmitting and tracking systems; and establish relevant infrastructure for fabrication, testing and qualification of spacecraft systems. It was also to provide Indian scientists with an opportunity to conduct investigations in space sciences — X-ray astronomy, aeronomy and solar neutron and gamma rays.

Aryabhata was quasi-spherical in shape with 26 flat faces, measuring 1.59 m across and 1.19 m in height. It weighed 358 kg at launch. The quasi-spherical shape was to obtain maximum surface area for deriving electrical power from the body-mounted solar cells with minimal fluctuations when the satellite was stabilised in the spinning mode. Further, the axi-symmetric shape provided the simplest configuration that could provide a uniform temperature distribution within the spinning satellite. The satellite employed a passive thermal system. The choice of the physical shape of the satellite had also to conform to the dynamic envelope of the Intercosmos Rocket of the erstwhile USSR that launched the satellite.

Aryabhata employed solar cells mounted on the body over a surface area of 36,800 cm^2 that generated a power of 46 W. The electrical power was backed up by a Ni-Cd chemical battery of 10 Ampere-hour capacity. The PCM/FM/PM telemetry system of Aryabhata, with a carrier frequency of 137.44 MHz, enabled monitor 91 parameters of the satellite with a time resolution of 250 milli-seconds to 4 seconds at a data rate of 256 bits/second. A tape recorder was also incorporated to store the data on board and play back when the satellite came within the visibility of Indian ground station; in the play back

Prof Satish Dhawan, the then Chairman of ISRO and Prof U R Rao, Project Director of Aryabhata signing the agreement with the erstwhile USSR Academy of Sciences in 1972.



Aryabhata Proto Model Integration

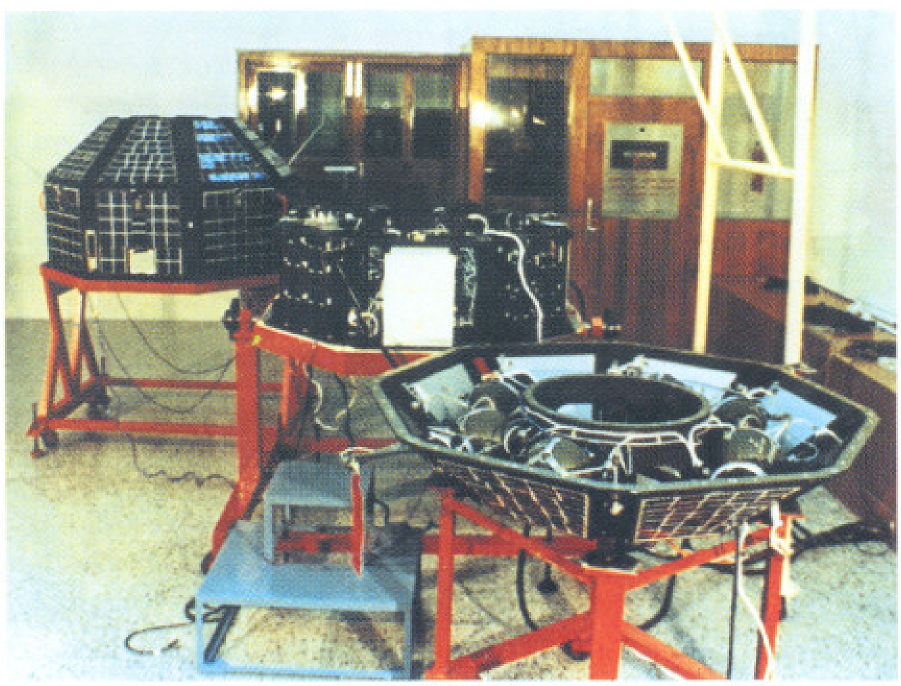
to investigate the X-ray sources in the energy range of 2.5 to 150 keV. It consisted of a proportional counter telescope of 15 cm^2 area and a NaI (TI) scintillator telescope with an effective area of 11.4 cm^2. Observations could be made in pointed scan modes both along the spin axis of the satellite and perpendicular to it. The solar neutron and the gamma ray instrument was designed to detect high energy neutrons in the energy range of 10-500 MeV and gamma-rays in the energy range 0.2-20 MeV. The basic detector was a 12.5 cm diameter CsI(TI) scintillator, 1.25 cm thick. The aeronomy instrument consisted of a retarding potential analyser for the detection of supra-thermal electrons up to 100 eV and two UV chambers to measure the intensities of Lyman alpha (1216 A) at F-region altitudes of the ionosphere.

The primary ground station for receiving data and commanding the satellite was located at Sriharikota (SHAR) near Chennai. The station consisted of a fully steerable yagi antenna and equipment to receive the data from the satellite, display them,

mode, data could be transmitted at 2,560 bits/second. For commanding the satellite, a PDM/AM/AM telecommand system, with a 1 kW transmitter on the ground, was employed with appropriate encoder on the ground and a matching decoder on board the satellite. The carrier frequency for the up link was 148.25 MHz. While no on-board tracking package could be included due to weight constraints, the available on-board communication packages, both receive and transmit chains, were effectively used to configure tone ranging, Doppler and interferometry system to obtain range, range rate and positional information of the satellite.

The satellite was stabilised in orbit by spinning it around the axis of maximum moment of inertia. The spin-up was achieved using cold gas jets stored in six gas storage bottles, each, capable of imparting a spin of 60 rev/min to the satellite. A fluid-in-tube nutation damper was used to arrest the precession arising out of disturbances during the separation of the satellite from the rocket.

The X-ray astronomy instrument on board Aryabhata was intended



Disassembled view of Aryabhata

Aryabhata

Aryabhata is said to have belonged to Kusumpura (Patna, in Bihar). On the basis of several astronomical data given in his works he is supposed to have born around 476 A.D. Aryabhatiya, also called as Arya-Siddhanta, written by Aryabhata is believed to have been completed about the beginning of the sixth century. It is a brief descriptive work intended to supplement matters and processes that were generally known and agreed upon. It gives the most distinctive features of Aryabhata's own system of astronomy. It consists of four parts or padas. The first part, Dasagitika, describes a system of expressing large numbers in Sanskrit alphabet. The second part, Ganita-pada, is on mathematics. The third, Kalakriyapada, is on reckoning time and the fourth is Gola-pada on sphere.

In his works, Aryabhata put forward new observations and contradicted certain old ones. Thus, contrary to the orthodox view of time, he stated that earth was a sphere and it rotated on its axis. He described the true theory of the cause of lunar and solar eclipses and said that the eclipses were caused by the shadows of the earth and the moon. He said that the moon was essentially dark and was illuminated by the sun. He noticed the motion of the solistical (one of the two extreme points of sun's yearly north-south travel) and equinoctial points (one of the two points at which the sun semi-annually crosses the celestial equator) but he restricted it to a regular oscillation and assigned the limit and the period. He developed the theory of epicycles (a small circle rolling on the circumference of a greater by which the motion of a planet is represented.)

Aryabhata also laid the foundation of algebra and made many new observations in geometry. He indicated a method of arriving at a solution of the indeterminate equations of the first degree (an equation which contains x to the power of one and in which the value of x cannot be obtained in integral terms). He is also probably the first to give a concept of pulveriser or Kuttakara which was later on developed further by others in India. He obtained the value of pi as 3.1416, which is correct to the fourth place of decimal. He gave a method of measuring the dimension of a shadow thrown by an object placed in the path of light and this formed the basis of calculating the eclipses. He also quoted the Pythagorean theorem in one of his verses.

Aryabhata expressed high numbers by means of syllables. He could do so since ancient Indian phoneticians had devised a phonetic alphabet which included 15 vowels, 25 stopped consonants (k-m) and eight other letters (y-h). Aryabhata used the stopped consonants to represent the numbers 1-25 when they preceded the vowel 'a' and high decimal powers of these numbers (up to 10^{16}) when they preceded other vowels. The letters y-h were used to represent the numbers 30-100. Thus while ta represented 3, ti stood for 300 and tu for 30,000. It is hard to believe that such a descriptive alphabetical notation was not based on a place-value notation. There is nothing to prove, however, that actual calculations were made by means of these letters. It is probable that Aryabhata was not inventing a numerical notation to be used in calculation, but was devising a system by means of which he could express large unwieldy numbers in verse in a very brief form. This alphabetical notation is employed only in Dasagitika. In others parts of the treatise, where only a few numbers of small size occur, the ordinary words which denote the numbers are employed.

Aryabhata was one of the most original scientific innovators of ancient India. He is the earliest known Hindu author to have created algebra. However, for his unorthodox views, he has been opposed strongly by later authors like Brahmagupta. Later Hindu opinion, however, has been more favourable. Aryabhata's system of astronomy became well known in Arabic world also in the middle of the eighth and the beginning of the ninth century A D. It is believed that Aryabhata was pronounced Arjabhar in Arabic.

Aryabhatiya, the text embodying the mathematical and astronomical doctrines of Aryabhata, shows that he was one of the greatest scientists of ancient India.

A job well done!
Prof. Satish Dhawan addressing the ISRO community after the launch. Prof. U.R. Rao and Dr. K. Kasturirangan are also seen.

and conduct preliminary analysis to quickly determine the health of the satellite. Telecommand station to command the satellite from the ground and a tracking network consisting of a Doppler, interferometry and tone ranging system were also installed at SHAR, to derive the orbital parameters of the satellite.

The work of setting up the necessary infrastructure for fabricating and testing various subsystems of the satellite was taken up immediately after the project was initiated. These facilities included electronics laboratories, a clean room for the final assembly of the satellite, thermal laboratories, control and stabilisation laboratories and antenna testing facilities. A few specialised facilities like dynamic balancing machine for balancing the fully integrated satellite, equipment for measuring the centre of gravity and moments of inertia of the satellite and, a thermo-vacuum chamber capable of simulating important space environmental conditions were also set up.

Four models of the satellite were fabricated — a mechanical mock-up, a pre-prototype version to evaluate electrical system, flight prototype and the flight model. After complete integration and testing of the flight model at Bangalore, Aryabhata was transported to the USSR Cosmodrome in a special container. The satellite inside the container in its three main parts — bottom shell, deck plate with instrumentation and top shell were integrated at the cosmodrome in erstwhile USSR for the launch.

Aryabhata was successfully launched at 1300 hr IST, on April 19, 1975 into an orbit with an apogee height of 620 km, perigee height of 562 km, and an inclination of 50.7° with respect to the equatorial plane. Aryabhata was controlled from the ground stations at Bears Lake in USSR, and SHAR ground station.

The satellite was powered immediately after its separation from the rocket, about 30 min after the launch, and the telemetry signals were received at SHAR ground station during the second orbit. It was noticed that the satellite was tumbling at a rate of about 0.3° per second instead of spinning, and the aeronomy instrument was not getting the 9V power supply. All other systems were functioning normally. In spite of the tumbling, the temperatures of various subsystems inside the satellite were within the expected limits. After the 17th orbit, some problems like sudden drop in the signals and non-synchronisation of telemetry frames were noticed and in the 41st orbit, the +9V power to the three scientific instruments failed even though all the other power lines were working normally. It was therefore decided to switch off the three scientific instruments and keep the satellite technologically functional. In orbit 45, a spin command was sent from the ground and the satellite was spin-stabilised at 50 rev/min.

Regular operations of the satellite, except for the three scientific instruments, continued for its designed operating life of six years and several experiments like relaying data, transmission of recorded speech, weather data and even an Electro-Cardio Gram (ECG) from SHAR Centre to Bangalore were successfully carried out. Even after its operating life, Aryabhata was being tracked from SHAR regularly. The signals during Aryabhata's 92,875th orbit, the last around the earth, were received by SHAR ground station at 627 hours (universal time) on February 10, 1992 minutes before it re-entered the earth's atmosphere after being in orbit for almost 17 years.

It was significant that Aryabhata could be realised within a period of 30 months by a young team of scientists and engineers led by Prof U R Rao, the then Project Director (who later became Chairman, ISRO and presently, Member, Space Commission). Prof Satish Dhawan the then Chairman of ISRO (presently Member, Space Commission) provided the necessary guidance to the project. The present Chairman of ISRO, Dr K Kasturirangan was a leading member of the Aryabhata team incharge of coordinating the scientific experiments, and Chairman of the Test Programme and Configuration Control Committee as well as Secretary to the Project Management Board which had Prof Dhawan as its Chairman.

To mark the 25th anniversary of the launch satellite 'Aryabhata', a function was organised at ISRO Satellite Centre, Bangalore on April 19, during which an exhibition of posters depicting the progress made by ISRO in different fields of satellite technologies, since the launch of Aryabhata, was arranged. It has been decided to henceforth observe April 19 every year as Satellite Technology Day in ISRO. Delivering the first Aryabhata lecture "Aryabhata — A Symbol of Excellence", as part of the first Technology Day on April 19, 2000, Prof U R Rao said that 'thinking always ahead' has been the main factor behind the success of ISRO in realising 26 satellites in the last 25 years. Prof Jayanth Narlikar, Director and Homi Bhabha Professor of Inter University Centre for Astronomy, Pune, delivered the invited talk bringing out the importance of space technology in astronomical observation and the role of space platforms for astronomical research.

Norms, Guidelines and Procedures for Satellite Communications

With the Government of India approving a) allocation of INSAT system capacity for non-governmental users, b) registration of Indian satellite systems by private Indian companies and c) limited use of foreign satellites in special circumstances, Department of Space (DOS) has become the administrative ministry in all matters related to satellite systems in India. INSAT capacity will henceforth be made available to non-government Indian Service Providers on a commercial basis subject to availability after meeting the government needs. DOS will allocate INSAT capacity for private users. DOS may also build capacity in INSAT system for private users on request on commercial basis.

A Committee for Authorising the establishment and operation of Indian Satellite Systems (CAISS) has been set up at the Headquarters of ISRO in Bangalore and private Indian companies with a foreign equity less than 74 percent can submit their applications for registering their satellite systems to CAISS. CAISS will give authorisation to operate the Satellite System and undertake the Orbit spectrum notification and registration. However, operating licenses for services to be provided by the Indian Satellite Systems will be issued only by the concerned administrative departments like Department of Telecommunication for telecom services and Ministry of Information and Broadcasting for TV/Radio broadcasting.

Foreign satellites will also allowed to be used in special circumstances for satellite communication services in India. The service licensing departments may allow the use of foreign satellites in consultation with the Department of Space. If suitable capacity/capability is available in INSAT or Indian Satellite Systems, operations with foreign satellites will not be permitted. For the use of foreign satellites for Internet Service Provider (ISP) gateways, the existing procedures established by Telecom Commission will continue.

INSAT-3B Dedicated to Nation

Prime Minister Mr. Atal Behari Vajpayee addressing the nation after dedicating INSAT-3B. Dr. K. Kasturirangan, Chairman, ISRO and Mr. Naveen Patnaik, Chief Minister of Orissa (Right) are also seen.

The Prime Minister Mr Atal Behari Vajpayee dedicated INSAT-3B satellite to the nation on May 24, 2000 at a function held at Raj Bhavan in Bhubaneswar, Orissa. He also inaugurated the Swaran Jayanti Vidya Vikas Antariksh Upagraha Yojana (Vidya Vahini) Gramsat pilot project for Orissa through the direct broadcast of the function to the villages in the Kalahandi-Bolangir-Koraput (KBK) region of Orissa.

The ISRO-built INSAT-3B, the first in the third generation INSAT-3 series of satellites, was launched on March 22, 2000 by the European Ariane Rocket from Kourou, French Guyana. The satellite, collocated with INSAT-2E at 83 degree East Longitude above the equator, is intended for business communication, developmental communication and mobile communication. It carries twelve extended C-band transponders each having a bandwidth of 36 MHz, three Ku-band transponders having a bandwidth of 77/72 MHz and mobile satellite service transponders operating in C X S band frequencies. INSAT-3B will carry important networks for banking and stock exchanges. It will also support Gramsat Pilot projects in different states.

Dedicating the satellite to the Nation, the Prime Minister said that India has established a vast technology base to design and develop INSAT and IRS series of satellites for two major applications of space technology, namely, communications and earth observation. He commended ISRO for bringing into reality his vision for the Vidya Vahini Yojana proposed two years back on the occasion of the nation's 50th year of Independence. The Prime Minister expressed his happiness that the Government of Orissa is launching a major development programme in collaboration with the Department of Space.

The Chief Minister of Orissa, Mr Naveen Patnaik said in his address that Orissa will strive to make best use of satellite network with computer connectivity to bring revolutionary changes through E-Governance. He said that his government will make information available to the people through this network so that the government system becomes truly responsive. He said that the worst ever cyclone late last year in Orissa has brought realisation at all levels about the need for an effective communication system and his Government will make best use of the network to make information available to people. Minister for Rural Development Mr Sunderlal Patwa, the

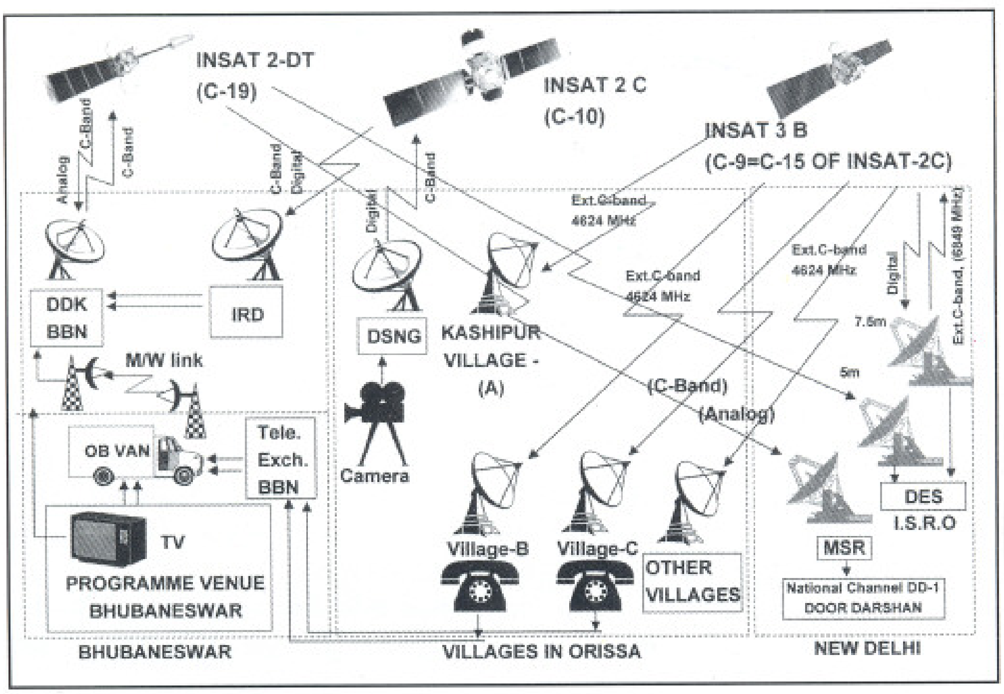
Governor of Orissa Mr Rajendran and Orissa Minister of Science and Technology Mr R P Swain also participated in the dedication function. Dr K Kasturirangan, Secretary, Department of Space and Chairman, ISRO, gave the overview of the INSAT and the Vidya Vahini Yojana.

Vidya Vahini

It is significant that India has always emphasised the use of satellite technology for developmental communication since the beginning of its space programme. It had conducted the Satellite Instructional Television Experiment (SITE) during 1975 using the US Satellite, ATS-6, which covered about 2,400 villages in six states in the country. SITE was heralded as the largest sociological experiment ever conducted in the world. With the establishment of INSAT system in 1983 and now one of the largest domestic communication satellite systems in the world, India continues to use the medium of satellite television for educational purposes. A major development communication project is underway since November 1996 in the tribal district of Jhabua in Madhya Pradesh. The Training and Developmental Communication Channel of INSAT, inaugurated in 1995, is used by several agencies like Indira Gandhi National Open University, National Dairy Development Board, State Bank of India and several State Governments for distance education in rural development, women and child development, Panchayati Raj and industrial training.

The Prime Minister had announced the Swarna Jayanti Vidya Vikas Antariksh Upagraha Yojana (Vidya Vahini) in his address to the nation on August 15, 1999 as one of the initiatives to mark the 50th Anniversary of India's independence. Vidya Vahini, that has now become a reality, is yet another important step in making use of space-based television for educational purposes. The Vidya Vahini Yojana will provide education, information and training to people in rural and remote areas of the country. This Yojana is being implemented in Orissa with the collaboration of Orissa Government as a "Gramsat-Pilot Project for Orissa". It will provide Orissa Government to reach out not only to its grassroots level functionaries, but also, directly to the people, the most important partners in the developmental process. This network will provide development communication to about 800 villages in the KBK region of Orissa and it has facility for interaction between participants. Thus it can help impart technical skill, while exposing them to greater opportunities in life and to motivate them to participate in the development of the State. The network will also have computer connectivity that can help in an efficient administration and to give the right information to the people of Orissa. Interactive training and computer networks will be set up in all the 340 block and district headquarters in Orissa. TV and data up link facilities will be set up at a Hub in Bhubaneshwar. The Gramsat pilot project network will also be used for telemedicine applications and disaster management in Orissa.

During the inauguration of Vidya Vahini in Orissa, villagers from Kashipur could talk face to face with the Prime Minister while those from Kesinga and Puntala could talk to him on audio link to share their problems and their aspirations.



INSAT network used for the interaction between Prime Minister and people in Orissa villages on May 24, 2000.

VSNL and ANTRIX Corporation Sign MOU

The Videsh Sanchar Nigam Limited (VSNL) and the Antrix Corporation, the commercial arm of ISRO signed a Memorandum of Understanding (MOU) on May 26, 2000 at Bangalore for acquisition of satellite capacity in the Indian Ocean region. The MOU will enable the two agencies to converge on the requirements of satellite, that will ideally serve the multi-service requirements of VSNL and its customers and lead to a co-ordinated augmentation of the satellite capacity at the earliest.

VSNL is witnessing a growing demand for satellite capacity for Internet services, multimedia satellite up-linking, Internet Multicast backbone services and regional high-speed data connectivity. It expects significant growth in its transponder requirements, both, in the C-band and Ku-band over the next three years that justifies augmentation of the space segment capacity. This expansion is planned through the Antrix Corporation.

Speaking on the occasion of the signing of the MOU, Dr K Kasturirangan, Chairman, ISRO said that ISRO is focussing on the development of satellite capacity in the Indian Ocean region. "The Memorandum of Understanding with VSNL will culminate in making available transponder capacity and help a number of users in India including VSNL to deploy high technology satellite connectivity applications" he said. Mr S K Gupta, Chairman and Managing Director, VSNL, said that the MOU with Antrix Corporation will help VSNL in acquiring much needed transponder capacity to meet the growing requirements of all satellite services in India and in the Indian Ocean region. This will also herald the entry of VSNL into a regional role in international operation. "We are highly optimistic towards the future satellite utilisation scenario and the MOU with Antrix marks an important stage in our plans for emerging as a strong regional player" he added.

VSNL, at present, uses the INTELSAT system for the bulk of its satellite connectivity requirement. VSNL has set up 30 earth stations that are deployed on six INTELSAT satellites operating at 60°, 62°, 64°, 66°, 83° and 359° east longitude and it has become the second largest shareholder in the INTELSAT system with increasing deployment of satellite capacities within India.

ISRO also has a close working relationship with INTELSAT and has leased eleven 36 MHz equivalent Transponder capacity on its INSAT-2E satellite to INTELSAT. ISRO is the first organisation from which INTELSAT has leased satellite capacity as a part of its international fleet of operating satellites. Nine of the transponders leased to INTELSAT are now being offered through VSNL to satellite broadcasters in India. VSNL, as a signatory to INTELSAT, was closely associated in the INTELSAT-ISRO partnership.

The present MOU marks another milestone in the cooperation between Antrix Corporation and VSNL for satellite operations in the Indian Ocean region.

PSLV to Launch German Satellite

Antrix Corporation, the commercial agency of the Department of Space, has signed an agreement with the German Space Agency, DLR, for launching its 94 kg BIRD satellite on board ISRO's Polar Satellite Launch Vehicle (PSLV). The satellite is expected to fly as a piggy-back to the Technological Experiment Satellite (TES) of ISRO on board the third operational flight of PSLV that is planned some time during the year 2000. It may be recalled that PSLV-C2, launched in May 1999, had carried two satellites, DLR-TUBSAT and Korean KITSAT-3, as piggy-backs to Indian Remote Sensing Satellite, IRS-P4 (OCEANSAT). All the three satellites were placed in the pre-determined orbit. Antrix has also signed an agreement with a Belgium Company for the launch of its satellite Proba as an auxiliary payload on one of the forthcoming flights of PSLV.

BIRD is a small satellite of DLR, 550 X 620 X 620 mm in size with the following scientific and technological objectives:

- Testing new generation of Infra-red array sensors adapted to earth remote sensing objectives by means of small satellites.
- Detection and scientific investigation of hot spots (forest fires, volcanoes etc.)
- Thematic on-board data processing, test of a neural network classificator in orbit
- Payload demonstration — precise information about leaf mass and photosynthesis for early diagnosis of vegetation condition and cloud analysis

The satellite will be launched into a 560 km sun-synchronous polar orbit by PSLV.

Beginning of all - industrial sheds under construction for the Aryabhata Project