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SPACE india

INDIAN SPACE RESEARCH ORGANISATION

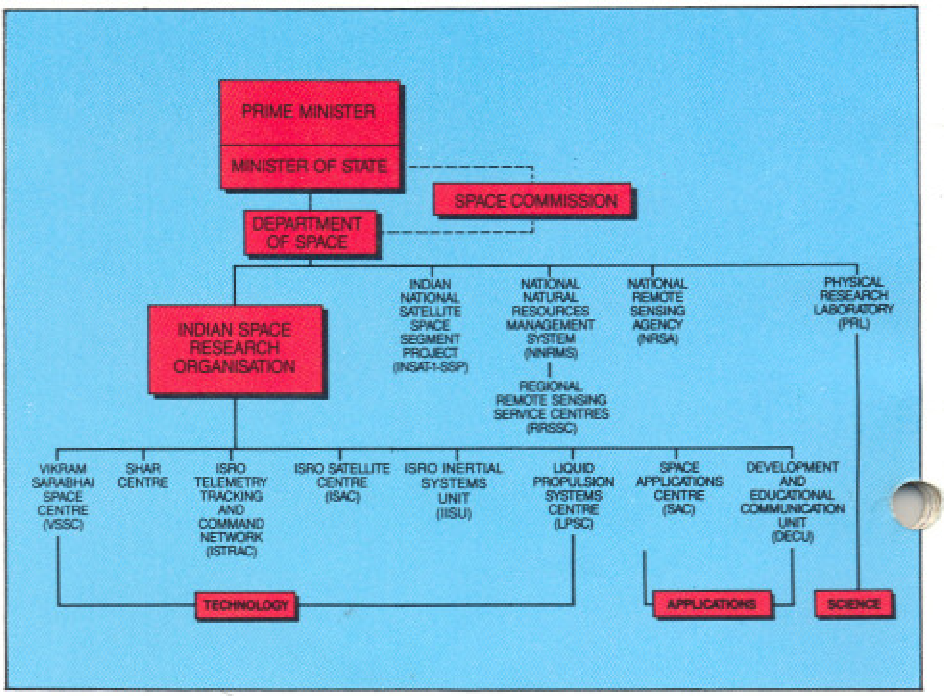
The Indian Space Programme

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.

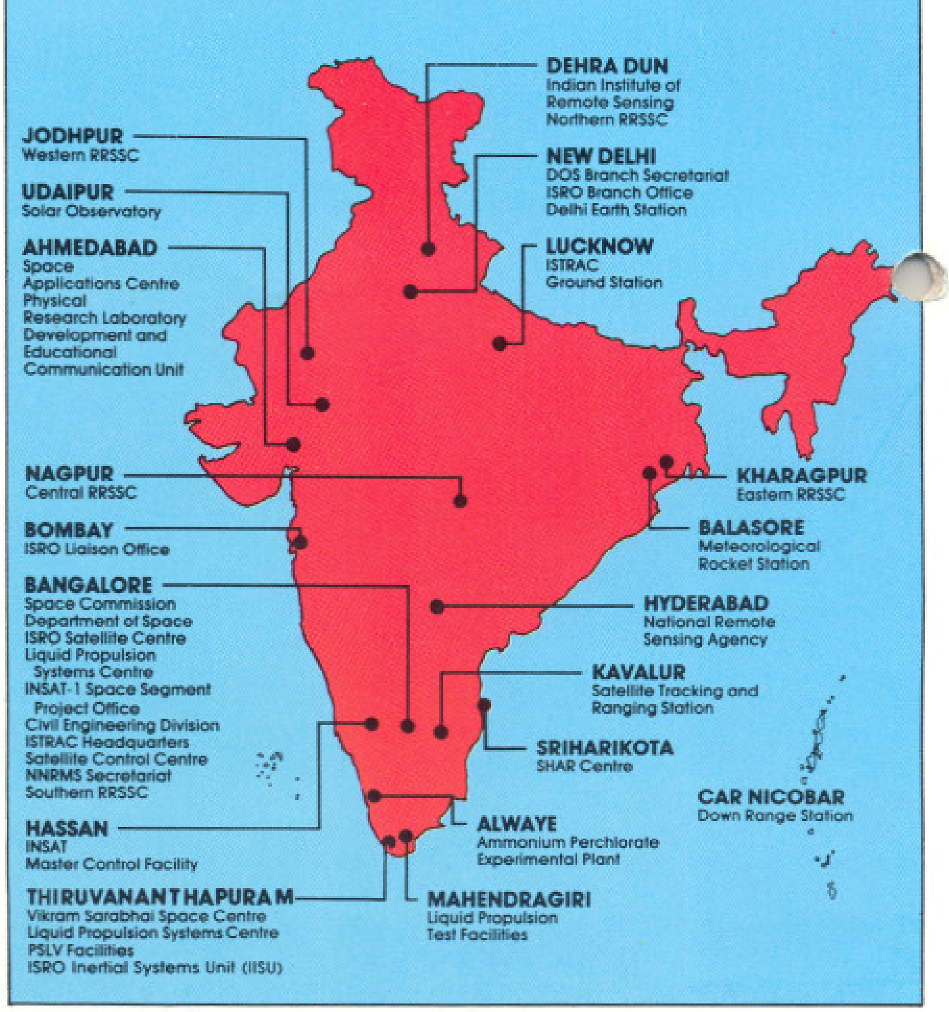
The Indian Space Programme is directed towards the goal of self-reliant use of space technology for national development, its main thrusts being: (a) satellite communications for various applications, (b) satellite remote sensing for resources survey and management, environmental monitoring and meteorological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

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The Moving Tower of SHAR

- Mobile Service Structure for PSLV

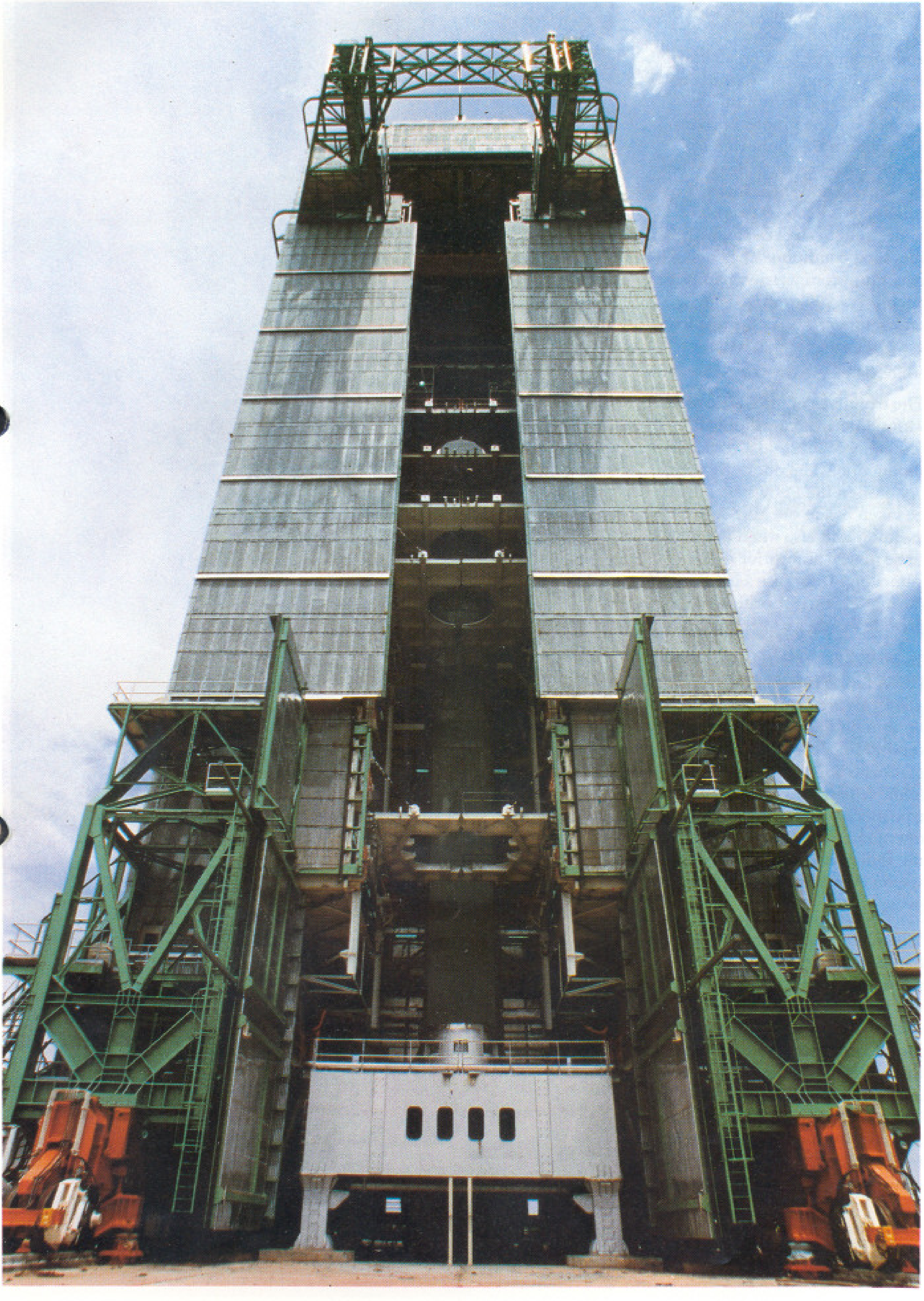
The giant Mobile Service Tower (MST), along with launch pedestal and umbilical tower, has been successfully fabricated and erected at SHAR Centre for the integration and launch of Polar Satellite Launch Vehicle (PSLV).

The mammoth, 76m tall, steel structure with a 21m X 23m cross section and weighing about 3,200 tonnes can move on a 200m long twin rail track by means of four wheel bogie systems. The structure is cladded on all sides with corrugated galvanised iron sheets. MST is normally anchored at launch pad end enclosing the launch pedestal and umbilical tower. In the anchored condition, it can withstand mean hourly wind speeds up to 160km per hour and gust wind speeds of 230km per hour for 3 seconds. MST has all the facilities required for the PSLV integration including a 60 tonne capacity crane and a 1,00,000 class clean room at 41m level.

The main structure of MST consists of column modules erected at the corners which are interconnected by beam modules. There are seven column modules at each corner to cover the total height of 76m connected by beam modules at 18 levels on three sides. The verticality tolerance for MST is just 15mm for the entire height. This close tolerance on the verticality is essential for the satisfactory operation of various mechanisms like vertically repositionable platforms, swing doors and sliding doors of the MST. A heavy duty crawler crane was used for the erection and alignment of the modules.

The complete MST is anchored to the ground through eight tongue

MST for PSLV - Fabrication of the tall order.



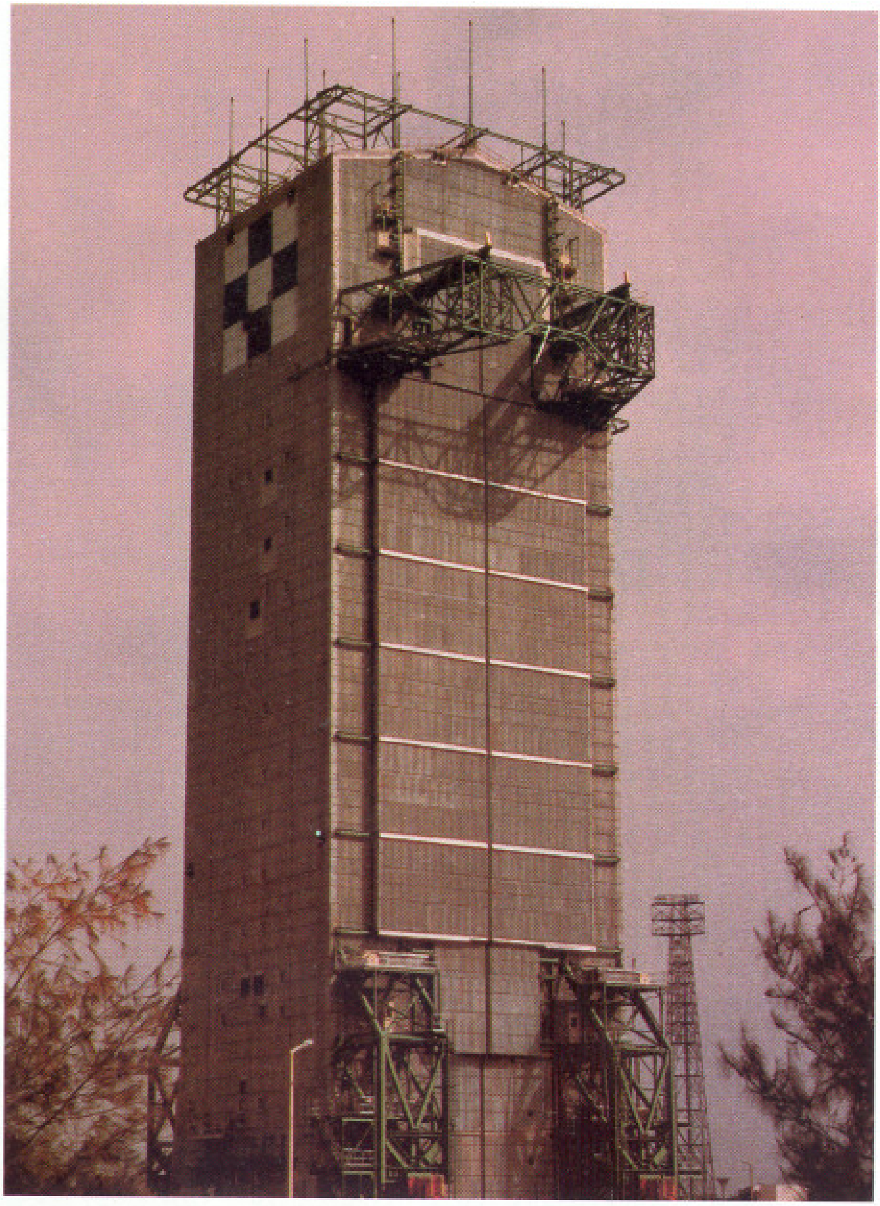
MST with Launch Pedestal and Umbilical Tower.

and groove type anchors, with the groove portion attached to MST and the tongue portion attached to the massive concrete foundation embedded in the ground. The tongue and the groove portions of the anchors are connected by stainless steel taper wedges to bear the tension and shear loads. Anchors were fabricated out of high strength steel castings. Under the worst conditions, the maximum compressive load on any anchor is 1,250 tonnes. The maximum tension and shear loads are 870 tonnes and 320 tonnes respectively.

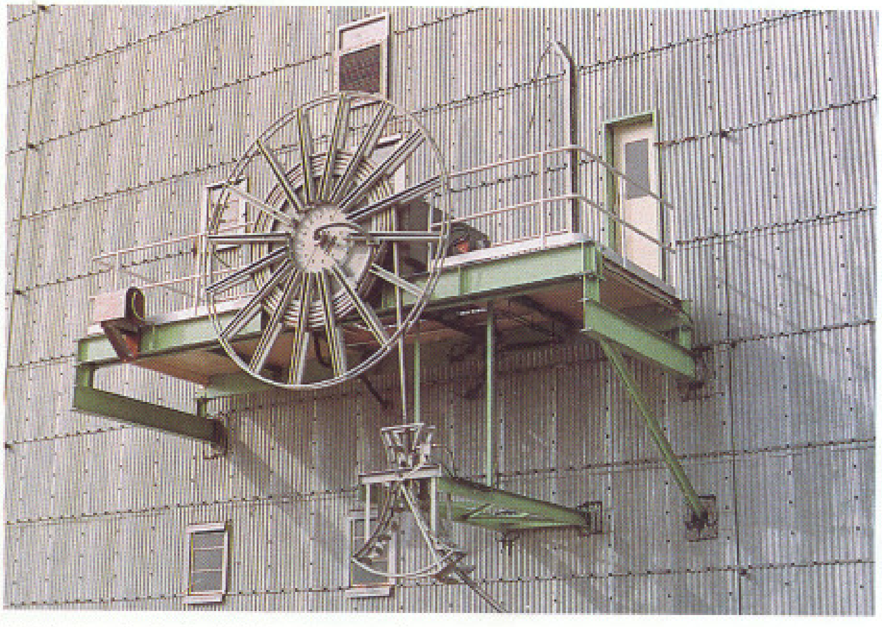
The front face of MST is provided with six horizontally sliding doors, four swing doors and a vertically sliding door. The doors are kept open when the PSLV stages are to be taken inside the MST for assembly and also when the MST is to be moved away prior to the launching. Doors are kept closed during vehicle integration to provide weather protection.

To approach various levels of the PSLV during integration, working platforms are provided. The bottom two platforms are vertically repositionable and foldable. Three platforms at the top levels are of foldable type. Wire rope-winch type mechanisms are used for the operation of all the platforms and the sliding doors. A screw rod-nut system is used for the operation of swing doors.

The 60 tonne capacity EOT crane flame-proof construction is provided at 64m level. The crane can be moved out of the tower on the crane projection structure to pick-up the stage motors from the trailors parked at the ground level and to move them inside MST for integration. The crane has an auxiliary hoist of 15 tonne capacity for handling PSLV first stage strap-on motors.



MST with all shutters and doors closed.



Cable drum for hydraulic drive power supply.

A clean room of class 1,00,000 for the assembly of spacecraft is provided at 41m level with aluminium partition on three sides and a sliding roof on top at 62m level. An antistatic flexible curtain is used to cover the front side of the clean room. A 5 tonne capacity pneumatic crane is provided in the clean room. The curtain can be rolled up and the sliding roof withdrawn when the clean room is not being used. The side walls and the roof of MST are thermally insulated with fibre glass wool panels to ensure efficient airconditioning of the MST. The air handling units located in the MST use chilled water, pumped from chilled water plants in an adjacent building at the ground level.

The MST is supplied with electrical power at 440V (3 phase) through cable couplers. Power distribution panels are located in pressurised rooms at 6m and 11.8m levels. All the light fittings in the tower are of flame-proof type. The central control panel for all the mechanisms of doors and platforms, control panel for the airconditioning system and hydraulic drive system of MST are located in the pressurised control room at 6m level. Power supply for the hydraulic drive system is supplied through cable reeling drum mounted on one side of MST.

The giant MST is able to move on a 200m long twin rail track through four bogies, one at each corner of MST, attached to flare structures. Each bogie contains eight wheels of 1.2m diameter each. In a bogie there are four dead axles on each side of which two wheels are attached. The wheels of the bogie run on a double rail track system. The MST moves on two such tracks. Each wheel is designed to take a maximum load of 125 tonnes. Wheel tread surfaces are deep hardened to withstand the high contact-induced stresses. Surface hardened flat rails are used to minimise the contact stresses. To ensure equal loading of the wheels, irrespective of the variation of the rail top level, oscillating blocks and balancers are employed. Sixteen of the 32 wheels are driven by hydraulic motors which give constant torque irrespective of the speed, thus making the movement smooth even at low speeds. Variation in speed is achieved by simple flow control of the oil. Each motor can develop a maximum torque of 4,500 kg-m and the MST can attain a maximum speed of 7.5m/minute. The skew of the MST during the travel is controlled to within 10mm by a digital control system, with encoders mounted on the opposite wheels on either side of the rail track. Both speed control and skew, induced by the variation in the diameters of the wheels on the opposite tracks, are detected by optical sensors in conjunction with flags mounted at identical locations along both the tracks and corrected by the control system.

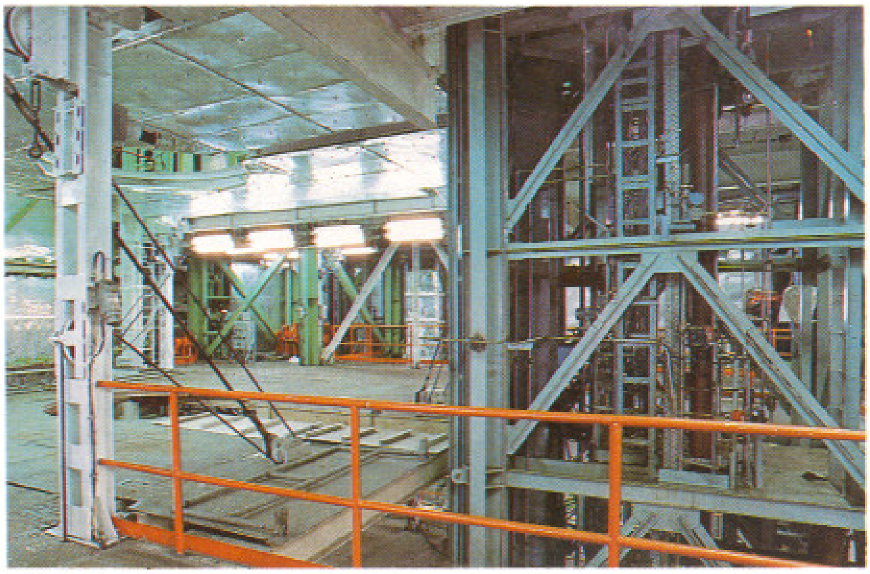
The wheel bogie system of MST - A powerful puller.

The whole MST is raised when it is on anchors and the wheels do not touch the rails. Eight hydraulic jacks of 500 tonne capacity each, two under each bogie, are used to lift the MST either to put it on anchors or on rails. When the MST is on bogies, it can withstand a maximum mean hourly wind velocity of 73km per hour and gust wind speed of 102km per hour for three seconds. Four hydraulically operated rail clamps serve as parking brakes when the MST is on bogies.

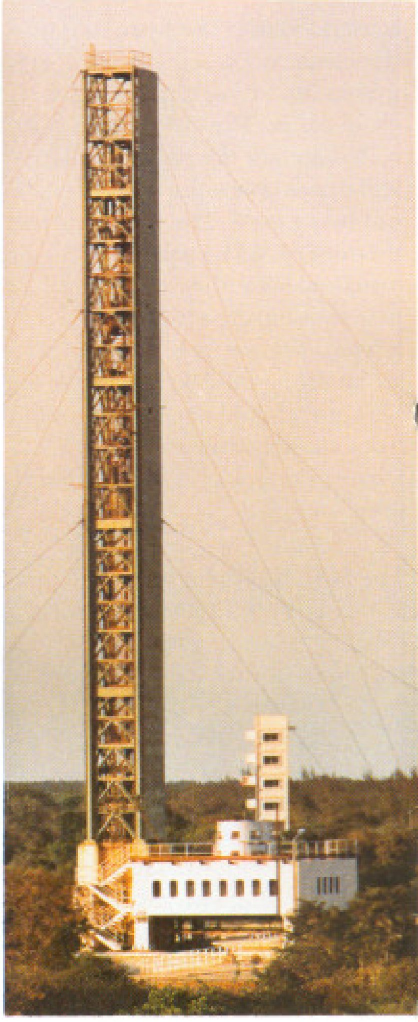
MST is provided with a special long life painting. All the steel surfaces are primer painted with 75 micron thick inorganic zinc silicate after sand blasting and cleaning. An intermediate coat of high build epoxy paint is then applied to dry film thickness of 70 microns and finally 30 micron thick polyurethane enamel paint is applied. The painting is expected to last for at least five years.

The launch pedestal is constructed of steel plates by welding. It acts as the base on which the stages of PSLV are assembled vertically inside the MST. The top surface of the pedestal is designed to be horizontal to an accuracy of 30 arc seconds and the differential deflection with the load of fully assembled PSLV acting on it does not exceed 1.5 arc minute. This has been achieved by high stiffness design, adopting a symmetrical shape for the pedestal to minimise differential deflections and employing elaborate welding fixtures, simultaneous symmetrical welding procedures, and hand

One of the foldable working platforms inside MST.



A section of the MST interior.



The Umbilical mast and Launch Pedestal.

scraping of the surface to obtain the required accuracy.

Launch pedestal is built with 10mx10mx3m steel box girders supported on 1mx1mx2m high column legs at four corners. The central ring girder which supports the PSLV, is connected by radial taper box girders to the outer box girders. The total weight of the pedestal is 175 tonnes. It is anchored over a wedge type jet deflector duct; the exhaust jet of the booster stage of PSLV passes through the central opening in the pedestal on to the jet deflector, and escapes from the sides. There are openings for the exhaust jets of strap-on motors to pass towards jet deflector.

An umbilical mast is located by the side of launch pedestal. It is a 51m tall steel structure with a cross section of 3m x 3m. It weighs about 75 tonnes. The umbilical tower houses propellant feed lines, check-out cables and duct for carrying cool air to equipment bay and satellite. Umbilicals along with retraction mechanisms are also connected to the tower. The front face of the tower is fully covered by steel shield plate to protect the cables against exhaust gases of booster stages of PSLV during lift-off.

The very fabrication and erection of the PSLV Mobile Service Tower is, both figuratively and literally, a tall order. Its successful fabrication is a tribute to the ever expanding space-industry collaboration. ☐

GROUND RESONANCE TEST ON PSLV

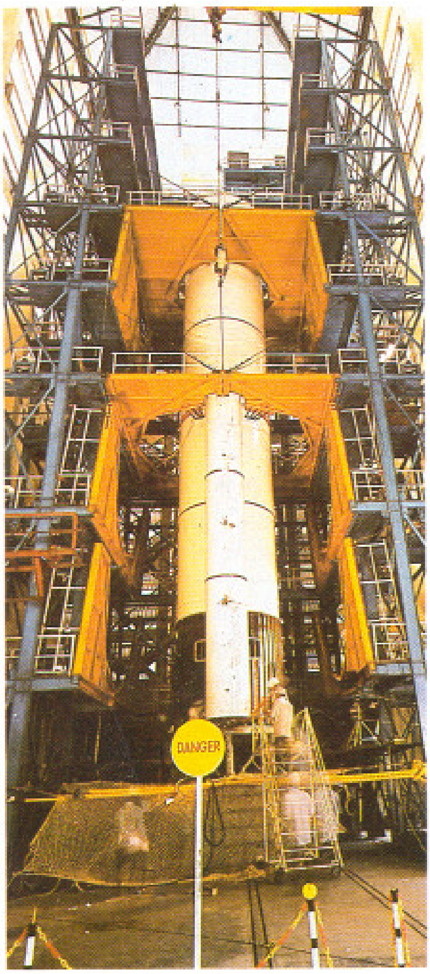
The Ground Resonance Test (GRT) on Polar Satellite Launch Vehicle (PSLV) first stage with strap-on motors in pitch and yaw axes was carried out during June-July 1990. The GRT for PSLV is planned to be conducted on two sub-structures independently - second stage and above (SD-2 model) and first stage with strap-on motors (SD-3 model).

Launch vehicles are acted upon by lateral forces, induced by wind and the vehicle control systems, during flight. These forces result in oscillating response of the vehicle which is picked by the inertial sensors on board. If these signals are not rejected by the control logic, unstable control-structure interactions may result leading to vehicle damage. It is, therefore, necessary to analyse the natural frequencies, mode shapes and damping characteristics of the complete launch vehicle. To estimate the natural frequency and mode shapes, a comprehensive mathematical model has to be developed and verified through dynamic characterisation tests.

The experimental results from the full scale structural dynamic model of PSLV will form the basis for the validation and updating of mathematical model used in the response studies, control- structure interaction studies and auto-pilot design.

The setup for the resonance test on PSLV includes a 30m tall assembly tower with platforms and a 50 tonne crane, low frequency suspension systems with six degree freedom using four 60 tonne hydro-dynamic bearings, model restoration system and snubber system for stability and safety. The facilities have been established at Valiamala near Thiruvananthapuram.

A dynamic test model with one to one similarity in stiffness and dimensional similarity with PSLV has been realised. The first and third stage solid propellant is simulated with dummy propellant and the second and fourth stage liquid propellant is simulated using water. The GRT is conducted in two sub-structures independently since the full length of the vehicle cannot be accommodated in the test set up.



PSLV first stage with strap-ons on the GRT setup.

The PSLV SD-3 model, weighing 227 tonnes, was floated on hydro-dynamic bearings during the test while the vibration response in lateral direction was obtained by excitation forces as low as 400N. The model was excited simultaneously by three shakers suspended from the tower. The response of the order of 100 to 1000 micro-g was measured using high gain piezo-electric vibration pick-ups. The data is being used for updating the mathematical model and to derive bending model of the complete PSLV through synthesis.

SALIENT FEATURES OF GRT

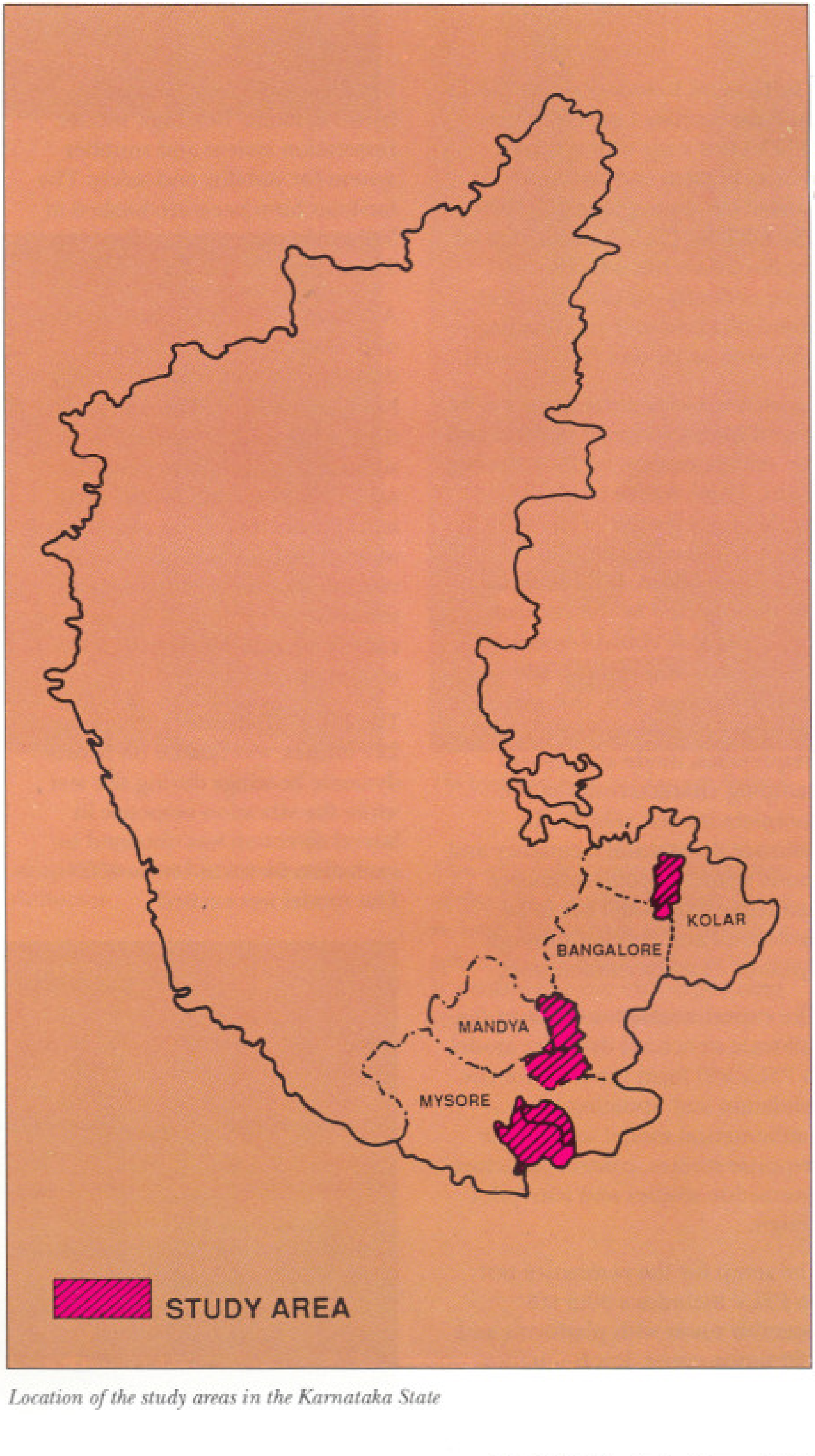
Mass of SD3 Supension	:	227 tonne Free-free simulation using 4 hydrodynamic bearings of 60t capacity enabling movements in rotation and translation.
Restoration system	:	Eight spring bank assemblies each at 2 planes meeting both static and dynamic stability criteria.
Test Methods used	:	Multi point normal mode and Single point transfer function
No. of shakers used	:	Five
Number of response measurements	:	55 (core) + 10 (strapon)
Frequency of operation	:	3Hz - 100Hz
Safety Devices	:	Snubber System at two locations and eight limit switches at top.

Satellite Data for Mulberry Crop Estimation

A pilot project, to evaluate the capability of satellite remote sensing techniques to identify and estimate the area under mulberry crop for five taluks in Karnataka State with a view to extending the methodology to larger areas, was recently undertaken by the Department of Space in collaboration with the Central Silk Board and the Department of Sericulture, Government of Karnataka. Assessment of mulberry garden condition, identification of suitable new sites for expansion of mulberry cultivation, and development of a model for forecasting silk cocoon production were the prime objectives of this project.

Sericulture, an important sector of rural economy in the country, plays a significant role in the programme of poverty alleviation. Mulberry, which accounts for 89 per cent of silk production, is cultivated mostly in the three southern States of India, viz. Karnataka, Andhra Pradesh and Tamilnadu. The domestic production of about 8000 tonnes of silk yarn is not adequate to meet the demands of the industry and imports have been steadily increasing. The demand for silk fabrics is growing at the rate of about 7 per cent per annum. To safeguard the domestic industry, one needs to achieve proper balance among imports, production and pricing.

Despite higher net return per hectare from mulberry (about Rs. 6,500/-) than from crops like jowar, ragi, sugarcane and pulses, mulberry cultivation is restricted to



Location of the study areas in the Karnataka State

Small fields of Mulberry cultivation coupled with coconut and mango trees.

A sample of Mulberry garden.

only a few pockets in the country even though congenial agro-climatic conditions prevail in other parts. There is a definite need for identification of suitable sites in new areas for extension of mulberry cultivation.

The Central Silk Board is responsible for the overall development of silk industry in the country and it examines the sericulture development programmes of the States. Area information is collected by statistical wings of the Department of Sericulture of each State Government. The forecasting of silk production is based on the actual distribution of Mysore Seed Cocoons (female) to sericulturists and rearing conditions of the silk worm. Although an elaborate information system exists at the grass- roots level, the accuracies of acreage estimation of mulberry and forecasting of silk production are no better than 80 per cent and 70 per cent, respectively. In this context, the Central Silk Board desired to use satellite remote sensing technology for a more accurate information.

A judicious mix of data collected by ground surveys and satellite-borne sensors was used in the pilot project. Both manual and computer-based automated data analysis procedures were adopted for mulberry crop identification and garden condition assessment.

The data from the Indian Remote Sensing Satellite, IRS-1A, were primarily used for estimation of mulberry crop acreage from the irrigated belt. Data from the US Landsat-Thematic Mapper (TM) were used in the preliminary studies to determine the spectral response of mulberry and associated cover types. Data from French SPOT satellite were used to supplement Landsat-TM and IRS-1A data for identification of rainfed mulberry crop.

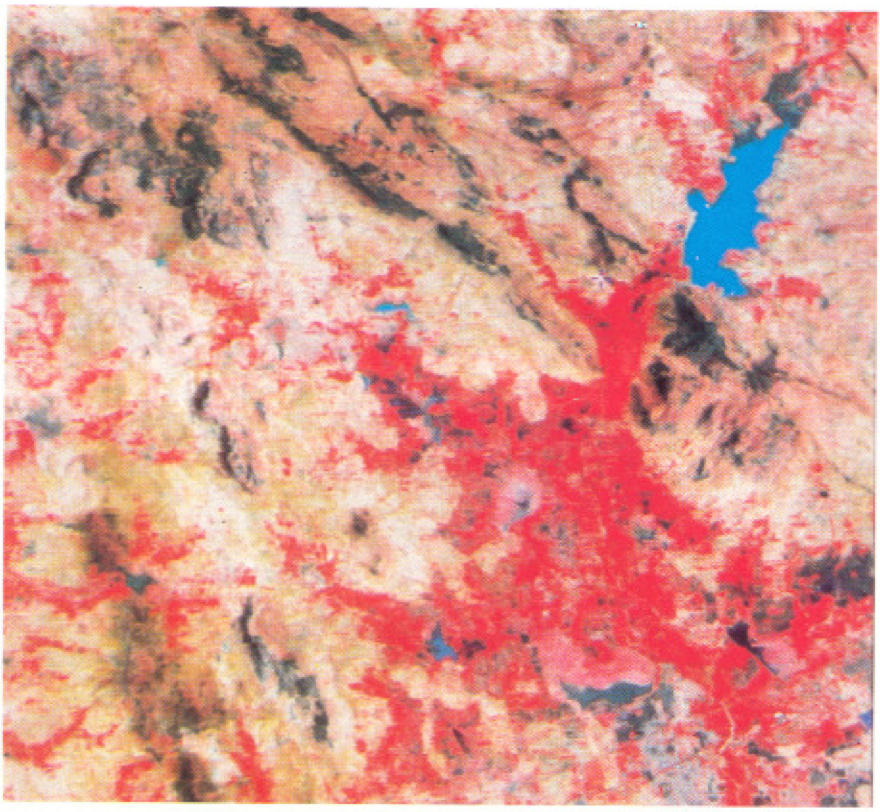
Based on the past statistics on mulberry acreage, physical environmental parameters such as soil type or garden management practices, five taluks were selected for the study. Due attention was paid to irrigated and rainfed mulberry zones in selecting the test sites. Channapatna taluk (Bangalore district) and Malavalli taluk (Mandya district) were selected from the irrigated belt. Chamarajanagar and Yelandur taluks (Mysore district) represent the rainfed tract. Sidlaghatta taluk (Kolar district) is unique for its well-irrigated mulberry plantations. These five taluks represent a wide range of soil properties, diverse cropping practices and frequent within-field variations.

For all the study areas, ground truth was collected using 1:50,000 scale standard False Colour Composite (FCC) of Landsat - TM. The scientists involved in ground truth collection were trained for visual interpretation as well as computer-aided digital analysis.

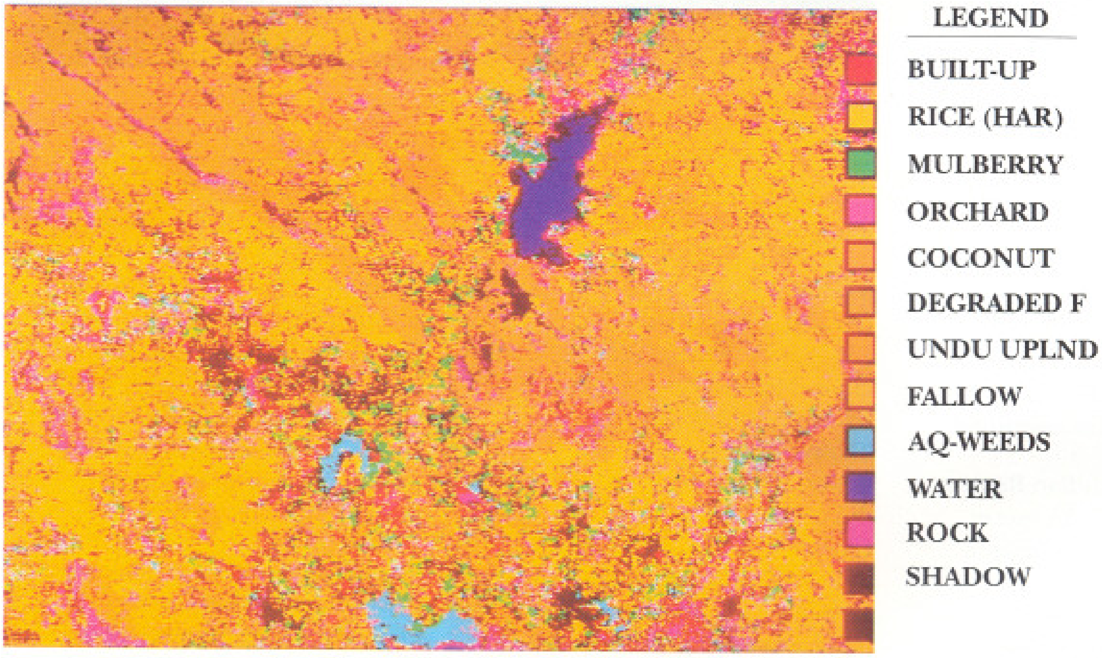
Prominent Ground Control Points (GCPs) were identified both on Landsat-TM FCC and on Survey of India (SOI) topographic maps on 1:50,000 scale. These GCPs were selected on the basis of easy approachability by road. Ground truth data, viz., crop types, soil type, mulberry garden condition and other cover types associated with mulberry were collected around these GCPs.

The Department of Sericulture, Government of Karnataka deployed a large number of field staff consisting of Taluk Sericulture Assistants and Sericulture Demonstrators for collecting detailed field-by-field information which was used for evaluating the classification- accuracy of acreage estimation.

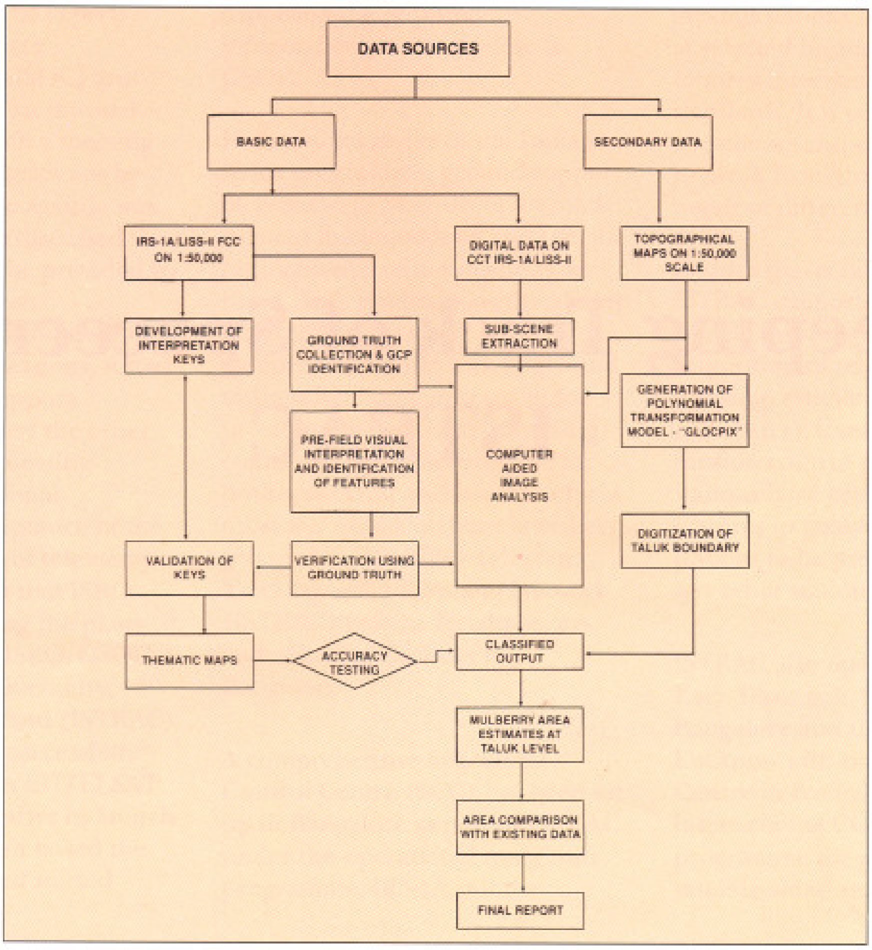
Analysis of spectral and temporal characteristics of mulberry and associated cover types was used in identifying mulberry plantations.



False colour composite of satellite data showing the crop land (top) and (bottom) Computer classified output of satellite data showing Mulberry (green) in the command area of Kanva Reservoir (Channapatna Taluk, Bangalore District).



The spectral response of mulberry crop was studied using Landsat-TM data covering visible (0.45 - 0.69 µm), near infrared (0.76-0.90 µm), middle infrared (1.55 - 2.35 µm) and thermal infrared (10.4 - 12.5 µm) regions. In general, the green plants show a dip in the red region (0.62-0.69 µm) due to chlorophyll absorption and a peak in reflectance in the near infrared (NIR) due to cellular structure of the leaf and leaf arrangement on the stem. A dramatic change in reflectance is seen in the shortwave infrared (SWIR) at 1.55 - 1.75 µm regions due to changes in the leaf water content. A combination of these four bands characterises the essential physiological functions of the green plants. Band combinations of red and NIR represent the photosynthetic capacity of the green plants, while the SWIR and middle infrared (MIR) represent the leaf water content which is governed by the rate of transpiration. Spectral transformations that provide good indications about plant parameters



Methodology for Mulberry crop inventory and mapping

are called Vegetation Indices. Further insight into the spectral separability of mulberry and associated cover types was obtained by studying spectral response of each cover type.

Based on the historical data, available from the Directorate of Agriculture and Department of Sericulture, Government of Karnataka, crop calendars (sowing and harvesting dates) were prepared. It was found that all crops, except perennials such as coconut, orchards and grasslands/ pastures, generally exhibit a rhythm in crop development which is different for different crops during the growing season.

The change in percentage of green cover through time could be monitored by plotting the variation in vegetation indices during the crop season. An analysis of temporal profiles of mulberry and associated cover types showed that the data acquisition in the middle of February or early March would be ideal for achieving greater separability of mulberry and associated cover types during the "rabi" season. Similarly, October and November were found to be the ideal period for best discrimination of cover types during the "kharif" season. Temporal profiles are important in determining the crop groups (kharif, rabi, annuals, perennials, etc).

Visual interpretation techniques were based on subtle tonal (colour) differences and other image elements such as texture (spatial variation), context (spatial relationship), pattern and associated scene. These techniques together with the spectral/ temporal characteristics of mulberry and associated crops were used for extraction of information through visual analysis. Visually identified features and crop types were used in subsequent digital analysis techniques. Computer-aided digital analysis of data from IRS-1A satellite was carried out on VAX-11/780 system at the Regional Remote Sensing Service Centre (RRSSC), Bangalore. The condition of the mulberry garden in terms of percentage of green cover (leaf area) was determined using Vegetation Indices.

The accuracy of mulberry crop acreage estimation is found to be 85 to 90 per cent even with one time satellite data. It is possible to further improve the accuracy by acquiring satellite data at least twice a year. Satellite derived vegetation index has proved to be very useful for assessing mulberry garden condition.

The approach for identifying potential sites for the extension of mulberry cultivation to new areas has also been conceptualised, and will be developed around a Geographical Information System. ☐

Keeping Track of Spacecraft - ISTRAC

A view of ISTRAC Facilities at Bangalore.

In June 1989, a team of experts from the German Space Operations Centre (GSOC) and ISRO had somewhat an unusual meeting. Not that such a meeting between the two agencies was by itself unusual, but the agenda was. In that meeting were discussed the details of support to be provided by ISRO for the European EUTELSAT launch mission. On a number of earlier occasions, it had all been about the support rendered and obtained the other way round. But this meeting marked the international recognition and acceptance of the standard and quality of telemetry and tracking support that ISRO can provide. Following the plans finalised during the ISRO- GSOC meeting, the ISRO Telemetry, Tracking and Command (ISTRAC) station at Bangalore successfully acquired signals from EUTELSAT satellite, 25 minutes after its launch on August 31, 1990 on board the Ariane-4 launcher and started supplying the required information on the satellite to GSOC.

In the initial stages of the Indian space programme, ground support facilities were basically tailor made to meet the immediate and specific requirements of the missions on hand. And, gradually, as the space programme got along, a comprehensive network of ground stations has come into being for providing the telemetry, tracking, command and other support for both spacecraft and launch vehicle missions. All the stations have been grouped under ISRO Telemetry, Tracking and Command Network (ISTRAC) with its Headquarters and principal facilities in Bangalore.

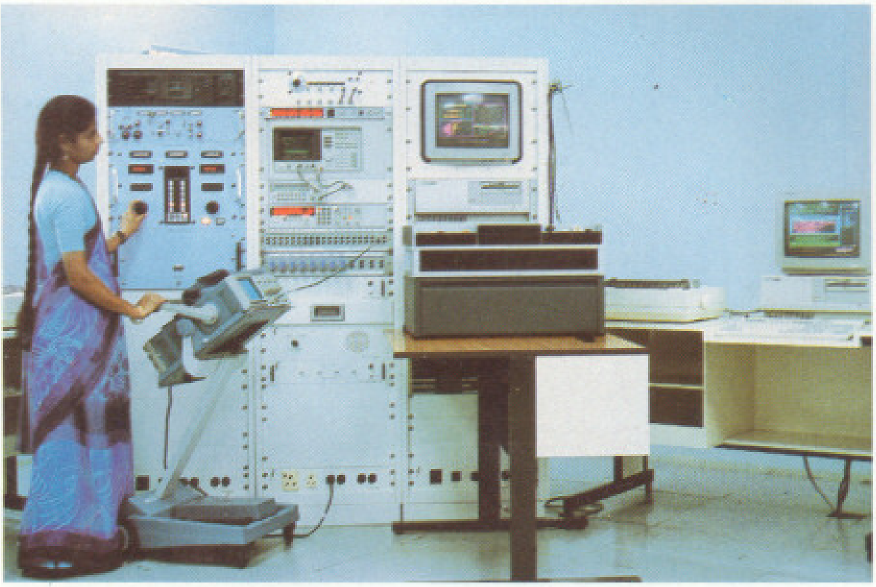
A comprehensive Spacecraft Control Centre (SCC) has been set up in Bangalore as part of ISTRAC under the operational spacecraft programme, IRS-1A. All the ground stations of ISTRAC, set up at selected locations, are designed to meet international performance standards. It is possible to coordinate and control the entire network from the SCC to meet the needs of different types of missions.

Besides spacecraft missions, ISTRAC supports all the launch vehicle missions of ISRO for acquisition of telemetry data, tracking, estimation of injection parameters, transmission of data to mission control centre, etc. The stations have certain common features to enable one of the stations to be used as a back up to any other station.

ISTRAC also operates two Local User Terminals (LUT), one in Bangalore and the other in Lucknow with the Mission Control Centre in Bangalore, under the international COSPAS-SARSAT programme for providing satellite-aided search and rescue

Sparecraft Control Centre at Bangalore

Mission Analysis room at Bangalore.



Local User Terminal at Bangalore for International Satellite-aided Search and Rescue Programme.

services. As and when the alert signals are detected, messages are flashed on to the four national rescue centres, viz., the National Airports Authority of India, Coast Guard, Navy and Airforce, which in turn initiate appropriate rescue operations. The Bangalore LUT and MCC also provide distress alert services to Bangladesh, Kenya, Somalia, Sri Lanka, Tanzania, Indonesia, Malaysia, Maldives, Singapore and Thailand.

The Laser and Optical Tracking Facility (LOTF) in the 100 acre campus of the Vainu Bappu Astrophysical Observatory at Kavalur, Tamil Nadu is part of ISTRAC network for specialised and accurate satellite tracking. The optical tracking system is capable of tracking Low Earth Orbit (LEO) satellites up to 9th magnitude over 120 degrees of the apparent arc of the orbit. Using a special technique, geostationary satellites up to 13th visual magnitude can also be photographed. After post processing, the camera provides an accuracy of the order of 2 to 5 arc second in position and one millisecond in timing.

The laser ranging system has an accuracy of 180 cm.

A major function of ISTRAC is to ensure close coordination between spacecraft and launch vehicle mission managers and the supporting ground stations, right from planning till the completion of the mission – a period that may span over several months or a few years. For this purpose, the ISTRAC Headquarters and its principal ground station and control facilities are located together in Bangalore. Besides providing a single point of contact to its users, the Headquarters carries out advance planning, scheduling, frequency coordination, monitoring and ensures maintenance of performance standards of the individual stations.

The ISTRAC facilities in Bangalore include:

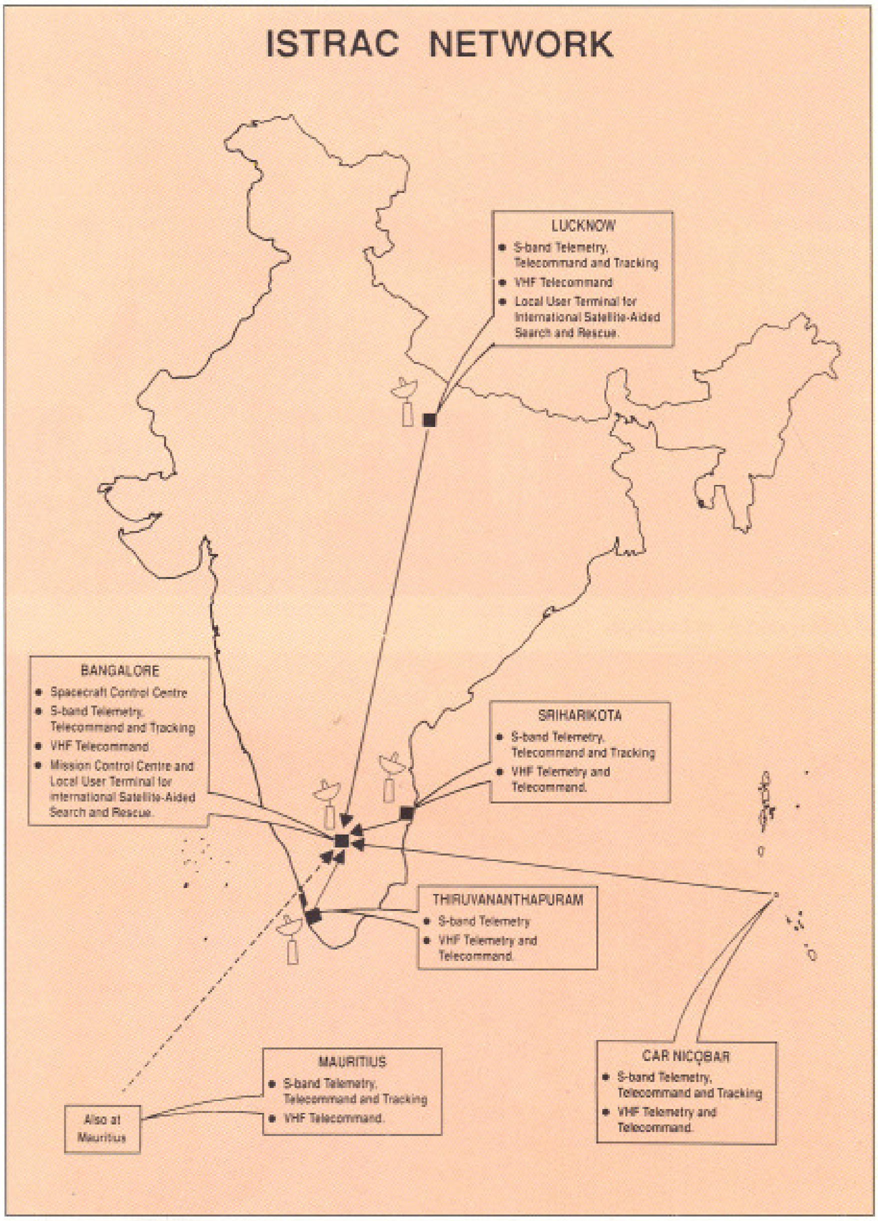
- Telemetry, Tracking and Command (TT&C) station.
- Multimission Spacecraft Control Centre (SCC)
- Communication Control Centre
- Local User Terminal and the Mission Control Centre for the international COSPAS-SARSAT satellite-aided search and rescue system.
- Computer facilities.

All the facilities are configured to form an integrated control complex for the entire ISTRAC network which acts as the focal point for the external support stations.

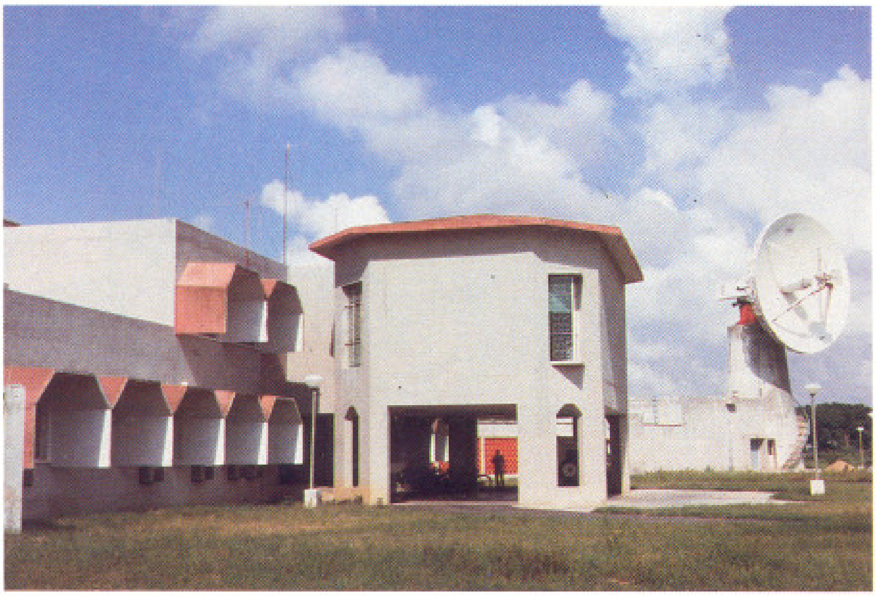
The operations and on-orbit maintenance of all near earth orbit spacecraft of ISRO are carried out by the SCC which can handle simultaneously up to four spacecraft missions, including one in its launch/initial phase of operations. Facilities are available for the individual spacecraft and mission control and analysis, each of which is equipped with operations control, monitoring and display consoles, data and voice links to all the concerned ground stations, etc. The computer facility enables real time and near real time analysis of the data received by the ground stations.

The extensive software capability available at the control centre for efficient operation of spacecraft missions, has been successfully demonstrated through the IRS-1A mission. Proven software packages are available for providing:

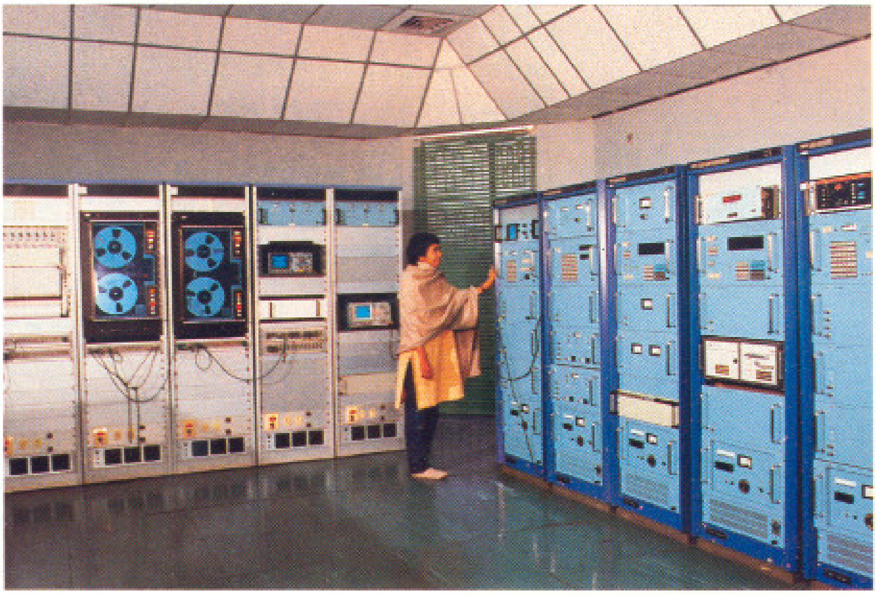
- real time and near real time status,
- trend analyses and display of spacecraft health from the telemetry data in a variety of formats and modes,
- orbit and altitude calculations,



ISTRAC Ground Station at Bangalore.



ISTRAC station at Lucknow.



TTC station at Lucknow.

Mobile TTC station at Mauritius.

- generation of ephemeris,
- target designation,
- eclipse conditions,
- ground track and visibilities of the satellite,
- orbit manoeuvre plans/strategies,
- execution of flight operations.

All the ground stations of ISTRAC network are linked to SCC through dedicated voice, data and TTY links. When needed, links are established with the supporting ground stations of agencies like European Space Agency, DLR of Germany, etc. The voice links enable coordination during all mission operations, pre-pass/post-pass briefing, checking the readiness and ensure availability of expert advice for problem solving. These voice links are normally terminated on the station intercom terminals but can be connected to dedicated telephone lines if needed.

The dedicated data links are used for transmission of telemetry and tracking data from the ground stations and for remote commanding from the SCC. The TTY links help exchange routine information and, in addition, act as a back-up for data links. The communication control centre ensures proper functioning of all links by regular monitoring and initiating corrective actions.

The computer facility supports round-the-clock operations of the SCC. The system, built around VAX-11 and micro-VAX class of machines, is configured as a dual computer system, each operating independently, and has a good real time capability. The system is provided with a communication processor in which the synchronous channels are switchable.

The Bangalore Complex houses the control centre of the entire ISTRAC ground stations network, apart from a full fledged S-Band TTC station.

The ISTRAC station at Lucknow provides continuity of coverage besides functioning as a full fledged backup for the Bangalore station. Two ground stations of ISTRAC, SHAR-I and SHAR-II are located at SHAR Centre, Sriharikota, which is the principal launch range of ISRO. These two stations support all the launch missions of ISRO and provide 100 per cent hot redundancy for the launch mission operations.

An ISTRAC station at Car Nicobar, south of the Andaman and Nicobar islands in the Bay of Bengal provides the main down range support for the launch missions carried out from SHAR Centre. The station is configured as a transportable terminal in five all-weather containers. The antenna, however, is mounted on a permanent frustrum.

The Thruvananthapuram ground station of ISTRAC is an additional down range station. It is located in Thumba Equatorial Rocket Launching Station (TERLS) of ISRO. The station is mainly used for launch vehicle missions.

An ISTRAC mobile station is also located in Mauritius, in the Indian Ocean, for providing support to IRS and the Polar Satellite Launch Vehicle (PSLV) missions.

Over the years, ISTRAC, while establishing the network of ground stations, has also developed inhouse capability for planning and providing complete ground systems support for operational spacecraft missions. It is now able to extend support to different types of spacecraft and launch vehicle missions not only for ISRO but also for external agencies. The support recently provided to the EUTELSAT mission is one such example. □

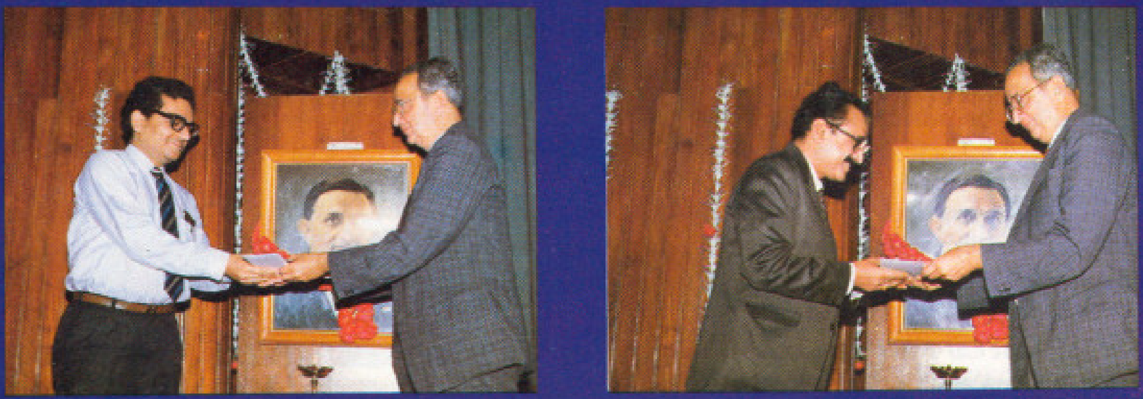
ISTRAC STATIONS AT A GLANCE

	Bangalore	Lucknow	Sriharikota		Car Nicobar	Thiruvananthapuram	Mauritius
			SHAR-I	SHAR-II			
Capability	*S-band TM, TC and Tracking *VHF TC	*S-band TM, TC and Tracking *VHF TC	*S-band TM, TC and Tracking *VHF TM & TC	*S- band TM, TC and Tracking	*S-band TM, TC and Tracking *VHF TM & TC	*S-band TM *VHF TM & TC	*S-band TM, TC and Tracking *VHF TC.
Number of carriers simultaneously receivable	2	2	4	3	3	2	3
Antenna dia. (m)	10	10	10	10	8	8	10
G/T db/deg.K (Min)	19.5	19.5	19.5	19.5	18	18	19.5
EIRP dBW (Max.)	75	75	75	75	73	-	75
Polarisation (S-band)							
- Transmit	RCP or LCP	RCP or LCP	RCP or LCP	RCP or LCP	RCP or LCP	-	RCP or LCP
- Receive	RCP & LCP	RCP & LCP	RCP & LCP	RCP & LCP	RCP & LCP	RCP & LCP	RCP & LCP
Uplink Frequency (MHz)	2025-2125	2025-2125	2025-2125	2025- 2125	2025-2125	-	2025-2125
Downlink Frequency (MHz)	2200-2300	2200-2300	2200-2300	2200- 2300	2200-2300	2200-2300	2200-2300

TM: Telemetry
TC: Telecommand
EIRP: Effective Isotopic Radiated Power

RCP: Right Circular Polarisation
LCP: Left Circular Polarisation

ISRO Scientists bag Vikram Sarabhai Awards



Prof. B.V. Sreekantan presenting the Vikram Sarabhai awards to Dr. Surendra Pal (left) and to Shri. M.G. Chandrasekhar (right).

Two ISRO scientists, Dr. Surendra Pal of ISRO Satellite Centre, Bangalore, and Shri M.G. Chandrasekhar of ISRO Headquarters, Bangalore, are the recipients of the prestigeous Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards for the year 1989. The biennial awards are instituted by the Hari Om Ashram at Nadiad in Gujarat, to foster and fulfill the ambitious programmes started by Dr. Vikram Sarabhai who was an outstanding scientist, an institution builder and a visionary. The awards are given to distinguished Indian scientists, below the age of 45 years, engaged in the fields of ;

a) Space Sciences,

b) Space Applications,

c) Electronics, Informatics, Telematics and Automation and

d) Systems Analysis and Management.

While Dr Surendra Pal received the award for his contribution in the field of Electronics, Informatics, Telematics and Automation, Shri M.G.Chandrasekhar was selected for the award for his contribution in the field of Systems Analysis and Management.

The awards were presented by Prof B.V.Sreekantan, the C.V.Raman Professor and former Director of Tata Institute of Fundamental Research, Bombay, at the investiture ceremony during the Vikram Jayanti celebrations at the Physical Research Laboratory, Ahmedabad, on August 9, 1990.

Dr. Surendra Pal joined ISRO, in 1971. He has been associated with all ISRO satellite programmes. His contributions towards realisation of telecommunication system (TTC-RF) for all Indian satellites are noteworthy. He now heads the Communication System Division at ISRO Satellite Centre, Bangalore. In his lecture, following the award, Dr Pal highlighted the innovative achievements and spin-offs of the technologies developed in the field of telemetry, tracking, command and data handling systems for the ISRO satellites. He also referred to the future trends in this area.

Shri M.G. Chandrasekhar, now Scientific Secretary, ISRO and Mission Director, IRS-1A, during his career spanning over 17 years in the Organisation, has made wide ranging contributions to the Indian space programme, particularly in the fields of systems analysis, satellite configuration studies, design and conduct of mission operations and programme management for all the satellite projects of ISRO. He has played a significant role as Deputy Project Director and as Mission Director of the Indian Remote Sensing Satellite, IRS-1A. Shri Chandrasekhar is also Director of ISRO Earth Observation Systems Programme Office at ISRO Headquarters. In his lecture, Shri Chandrasekhar presented an overview of the various elements that had gone into the mission planning of IRS-1A, and the multifarious factors involved in its mission analysis. He also talked about the methodologies and organisational tasks undertaken and described some of the unique developments related to the software for the spacecraft health monitoring, analysis and control. □

A
University for the World Community

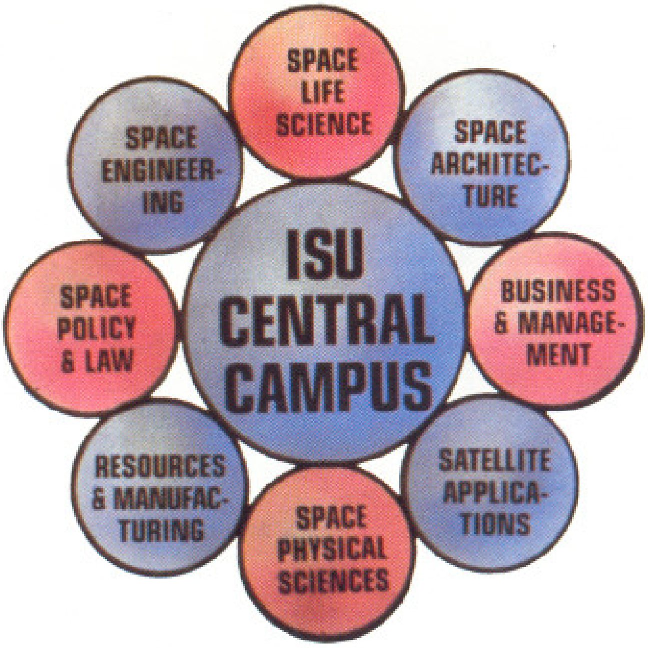
- International Space University

The International Space University (ISU), with its headquarters in the USA, is a non-profit international institution conducting graduate education programme in space research and development. The first educational institution of its kind, ISU was founded in 1987 to provide graduate level young professionals of demonstrable academic excellence and leadership qualities, with summer session programmes in space education. These include, but are not limited to, space science, engineering, policy, law, economics, architecture, research, business and applications.

ISU aims at becoming a global institution for space studies with student, faculty and financial participation from countries around the world. It aspires to excellence in education and research in every aspect of space, including the granting of appropriate degrees, producing text books and other academic materials, creating tele-education courses for satellite distribution and carrying out appropriate research. It is also expected that the alumni of ISU will, in time, form a cadre of dedicated space professionals that will provide leadership to launch humankind permanently into space.

The activities of ISU are guided by a Board of Advisors consisting of eminent scientists from different countries. Prof. U.R.Rao, Chairman, ISRO is a member of the Board of Advisors. "Through ISU, the world is witnessing the birth of a 21st century institution. Providing academic programmes that keep pace with the rapid growth of space research and development, ISU is truly cultivating a new generation of leaders dedicated to the peaceful use of outer space", says Dr. Arthur C. Clarke, the space visionary who is the Chancellor of the ISU.

The inaugural summer session of ISU took place at the Massachusetts Institute of Technology (MIT), USA in 1988. The programme for 1989 was held at the Universite' Louis Pasteur (ULP) in Strasbourg, France. The summer session for 1990 is being held at York University in Toronto, Canada. The 1991 summer session is planned to be in Moscow, USSR



and the 1992 session in Japan. ISU is also pursuing the goal of establishing a permanent campus during the International Space Year (1992), and adding satellite campuses for advanced research and study in existing centres of excellence located around the world.

The ISU aims at being financially independent while establishing equitable partnership with co-operating institutions. Endowment funds for academic programmes, professorships and research scholarships and campus facilities are sought from government and industry from all partcipating countries.

The International Space University summer sessions are designed to provide students with opportunities to:

- gain a general understanding of all technical and non-technical areas of importance in the exploration and development of outer space,
- study and work with the world's finest educators involved in space development,
- meet peers with common interests from leading universities around the world,
- participate in a real-world design project of importance to near- term space research and development, with opportunity to continue this work at their home institutions,
- discuss common goals, motivations, and ideals towards enhancing international collaboration on space development projects in the years to come, and
- share dreams, ideas, and plans for the future of international space development.

The countries participating in ISU activities are Australia, Austria, Belgium, Brazil, Canada, Colombia, Ecuador, Egypt, F.R. Germany, Finland, France, Great Britain, Greece, **India**, Ireland, Italy, Japan, Kenya, Luxembourg, Mexico, The Netherlands, Nigeria, Norway, P.R.China, Philippines, Poland, Saudi Arabia, Spain, Sri Lanka, Sweden, Switzerland, Syria, Taiwan, UAE, the USA and the USSR.

ISU operates worldwide through a series of liaisons - individuals or institutions who take on the initial 'advocacy' role for their nation's involvement in the ISU mission. ISU hopes to establish in each nation a national liaison to act as chief coordinator for that nation's participation. Among the liaisons' most important functions are student selection, fund raising, and helping ISU identify faculty members from that country.

International Space University believes that the peaceful exploration and development of space is a universal objective. With the co-operation of all nations, ISU is helping to prepare tomorrow's leaders for the international outer space activities. ☐

Role of Computers in Indian Space Programme

A three day Workshop on "Trends of Computing in ISRO" was conducted during July 24-26, 1990 in Bangalore to discuss the spectrum of computer applications and strategies for the future. Representatives from the Indian computer industry and computer professionals from Department of Space\ISRO and Department of Electronics participated in the Workshop.

Computers play a dominant role in both the development and operational phases of launch vehicles and satellites. To meet the requirement of space programme, a number of computers has been procured in ISRO over the years, both from indigenous and foreign sources. The percentage of indigenous content in the computer equipment procured by ISRO has been growing rapidly. The indigenous content which was hardly ten per cent during the Sixth Plan period went up to 50 per cent during the Seventh Plan period (not including the PCs).

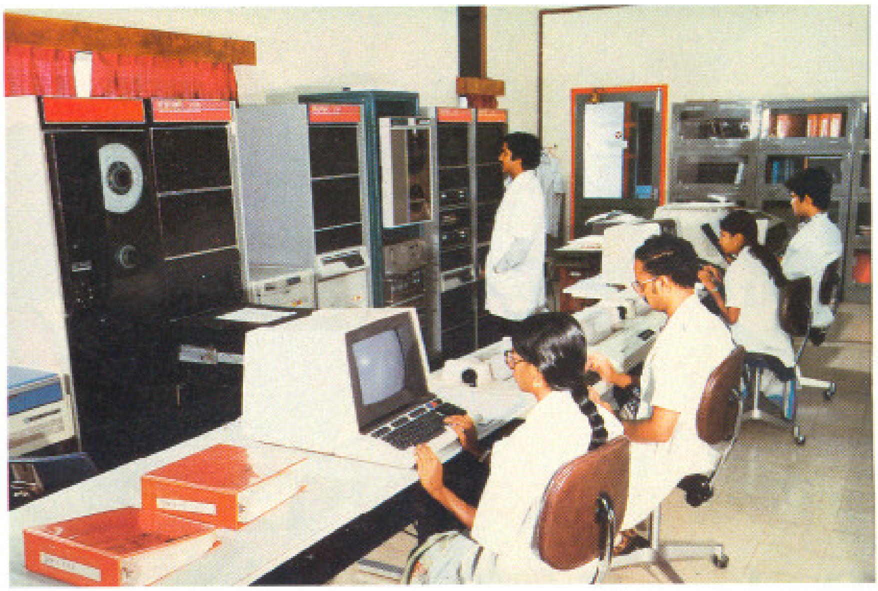
Vax-11/780 Computer used in NRSA for image processing.

The Workshop was organised to coincide with the beginning of the Eighth Five Year Plan during which the indigenous computer industry is expected to play a vital role in saving precious foreign exchange. It is to be noted that there are uncertainties in importing high-tech computer items due to import restrictions. It is time that the Indian computer industry adopted a "niche market" type of approach where each company specialises providing a total solution in a few selected application areas.

Computer applications in ISRO can be broadly classified into application areas such as large scale scientific computing, simulation, CAD/CAM, data acquisition and control, check-out systems, real time systems, image processing systems, integrated data bases and project management.

Large scale scientific computing covers the basic design of the launch vehicles and satellites where detailed structural, control, aerodynamic and optimisation analysis have to be performed. During the last ten years such analyses have been performed on mainframe computers of the CYBER/UNIVAC/DEC type which are inadequate for the present day requirements of ISRO. Therefore, new approaches including parallel processing using transputer boards are being explored to meet the current and future requirements. It is possible that several levels of computers such as work stations, super-minis in conjunction with large mainframes have to be planned. Much of the application code used in ISRO has been standardised.

Detailed simulations need to be conducted at every stage of the design of launch vehicles and satellites to ensure proper performance under specified constraints. These are conducted by "carrying out the mission" on the computer. At the beginning of the project the simulation is purely digital. As the hardware



PDP-11 Computer used for Spacecraft checkout at ISAC.

Computer used for Hardware-in-loop simulation at VSSC.

Terminals of Cyber mainframe system at VSSC.

development progresses, more and more hardware is put into the simulation loop (hardware-in-loop simulation), so that the hardware also gets tested in a simulated flight environment. High computational speeds and I/O bandwidths are the important features required for this purpose. In future, ISRO plans to expand these facilities to have more processing power, high speed I/O devices and real time graphics.

The detailed design of the various sub-systems, both electrical and mechanical, of launch vehicles and satellites is performed using Computer Aided Design. Although ISRO has got into these areas only two to three years back there has been a considerable growth in the requirements for such stations. Since the work at ISRO is highly development oriented, it calls for design modifications made from the engineering model stage up to the final flight model. In this context, use of CAD/CAM stations has led to better productivity and lesser turn-around time. Workstations networked on a token ring are used for schematic capture, circuit simulation and PCB layouts for different electronic sub-systems. For detailed analysis, the workstations are linked to a mainframe. Expansion with more emphasis on CAM, PC-based workstations and integrating the work on electrical CAD with related mechanical CAD are some of the future plans.

Real time data acquisition and control systems are used during the qualification tests of subsystems such as static testing of rocket motors. Since some of these tests are expensive to conduct, reliable data acquisition systems are required to ensure that no data is missed and proper interpretation can be made.

As the flight hardware gets realised, it is subjected to detailed checkout at various stages to ensure its compliance with specifications laid down. This continues till the launch when a final checkout is made on the

UNIVAC system at ISAC.

Large Space Simulation Chamber Data Processing System at ISAC.

A view of the Exhibition organised at "Antariksh Bhavan", Bangalore during the Workshop "Trends of Computing in ISRO".

launch vehicle and the satellite. ISRO has automated this process using software developed in-house with real time interfaces of the operating systems, digital/analog inputs, external hardware interfaces and associated device drivers connected to minicomputers.

The flight of the launch vehicle, though of short duration, is critical and demands reliable computer support. In the initial phase of the flight, safety is the primary consideration since any deviation in the launch vehicle trajectory may endanger populated areas near the launch pad or around the down range. Soon after injection of the spacecraft, a number of critical operations are to be performed within a short period to stabilise the spacecraft in the intended orbit. Subsequently, the satellite health is to be monitored continuously. Hence, good communication handling capabilities along with fast interrupt response are required. ISRO has developed software in-house for all these applications and the investment in software amounts to several hundreds of man years.

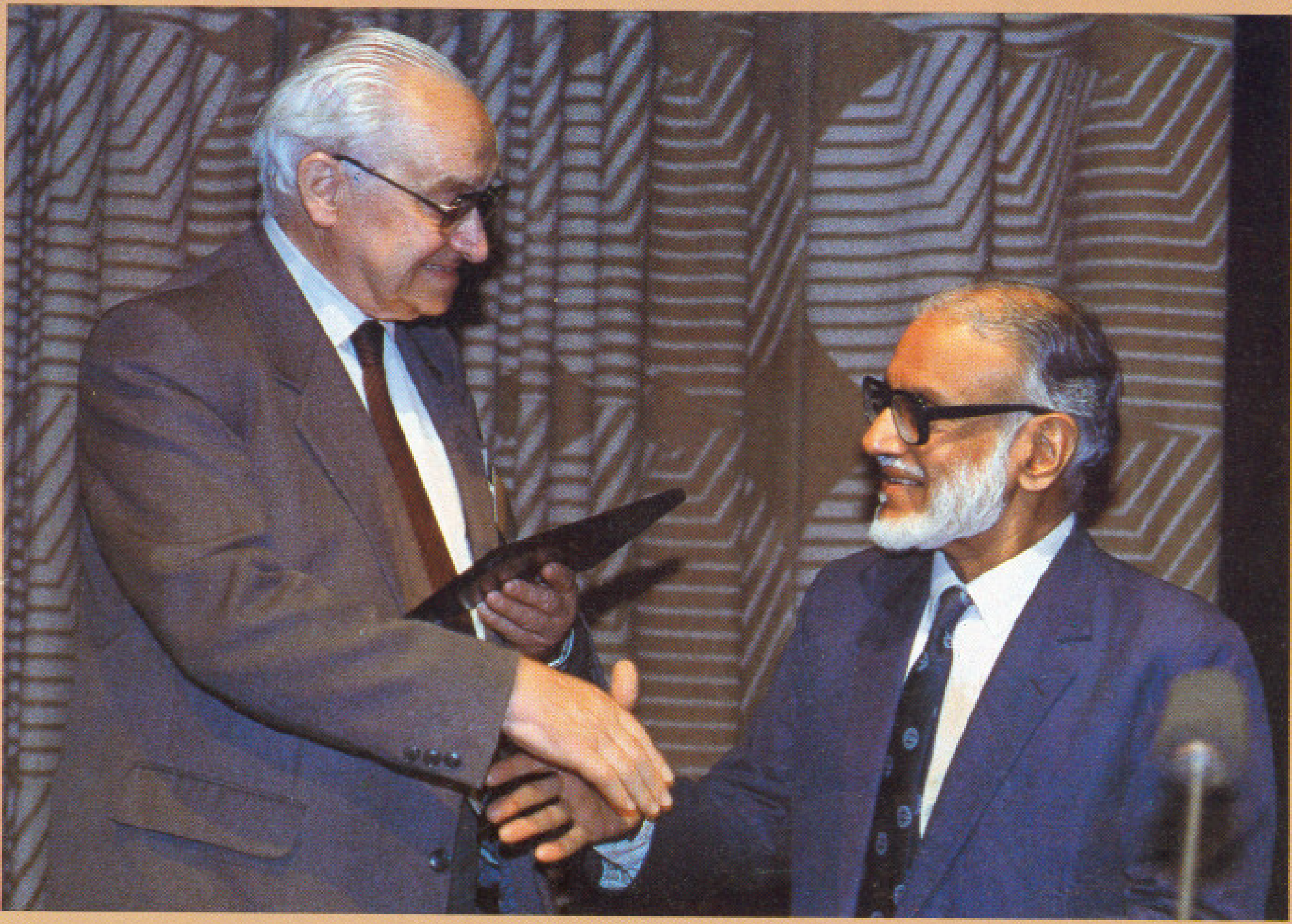
A dual VAX-11/785 system is now being used for launch vehicle trajectory monitoring for range safety purposes. The system also provides post-flight analysis to assess the vehicle and ground station performances.

Multiple VAX/Micro VAXs with front end I/O computers and floating point array processors are used for acquisition and pre-processing of all remotely sensed data from the satellites. Data acquired during a satellite pass is framed, radiometrically corrected, formatted and suitably annotated in real time. The imageries consisting of millions of pixels are to be processed within a reasonable turn-around time. This requires powerful image processing computers augmented with array processing with interactive facilities.

The data collected by remote sensing, meteorological and scientific satellites need to be stored on a long term basis to facilitate easy retrieval when required.

The execution of ISRO projects involves many work Centres not only within ISRO but also in the public and private sectors. To keep track of the large number of activities, ISRO has been using different project management software.

The Workshop "Trends of Computing in ISRO" provided an opportunity for ISRO and industry to come face to face and exchange views on the ISRO computer requirements in the current decade. It is, perhaps, for the first time that a major computer user like ISRO has projected its requirements to the indigenous industry well in advance so that the industry can gear up to meet the challenges.



The first Vikram Sarabhai Award instituted by the Indian Space Research Organisation (ISRO) being presented to Academician V.A. Kotelnikov of the USSR by Prof. M.G.K. Menon, Minister of State for Science and Technology, Government of India, during the 28th COSPAR meeting held on June 25, 1990 at The Hague, The Netherlands. (See Space India 2/1990). Prof. Menon delivering his address (bottom)

An evening near Mobile Service Tower at Sriharikota.