2/1990

SPACE india

INDIAN SPACE RESEARCH ORGANISATION

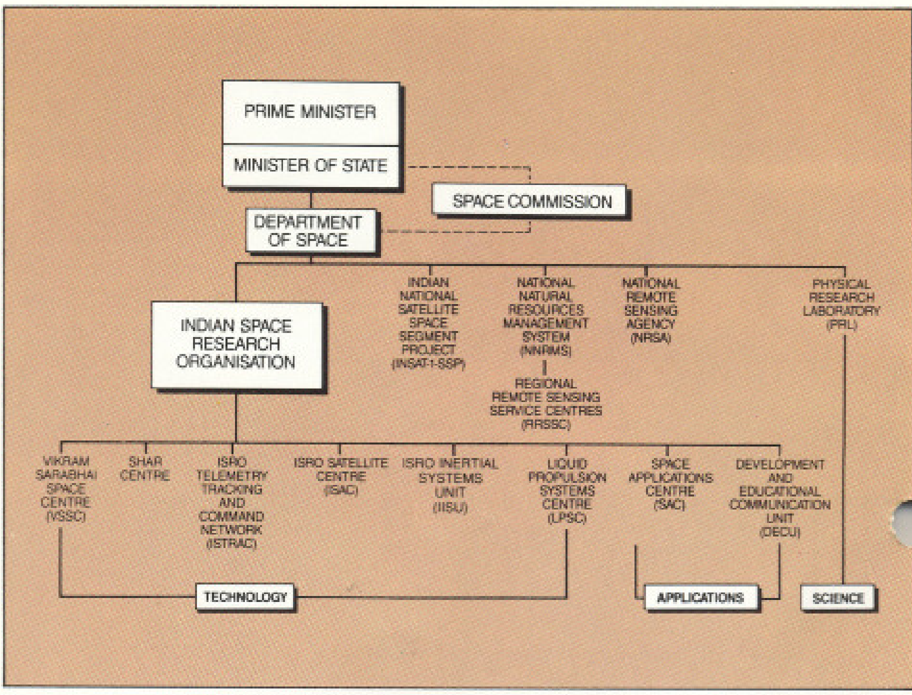
The Indian Space Programme

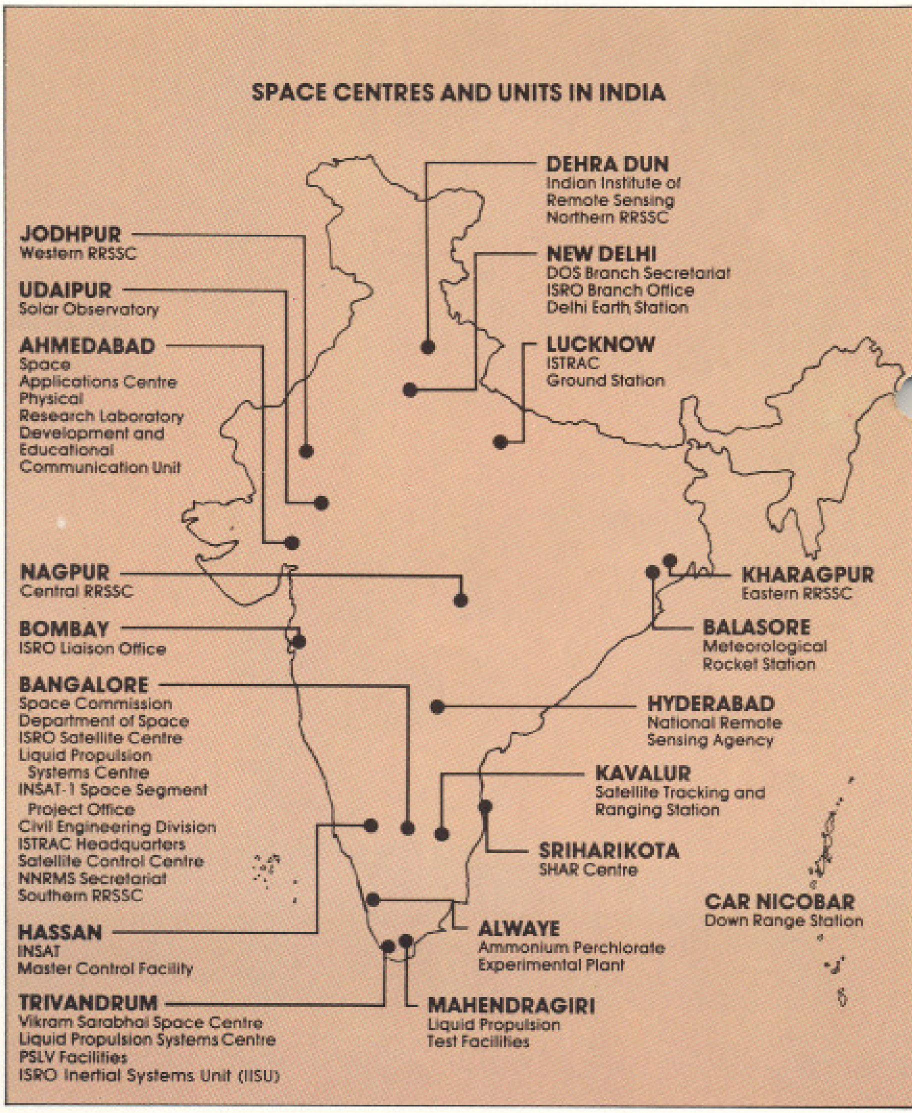
The setting up of the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 marked the beginning of the Indian Space Programme. The Space Commission and the Department of Space (DOS) were established by the Government of India in 1972 to promote unified development and application of Space science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





FRONT COVER

INSAT-1D and Master Control Facility – an artist's view

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Contents

April – June, 1990

SPACE India is published quarterly by the Indian Space Research Organisation for limited circulation. Articles appearing in *SPACE India* may be reproduced accompanied by the credit line "Reprinted from *SPACE India*" along with the date of issue.

Editorial/Circulation Office:
Publications & Public Relations Unit, ISRO Headquarters, Antariksh Bhavan, New BEL Road, Bangalore-560 094. India.

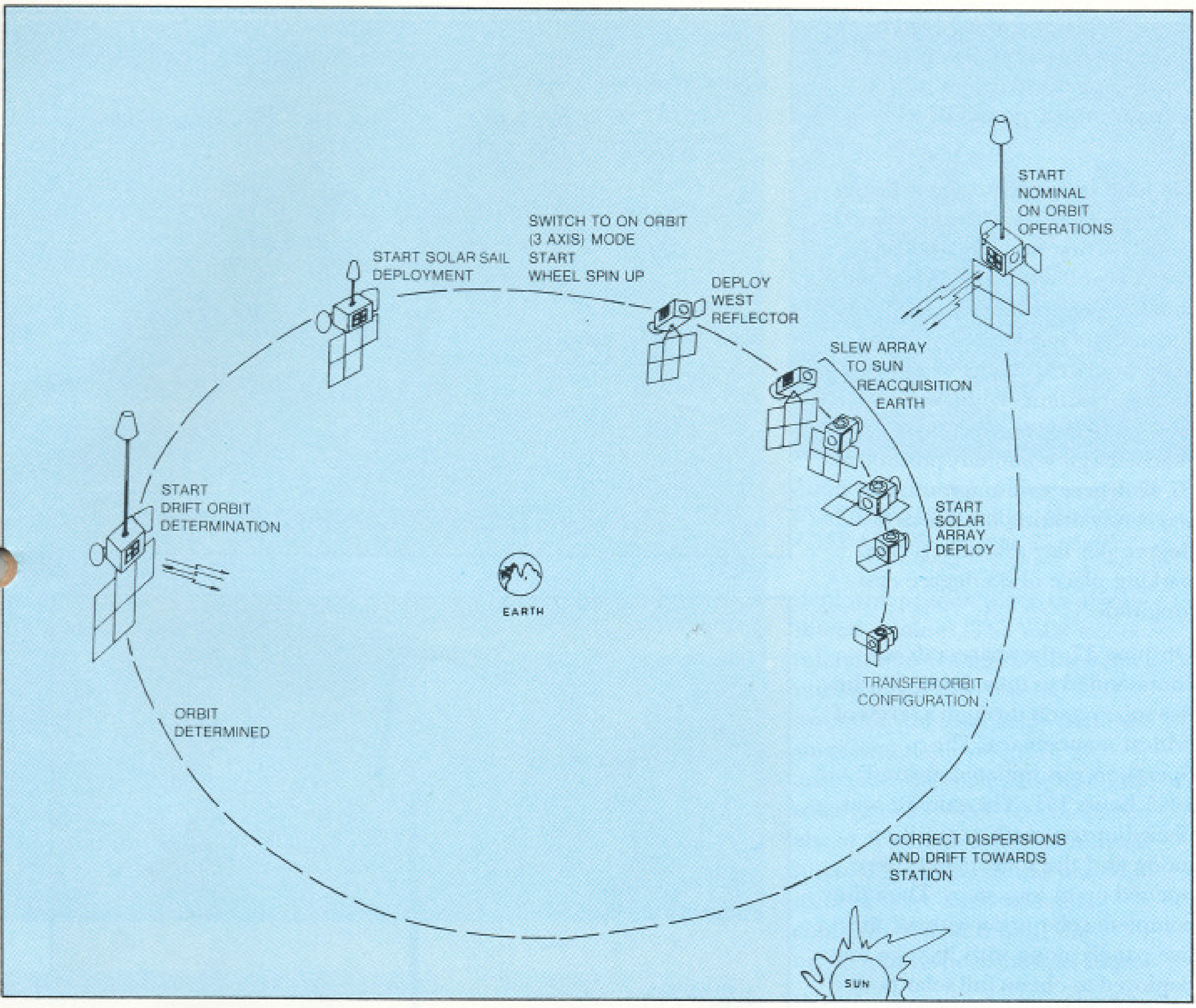
Printed at Thomson Press, Faridabad, India

INSAT-1D Launched

The INSAT-1D spacecraft was successfully launched on June 12, 1990 by the Delta 4925 Launch Vehicle of McDonnell Douglas Space System Company, USA. The Launch took place at 1122 hours IST from the Eastern Space and Missiles Centre, Florida, USA. The Delta Launch Vehicle delivered the INSAT-1D Spacecraft into a geosynchronous transfer orbit. INSAT-1D is the last of the first generation INSAT satellite series built by the Ford Aerospace Corporation (FAC), USA. It will provide communication, TV broadcasting, radio networking and meteorological services to the entire country. It has, like its predecessors, twelve C-band transponders, two high power S-band transponders and a very high resolution radiometer which can take meteorological pictures both in the visible and in infrared bands.

Delta launch vehicle with INSAT-1D on board ready for lift-off.

The injection of INSAT-1D occurred over the continent of Africa at 1146 hours IST on the launch day. The Master Control Facility (MCF) at Hassan in Karnataka State acquired the satellite telemetry signal at 1203 hours IST. INSAT-1D was separated from the Payload Assist Module, which is the last stage of the rocket, by commanding from MCF at 1238 hours. Thereafter a check on the satellite health was made and the satellite was despun and commanded to the 'sun acquisition mode' whereby the west face of the satellite was oriented towards the sun. Two of the five solar panels (No.4 and 5) were deployed at 1303 hours to provide electrical power in the transfer orbit of the spacecraft and a minute thereafter, C-band antenna was also deployed. The orbit of INSAT-1D was computed before attempting the next manoeuvre of raising the perigee and taking the satellite from the transfer orbit to near-synchronous orbit. The transfer orbit after the launch had the apogee at 39,860km and the perigee at 173km with an inclination of 26.9



INSAT-1D on-orbit deployments.

degree. The period of revolution in the transfer orbit was about 11 hours. Towards the end of the first orbit the satellite went out of radio-visibility from MCF. Using support from a global network of tracking stations, it was possible to receive all spacecraft telemetry continuously.

INSAT-1D came again within the visibility of MCF at 1143 hours IST on June 13, and the signal reacquisition took place as expected. The apogee motor firing was successfully carried out for about 56 minutes at 1700 hours IST to raise the spacecraft perigee to near-synchronous orbit. With this manoeuvre, the perigee was raised from 173km to 32,377km and the inclination brought down

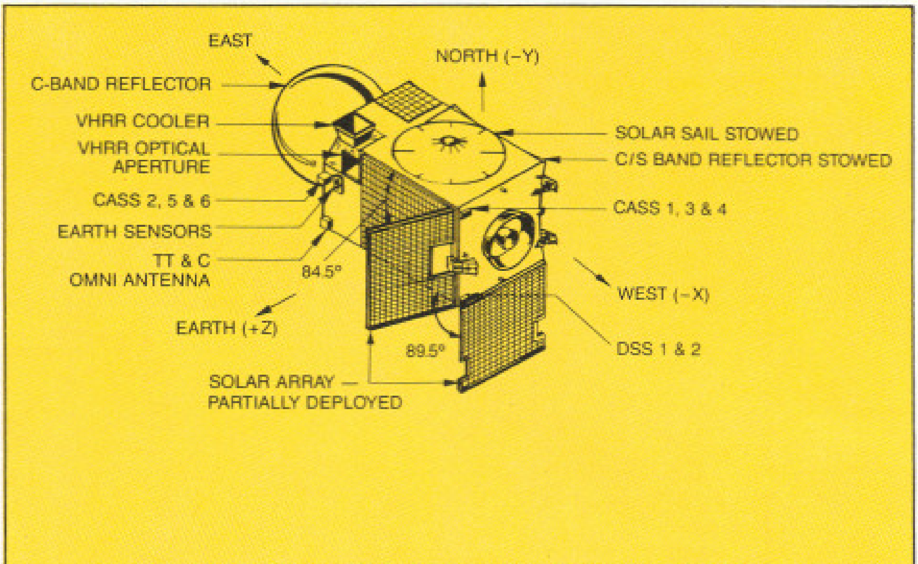
INSAT Master Control Facility, Hassan.

from 26.9degree to 0.5degree. Thus the spacecraft was placed into near-geosynchronous orbit with an orbital period of 24.9 hours.

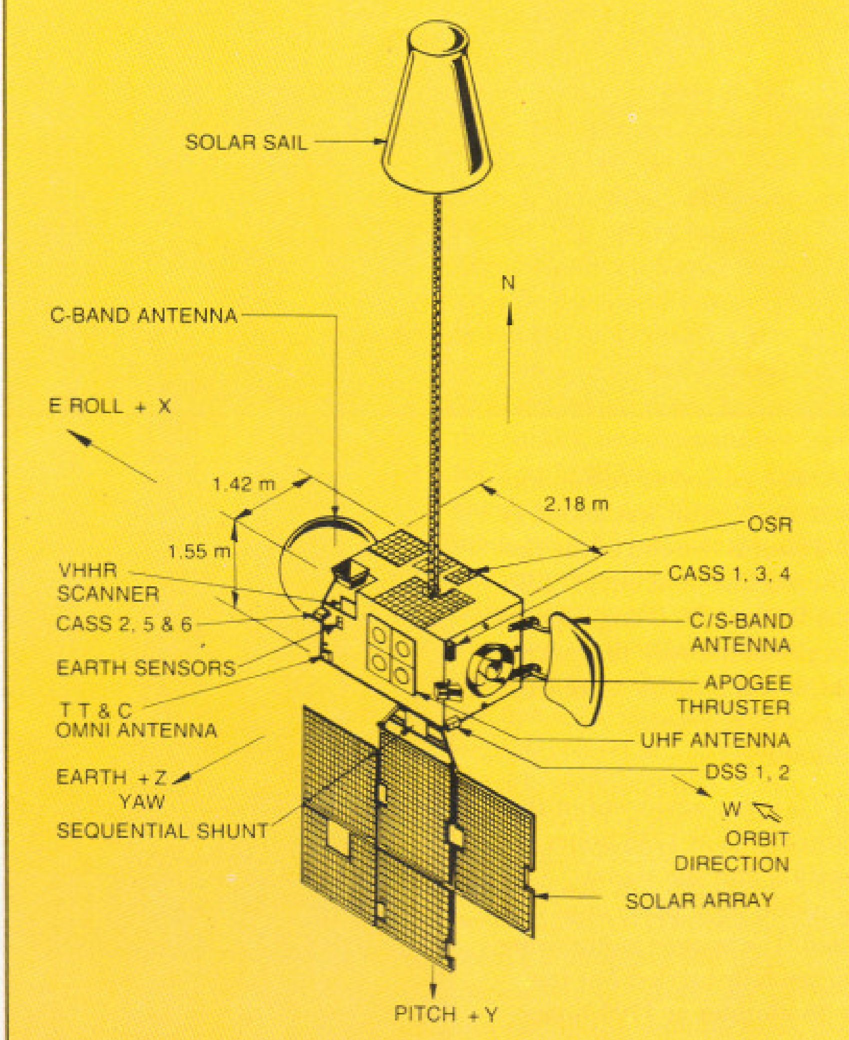
On June 16, two more short firings of the apogee motor were carried out. The first one was for 106 seconds at 0500 hours IST at the satellite perigee position and the second one was for 107 seconds at 1600 hours IST at the satellite apogee position. With these two trim manoeuvres INSAT-1D reached a geostationary position at 87.42 degree east longitude and it was slowly drifting westwards at 1.2 degree per day towards its final parking place of 83 degree east longitude.

On June 17, the spacecraft was commanded to fully deploy all the five solar panels through a series of critical manoeuvres. The operation was initiated around 1445 hours IST. The satellite was placed in the earth acquisition mode and the solar panels were opened up in four steps. Then the complete solar array with all the five panels along with its yoke was deployed to obtain full solar power of about one kilowatt. Subsequently the satellite was placed in a body-stabilised mode with the help of one Momentum Wheel (spinning at a speed of about 5900 rpm) and Reaction Wheel (spinning at a speed of about 2700 rpm) on board the spacecraft. The solar panels were slewed to continuously track the sun.

On June 18, commands were issued from MCF to deploy the C/S band antenna, simultaneously releasing the solar sail boom. The C/S band antenna is used to provide downlink transmissions from the spacecraft in the C-band for telecommunication applications and in the S-band for TV and radio networking applications.



TRANSFER ORBIT CONFIGURATION



ON-ORBIT CONFIGURATION

INSAT-1D CHARACTERISTICS

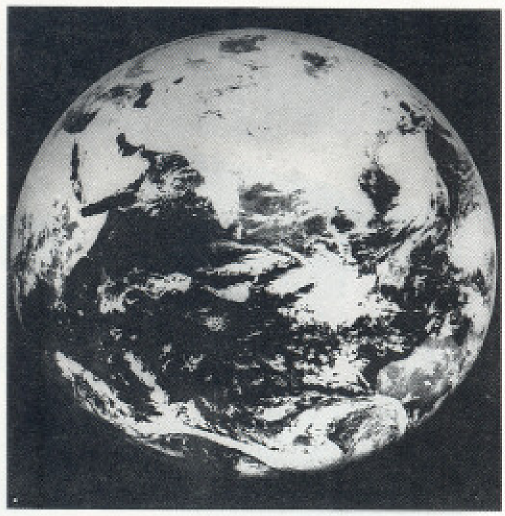
Mass	: 1293 kg at lift-off
Size	: 19.4x1.68x5.84 m (in deployed configuration)
Solar array power	: 1150 watts at the Beginning of Life (BOL) summer solstice (minimum)
Battery	: 2x18 Ah Ni-Cd batteries
TTC frequency	: C-band

SERVICE PAYLOADS

Fixed Satellite Service	: Twelve, 36 MHz wide, 35dBW (peak) transponders operating in 6GHz (uplink) and 4GHz (down link) bands.
Broadcast Satellite Service	: Two, 36MHz wide, 45dBW (peak) transponders operating in 6GHz (uplink) and 2.5GHz (down link) bands
Data Relay	: One transponder operating in 402MHz (uplink) band
Meteorological Imaging	: A Very High Resolution Radiometer (VHRR) instrument operating in visible (0.55-0.75 u m) and IR (10.5 – 12.5 μ m) bands. 2.75 km resolution in visible,11km resolution in IR.

Satellite Control Centre at MCF, Hassan.

In the stowed position, the solar sail boom is coiled within a canister and the sail mounted at the tip of the boom folded against the north face of the spacecraft (opposite the solar array). After reconfiguring the satellite, the full deployment of the solar sail extending to 12.66 metres was successfully achieved. The boom slowly extended to its full length latching on to a stiff configuration. The complete sail deployment took place in about fifteen minutes. The solar sail is intended to counteract the solar radiation pressure on the asymmetrical solar array. With the successful deployment of the antennae, the solar panels and the solar sail of INSAT-1D completed ahead of schedule and without any hitch, the spacecraft was placed in its final three-axis-stabilised configuration with both the momentum wheels in operation.

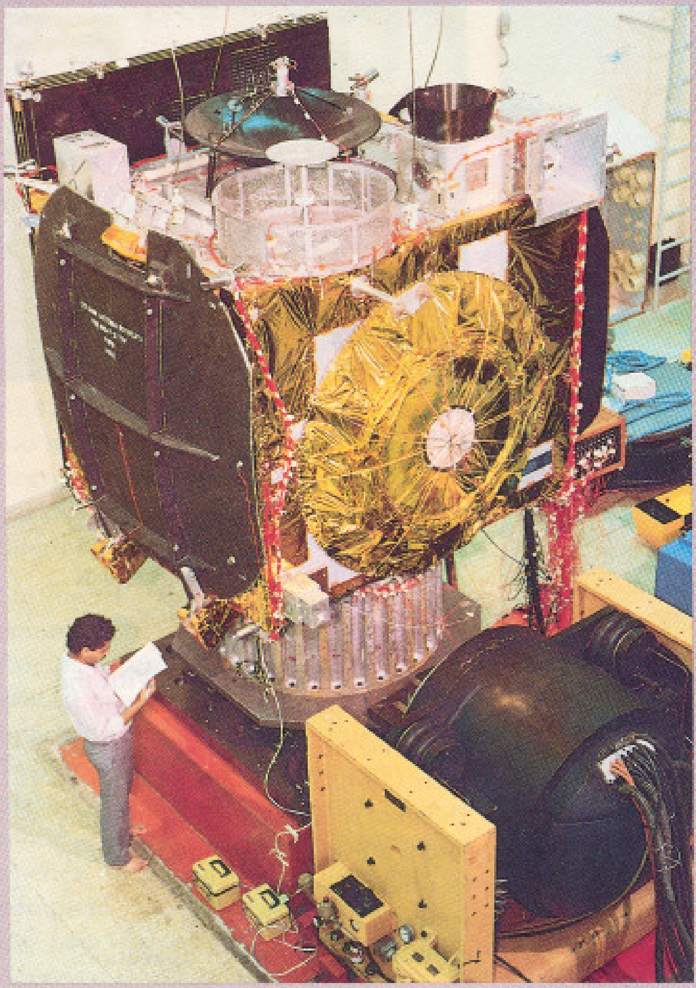


Initial cloud cover picture received from INSAT-ID VHRR (visible channel) at 11.52 hrs. IST on June 23, 1990.

INSAT-1D reached its parking slot at 83 degree east longitude on June 21, 1990.

From June 20, 1990 onwards, various payloads were switched 'On' phase by phase. The twelve C-band transponders and the two high power S-band transponders were switched 'On' to confirm their satisfactory functioning. The data relay transponder meant for collecting meteorological and other data from remote locations was also confirmed to be working well. The Very High Resolution Radiometer (VHRR), which takes meteorological pictures was also turned 'On' and the cloud cover pictures in the visible band obtained.

After detailed in-orbit characterisation of the payloads the satellite will be put into operational service. □

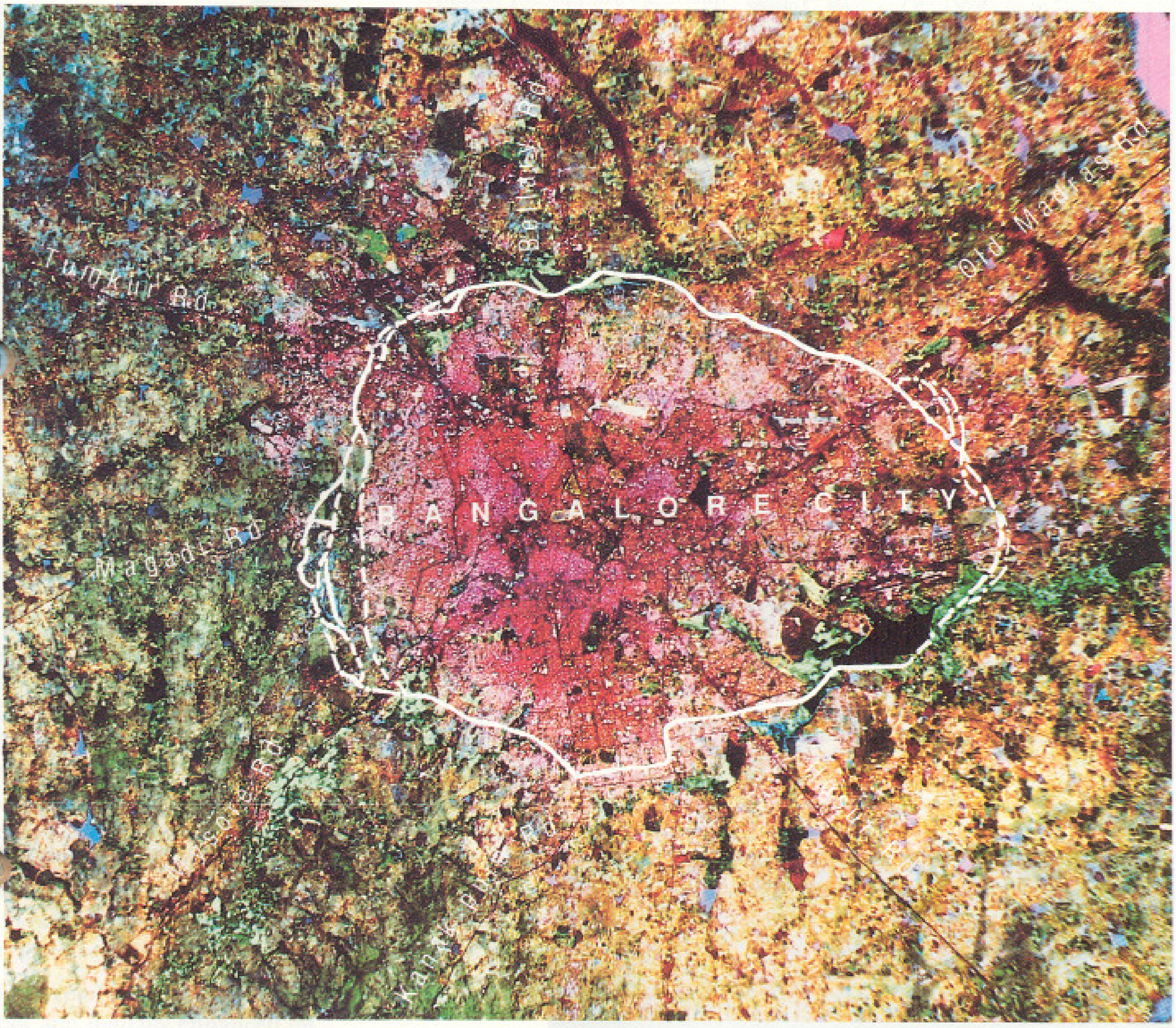


INSAT-2 structural model undergoing vibration test

INSAT-2 Series

The fabrication of three more spacecraft in the INSAT-2 series, namely, INSAT-2C, 2D and 2E has been approved by the Government of India. These will be in addition to the two test spacecraft (INSAT-2A and 2B) in the second generation INSAT series, already approved in April 1985. The approval for additional operational spacecraft comes in the light of the INSAT-2 spacecraft project having made substantial progress in the realisation of the structural and electrical thermal models and the need to carryout the transition from INSAT-1 Space Segment to INSAT-2 Space Segment in the time frame 1993-95. The INSAT-2 Space Segment will consist of three Indian designed and built spacecraft, each having significantly larger Space service capabilities than those of INSAT-1 spacecraft. Each of the INSAT-2 spacecraft will have eighteen C-band fixed satellite service transponders, two S-band broadcast satellite service transponders, Very High Resolution Radiometer with 2 km resolution in visible and 8 km resolution in infrared channels, a data relay transponder for meteorological services, and a 406 MHz transponder for satellite aided search and rescue mission. □

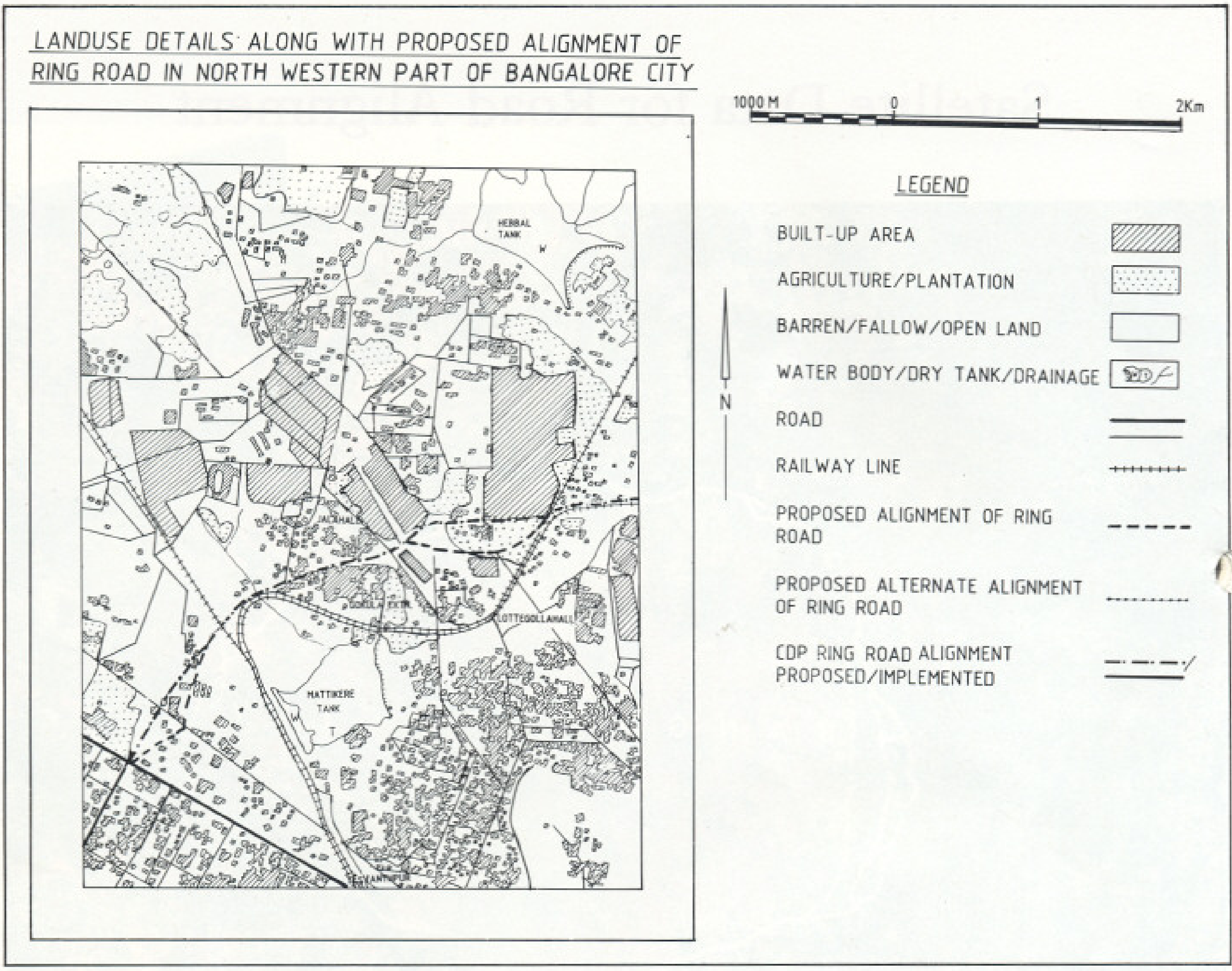
Satellite Data for Road Alignment

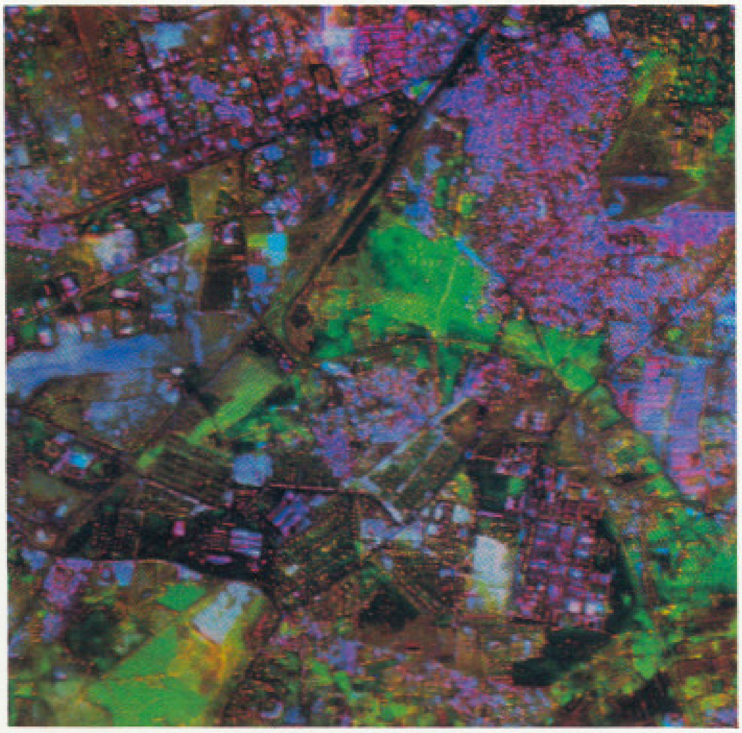


Satellite imagery of Bangalore with proposed ring road overlaid.

Data from remote sensing satellites like the Indian Remote Sensing Satellite, IRS-1A, US LANDSAT and French SPOT which provide repetitive regional views of a given terrain, combined selectively with aerial and other conventional data, enable timely and reliable appraisal of features such as current land use and land cover, land forms, broad soil types, rock assemblages and surface and ground water conditions. Integration of this information with topographic data can be conveniently used to select an optimal corridor for road formation in fast growing metropolitan cities. The Department of Space along with Karnataka State Remote Sensing Technology Utilisation Centre, (KSRSTUC), has recently completed a study for ring road alignment in three specific stretches around Bangalore city using remote sensing data from aircraft and satellite sensors.

Bangalore city is one of the fastest growing cities in the world. The population of the city has increased phenomenally from around 29 lakhs in 1981 to around 50 lakhs today. Such a rapid growth has put tremendous pressure on





Satellitte imagery (left) and Interpreted data (above)

the city's transportation network. In order to ease the enormous pressure on the existing roads, Bangalore Development Authority (BDA) is implementing many new schemes under a Comprehensive Development Plan (CDP) for the city. Formation of an outer ring road for a total length of about 60km is an important project taken up under the CDP. But the inevitable time gap between planning and implementing the project allowed several unforeseen developments such as new settlements and other activities to creep into the zones identified earlier under CDP for the ring road, specifically in its north-western, western and eastern stretches. This has necessitated realignment of the ring road in these three stretches.
Conventional ground survey to realign the road would involve so much time, that further encroachment cannot be avoided. In this context BDA approached the DOS to take up the task of identifying modified corridors and alignments using remote sensing techniques, which could serve as the basis to take up further work expeditiously. The Department of Space, along with KSRSTUC, took up the task of identifying alternate corridors and alignments for the above three stretches, using remote sensing data.

High resolution satellite data, both raw and digitally enhanced on 1:12,500 and 1:25,000 scales, were used in the above study in conjunction with (a) aerial photographs on 1:10,000 scale, (b) Survey of India (SOI) topographic maps on 1:25,000 and 1:50,000 scales and (c) the city guide map (of SOI) on 1:20,000 scale.

The main criteria adopted to identify the new corridor and alignment of the ring road are the following:

* Short length, easy manoeuvrability and economical;
* Avoid features like dense settlement, industrial and religious places, etc;
* Optimal use of existing major roads;
* Minimise earth work by closely following the topography;
* Avoid erosion prone areas, loose ground, etc;
* Minimise curves, drainage cuttings, etc;
* Conserve agricultural, plantation and forest areas;
* Provide scope for future development.

Visual interpretation of satellite data products was carried out in consultation with necessary collateral and ground data to derive information on current land use and land cover, land forms, drainage and other terrain characteristics. Necessary topographic details were synthesized from the topographic maps. Integrating the above with due weightage to the criteria listed, corridors were identified for alignment of ring road in the three stretches. Detailed information of land use and land cover and other terrain features for the identified corridors were then extracted from aerial photographs and used to modify the alignment of the ring road.

Land use and land cover map on 1:25,000 and 1:10,000 scales and land forms map on 1:25,000 scale were prepared for all the three stretches. An overlay showing the existing and proposed ring road alignment for the city was also prepared on 1:50,000 scale.

Modified or alternate alignments were proposed based on the study in all the three stretches. In the north-western part which is more or less flat, modifications have been made for small segments. In the western stretch with an undulating terrain, the alignment as per BDA's Comprehensive Development Plan has been totally shifted from the east of a river valley which is densly built up, to the west of the valley with open, barren or fallow land. While doing so, care has been taken to see that the proposed alignment closely follows the topography, and that the earth work is kept to the minimum. Alternative alignment satisfying the listed criteria have also been suggested in this stretch. In the eastern part, the terrain is plain and the BDA's plan has been modified to avoid running through villages/settlements and to keep the road as straight as possible.

The satellite-data based survey was completed in about a month's time. A detailed presentation of the work was made to the BDA, who have accepted the report and initiated further actions.

The use of satellite-based data for carrying out a survey for the formation of a ring road in Bangalore, in an incredibly short time and low cost, has demonstrated the potential of satellite remote sensing as a quick and economical method for conducting surveys for road formation. □

Up Above The World Not So High !

Large Space Simulation Chamber

A Large Space Simulation Chamber (LSSC) has been established at the ISRO Satellite Centre (ISAC), Bangalore, for conducting detailed thermal vacuum performance and thermal balance tests on integrated spacecraft. There are only six to eight such facilities in the world. LSSC can simulate the vacuum, heat and solar radiation conditions of Space. It will now enable ISRO satellites of the IRS and INSAT class to be tested in India itself without the hassle of transporting them abroad for such tests. It will save much time, cost and effort for the spacecraft programmes of ISRO. The facility has been built by Bharat Heavy Plates and Vessels (BHPV), Vishakapatnam, to ISRO's specification. LSSC is undergoing commissioning trials.

LSSC (auxiliary chamber in the foreground).

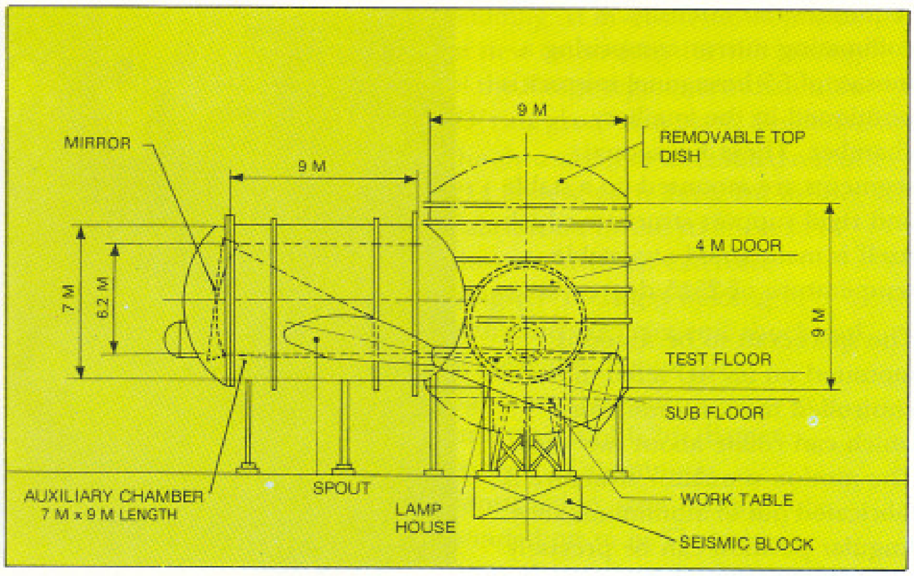
All spacecraft need to undergo detailed thermal vacuum performance test to ensure and demonstrate their performance in Space environment. Thermal balance tests are required to evaluate the spacecraft thermal design. These tests, generally performed at an advanced stage of realisation of the spacecraft, are conducted for durations extending upto 20 days. Such tests have been performed so far using facilities abroad and, to some extent, in 4 m. and 2 m. chambers already established in ISRO. With the increase in the number of spacecraft, their size and complexity, and the extra reliability to be built in their design for use in an operational mode, dependence on external facilities for such long duration tests has become unviable and uneconomical. This is especially so when contingencies or anomalies occur during a test and when the repeat of a test becomes necessary. All present day Indian satellites have several appendages which do not permit frequent assembly and disassembly operations, packing and repacking and transportation. LSSC, established next door to the satellite integration and assembly facility at ISAC will be of great advantage for the satellite programmes of ISRO.

LSSC has been established as one of the major facilities under the INSAT-2 project. It is configured with two stainless steel chambers – a 9m diameter vertical main thermo-vac chamber housing the test object and a 7m diameter horizontal auxiliary chamber, juxtaposed to the main chamber, for projection of collimated solar beam. The facility has a solar simulator with a beam of 4m diameter expandable to 4 ½m diameter and a 2-axis turn-table to orient the test object in the desired direction to simulate the orbital conditions. Automated instrumentation for several modes of operation, and other state-of-the-art features have also been incorporated.

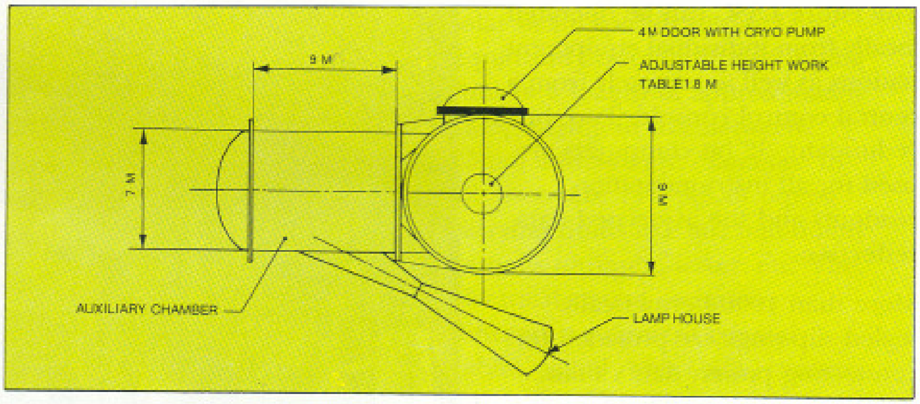
LSSC can be operated in several modes. In the vacuum mode, mainly used for dynamic balancing of spacecraft, it is possible to evacuate the chamber from 1m bar to hard vacuum. The tests in this mode are conducted mainly on spin-stabilised satellites carrying payload requiring high pointing accuracies. In the vacuum and cryogenic mode, the shrouds are kept at a low temperature of 100 K under hard vacuum conditions and the satellite is tested for thermal balance conditions using a system of heaters. In the solar simulation mode, the satellite is exposed to the Space conditions of vacuum and thermal environment, including the solar illumination.

The facility can be also used for testing large sized sub-systems like solar panels, optical systems, etc.

The chamber is fabricated out of stainless steel sheets, 22mm to 29mm thick, with inner surface highly polished. The chamber is strengthened by the addition of stiffner rings which enable it to withstand external pressure and at the same time to limit the deflection of the critical parts interfacing with the optics of the solar simulator. The shrouds, which line the chamber walls, are also made of stainless steel with single-embossed plate-coil design. The internal surface of these shrouds are painted black and the external surface electro-polished. A liquid nitrogen system, capable of removing heat energy at a rate of 100kW, is employed for cooling these shrouds to liquid nitrogen temperatures. The liquid nitrogen is circulated in sub-cooled condition to ensure unidirectional single phase flow even at high heat input to the shrouds. For intermediate temperatures stretching from 100 K to 373 K, gaseous nitrogen is circulated

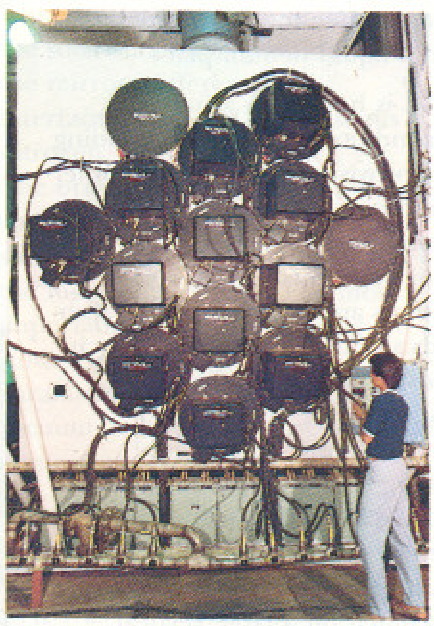


Line Schematic of LSSC – elevation (top) and plan (bottom)



using centrifugal blowers. The entire shroud assembly is divided into 48 zones with independent control loops for controlling temperatures of individual zones. A helium cooled cryopanel is provided for fast and efficient pulldown of the chamber pressure to hard vacuum of the order of 10^{-6}m bar. In addition, there are redundant close cycle refrigerated cryopumps and turbo-molecular pumps for attaining the required level of vacuum.

The solar simulator consists of lamp modules, transfer optics and cooled beam-shutter, all housed in the protected environment inside the lamp house which interfaces with the main chamber via a 900mm diameter quartz window. Ten 20kW xenon lamps are used in the lamp house to generate the



Lamp house rear view.

required solar intensity. A collimating mirror comprising a mosaic of 55 hexagonal mirrors is positioned in the auxiliary chamber. These hexagonal segments are mounted on a stable and rigid support structure which itself is maintained at a stable temperature of 25±5 degree C.

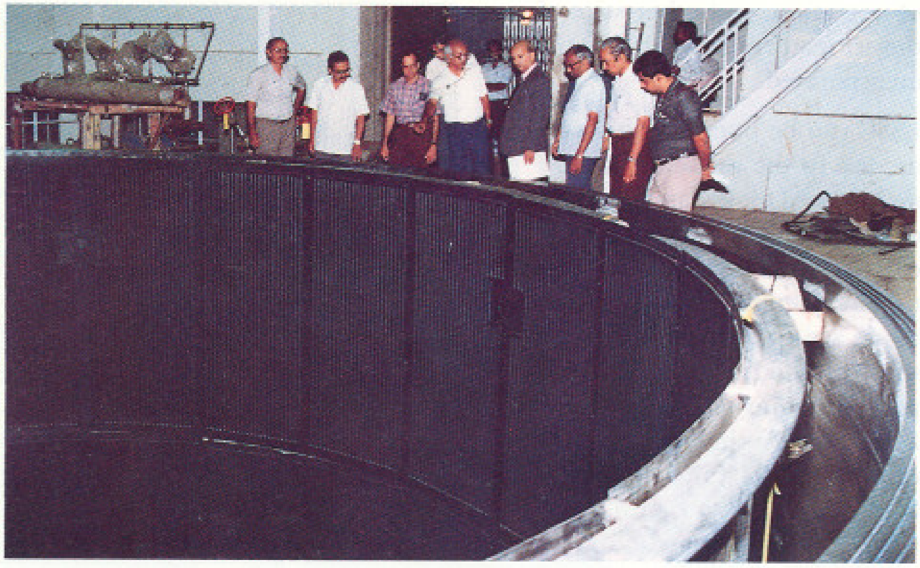
The spacecraft to be tested is mounted on an AC servo motor-controlled motion simulator which can rotate about two axes. The motion simulator structure is fabricated out of aluminium alloy. Angular position can be precisely controlled and read out through inductosyn position transducers.

The entire LSSC can be operated locally from individual equipment stations as well as remotely from a central control console. Two, hot redundant, 32 bit computers are used for all instrumentation readouts and the associated data reduction.

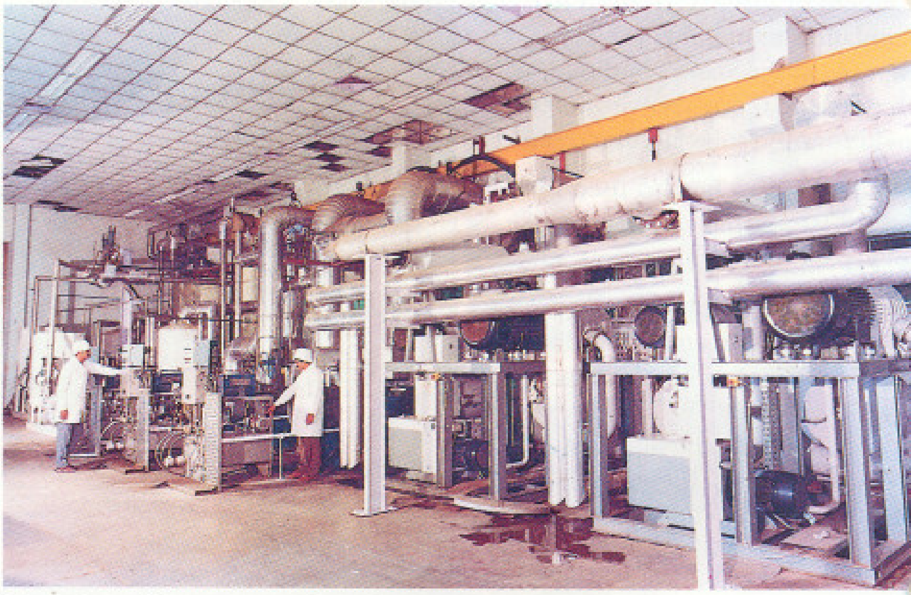
More than 1000 hermetically sealed slip-rings are provided for connecting power, data cables, thermocouples, etc.

The auxiliary facilities to the LSSC include two one million litre storage tanks and associated pumps for liquid nitrogen, gaseous nitrogen generation equipment and a liquid helium plant.

LSSC is housed in a fully airconditioned 26m high building with provisions for crane and other handling equipment. The chamber was constructed at site using segments of rolled shell sections and parts of formed dish-ends shipped from the factory in transportable sizes. The fabrication of the chamber involved more than 2km of welding to the required helium leak tightness. The main flanges of the top dished ends and the mating flanges of the cylinder were machined on a large vertical boring machine in two parts and welded in place in the LSSC

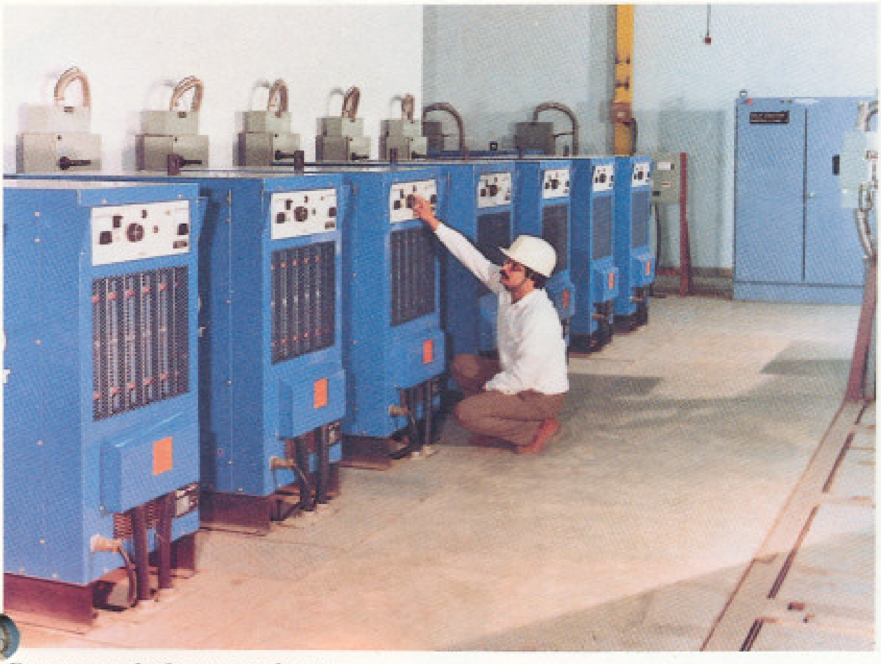


Prof. U.R. Rao, Chairman, ISRO (fifth from left) reviewing the Chamber erection.

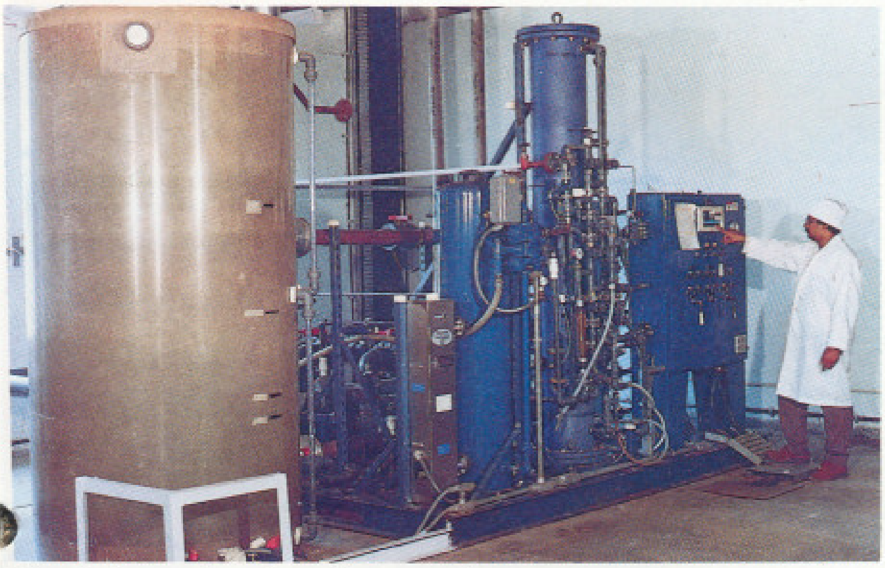


Cryogenic and vacuum machinery.

One million litre capacity liquid nitrogen tanks.



Power supply for xenon lamps.



De-ionised water plant for cooling xenon lamps.

Central Control Console.

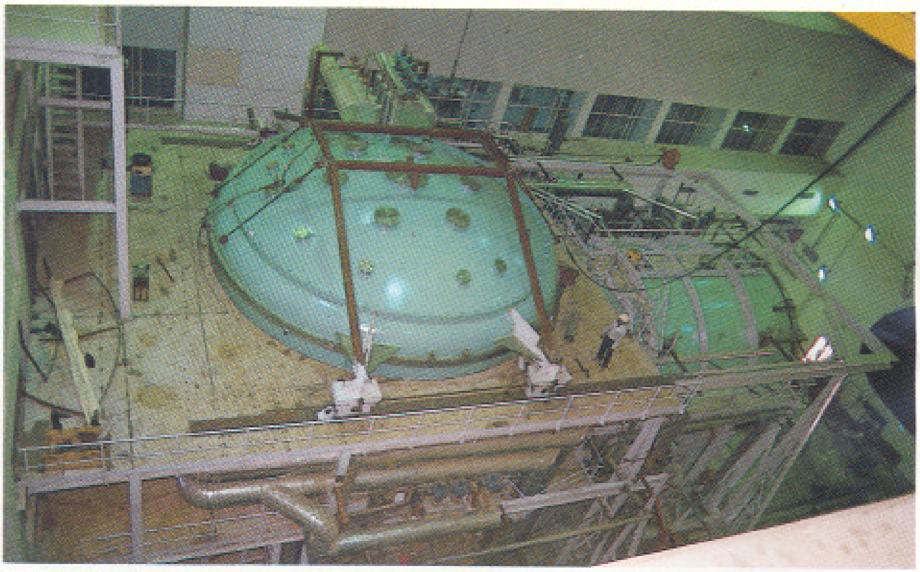
building. It involved development of new technology for the joining of the flange segments with double 'O' ring grooves in place. Similarly, the shrouds were assembled out of 214 panels, each 2m x 2m in size. Fabrication of the stainless steel shrouds involved extensive tungsten inert gas welding to withstand the cryogenic shock and achieve the required leak tightness. The mirror support structure is of 6.2m diameter, entirely of aluminium construction, with cooling tube bonded on to it. The mirror support structure is integrated with the chamber to the required optical tolerances for realising solar beam specifications. The liquid and gaseous nitrogen piping runs to a length of approximately 1km, varying in size between 25mm and 400mm diameter. In all, there are 14 types of piping carrying fluids like air, liquid and gaseous nitrogen, water, etc. The electrical system comprises different equipment control cables, signal cables, etc., running into a few kilometres.

The establishment of LSSC involved extensive system engineering. This includes mechanical interfaces like the sizing of the chamber window for the solar simulator, positioning of the mirror, different fluid interfaces for liquid and gaseous nitrogen, helium, air, water, etc. The optical precision required, combined with the large structural sizes, made the engineering task all the more challenging. The most important system engineering studies were related to the parametric interfaces, such as vacuum, temperature, pressure and contamination conditions.

The specifications and conceptual design were arrived at by ISRO and the execution was carried out by BHPV as the prime contractor. In turn, BHPV subcontracted works to various other Indian industries.

Some systems were, however, imported – solar simulator from Spectro Lab, USA., System Engineering Consultancy and high vacuum and thermal shrouds from High Vacuum Engineering Corporation, U.S.A. and motion simulator from Contraves, USA.

The successful establishment of LSSC marks an important milestone in the long standing ISRO-Industry partnership which has demonstrated the Indian industry's capability to take up, on a turnkey basis, establishment of such high tech, sophisticated facilities. □



LSSC top view.

LSSC Specifications

Configuration:

- Vertical main chamber of 9m diameter and 13.5m height
- Horizontal Auxiliary Chamber of 7m diameter and 10 m long, juxtaposed to the main chamber.
- Removable top cover for loading satellite/test object

Vacuum:

- Clean vacuum of 1×10^{-5} milli bar or better.

Solar Simulator:

- Off axis collimated beam of diameter 4m (extendable to 4.5m.)

Motion Simulator:

- To provide tilt and spin relative to the solar beam from 1 rpm to 10 rpm.
- Over 1000 channels for power and data transmission via slip rings/multiplexer.

Shroud and Nitrogen Circulation Equipment (SNCE):

- Sub-cooled liquid nitrogen/gaseous nitrogen for attainment of temperature from 100 K to 373 K inside the chamber.

Test Volume (usable):

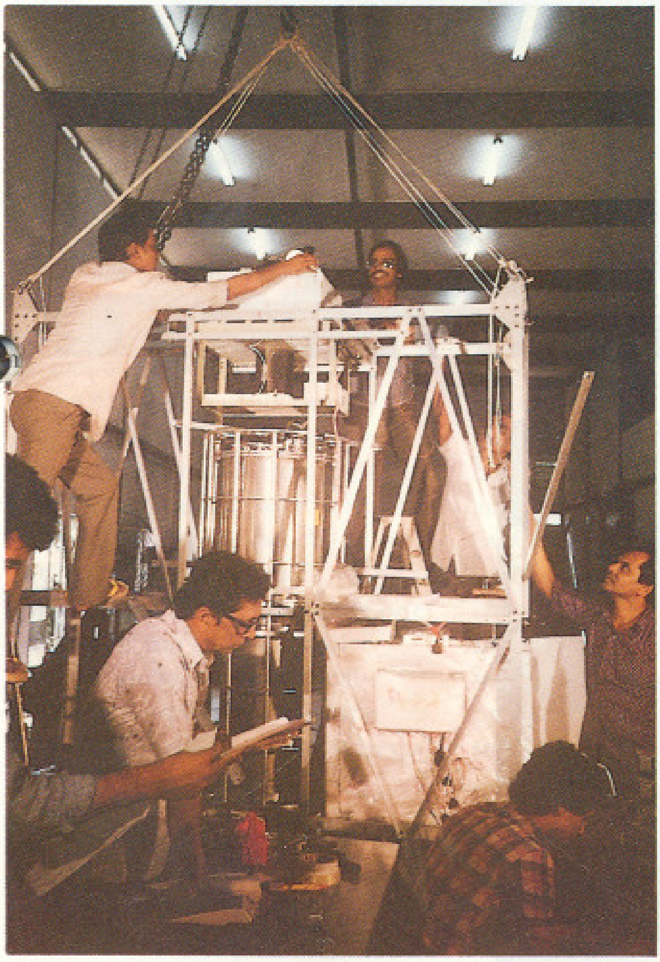
- 8m diameter x 9.3m height

Satellite/Test Specimen Size:

- 4m diameter, 5m height, Weight upto 3 tons.

Trace Gas Measurements in the Indian Tropical Region

A balloon ready for launch.



Balloon payload being readied.

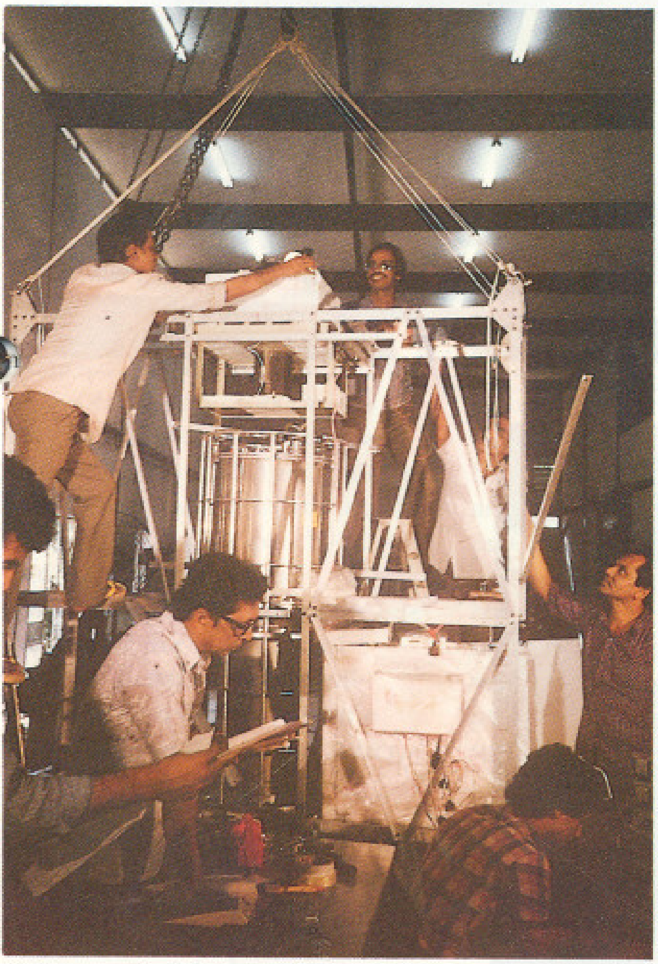
A 1,40,000 cubic metre balloon was launched on April 9, 1990, at 5.30 am from Hyderabad as part of the programme to study trace gas abundances and their vertical distributions in the tropics. The balloon, carrying a composite payload consisting of a cryogenic sampler developed by Max Planck Institute for Aeronomie (MPAE), Lindau, Federal Republic of Germany (FRG) and a radiometer developed by Physical Research Laboratory (PRL), Ahmedabad, reached a ceiling altitude of 35 km. Fifteen air samples were collected between 10 and 35 km altitude during the ascent and slow valve-controlled descent trajectory of the balloon. Both the payloads were recovered successfully after the flight termination.

Study of trace gases in the atmosphere has assumed great importance in recent years. Several trace gases play an active role in the warming of the earth's atmosphere due to green-house effect. Some of them are also responsible for catalytic destruction of atmospheric ozone which not only protects the biological life on the earth by absorbing the lethal solar ultraviolet (UV) radiation from the sun but also causes warming up of the earth's atmosphere in the 15 to 50 km height region.

Several of these trace gases, which play an important role in atmospheric chemistry and radiation balance, are released near the earth's surface due to natural as well as anthropogenic activities. Notable among these are various types of freons, nitrous oxide, methane, carbon monoxide and carbon dioxide. Increasing abundance of these gases in the atmosphere is causing a major

Trace Gas Measurements in the Indian Tropical Region

A balloon ready for launch.



Balloon payload being readied.

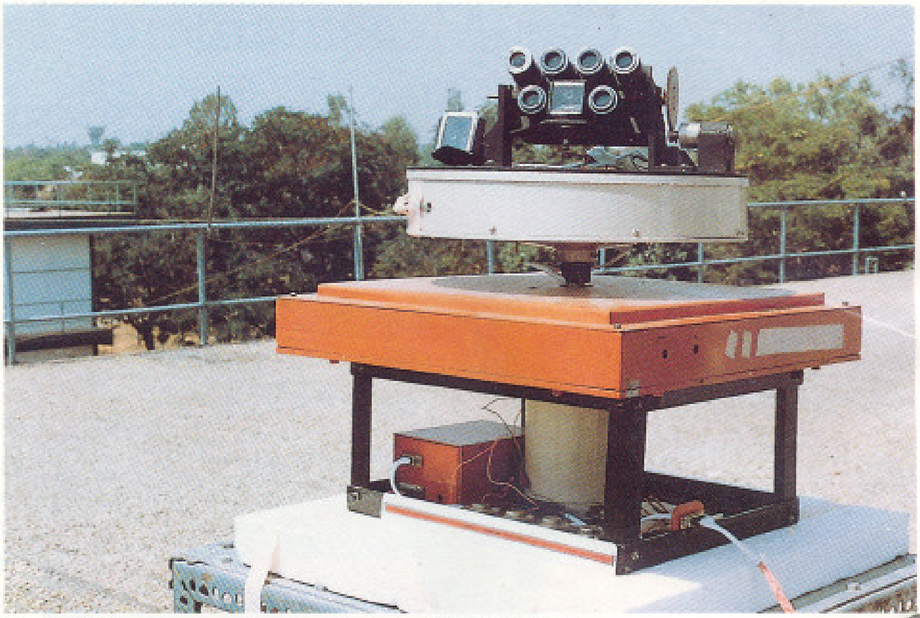
A 1,40,000 cubic metre balloon was launched on April 9, 1990, at 5.30 am from Hyderabad as part of the programme to study trace gas abundances and their vertical distributions in the tropics. The balloon, carrying a composite payload consisting of a cryogenic sampler developed by Max Planck Institute for Aeronomie (MPAE), Lindau, Federal Republic of Germany (FRG) and a radiometer developed by Physical Research Laboratory (PRL), Ahmedabad, reached a ceiling altitude of 35 km. Fifteen air samples were collected between 10 and 35 km altitude during the ascent and slow valve-controlled descent trajectory of the balloon. Both the payloads were recovered successfully after the flight termination.

Study of trace gases in the atmosphere has assumed great importance in recent years. Several trace gases play an active role in the warming of the earth's atmosphere due to green-house effect. Some of them are also responsible for catalytic destruction of atmospheric ozone which not only protects the biological life on the earth by absorbing the lethal solar ultraviolet (UV) radiation from the sun but also causes warming up of the earth's atmosphere in the 15 to 50 km height region.

Several of these trace gases, which play an important role in atmospheric chemistry and radiation balance, are released near the earth's surface due to natural as well as anthropogenic activities. Notable among these are various types of freons, nitrous oxide, methane, carbon monoxide and carbon dioxide. Increasing abundance of these gases in the atmosphere is causing a major concern. To assess the impact of these gases on the loss of ozone and on the warming up of the atmosphere, it is important to know their vertical distribution and growth rates. Eventhough information regarding the vertical distribution of various trace gases is available for the mid-latitude region, such information is scanty in respect of the tropical region. Due to the strong upwelling, the tropical region plays a crucial role in transporting these gases into the stratosphere. Measurement of trace gases in this region is important since this region contributes about 50% of the global emission of biogenic gases like methane and nitrous oxide.

A joint programme between PRL, Ahmedabad and MPAE to study the trace gas abundances and their vertical distribution in the tropics was initiated in 1985 under the ISRO-DLR (German Space Research Establishment), collaboration. The programme envisaged a composite payload consisting of a cryogenic air sampler supplied by MPAE, and a multichannel sun-tracking radiometer developed by PRL to be flown on balloon. A test flight had been conducted in March 1985 from the Tata Institute of Fundamental Research – Indian Space Research Organisation balloon launch facility at Hyderabad to test the compatibility of the two instruments. A full-fledged measurement had been carried out on March 26, 1987 before the recently conducted flight on April 19, 1990.

The air samples taken during the balloon flight will be analysed both at PRL where an ultra sensitive gas chromatograph has been installed and at MPAE. The results are expected to yield important information on the growth rates and vertical distribution of various trace gases. □



Optical Ozone measuring payload developed by PRL.

Trace gas measuring facility at PRL.

Cryo sampler.

Technology Transfer and Space-Industry Co-operation

Face to face! – Review of PCMC Radar Project by Chairman, ISRO (third from left)

... and Chairman, BEL. (second from right)

As a matter of policy, the Indian Space programme seeks active participation of Indian industries in the execution of its various programmes. The co-operative efforts between ISRO and industry involve the transfer of advanced technologies developed by ISRO and providing technical consultancy to industry on the one hand, and the utilisation of industry's own technological potential and expertise by the Space programme on the other.

Technology transfers from the Space programme to the Indian industry have won acclaim from different quarters and have recorded a good success rate. The programme picked up momentum in the late seventies and witnessed considerable growth through the decade of eighties. The Indian Space programme has so far transferred as many as 164 technologies covering diverse disciplines. Of these 130 items have already been productionised and the remaining are in the process of productionisation. The recipients of these technologies constitute some 100 industries in the public, private and joint sectors. Notably, a predominant proportion of them are in the small scale sector.

In the developed countries advances in Space technology have the backing of a well established industrial infrastructure. The Indian Space programme on the other hand had to mainly rely on inhouse research and development. The importance of filling up this technology gap between the Indian industry's capability and the Space programme's requirements, was recognised even in the early stages of evolution of the Indian Space programme. Active participation from industries was sought in several areas, particularly, in fabrication. At the time of inception of the technology transfer programme, ISRO laid emphasis on areas where industries were not geared up to develop by themselves such technologies.

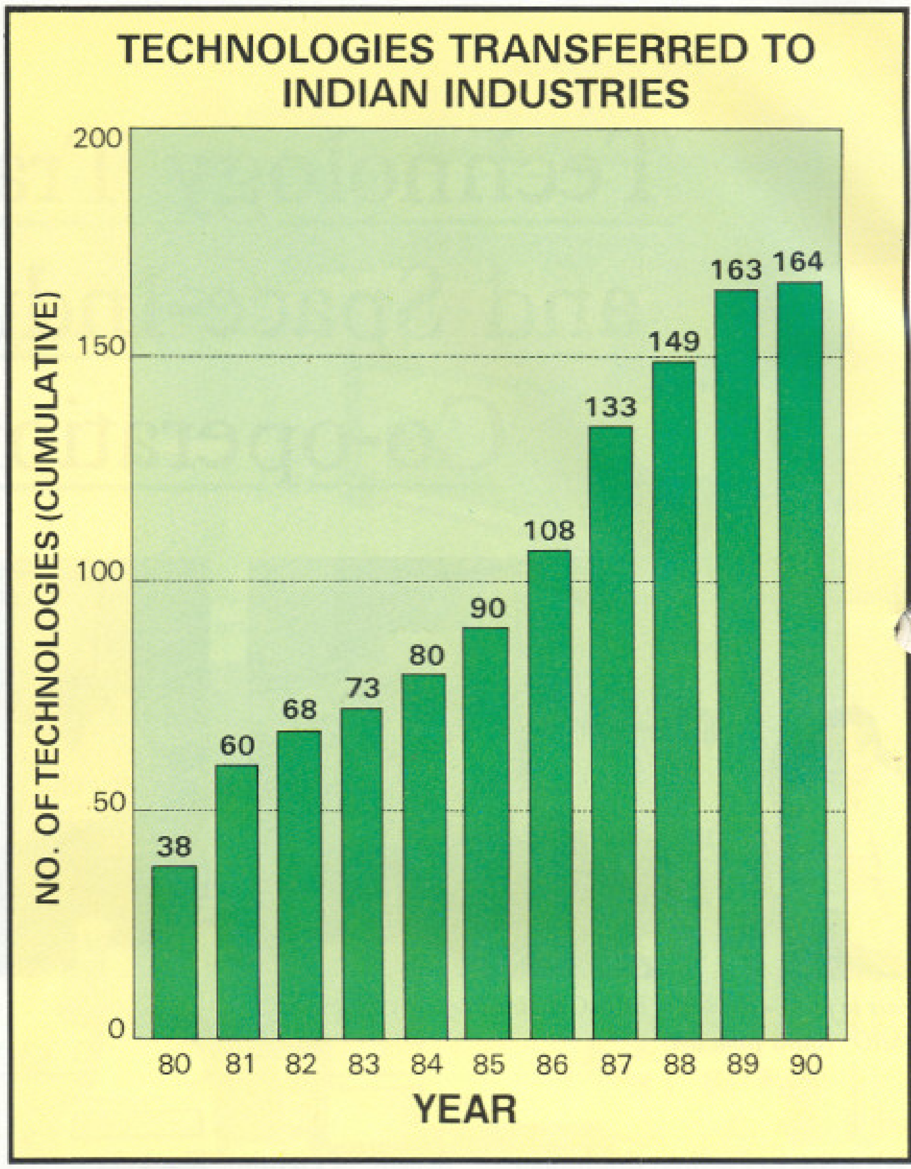
The technology transfers from ISRO basically fall under the following three categories.

- Primarily for ISRO buy-back such as rocket propellants, high-silica cloth, high reliability sealed chemical batteries and liquid phenolic resin;

- Primarily for development of Space applications and Space systems utilisation such as direct reception systems for satellite TV, image analysis systems for remote sensing applications, disaster warning receivers, news facsimile and meteorological data dissemination equipment and radio networking terminals;
- Primarily for development of non-Space applications such as dry powder extinguishants for metal and oil fires, polyols derived from castor oil, precipitated silica from rice husk ash, thermal sensors, pressure transducers, a range of specialised adhesives and sealants.

To promote healthy competition in the market and to minimise the risks, ISRO has gone for non-exclusive licencing of technologies. Nevertheless, care is also taken to ensure that the number of licencees is commensurate with the market potential of the technology and ISRO's ability to service them effectively during the course of implementation. It is interesting to note that over the years the number of technologies that serve non-Space applications has increased in proportion among ISRO's knowhow transfers.

Since the technologies developed by ISRO are primarily for its own programme, marginal cost-based approach is adopted for pricing these technologies for transfer to industry. To spread the risks between the donors and the recipients of the technologies, a combination of down-payment and royalty is charged. Inspite of overriding concerns for maximum exploitation of ISRO knowhow and for winning the market's acceptance, free technology

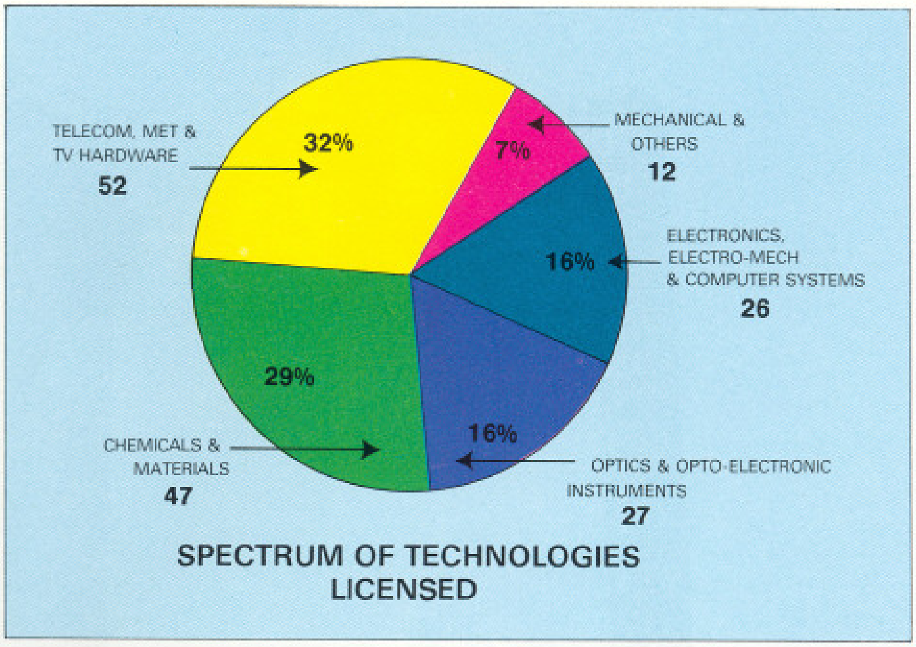


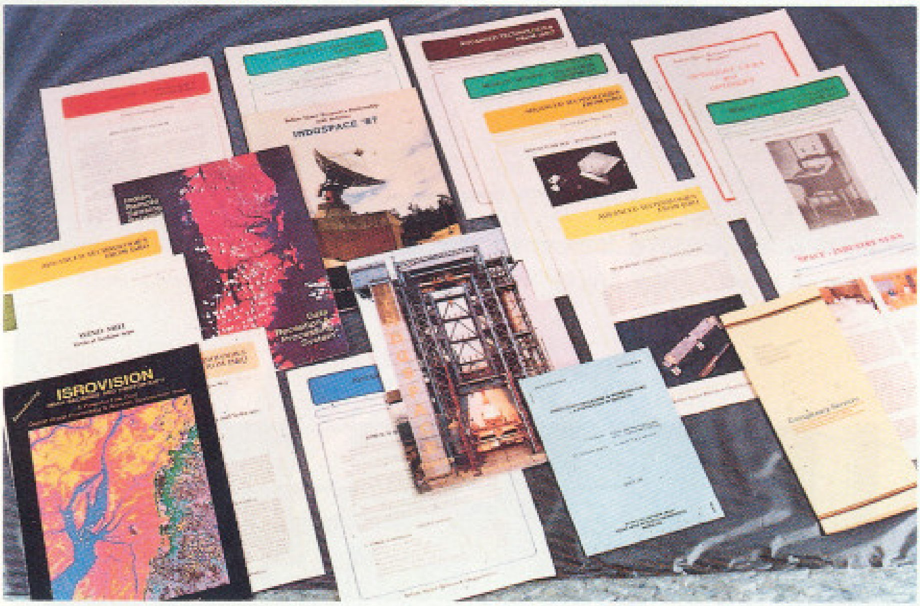
Personal locator beacon – technology transferred from ISRO.

transfer is discouraged to ensure earnestness among the applicants. If and when the market expands, additional licencing is given. Product pricing in the cases of non-Space applications is left to be determined by the market forces, while in the case of certain items for ISRO's own buy-back, the prices are regulated.

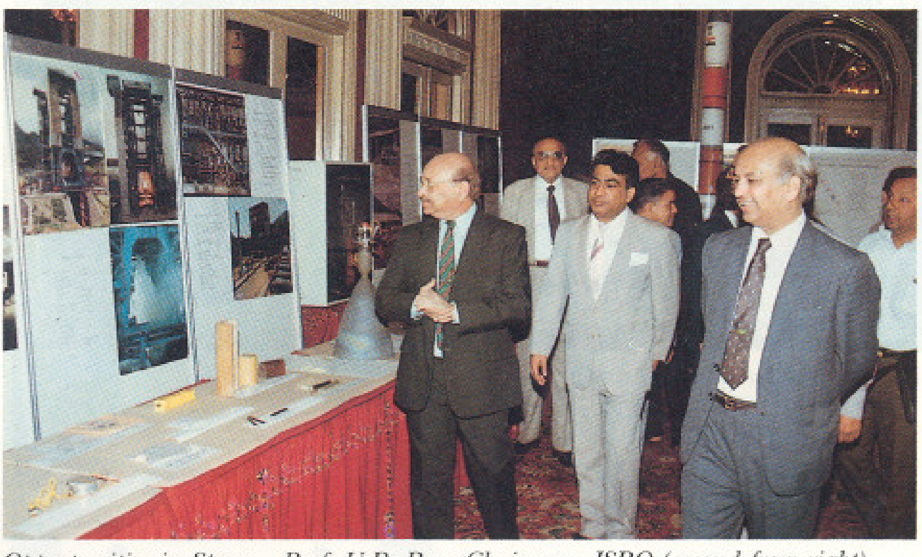
ISRO's technology transfer system ensures direct communication between the scientists engaged in development of the technology and the recipient industries which is vital for the success of the transfer. The infrastructure, experience, human resources and keenness for acquiring and exploiting the technology in the quickest possible time are evaluated thoroughly among the applicants. Information on new developments and innovations in ISRO is disseminated among the industries through brochures, reports and interest exploration notes. Information is also disseminated through newspapers and journals. Besides, ISRO participates in industrial exhibitions and trade-fairs. Technology briefs are mailed to select institutions and industry associations, and technical presentations are made to industries. Demonstrations of specific products, ready for knowhow transfer, are also arranged in various ISRO Centres from time to time. Publications such as 'INDUSPACE', published annually, and 'Space Industry News', published quarterly by ISRO evoke considerable interest among the industries.

ISRO receives regular reports on the status of production and sales of the products governed by its technology transfers. Meetings between ISRO scientists and licencees are also arranged to get feed back on technology utilisation and market status. ISRO Centres are provided feedback on various

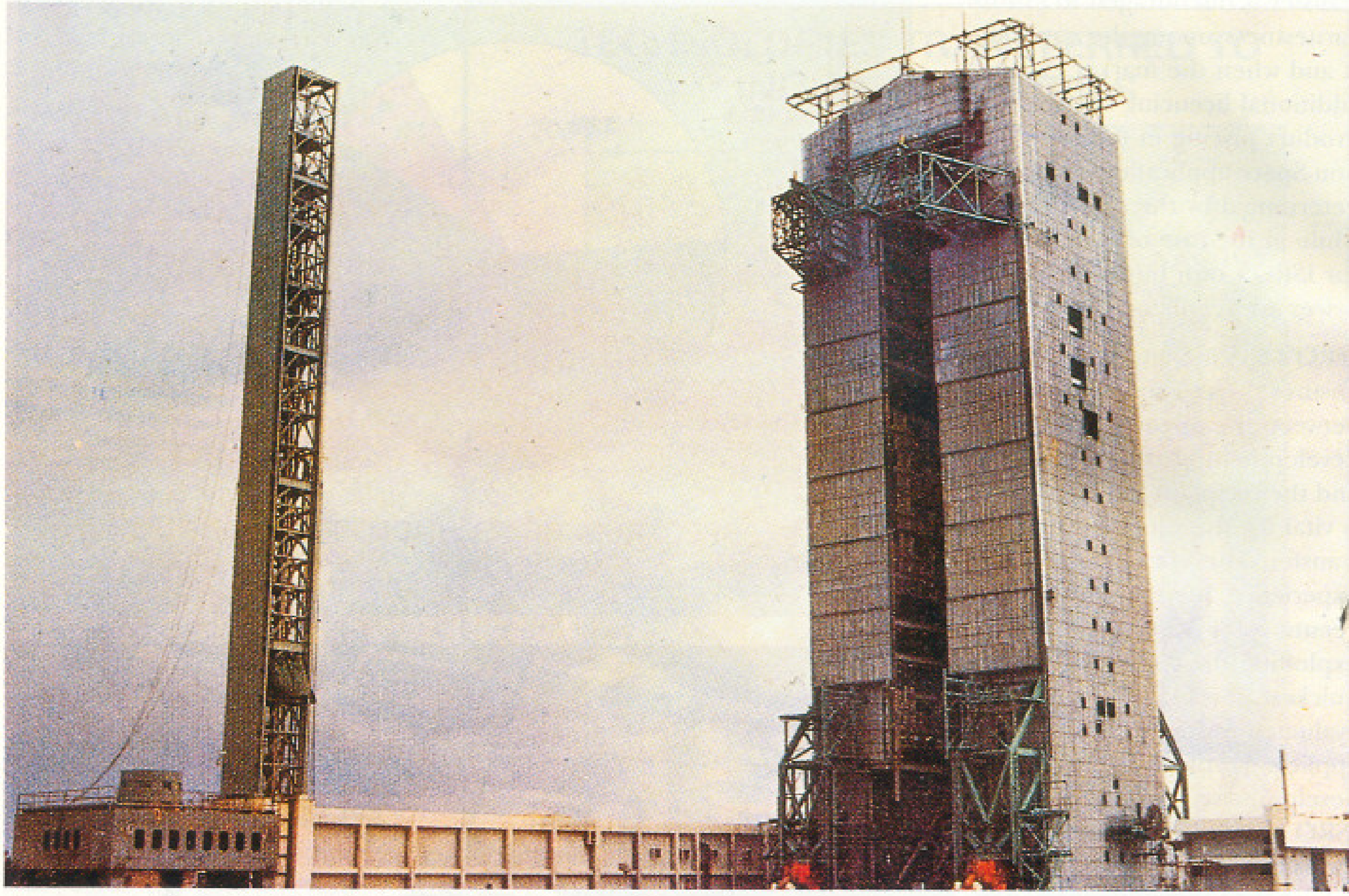




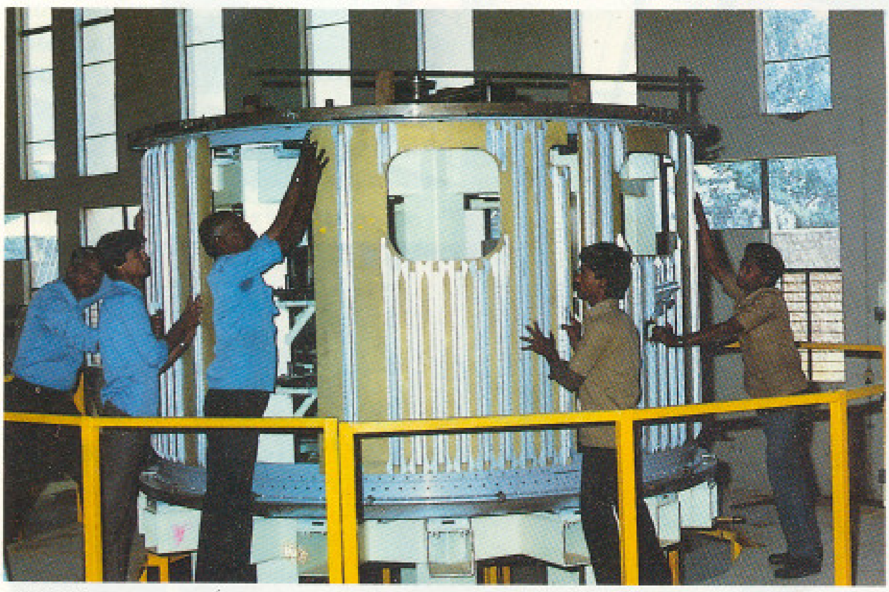
Publications on Space-Industry Co-operation.



Opportunities in Space – Prof. U.R. Rao, Chairman, ISRO (second from right) at an exhibition during a joint Seminar by ISRO and Confederation of Engineering Industry.



A mammoth effort – PSLV Mobile Service Tower fabricated by a private industry.



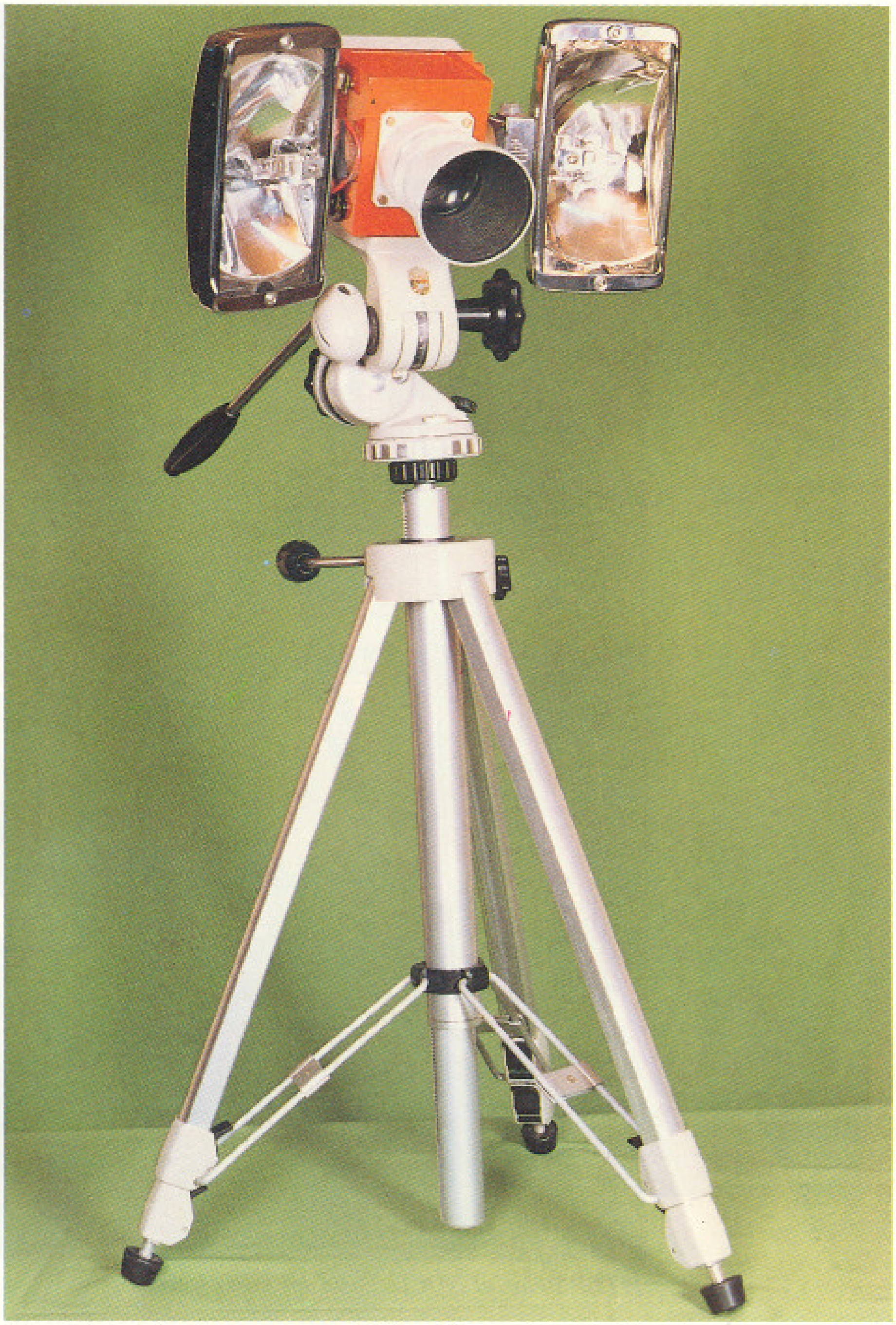
PSLV interstage structure under fabrication at HAL.

developments and potentials emerging in Indian industries through survey of current literature and interactions with industries. With a view to promote the use of indigenous technologies developed by it, ISRO actively interacts with other national agencies responsible for the promotion and regulation of industrial development and supplies them with upto-date information on the status of development and use of ISRO's technologies.

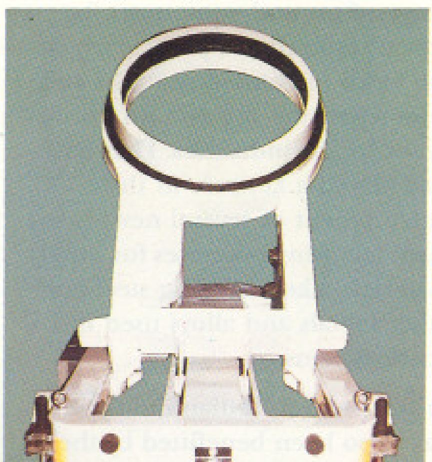
Protection of intellectual property rights is important to safeguard the interests of technology development agencies on the one hand and those of the technology licencees on the other. ISRO provides the necessary support within the organisation to identify and obtain patents, copyrights and trademark registrations.

Studies relating to novel contract systems and pricing approaches have been undertaken in ISRO on professional lines. In addition, preliminary market surveys on technologies and products developed by ISRO are conducted by utilising services of young professionals from the renowned national institutes of management.

The initiatives taken by the Space programme for co-operation with industries have resulted not only in a steady growth in the volume of work handled by the national industries for the Space programme, but also in upgradation of the technologies. Currently, certain premier industries in the field of aeronautics, communications and engineering have their own specialised divisions or manufacturing lines to deal with Space products. These products include, among other things, hardware for rocket motor cases, spacecraft structures, light alloy



Hygrophotometer for measurement of moisture content in plant leaves – Technology transferred from ISRO



Spacecraft integration fixture by a private industry – Space age fabrication.

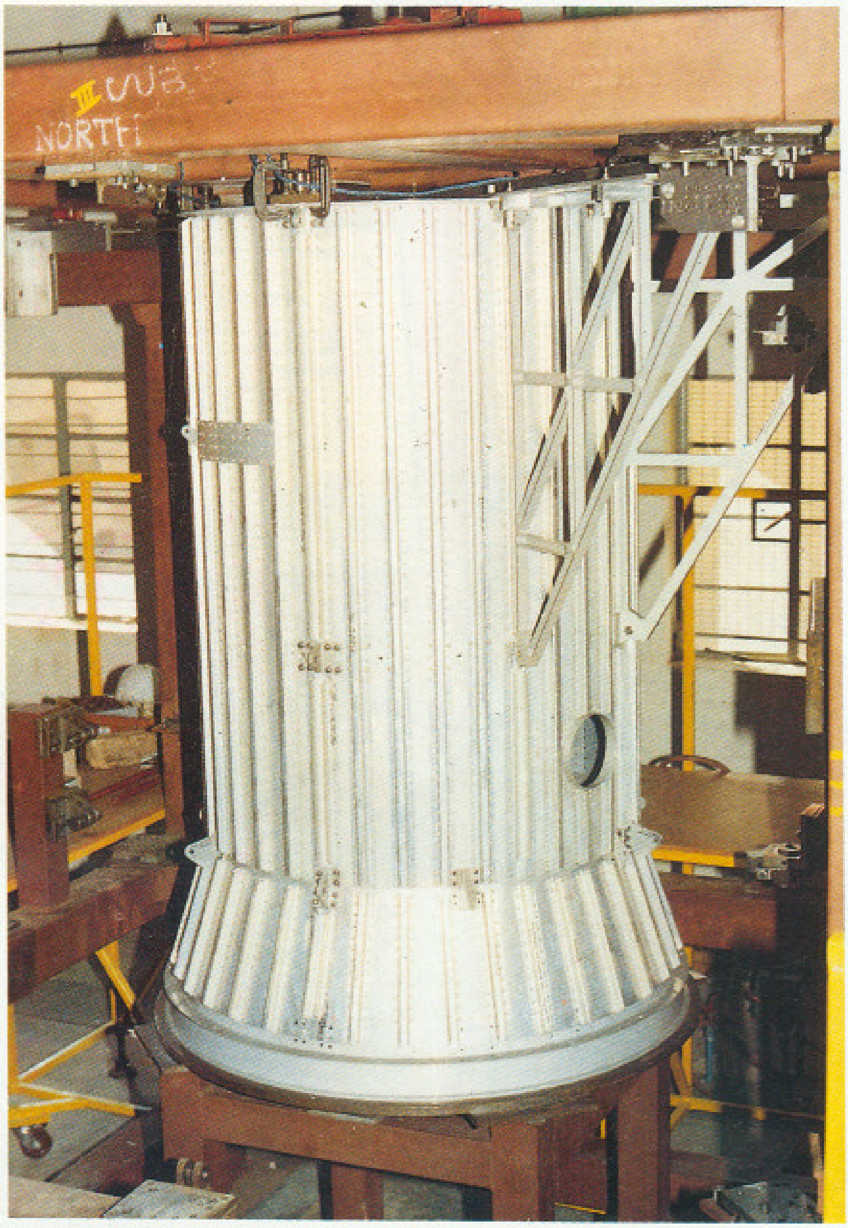
HTBP Plant at NOCIL based on ISRO technology.

structures and liquid propulsion engines. Indian industries are also now geared up, with assistance from ISRO, to produce and supply rocket fuels, oxidisers and other components that go into the solid and liquid propellant motors of the Indian launch vehicles. Industries have played a major role in the establishment of some of the specialised facilities for the Space Programme like the mobile service towers and the Large Space Simulation Chamber. They have also manufactured various systems for the ground stations for satellites and launch vehicles. A range of ground equipment for Space applications, particularly in the fields of communications and remote sensing, are now produced by the Indian industries. They have also played a key role in the development of several new manufacturing processes for novel materials, like maraging steel and other metals and alloys used in Space systems.

In the process, Indian industries have also been benefitted by their participation in the Space programme. The value of procurement orders/contracts for a variety of goods and services placed by the Space programme on the Indian industries over the last ten years is close to Rs.1000 crores, which represents about 50% of the outlay for the Space programme itself. A new breed of technocrat-enterpreneurs, promoted by the Space programme has been serving the users of Space-based remote sensing data.

The technological innovations like miniaturisation, automation, weight and volume optimisation, use of new materials, and quality and reliability engineering practices provide several spin-off benefits to industries which participate in the Space programme. The operational Space services in the fields of telecommunications, TV, radio networking, weather observation, disaster warning, survey and monitoring of agricultural, forest, water, geological/mineral and marine resources are poised for considerable growth in the coming years. These in turn will necessitate large investments by several user agencies in ground segments which are atleast 2 to 3 times that of Space segment. This will provide further scope for growth in the Indian industry.

It will be possible for the Indian industries to tap overseas markets in a number of areas, particularly for ground systems associated with the communication and remote sensing applications and, in selected cases, for hardware used in Space-borne systems. The expanding Space markets, both within India and abroad, offer many new and promising opportunities for competent industries to diversify and derive benefits from their involvement in the Space programme and its services. □



INSAT-2 structure under fabrication at HAL.

Vikram Sarabhai Award for Academician Kotelnikov

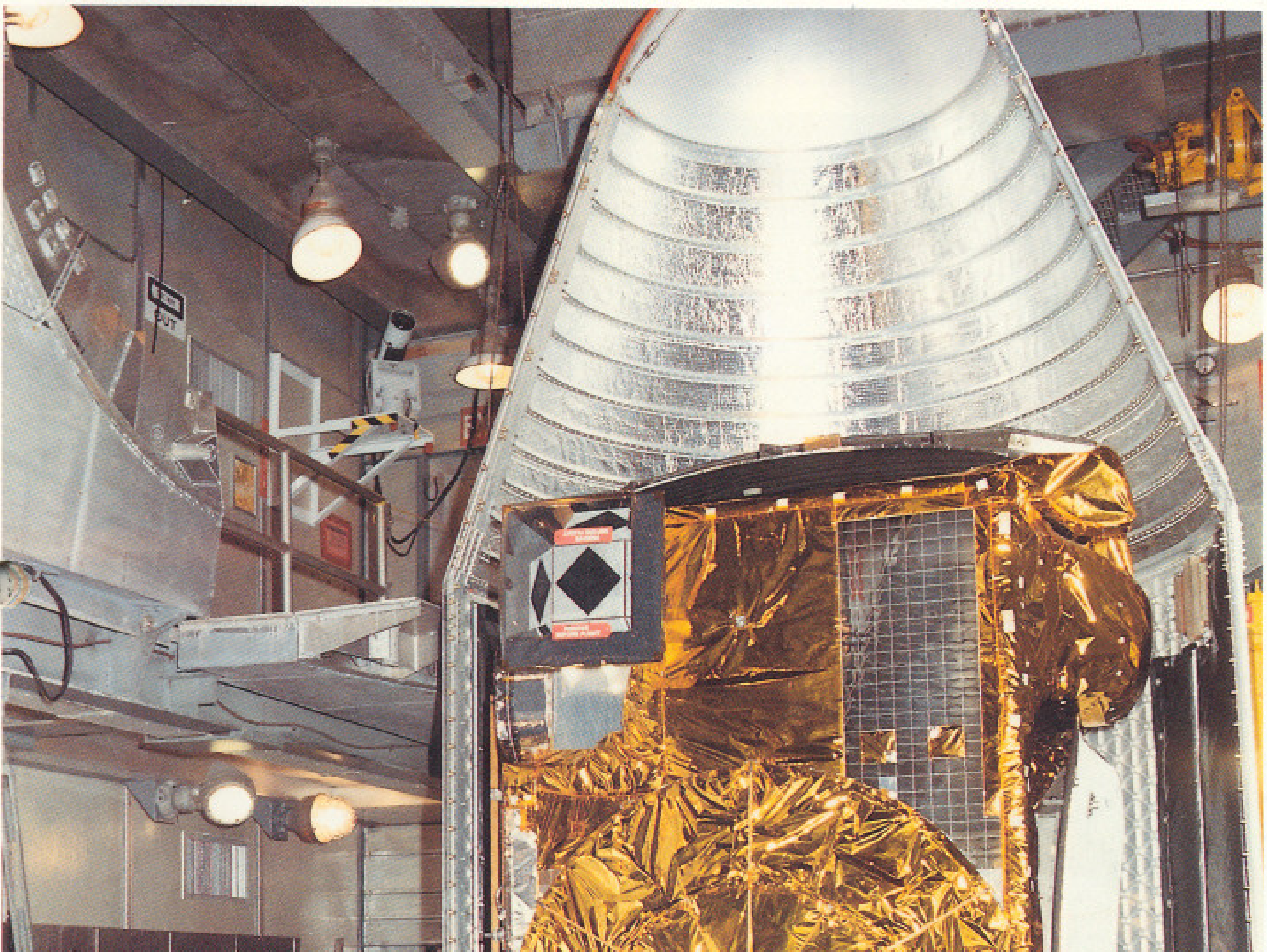
The first Vikram Sarabhai Award instituted by the Indian Space Research Organisation (ISRO) was presented to Academician V.A.Kotelnikov of USSR by Prof.M.G.K.Menon, Minister of State for Science & Technology, Government of India, during the opening ceremony of the twentyeighth COSPAR (Committee on Space Research) Bureau meeting held on June 25, 1990 at The Hague, The Netherlands.

The international Vikram Sarabhai Award has been instituted by ISRO to recognise outstanding contributions made by individual scientists to Space research in developing countries. India is one of the earliest members of COSPAR established by International Council of Scientific Unions (ICSU) in October 1958 to provide a forum for the world scientific community pursuing Space research.

The Vikram Sarabhai Awards consisting of a gold medal and a citation are presented once in two years starting from this year. Academician Kotelnikov was presented the award in recognition of his outstanding contributions to Space research in developing countries. As Chairman, Intercosmos Council, USSR, he has been closely associated with many of the collaborative programmes between USSR and other countries including India.

It is under the INDO-USSR collaboration, that ISRO was provided launches for Aryabhata, the first Indian satellite, Bhaskara 1 and Bhaskara 2 satellites. The joint Indo-Soviet manned space flight, which carried the India's cosmonaut Rakesh Sharma into Space, and joint gamma-ray astronomy balloon experiments from Hyderabad, were also carried out under this collaboration.

Academician Kotelnikov was also involved in the joint manned Space programmes between the USSR and Cuba, Syria, Afghanistan, Vietnam, etc.



The last glimpse on the ground
– INSAT-1D on board Delta Launcher
just before heat-shield was closed.

Delta launch vehicle lifts-off with INSAT-1D on board.