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22 JUNE 1990



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# ***JPRS Report***

# **Science & Technology**

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***Third World  
India's Annual Space Report 1989-90***

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## SCIENCE & TECHNOLOGY

### THIRD WORLD

#### INDIA'S ANNUAL SPACE REPORT 1989-90

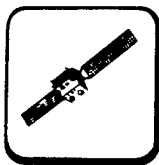
18680002 Bangalore DEPARTMENT OF SPACE ANNUAL REPORT 1989-90  
in English pp 1-83  
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# Highlights 1989-90



## INDIAN REMOTE SENSING SATELLITE (IRS)

IRS-1A is the first in the series of indigenous state-of-art remote sensing satellites. Since its launch on March 17, 1988 on board the Soviet Vostok rocket, IRS-1A has been functioning satisfactorily and has become the mainstay for National Natural Resources Survey and Management. The satellite weighing 975 kg carries two cameras, LISS-I and LISS-II, with resolutions of 73 m and 36.5 m respectively for imaging over the Indian continent with a swath width of 148 km. IRS-1A has provided over 1,80,000 imageries so far covering the entire country.

Integration of various subsystems for IRS-1B model has already commenced. IRS-1B will be launched on board the Soviet Vostok launcher by mid 1991. IRS-1B will be identical to IRS-1A. Integration of IRS-1E is also in progress for its launch on board the first developmental flight of PSLV. Work on IRS-1C and 1D has also started and these satellites will have improved spectral and spatial resolutions, revisits, stereo viewing and onboard video data recording capabilities.



## INSAT-1

INSAT-1B launched in 1983 has

continued to provide operational services during 1989 in the areas of telecommunications, meteorology, TV and radio networking. As many as 4,372 two-way voice or equivalent circuits are in operational use over telecommunication routes through INSAT. 28,447 meteorological VHRR images were commanded as of September 30, 1989. Over 500 TV and 100 radio stations are in the INSAT network.

INSAT-1C launched on July 22, 1988 could operate with only partial capacity due to a power bus anomaly in the spacecraft soon after launch. The spacecraft lost its earth lock on November 22, 1989 and could not be put into safe mode due to a command receiver anomaly which existed in the spacecraft since its launch.

INSAT-1D which was scheduled for launch in June 1989 on board the US Delta 4925 launcher suffered accidental damage while being mated with the launcher. The launch of INSAT-1D is now scheduled during the middle of 1990.

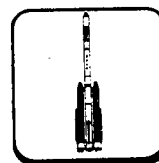


## INSAT-II TS

INSAT-II satellites are being indigenously fabricated to replace the foreign procured and foreign launched INSAT-1 series of satellites. The INSAT-II space segment consists of three spacecraft with two of them collocated. Each of the spacecraft will have about one and a half times the capacity of INSAT-1 spacecraft and consequently is

heavier and more complex. The first INSAT-II test spacecraft (INSAT-IIA) is scheduled for launch by the end of 1991 and the second test spacecraft (INSAT-IIB) about a year thereafter on board the European Ariane launch vehicle.

During the year Structural Model and Electrical Thermal Model hardware of INSAT-II test spacecraft were realised and assembly, integration and test are in progress. Flight model components fabrication has also commenced.



## AUGMENTED SATELLITE LAUNCH VEHICLE (ASLV)

ASLV is designed to provide a low cost operational vehicle to launch 150 kg class satellites into low earth orbits and also to validate advanced technologies needed for the larger vehicles such as PSLV. The first development flight in 1987 and the second in 1988 did not realise the mission.

Notwithstanding these, ASLV flights have provided valuable design inputs in the areas of strap-on technology, strap-on separation, inertial navigation technology, digital autopilot and closed loop guidance system, aero-structure control interaction, transonic buffeting, acoustic levels, S-band TTC technology, metallic bulbous heat-shield and improved data base on aerodynamic co-efficients, wind-

gust effects and control requirements.

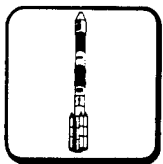
The preparations for the ASLV-D3 based on the recommendations of Experts' Review Panel and the Failure Analysis Committee are in progress to realise the flight in 1990-91.



### **STRETCHED ROHINI SATELLITE SERIES (SROSS)**

The 150 kg SROSS-1 and SROSS-2 missions could not be fulfilled due to ASLV failures.

The future SROSS are expected to carry out a number of scientific experiments in aeronomy provided by the National Physical Laboratory (NPL) and the Physical Research Laboratory (PRL) and astronomy experiments developed by the Indian Space Research Organisation (ISRO) and the Tata Institute of Fundamental Research (TIFR).

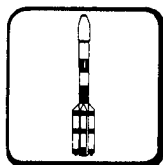


### **POLAR SATELLITE LAUNCH VEHICLE (PSLV)**

PSLV is designed to place 1,000 kg class remote sensing satellites into 1,000 km sun-synchronous polar

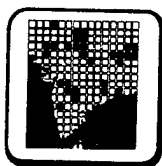
orbits. PSLV, unlike its all-solid stage predecessors, incorporates a liquid propellant second stage motor and a liquid upper stage.

The most significant achievement during the year was the successful static testing of the 125 tonne first stage motor (PS-1), the third largest in the world. With this, qualification tests on all the four stages of PSLV have been completed.



### **GEO-SYNCHRONOUS SATELLITE LAUNCH VEHICLE (GSLV)**

Configuration studies on GSLV capable of placing 2 tonne class payloads in geo-synchronous transfer orbit are in progress. In addition to use of existing/improved solid/liquid stages, indigenous development of a cryogenic upper stage is also planned.

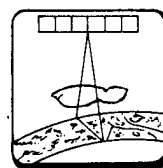


### **NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM (NNRMS)**

The Department of Space is the nodal agency for the establishment

of NNRMS with the participation of Central and State agencies. A number of resources survey and monitoring projects were undertaken during the year by NNRMS. Several steps have been taken towards making available remote sensing data on a continued, assured basis for the various user agencies in the country.

Five Regional Remote Sensing Service Centres (RRSSCs) and a number of associate centres have been already set up in the country under NNRMS. About 19 States have established State Remote Sensing Application Centres.



### **MICROWAVE REMOTE SENSING PROGRAMME**

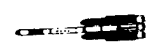
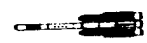
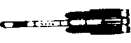
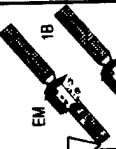
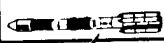
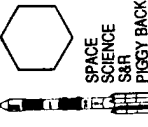
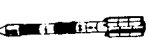
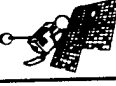
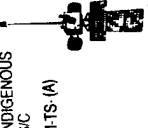
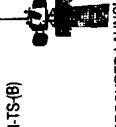
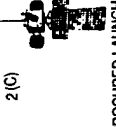
Design and development of a C-band airborne Synthetic Aperture Radar (SAR) has been undertaken.

PDR of the project was completed during the year. Establishment of ground segment to receive and process the SAR data from ERS-1, is planned to familiarise the users with SAR data.

Five application areas for SAR data have been identified including soil moisture, geological exploration, monitoring of oil slick, flood area mapping and snow-melt run-off.

The X-band Side Looking Airborne Radar (SLAR) has been made operational and aircraft flights were conducted during the year.

# MAJOR INDIAN SPACE MISSIONS 1985-95

| MISSIONS              | SEVENTH PLAN |         |                                                                                                           |                                                                                                                             |         | EIGHTH PLAN                                                                                                               |                                                                                                                                   |                                                                                                                                   |                                                                                                                               |                                                                                                                               |
|-----------------------|--------------|---------|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------|---------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
|                       | 1985-86      | 1986-87 | 1987-88                                                                                                   | 1988-89                                                                                                                     | 1989-90 | 1990-91                                                                                                                   | 1991-92                                                                                                                           | 1992-93                                                                                                                           | 1993-94                                                                                                                       | 1994-95                                                                                                                       |
| <b>SROSS<br/>ASLV</b> |              |         |  D-1                   |  D-2                                     |         |  D-3/C-1                                 |                                                                                                                                   |  D-4/C-2                                         |                                                                                                                               |                                                                                                                               |
| <b>IRS</b>            |              |         |  1A<br>PROCURED LAUNCH |                                                                                                                             |         |                                                                                                                           |  1B<br>EM<br>1C<br>PROCURED LAUNCH OR PSLV D301  |                                                                                                                                   |                                                                                                                               |                                                                                                                               |
| <b>PSLV</b>           |              |         |                                                                                                           |                                                                                                                             |         |                                                                                                                           |  D-1                                             |  D-2<br>SPACE SCIENCE S&R PIGGY BACK             |  D-301                                       |                                                                                                                               |
| <b>INSAT</b>          |              |         |                                                                                                           |  1-C<br>PROCURED S/C<br>PROCURED LAUNCH |         |  1-D<br>PROCURED S/C<br>PROCURED LAUNCH |  II-TS (A)<br>INDIGENOUS S/C<br>PROCURED LAUNCH |  II-TS (B)<br>INDIGENOUS S/C<br>PROCURED LAUNCH |  2 (C)<br>INDIGENOUS S/C<br>PROCURED LAUNCH |  2 (D)<br>INDIGENOUS S/C<br>PROCURED LAUNCH |
| <b>GSLV</b>           |              |         |                                                                                                           |                                                                                                                             |         |                                                                                                                           |                                                                                                                                   |                                                                                                                                   |  D-1<br>TMP/PIGGY BACK                     |  D-2<br>TMP/PIGGY BACK                     |

S&R - SEARCH & RESCUE  
TMP - TECHNOLOGY MONITORING PAYLOAD

# Introduction

The Indian Space Programme continued to provide operational services in the areas of satellite-based remote sensing and communication during the year 1989-90. The first Indian Remote Sensing Satellite, IRS-1A, launched in March 1988 has been functioning well over the last two years, providing quality imageries covering the entire country several times. Having become the mainstay of the National Natural Resources Management System, it has demonstrated the indigenous capability for building and operating state-of-the-art remote sensing system—both space segment and ground segment. INSAT-1B was expected to reach its end of life by September/October 1989, but continued its operational services into the 1990 as the result of a carefully planned mission operations strategy. In order to augment space segment capacity, keeping in view the partial availability of INSAT-1C (which subsequently lost earth lock) and the delay in the launch of INSAT-1D, alternate arrangements were made through lease of transponders from other satellites. The successful static testing of PSLV first stage motor, the third largest in the world, was a major achievement during the year in indigenous launch vehicle development effort.

The first Indian Remote Sensing Satellite, IRS-1A, launched on March 17, 1988 by a Soviet Vostok rocket, continued to provide quality imageries. The satellite carrying two types of imaging sensors with spatial resolutions of 72.5 m and 36.25 m (LISS-I & LISS-II) returns to its original orbital trace every 22 days enabling repeated collection of data at the same place and at the same local time. The IRS-1A data products generation and dissemination are carried out by National Remote Sensing Agency and Space Applications Centre. Work on follow-on satellite, IRS-1B, to be launched by the middle of 1991, made satisfactory progress during the year. The second generation IRS, namely, IRS-1C and IRS-1D, designed to have better spectral and spatial resolutions, more frequent revisits, stereo viewing and onboard recording capability, are planned to be launched during 1993-94 and 1995-96 period respectively.

INSAT-1B which was launched in August 1983 continued to provide operational services during the year. The satellite which was earlier expected to reach its end of life in September/October 1989 continued its operations into the 1990 through certain carefully planned mission operations strategy. INSAT-1C, launched in July 1988, was working with partial capacity due to a suspected grounding in one of the two power buses. The loss of the power bus had made the thermal and power management difficult. The satellite was also experiencing command anomaly intermittently and the satellite lost earth lock on November 22, 1989 during one such period of command anomaly because of which it could not be put into safe mode.

INSAT-1D was planned to be launched on board the US launch vehicle, Delta 4925, in June/July 1989. The satellite was damaged by an accident while being mated with the launch vehicle at the Kennedy Space Centre, USA, on June 29, 1989. The satellite was subsequently depressurised, defuelled and transported to the contractor's facility at Palo Alto, USA. A detailed assessment of the damage and recovery plans have since been made and the satellite is expected to be launched by the middle of 1990. In order to augment/back up the INSAT space segment capacity, twelve transponders from the ARABSAT-1B satellite have been leased with effect from October 1, 1989 for a period of two years. Also, one transponder from the INTERSPUTNIK (Statsionar-13) and two transponders from INTELSAT are available on lease.

The development of the indigenous INSAT-II Test Spacecraft made marked progress during the year with the successful completion of structural static tests and realisation of the Engineering Thermal Model (ETM) of the communication payload. The integration and test of ETM is progressing satisfactorily. Flight components fabrication has also commenced. The launch of first INSAT-II TS is planned by end of 1991 on board the European launch vehicle, Ariane, and that of

the second during 1992. Action for building follow-on satellites, INSAT-2C, 2D and 2E, have also been initiated and the project report finalised.

All the four propulsion stages of PSLV have been successfully tested. The most important achievement was the successful static testing of the first stage motor, PS-1, the third largest solid booster in the world, on October 21, 1989. The test data on the 125 tonne, five-segmented motor incorporating the secondary injection thrust vector control system confirmed normal performance of all sub-systems. Test and evaluation of engineering model electronics packages, stage separation systems and structural testing of interstage hardware made substantial progress during the year. The giant mobile service structure, the umbilical tower and launch pedestal have also been erected at SHAR Centre.

Meanwhile, the Expert Review Panel at the national level and the Failure Analysis Committee on the Augmented Satellite Launch Vehicle (ASLV) finalised their recommendations and suggested certain modifications in the vehicle. The follow-up actions are already on and the launch of ASLV-D3 is planned during 1990-91.

The National Natural Resources Management System (NNRMS), for which the Department of Space is the nodal agency, made substantial contribution in various key areas through its application projects on wasteland mapping, ground water potential zone mapping, geology and mineral resources, urban sprawl mapping, crop acreage and production estimation, drought monitoring, saline and alkaline soil mapping, marine fisheries, flood area mapping, bio-resources and environment, ocean resources and coastal environment, snow cover mapping, etc. Land use/land cover mapping for agroclimatic zones also made sub-

stantial progress during the year and district-wise land use/land cover maps on 1:2,50,000 scale is under preparation using the IRS-1A data in collaboration with a number of Central/State government organisations.

Production of developmental TV programmes in the areas of agriculture, health and animal husbandry were continued during the year.

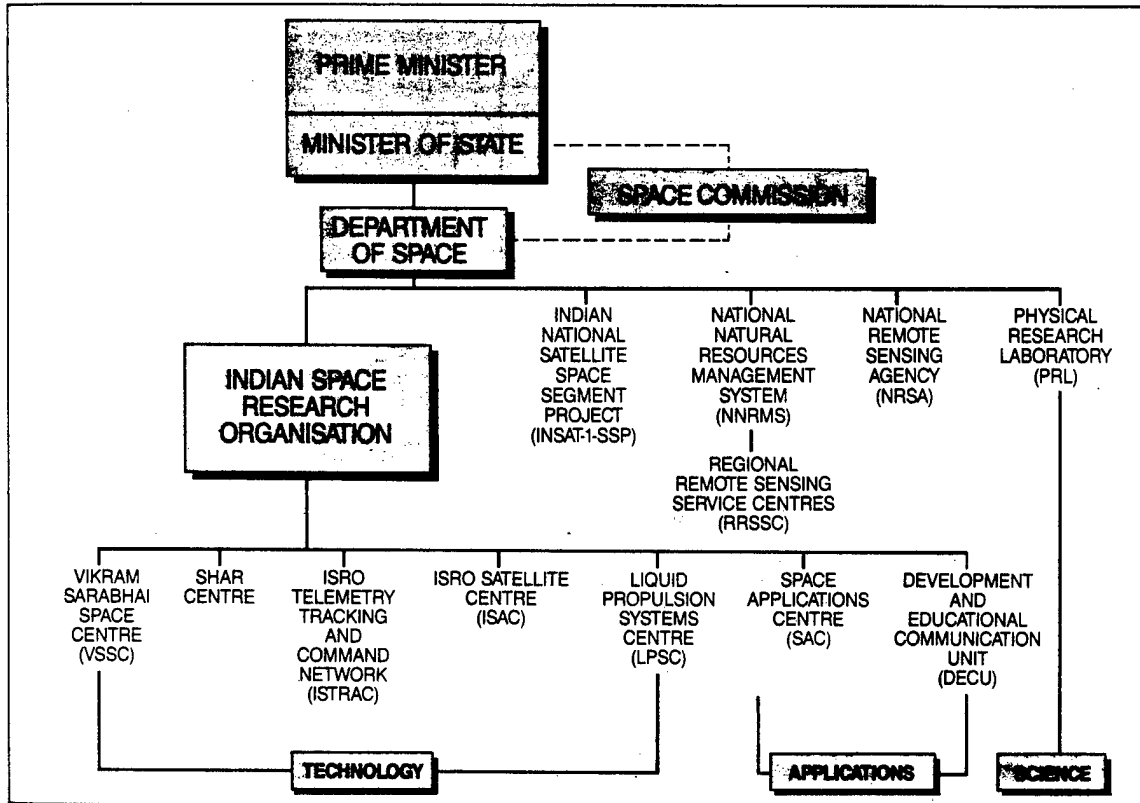
As part of the International Satellite-Aided Search and Rescue programme (COSPAS-SARSAT) network, an Indian Local User Terminal (LUT) along with a Mission Control Centre (MCC) has been established at Bangalore. India is the first country in Asia to establish such a system. The Indian LUT/MCC will also provide distress alert services to Bangladesh, Indonesia, Kenya, Malaysia, Maldives, Singapore, Somalia, Sri Lanka, Tanzania and Thailand. The Department of Space is the nodal agency for this inter-agency effort and the other agencies involved are the Department of Shipping, Civil Aviation, Coast Guard and Defence. The second LUT is being set up at Lucknow to provide better coverage to north-eastern areas.

Studies and advanced research continued during the year keeping in view the future space projects and programmes. Work on an airborne Synthetic Aperture Radar (SAR) was taken up during the year.

The programme of transferring ISRO/NRSA technology to external agencies for commercial applications also continued.

A major exhibition, "Space and Man's Future", organised at Teen Murti House, New Delhi, as part of the Jawaharlal Nehru Centenary Celebration, depicted the Indian Space efforts for the national development. □

# Organisation



The Space Commission and the Department of Space were created in 1972 to promote unified development and application of Space Science and Technology for various national uses. The policies framed by the Space Commission are implemented by the Department of Space (DOS) through Indian Space Research Organisation (ISRO), National Remote Sensing Agency (NRSA), INSAT-1 Space Segment Project Office and other agencies. DOS is also the nodal department for the establishment of the National Natural Resources Management System (NNRMS) in association with various Central and State agencies.

The development activities of ISRO are carried out through its Centres/Units: Vikram Sarabhai Space Centre (VSSC), Trivandrum; ISRO Satellite Cen-

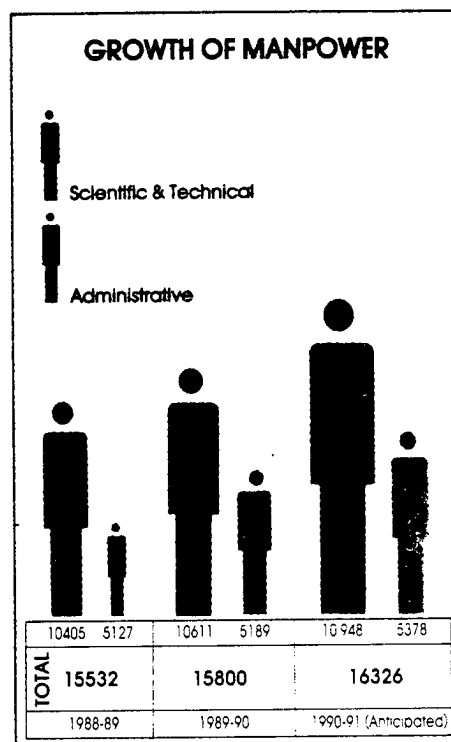
tre (ISAC), Bangalore; SHAR Centre, Sriharikota (Andhra Pradesh); Space Applications Centre (SAC), Ahmedabad; Liquid Propulsion Systems Centre (LPSC) with its facilities at Bangalore, Trivandrum and Mahendragiri; ISRO Telemetry Tracking and Command Network (ISTRAC) with its network of stations, and Development and Educational Communication Unit (DECU), Ahmedabad. The ISRO Council and the ISRO Headquarters at Bangalore provide the overall guidance and direction to the scientific, technological and managerial tasks. Programme offices in specialised areas function as part of the Central Management at ISRO HQ.

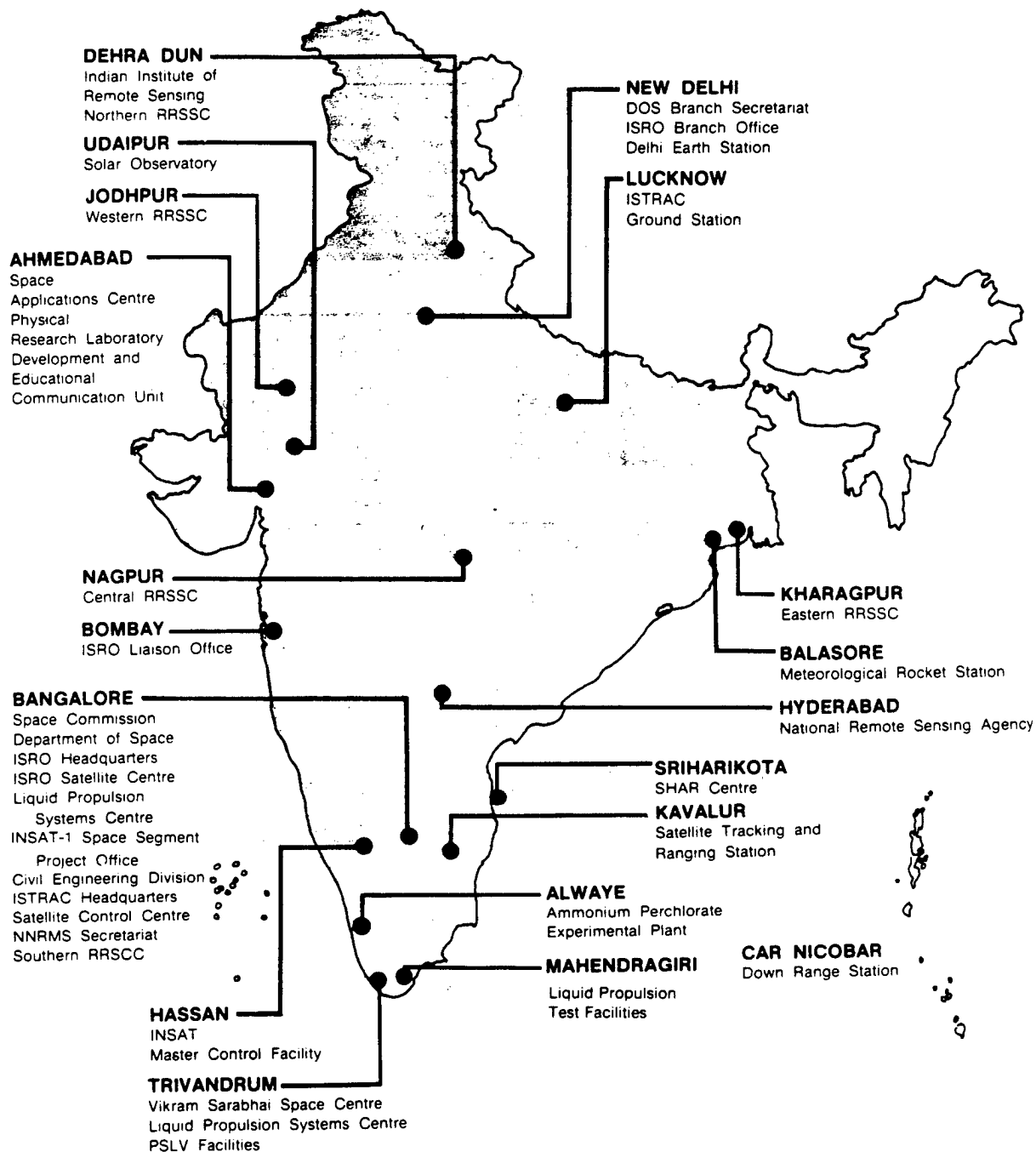
ISRO also supports research activities at the academic and research institutions of the country

in the areas of Space Science, Technology and Applications through its sponsored research scheme known as RESPOND.

The Physical Research Laboratory (PRL) at Ahmedabad, an autonomous institution, supported mainly by DOS, carries out research programmes in space sciences.

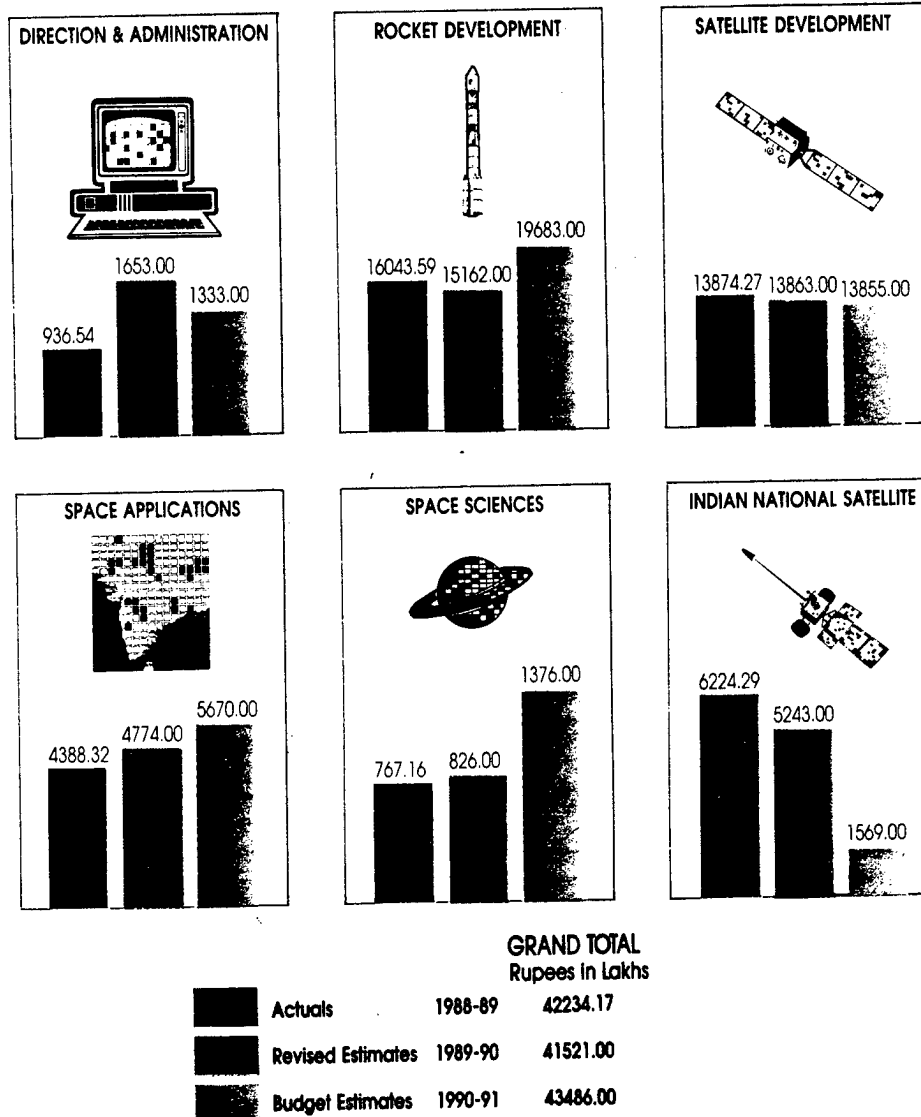
The civil works, including specialised structures for the Space Programme, are executed by the centralised Civil Engineering Division (CED). □





## SPACE CENTRES AND UNITS

## AREA WISE DISTRIBUTION OF FUNDS



# Space Applications

Indian Space Programme is directed towards self-reliance in the use of Space Science and Technology for national development. The main thrust is in the areas of (i) satellite communication for various national applications including telecommunication, TV broadcast and radio networking, (ii) resources survey and management, environment monitoring and meteorological services through remote sensing, and (iii) development of indigenous satellites and launch vehicles to achieve the above objectives.

## INSAT SYSTEM

The first generation Indian National Satellite (INSAT-1) system represents India's first step towards implementing operational space systems for identified national requirements. INSAT-1 is a multipurpose operational satellite system for domestic telecommunications, meteorological observation and data relay, nation-wide direct satellite TV broadcasting to augmented community TV receivers in rural and remote areas, and nation-wide TV programme distribution for re-broadcasting through terrestrial transmitters.

The INSAT system is a joint venture of Department of Space (DOS), Department of Telecommunications (DOT), India Meteorological Department (IMD), All India Radio (AIR) and Doordarshan. The overall co-ordination and management of the INSAT system rests with the high level inter-ministerial INSAT Co-ordination Committee (ICC). The Secretariat of this Committee resides in the Department of Space. The Department of Space has the direct responsibility for establishment and operation of the INSAT space-segment facilities.

The INSAT-1 system was envisaged with a space segment consisting of two multi-purpose satellites, one as the primary satellite providing all services and the other as a major path satellite providing certain additional Fixed Satellite Service (FSS) and also certain on-orbit back-up capability. The

INSAT-1 series of satellites are built by Ford Aerospace Corporation (FAC) of USA under contract with DOS. Each INSAT-1 satellite provides the following capabilities over its individual seven-year in-orbit design life:

(1) Twelve national coverage telecommunications transponders of 36 MHz bandwidth, each operating in 5935–6425 MHz (earth-to-satellite) and 3710–4200 MHz (satellite-to-earth) frequency bands, with 32 dBW (min) EOL eirp over the primary coverage area.

(2) Two high-power national coverage TV broadcast transponders operating in 5855–5935 MHz (earth-to-space) and 2555–2635 MHz (space-to-earth) frequency bands, each capable of handling one direct broadcast (community reception) TV channel and five low-level carriers for services like radio programme distribution, disaster warning, etc., with a 42 dBW (min) EOL eirp over the primary coverage area. These transponders also support the dissemination of certain disaster warning and standard time and frequency signals.

(3) A VHRR instrument for meteorological earth imaging with visible (0.55–0.75  $\mu\text{m}$ ) and infrared (10.5–12.5  $\mu\text{m}$ ) band channels, with resolutions of 2.75 and 11 km respectively, with half-hourly full earth coverage and sector scan capability.

(4) A data relay transponder with global receive coverage with a 402.75 MHz earth-to-satellite link for relay of meteorological, hydrological and oceanographic data from unattended land and ocean-based automatic collection-cum-transmission platforms.

## INSAT-1B

The INSAT-1B satellite, launched in August 1983, has completed 77 months in orbit and over 75 months of operational service as of January 31, 1990. INSAT-1B is located at 74 degree E longitude. All the four service payloads on board

INSAT-1B are 'ON' and, all except one of the twelve FSS C-band transponder channels, are in satisfactory operation.

### **INSAT-1C**

INSAT-1C was launched on July 22, 1988 on board the Ariane launch vehicle. After its successful orbit raising operations and deployments, the satellite was placed in its "on-orbit" configuration on July 27, 1988. On July 29, 1988 the spacecraft experienced a 'loss of earth lock' because of a suspected grounding in one of the power buses resulting in loss of about half of the payloads/house-keeping equipment. In view of the above losses, the thermal and power management of the satellite had become difficult. In spite of the above setbacks, INSAT-1C was being utilised for telecommunications traffic, national TV and VHRR imaging till November 22, 1989, when the spacecraft lost earth lock.

### **INSAT-1D**

The procurement of INSAT-1D spacecraft from FAC was approved by the Government of India in 1985. INSAT-1D spacecraft is similar to the earlier INSAT-1 series of spacecraft, INSAT-1A, B and C except for higher battery capacity, 3:2 redundancy for output devices (TWTs) of CxC transponder channels No. 11 and 12 and a larger propellant tank to permit additional propellant loading, etc.

INSAT-1D was slated originally for NASA shuttle (STS) launch. Due to non-availability of a timely STS launch in mid '87, the launch was moved to a commercial Delta 4925 of McDonnell Douglas Astronautics Company. The spacecraft was delivered for launch in April 1989. Unfortunately, in June 1989 while the spacecraft was being mated with the launcher at the Kennedy Space Centre, Florida, USA, a crane hook assembly accidentally fell on the spacecraft. One of the two antennae on the spacecraft was severely damaged necessitating replacement. Some other parts were also affected. These are being repaired/replaced. The spacecraft was defuelled and transported to FAC, Palo Alto,

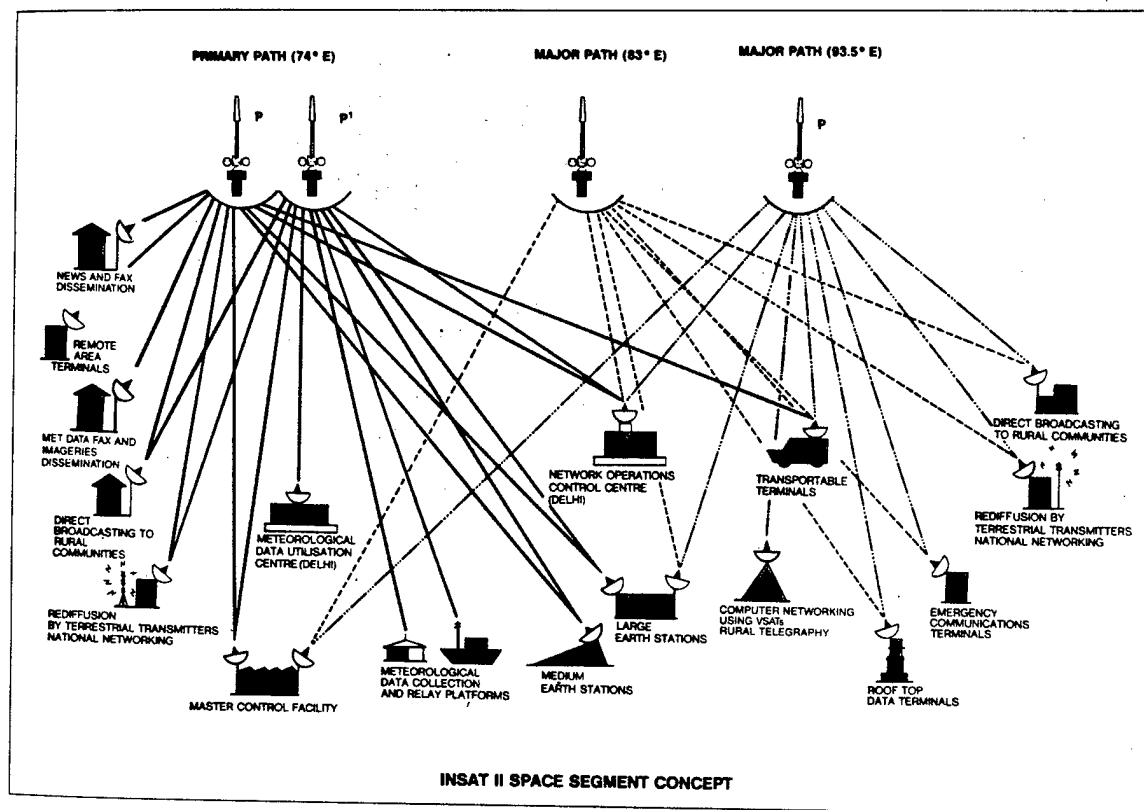
for rework. The recovery plan calls for the repair of, among other things, east panel, the C-band reflector, solar array hinges, east panel thruster, heatshields and some thermal blankets.

Validation tests at subsystem levels and certain spacecraft all-up tests for essentially checking the overall spacecraft performance after the necessary repairs/replacements will be performed as per the comprehensive test plan. The spacecraft is expected to be ready for shipment to the launch base in April 1990. The launch window for the Delta 4925 launch of INSAT-1D has been fixed between mid May 1990 and mid June 1990.

### **INSAT-II TEST SPACECRAFT**

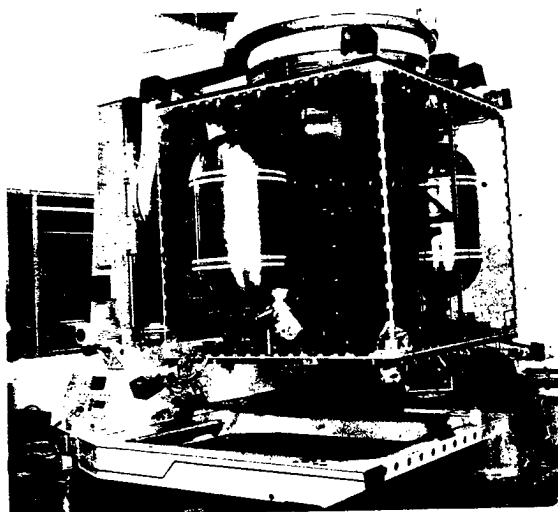
The foreign-procured and foreign-launched INSAT-1 spacecraft will be gradually replaced by indigenously developed second-generation INSAT spacecraft, INSAT-II, which will eventually be launched from India by the Indian Geosynchronous Satellite Launch Vehicle (GSLV) during the 1990s. The operational INSAT-II spacecraft are to be preceded by two INSAT-II Test Spacecraft (INSAT-II TS) to be launched in 1991 and 1992, to demonstrate and flight-test the indigenous design and engineering of the spacecraft before pressing them into operational service.

The second-generation INSAT-II space segment and the associated spacecraft configuration have been defined under the umbrella of the INSAT Co-ordination Committee based on the requirements for satellite services for the 1990s projected by the participating user agencies, namely, Department of Telecommunications, India Meteorological Department, All India Radio and Doordarshan. The initial all-up INSAT-II space segment will have three multi-purpose satellites, two of them collocated at the primary orbital position and one at the major-path orbital position. The two collocated spacecraft at the primary orbital position are station-kept in such a manner that they appear as a single large-capacity spacecraft in terms of their total Fixed Satellite Service (FSS) capacities in conventional and upper extended C-band, through use of orthogonal polarisation.



INSAT-II satellites will have enhanced capabilities and will be about 50% heavier than INSAT-1. INSAT-II will weigh about 1,900 kg at lift-off and about 860 kg in geo-synchronous orbit. The satellite has a length of about 23m in the fully deployed condition and has the capability to generate minimum End of Life (EOL) power of 1,180 Watts. INSAT-II, like INSAT-1, is a three-axis-stabilised satellite with similar structure except for some modifications. The solar array consists of three full panels and two half panels and, unlike in INSAT-1, are arranged in such a way as to avoid partial deployments during transfer orbit phase. Apart from having two 1.77m deployable communication antennae on east and west faces of the satellite for providing C-band and S-band transmit function, INSAT-II has a third fixed antenna of 0.9m diameter added for all 6 GHz receive and VHRR, DRT and SAS&R data transmit functions, resulting in greater mission function savings in case of deployment anomalies.

To provide improved coverage for TT&C during on-orbit phase, a global horn is provided apart from the TT&C omni antenna. Each of the INSAT-II satellites will have a total of 18 FSS transponders, 12 in normal C-band and 6 in extended C-band with a capability to provide 32 dBW Edge of Coverage (EOC) eirp from 16 transponders for communication and television distribution services and 34 dBW from 2 high-power transponders for specialised telecommunication requirements using roof-top terminals. For Broadcast Satellite Service (BSS), each INSAT-II will use 2 high-power (42 dBW-eirp) S-band transponders. For the meteorological applications, INSAT-II will have a VHRR with improved resolution compared to INSAT-1, viz., 2 km in the visible and 8 km in the infrared band. It will also have a Data Relay Transponder (DRT) with global receive coverage in UHF band for receiving meteorological, hydrological and oceanic data from unattended land and ocean-based platforms



*INSAT-II TS ETM under integration*

and transmit them to a central facility. DRT also caters to the payload for satellite-aided search and rescue mission which is a new addition to INSAT system. This payload will provide for an instantaneous emergency alert capability in this part of the world and will form part of the international COSPAS-SARSAT system.

The INSAT-II TS project, formally sanctioned in April 1985, covers delivery of two INSAT-II Test spacecraft along with required spares and augmentation of the INSAT Master Control Facility (MCF) at Hassan to simultaneously handle two INSAT-1 and two INSAT-II(TS) spacecraft, with one of the two INSAT-II(TS) spacecraft being in the orbit-raising phase. The programme elements of the project also cover establishment of the necessary infrastructure around the existing facilities of DOS/ISRO. One of the major facilities being established in this connection at the ISRO Satellite Centre, Bangalore, is the Large Space Simulation Chamber (LSSC). It is expected to be commissioned during the first quarter of 1990. The first INSAT-II Test Spacecraft launch is expected by the end of 1991 and that of the second during 1992. Launch services agreements have been signed with Ariespace for the launch of both the INSAT-II Test Spacecraft.

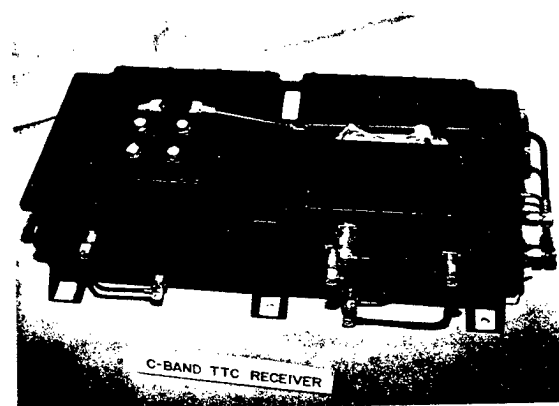
Static test on the first structural model of INSAT-II TS has been successfully completed. Dynamic

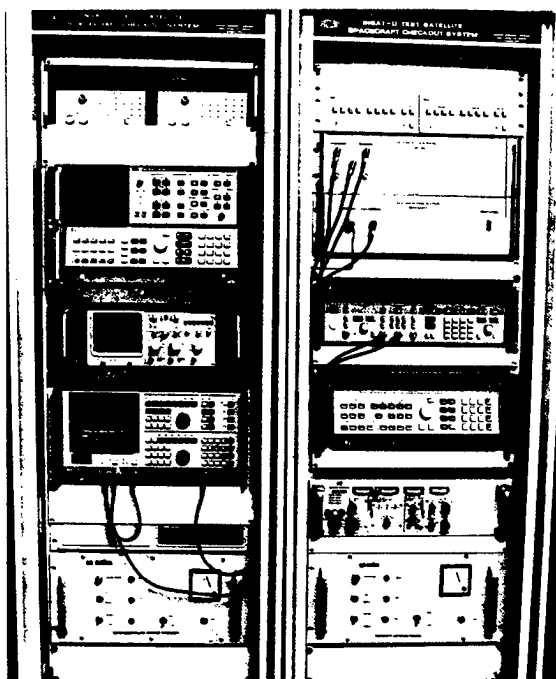
tests preparations are under way. All systems for the structural model have been realised and integrated.

The Critical Design Review (CDR) of the INSAT-II TS communication payload was successfully completed in November, 1989. All the communication payload packages of the Electrical Thermal Model (ETM) have been integrated on spacecraft equipment panel. Vertical high-bay deployment of solar sail/boom has been successfully carried out. Propulsion tanks have also been integrated on ETM.

The ETM integration and testing are progressing satisfactorily and expected to be completed by early 1990. The spacecraft level CDR is planned to be held by the middle of 1990.

Procurement of flight components are in the final phase. Contract for the procurement of micro-





*Automated communication payload checkout system for INSAT-II TS*

processor for AOCE has been finalised after export licence clearance. Fabrication of flight model components/subsystems have commenced.

### **INSAT-2 Operational Spacecraft**

The INSAT-2 operational spacecraft will be identical to INSAT-II Test Spacecraft and the first of the series is planned to be launched in 1993-94. The operational INSAT-2 space segment configuration consists of three spacecraft, two collocated at the primary orbital location, and one at the major path location.

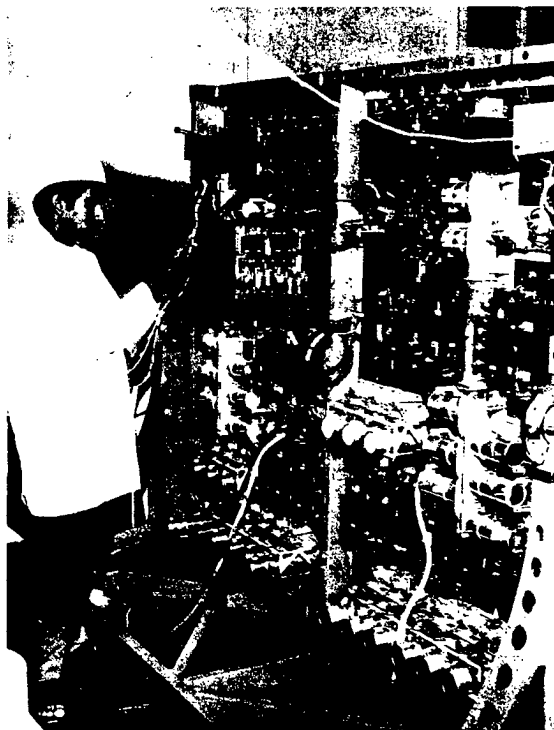
### **INSAT-3**

The definition of the third generation INSAT spacecraft (INSAT-3) has been initiated. The user departments have been requested to project their requirements in terms of space segment capacity.

### **INSAT Master Control Facility (MCF)**

The performance of the INSAT MCF systems has continued to be satisfactory. MCF availability for INSAT-1B & 1C TT&C functions has been 100%. MCF has been augmented with a 7.5 m diameter antenna and associated earth station equipment, a new stand-alone telemetry and telecommand console for on-orbit control of INSAT-1B and also a back-up command generator. The new limited-steerability 7.5 m diameter antenna and the stand-alone T&C console were able to handle on-orbit control of INSAT-1B during INSAT-1C launch/orbit-raising phase, and freed the two 14 m diameter antennae and the main Satellite Control Centre (SCC) T&C consoles for launch phase/orbit-raising operations of INSAT-1C.

MCF is under augmentation for INSAT-II TS. The augmentation includes one new 11 m diameter limited-steerability antenna with associated earth station equipment, INSAT-II Satellite Control Centre (SCC) with associated computer facilities,



*ETM communication payload panel for INSAT-II TS*

associated civil works, etc. The INSAT-II TS-related civil works at MCF have already been completed. The contract for the 11 m diameter antenna, all C-band equipment, tracking receiver, etc., have been awarded on a turn-key basis. The equipment in the extended C-band are supplied by SAC.

Both the 11 m diameter antennae for INSAT-II TS Programme (one with limited-steerability) have been installed at MCF. These antennae will provide support during INSAT-1D launch also.

### **INSAT Utilisation**

As of January 1, 1990, a total of 97 receive/transmit telecommunications terminals of various sizes and capabilities (excluding NICNET micro-terminals) were operating in the INSAT telecommunications network providing some 4,372 two-way speech circuits or equivalent over 118 routes. These comprise 61 fixed, 17 transportable and 19 in captive networks (ONGC, ITI, NFL, Master Earth Stations of NICNET and Government). Use of satellite capacity on Madras-New Delhi route by 'The Hindu' newspaper for facsimile transmission of fully composed pages for printing of its Delhi edition has continued. Over 100 additional earth stations, including 50 Rural Telegraphy Networks (SBRTN) Pilot Project in the north-eastern region are under various stages of implementation in the DOT network. 32 additional telecommunications earth stations are also under implementation for eight different captive/business networks. In the National Informatics Centre Network (NICNET), at present over 360 micro-terminals are operating and the plan is to eventually have one NICNET micro-terminal in every district headquarters. Various other networks for dedicated use are under implementation.

As of September 30, 1989, the INSAT-1B satellite had been commanded to give 28,447 meteorological images—28,336 full earth and 111 sector scans. Now in its seventh year of satisfactory operation, the INSAT-1B VHRR is one of the very few geo-stationary VHRR instruments that have completed long term satisfactory space operation without exercise of any redundancy. The Meteorological Data Utilisation Centre (MDUC)

of IMD processes, utilises and disseminates the INSAT-1 meteorological images. Upper winds, sea surface temperature and precipitation index data products are regularly generated by MDUC/IMD. The 0600 hrs GMT VHRR image-derived winds are regularly put on the Global Telecommunications System (GTS) of the World Meteorological Organisation (WMO). 0300 hrs GMT full-disk IR pictures are being transmitted as radio facsimile broadcast every day for reception in the neighbouring countries. The INSAT-1B VHRR imageries are regularly used on Doordarshan's daily night news coverage as well as by some newspapers for daily weather reporting. At present, repetitive and synoptic weather systems observations over the Indian Ocean area from geo-stationary orbit are available only from the INSAT system.

The MDUC/IMD-processed INSAT-1B VHRR data is now available in near-real-time at some 22 Secondary Data Utilisation Centre (SDUC) locations in various parts of the country. Two of these locations are provided with the processed data over a CxS direct satellite retransmission facility. With the commissioning of this direct satellite retransmission facility, which also uses INSAT-1B, it is now possible to provide SDUC-type data at any location in the country irrespective of its distance from Delhi (MDUC/IMD) and availability of point-to-point terrestrial transmission circuits. A Meteorological Data Dissemination Service (MDDS), that transmits processed VHRR imagery, weather charts and weather data, has been operationalised via INSAT-1 satellites to enable SDUCs or any one interested in this data to receive the same on a broadcast mode. After INSAT-II TS launch, it will be necessary to process meteorological data from both satellites simultaneously in view of the overlapping life spans of INSAT-1 and INSAT-II. The present MDUC will not be able to process INSAT-II data because of differences in data formats, and the large volume of data to be handled. A joint IMD/DOS task group has defined the INSAT-II(TS)/INSAT-II VHRR data processing facility at MDUC/IMD, New Delhi. The implementation of the earth station segment of this facility has been taken up at SAC, Ahmedabad, on a turn-key basis. This earth station which will work in the extended

## INSAT-I SYSTEM UTILISATION

### TELECOMMUNICATION

- **Operational**
  - 4372 Two-way voice circuits or equivalent
  - 117 Routes
  - 90 Earth Stations including 14 captive networks and 16 transportable terminals
  - Over 300 micro-terminals in NICNET
- **Under Implementation**
  - Over 100 Earth Stations including 50 for N.E. Region Telegraphy, more VSATs, in NICNET
  - 32 additional earth stations for captive networks
- **Under Definition**
  - Data Networks
  - More captive business networks

### INSAT

#### PTI

- **Commissioned**
  - Direct dissemination of news, stories & Fax to newspapers

#### NPL

- **Operational**
  - Standard time and frequency signals dissemination

### TELEVISION

- **Operational**
  - 2 channel national service covering over 300 TV stations
  - 8000 DRSs
  - Regional Services for Maharashtra & AP
  - Two captive transportable TV uplinking terminals
  - Regional service to Tamilnadu in CxS transponder
- **Under Implementation**
  - Three Regional Services
  - 50 additional TV transmitters in INSAT network by end of Seventh Plan
  - Deployment of 1100 DRSs in N.E. Region

### METEOROLOGY

- **Operational**
  - Half-hourly, synoptic full disc & sector scan
  - 20 secondary data utilisation centres
  - 100 DCPs
  - 14 DCPs in Yamuna catchment area deployed 100 DWS
- **Approved for/ under Implementation**
  - Anchored buoy DCPs
  - CxS broadcast of live images & Data
  - Improved system to transmit processed VHRR imagery and other met data on one carrier to SDUCs and any location in the country More DWS Receivers

### RADIO

- **Operational**
  - 3-channel national regional radio network
  - Uplinking facilities from Delhi, Bombay, Calcutta, Madras
  - Two channels direct earth terminals at over 100 AIR stations
  - National service channel feed
- **Under Implementation**
  - 18 AIR stations to have 3-channel RN terminals
  - Captive uplinking terminal
  - Two channels direct to Lakshadweep Islands

C-band is expected to be completed in 1991. All the intended initial set of 100 Data Collection Platforms (DCPs) have been installed. DCP data is also processed, utilised and disseminated by MDUC IMD. One of these INSAT DCPs is deployed at the Indian base station, Schirmacher Hills, Antarctica. The Central Water Commission (CWC) has deployed 14 DCPs in the Yamuna catchment area for flood forecasting purposes. DCPs on buoys are undergoing test from April 1988.

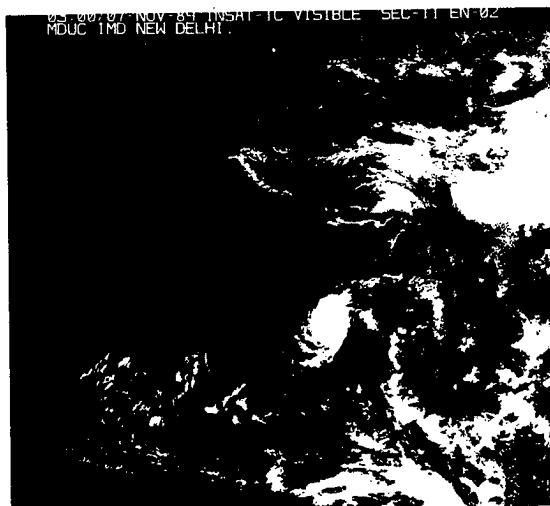
All the intended initial set of 100 Disaster Warning System (DWS) receivers have also been installed in selected cyclone-prone east coastal areas of Andhra Pradesh and Tamil Nadu and the DWS uplink from Madras has been available. These DWS receivers are selectively addressable. The first operational use of the INSAT Disaster Warning System was in 1987. IMD is also planning deployment of additional units of receivers in other cyclone-prone coastal areas of the country.

The two high-power S-band transponder channels on board INSAT-1B are utilised by Doordarshan for nationally-networked TV programmes feed, for Delhi-originated TV programmes feed for a large number of low-power TV transmitters operating in the national TV system, for transmitting UGC-sponsored higher education enrichment TV programmes, for school ETV programme feed in selected States and for area-specific direct TV broadcast to augmented community TV receivers in selected rural areas. These S-band transponders are also supporting a six-channel radio networking service, the cyclone disaster warning service, standard time and frequency signal dissemination (by the National Physical Laboratory) and a direct satellite retransmissions facility for processed INSAT meteorological (VHRR) images. In addition, a C-band transponder channel is providing regional feeds for Maharashtra and Andhra Pradesh in a half-transponder TV mode. As of November 1989, over 500 TV stations operating in the coun-

try were in the INSAT-1B network.

Some 2,000 Direct Reception Sets (DRSs) have been installed in the various parts of the country with funding by the Ministry of Information and Broadcasting (MI&B). In addition, about 4,000 DRSs are deployed through other programmes/initiatives. MI&B plans to deploy another 1,100 DRSs in the north-eastern region out of which 75 DRSs have been supplied by KELTRON and are operating satisfactorily. From December 1988, the monthly use of the two S-band transponder channels and one C-band transponder channel has registered over 1,000 hrs per month. Since August 1988, a regional service for Tamil Nadu is being provided through the CxS transponder of INSAT-1B. Recently regional services have also been provided to Maharashtra and Andhra Pradesh. MI&B/Doordarshan now have two captive transportable TV uplink terminals in addition to three of DOT. Thus, there are now five transportable TV uplinking facilities available/operating in the INSAT TV network.

The Radio Networking Service via INSAT provides reliable, high-fidelity, five channel national/regional feeds for retransmission by AIR stations. At present all the intended centres of AIR numbering 102 are equipped with five-channel S-band receive terminals and are in the INSAT Radio Network. In addition to a five-channel Radio Networking (RN) uplink capability available from Delhi, single channel uplinking capabilities are also available from Calcutta, Bombay and Madras. AIR has also taken action to add certain captive transportable RN uplinking terminals. The cumulative monthly utilisation of the five RN channels is now registering about 2,400 hrs per month. A sixth radio networking channel for programme feed to the national service channel radio transmitter at Nagpur has also been operational for over a year now. This channel will support programme feeds to other radio transmitters as and when they get introduced in the national service channel network. This channel will also be used later for synchronisation of transmitters in the national channel network. A scheme for a regional radio service to Lakshadweep group of islands using INSAT-based programme feed from Kavaratti is under finalisation. The satellite signal will



*Cyclone off east coast—INSAT imagery*

also be used for tele-operation of this Very Low Power Radio Transmitter (VLPRT) network.

A Standard Time and Frequency Signal Dissemination Service (STFSDS) using a Radio Networking (RN) like CxS carrier on INSAT-1B, has been commissioned by National Physical Laboratory (NPL), New Delhi. This service is available round the clock in a broadcast mode at downlink frequency in S-band and is receivable on a set-up consisting of an 8 ft diameter chicken-mesh antenna, a front-end converter, an FM demodulator and a micro-processor-controlled signal decoder.

The Press Trust of India (PTI) is implementing a system to provide its news and information services at higher speed and in increased volume and variety, directly to a wider range of media and other users across the country by utilising the broadcast facilities of INSAT-1B satellite. The project will utilise a Radio Networking (RN) type channel on one of the broadcast (CxS) transponders of the satellite. The PTI Satellite News and Facsimile Dissemination Project is operational with 13 terminals (12 of PTI and 1 shared with AIR). The three main features of the project are:

1. Time division and frequency division multiplexing/demultiplexing of news and newsphoto-carrying communication channels

to enable PTI to simultaneously broadcast its English, Bhasha (Hindi) and other Indian language and commercial news services, News-scan and Comscan (video-text) and other services as well as its news-photo service directly to media and other users all over the country as required.

2. Dynamic time-sharing of the RN channel by multiple uplinks which will enable PTI to transmit its news and news-photo services simultaneously from its four main news bureaux at New Delhi, Calcutta, Bombay and Madras.
3. Sharing of All India Radio and Doordarshan direct reception facilities for parallel reception of PTI news services along with their own signals.

In view of the importance of the project in improving the dissemination of news and information in the country, the INSAT Coordination Committee (ICC) has allotted the RN channel for the project free of space-segment costs for one year and the Ministry of Information & Broadcasting has provided financial assistance for the project. The planning and implementation of the project is being monitored by a working group comprising representatives of All India Radio, Doordarshan, Departments of Electronics and Telecommunications, PTI and ISRO.

The project envisages the setting up of transmission-cum-reception systems in New Delhi, Bombay, Calcutta and Madras and direct reception terminals in 22 other centres (nearly half of them sharing uplink at New Delhi). The first phase has begun with the installation of the transmission and reception systems. Experiments with units manufactured indigenously are planned to be implemented in the second phase. The one-year project is expected to flow into regular operational news services.

The INSAT Systems Group (ISG) which is a part of Systems and Application Engineering Group (S&AEG) of SAC has carried out several studies for enhancing the INSAT system planning and utilisation. Development of Satellite News Gathering (SNG) service in CxS band and CxC band using ultra-portable vehicle-mounted terminals for TV/Radio was initiated.

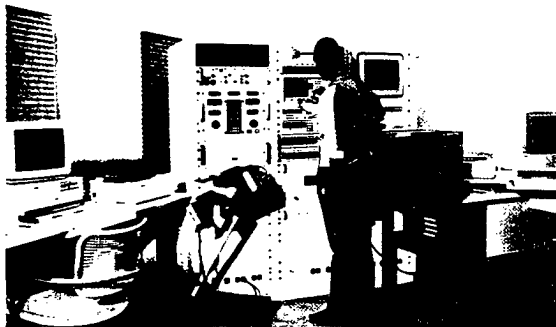
## **Lease of Transponders**

As a back-up to INSAT System two transponders from INTELSAT are available on lease. To further augment/back-up INSAT space segment capacity, an agreement to lease twelve C-band transponders was reached with ARABSAT Organisation. The lease is from ARABSAT-1B spacecraft located at 26 deg E for two years and is effective from October 1, 1989. Also, one transponder has been leased from INTERSPUTNIK (Statsionar-13 satellite situated at 80 deg. E) for a period of nine months to provide back-up for National TV services. The Delhi Earth Station (DES) has been used extensively to uplink Doordarshan TV programmes to INTELSAT and Statsionar-13 satellites. The C-band FSS capacity has been supplemented by two C-band transponder channels leased on an Indian Ocean Region (IOR) INTELSAT satellite.

## **SATELLITE-AIDED SEARCH & RESCUE PROGRAMME**

The activities under the satellite-aided Search & Rescue (SAS&R) programme made substantial progress during the year. India had already signed an agreement with COSPAS-SARSAT parties for the use of the systems and operation of Local User Terminal(s) (LUT) in India. In the light of the changed structure of the earlier COSPAS-SARSAT organisation from an inter-agency programme to an inter-governmental programme, the COSPAS-SARSAT Council has replaced the COSPAS-SARSAT Steering Committee, and India would be shortly signing the Letter of Notification, as required by the new procedures, as a ground station provider.

The first LUT and the Indian Mission Control Centre (MCC) at Bangalore have been established as per schedule. The second LUT at Lucknow is expected to be ready by March 1990. The 406 MHz SAS&R payload for putting on board INSAT-II TS has been developed and the engineering model completed. The work on the Receive Terminal for INSAT-II down link has also been taken up at SAC. The 406 MHz beacon development is progressing well within ISRO



*The signal processor of Local User Terminal*

as well as in the industry and is expected to be ready by April 1990.

The first LUT and MCC are located at the premises of ISTRAC, Bangalore. They are funded by the participating agencies, viz., Services, Shipping, Civil Aviation and Coast Guard. The establishment of the Bangalore LUT and MCC as a part of COSPAS-SARSAT network is a significant milestone in the Indian Satellite-Aided Search and Rescue programme. The Indian LUT and MCC have been accepted as part of the international COSPAS-SARSAT network. Since this is the first LUT to be established in the Indian Ocean region, providing realtime coverage to a large part of the hitherto uncovered area, India has been requested by COSPAS-SARSAT organisation to include the countries in the neighbouring region as part of the Indian MCC service area. The countries are Bangladesh, Indonesia, Kenya, Malaysia, Maldives, Singapore, Somalia, Sri Lanka, Tanzania and Thailand.

The Indian MCC operations are routed through National Airports Authority of India (NAA) which has Rescue Co-ordination Centres (RCC) at Bombay, Calcutta, Delhi and Madras. The search and rescue activities are carried out by Coast Guard, Navy and Air Force and co-ordinated by the NAA's RCCs. MCC is linked with the RCCs through automatic telex mode. As an alternative, MCC is also being provided with the Aeronautical Fixed Telecommunication Network linkage with the Indian RCCs and other international RCCs as well as MCCs.

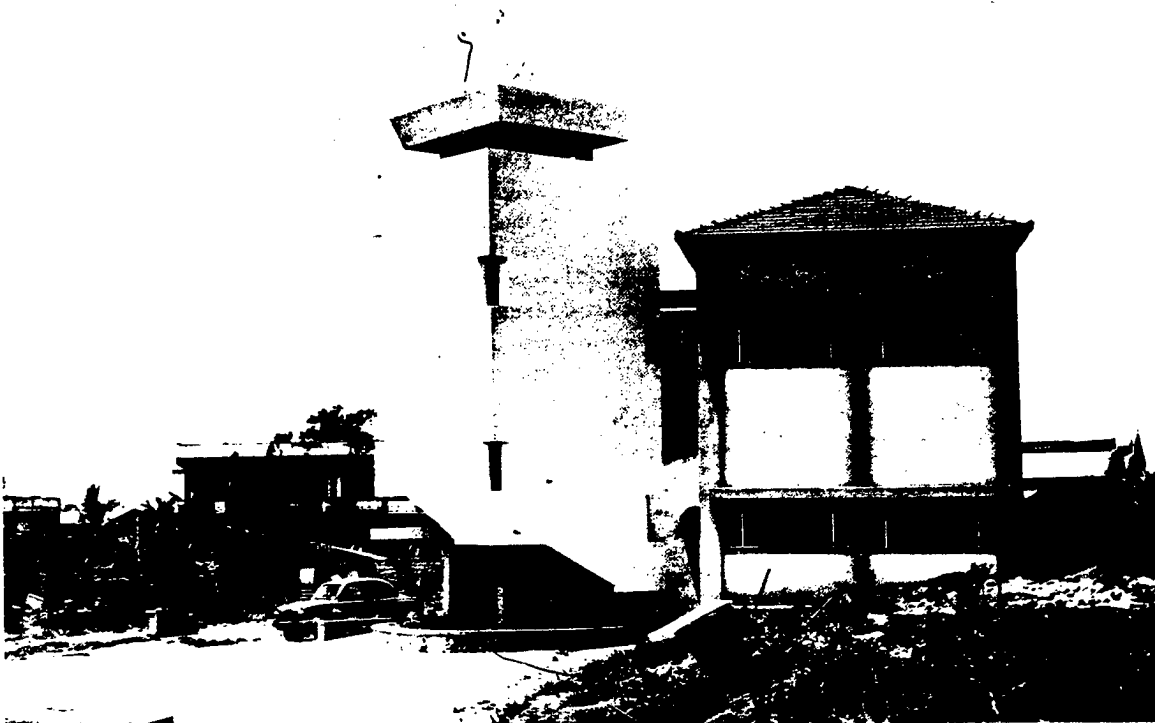
India has been taking part in the COSPAS-SARSAT operations, technical working groups and Exercise Co-ordinating Committee meetings called by the COSPAS-SARSAT Secretariat and ensuring that the Indian inputs are reflected properly in the procedures under evolution. India is one of the few MCCs which participated in the International 406 MHz Beacon Exercise carried out during November 1989, since our system incorporates all the latest Standard Interface Requirement specifications which are essential for inter-MCC communications on a computer-computer basis.

On the international co-operation front, the compatibility testing of the existing 243 MHz beacons has been carried out at GSFC of NASA. Based on the discussions with Glavkosmos, one USSR team visited India in January 1989 with some 406 MHz beacons which were deployed in mountainous and high-sea conditions to evaluate the system performance in adverse conditions. Some of the existing 121.5 MHz beacons were deployed in the north to check their compatibility with COSPAS-SARSAT system and the limit of visibility from USSR's Novosibirsk LUT during December 6-8, 1988.

The year 1990-91 will see the operationalisation of the COSPAS-SARSAT ground systems, production of 406 MHz beacons in the country, readiness of the INSAT-II receive terminal subsystems, etc. Planning for an Indian orbiting payload with all the three frequencies (121.5, 243 and 406 MHz) will also be taken up during the next year.

## **RADIO DETERMINATION, NAVIGATION AND MOBILE SATELLITE COMMUNICATION SERVICES**

ISRO is planning an aeronautical satellite communication demonstration using INMARSAT space segment in the early 1990s. The participating agencies include Videsh Sanchar Nigam Limited (VSNL), Department of Telecommunications (DOT), National Airports Authority (NAA) and Directorate General of Civil Aviation (DGCA) besides DOS. This is a new field of service being conceived for the purpose of providing data and



*Local User Terminal and Mission Control Centre at Bangalore*

voice communication between aircraft and ground. For this demonstration, INMARSAT is providing one set of Aeronautical Earth Station (AES) avionics, an associated high gain aircraft antenna system and one set of AES functional test equipment.

ISRO has undertaken development of the INMARSAT Standard-C terminal and is involving many electronics industries from the design stage itself so that the terminals could be productionised early, after technology transfer. The primary communication function of the Standard-C terminal is text and data transmission to and from ships/remote location and terrestrial subscribers via a variety of public network. The Standard-C terminal development is in an advanced stage and is expected to be completed shortly.

Under the Inter-Agency Steering Committee

(IASC) on Radio Determination Satellite Service (RDSS) and Mobile Satellite Service (MSS) a task team was constituted to lay down specifications and standards for development of Global Positioning System (GPS) receiver in India. ISRO has taken up the development of a sequential GPS receiver capable of receiving the Coarse Acquisition (C/A) code from the US GPS satellites meant for satellite-aided navigation globally.

## **FREQUENCY MANAGEMENT**

The main objective of frequency management is to ensure that the usage of frequencies by DOS/ISRO projects and programmes are in accordance with guidelines and rules set at national and international levels, and to find ways and means for overcoming technical compatibility problems, if any. This involves projection of DOS/ISRO frequency re-

quirements to the national agency responsible for frequency allocation and carrying out suitable co-ordination activities required for national and international frequency clearance in consultation with Centres and Units. Protection of operations of DOS/ISRO projects/programmes from inter-system interference point of view is an important activity. The frequency management activities include participation in the work of International Telecommunication Union (ITU)/CCIR Study Groups and other international fora like Space Frequency Co-ordination Group (SFCG) and providing technical contributions in Frequency Management area.

## **NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM (NNRMS)**

The major components of National Natural Resources Management System (NNRMS) being implemented in the country with DOS as its nodal agency are the following: (i) ensuring the supply of remote sensing data and facilitating its integration with the conventional system through appropriate collaborative application studies, (ii) establishment of infrastructure and generation of trained manpower and (iii) application studies as building blocks for generation of data base for Natural Resources Information System. Considerable progress has been made in respect of operationalisation of NNRMS in the country since its evolution. Initially data from Landsat and SPOT missions were used to exploit the potential of remote sensing data for national natural resources survey and management. The experience gained are being utilised for full exploitation of potentials of data being obtained continuously from the indigenous IRS-1A satellite. In addition, a wide range of ground based systems for reception, processing, dissemination and utilisation of data have been established.

### **Space Segment**

India's first indigenous remote sensing satellite, IRS-1A, was launched on March 17, 1988 into a near-circular polar sun-synchronous orbit of 904 km thus marking a transition from experimental applications of remote sensing technology to fully operational domestic system. IRS-1A carries two

types of imaging sensors, with spatial resolution of 72.5 metres and 36.25 metres (LISS-I & II). LISS-I provides a swath of 148 km while a composite swath of 145 km is obtained by the two LISS-II sensors. The satellite returns to its original orbital trace every 22 days, enabling repeated collection of data at the same place at the same local time. The orbit of IRS-1A is controlled in such a way as to keep the ground track at the equator within  $\pm 14.8$  km from the nominal value. In order to facilitate convenient and unique identification of any of the geographical regions of interest and cataloguing of data products, an image referencing scheme designated by path and row numbers has been evolved for the Indian sub-continent and the world.

Based on the nominal life time estimate of two and a half to three years for IRS-1A, the launch of IRS-1B, which is identical to IRS-1A, is planned during mid 1991 to provide continuity of services. The second generation IRS series of satellites, namely, IRS-1C and 1D, will have better spectral and spatial resolutions, more frequent revisit capabilities, stereo viewing and on-board data recording capability. IRS-1C and 1D are being designed to incorporate sensors in visible, near IR and shortwave infrared (SWIR) with spatial resolution of around 20 metres in the multispectral bands (70 m in SWIR) and better than 10 metres in the panchromatic band. They are scheduled for launch during 1993-94 and 1995-96 respectively. The preliminary design review for the space segment has been completed.

### **Ground Segment**

#### *Spacecraft Control Centre*

The Spacecraft Control Centre located at Bangalore is the focal point for IRS-1A spacecraft health monitoring and control and mission analysis, planning of spacecraft operations and carrying out tracking network co-ordination. Payload operation is being carried out on a routine basis during all day-time passes over India and payload calibration once in a cycle of 22 days, during night.

#### *Data Reception, Processing and Dissemination*

The Data Reception Station at Shadnagar near

Hyderabad receives data from IRS-1A satellite in both S and X-bands. It has a provision for quick-look display of one selected spectral band data received from any of the selected imaging sensors. The data reception station also provides facilities for carrying out calibration data analysis and cloud cover estimates. Besides these, attitude and orbit-related elements for the satellite are computed with respect to paths and rows of image scenes acquired at the station and are suitably formatted in Auxiliary Computer Compatible Tapes (ACCT). These tapes are used for further higher level processing of data.

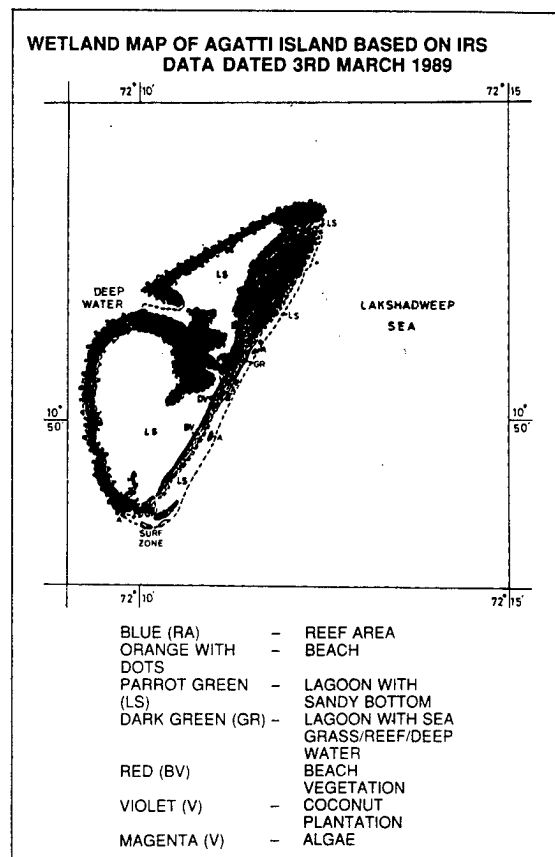
The IRS-1A data products generation and dissemination are done from the facilities established at NRSA, Balanagar, Hyderabad, as well as Space Applications Centre, Ahmedabad. The system is designed to generate on an operational basis the photographic and digital data products at various levels, and all acquired data are generated routinely and supplied to the users on demand. The major functions of IRS data product system are data processing and product generation, GCP Library creations for Indian region, data quality evaluation and archival.

Besides IRS-1A data reception, NRSA, Hyderabad, continued to receive, process and disseminate data from Landsat, SPOT and Metsat. Catalogues of entire acquisition for 1988-89 indicating quality of data have been sent to major users. An Integrated Information Management System (IIMS) is being developed to efficiently manage the growing information on acquisition, archival, processing and dissemination of remote sensing data and to optimally utilise the expanding data processing capability. Data products acquired from IRS-1A involving around 1,80,000 imageries collected over 29 cycles of total coverage of India are available in NDC archival.

NRSA Data Centre has supplied around 12,500 data products during Jan-Dec, 1989 out of which 64% is from IRS, 21% from Landsat, 8% & 7% from SPOT and Metsat respectively. NDC started supplying IRS, Landsat Thematic Mapper and SPOT data in the form of floppy diskettes and cartridge tapes apart from the regular photo products and computer compatible tapes.

The major Central Government agencies like GSI, CGWB, ONGC, AMD, FSI, NBSS & LUP, etc., and State Departments of Geology, Ground Water and Agriculture and various other agencies are the regular users of IRS data for their projects/studies.

Subsequent to National Seminar on IRS-1A Mission and its Application Potential which was held during December 1988 at Hyderabad and as a part of user awareness programme, Regional Workshops on IRS-1A Mission and its Application Potential have been conducted during 1989 at Goa, Calcutta, Bhopal, Bhubaneshwar, Nagpur, Jaipur, Jodhpur, Ludhiana, Gauhati, Chandigarh, Dimaipur, Trivandrum, Simla, Srinagar, Patna, Dehra Dun, Madras and Lucknow and the same are planned to be held at Gandhi Nagar (Gujarat), Shillong, Hyderabad, Bangalore, Gangtok, Andaman and Nicobar islands in 1990.



Various application studies carried out so far indicate that the quality and information content of IRS-1A data is comparable to that of contemporary satellite such as Landsat. The major applications of IRS-1A data include regional geology, geomorphology, forest type and density mapping, mapping turbidity levels in reservoirs, crop type discrimination and crop acreage estimation, sand dune migration, delineation of ground water potential zones and of salt affected soils, landuse and urban sprawl mapping, mapping of floods and water bodies, fisheries, watershed characterisation, environmental impact of mining and super thermal power stations, integrated drought management, wasteland mapping, etc.

#### *Progress on Airborne Remote Sensing Data Acquisition*

The aerial remote sensing facilities of NRSA, Hyderabad, were utilised for aerial survey tasks for various users. About 616 hours of flying was undertaken during the year. A new Super Beachcraft has been added to the existing fleet of one Avro and two Dakota aircraft. The aircraft has been specially modified for installation of two aerial survey cameras, one multispectral scanner and an airborne magnetometer system. It has a Laser Navigation System and a Radar Altimeter. A Multispectral Scanner and HDDT/CCT ground conversion system have been procured and installed in the aircraft. The aircraft has been successfully test-flown and declared operational. A second Beachcraft will also be available for operations shortly.

#### *Side-Looking Airborne Radar (SLAR)*

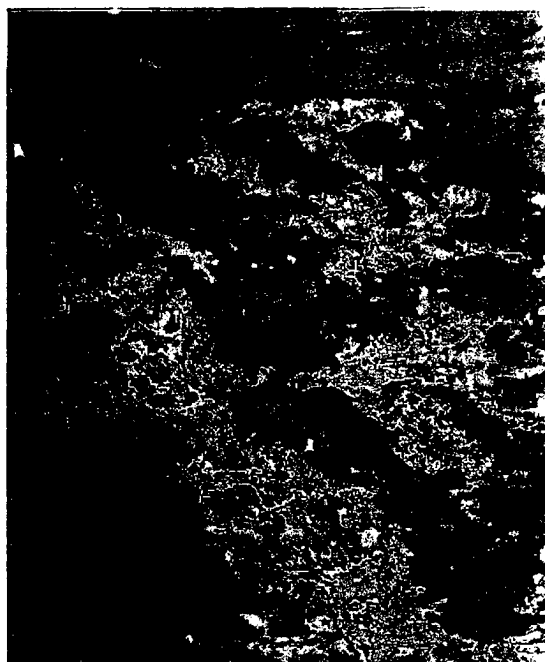
The X-band Side-Looking Airborne Radar (SLAR) system has been made operational. The data has been corrected for radiometric and geometric distortions using the Inertial Navigation System (INS) data recorded along with SLAR data. The SLAR is installed in Dakota and flights conducted.

#### *Synthetic Aperture Radar (SAR) Data Acquisition*

System studies have been undertaken on Synthetic

Aperture Radar, Scatterometer and Altimeter aimed at optimising system parameters for sensors and their interdependence. Effect of satellite parameters like altitude, attitude, etc., on the performance of these sensors and their parameters have also been analysed. Necessary softwares for simulation and analysis of these have also been developed.

The SAR data was acquired during October, 1988 using the X-band STAR-1 SAR system over Andaman and Nicobar islands, Cauvery basin, Godavari basin and Orissa coast totalling about 65,000 sq km. The dissemination of this data to users is being taken up.



*Aerial pre-dawn thermal infrared image showing temperature anomalies in South Tisra fire area, Jharia coal fields, Bihar*

| Colour          | Temperature °C | Colour | Temperature °C |
|-----------------|----------------|--------|----------------|
| Light-Turquoise | 0-15           | Cyan   | 41-45          |
| Light grey      | 16-25          | Blue   | 56-55          |
| Brown           | 26-30          | Yellow | 56-65          |
| Orange          | 31-35          | Red    | 65             |
| Green           | 36-40          |        |                |

A project for design and development of a C-band airborne Synthetic Aperture Radar has been undertaken and towards this, priority applications and corresponding system parameters have been finalised. A Preliminary Design Review (PDR) of the project has been conducted during November 1989. The airborne C-band SAR system is expected to be operational by mid 1992. Meanwhile, in order to enable the users to have the necessary experience, actions have been initiated to establish the ground segment to receive and process Synthetic Aperture Radar (SAR) data from the ERS-1 satellite of European Space Agency (ESA) scheduled for launch during 1990-1991.

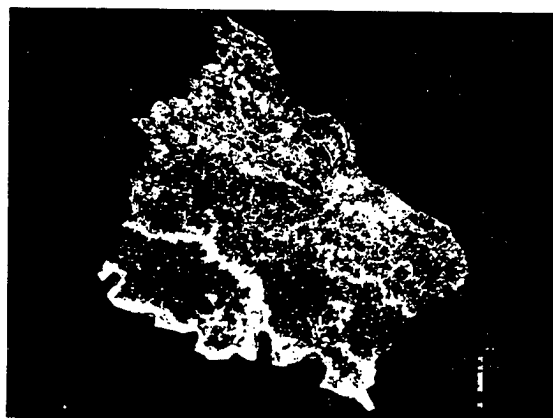
An Inter-Agency Committee formed for identifying possible utilisation of SAR data has identified a set of five application areas (soil moisture, geological exploration, monitoring of oil slick, flooded area mapping and snow melt run-off) for further follow-up.

R & D efforts are on for the retrieval of oceanographic parameters using remotely sensed data from active microwave sensors—mainly from the currently operating radar altimeter onboard US GEOSAT satellite. A SAC-NIO joint project has been taken up for mapping wind-wave conditions over the seas adjoining India based on GEOSAT-derived information.

### **Application Projects**

Several application projects carried out under the IRS-Utilisation Project (IRS-UP) with the participation of national and state-level user agencies, have resulted in the development of operational packages for effective utilisation of remote sensing technique in various natural resources themes.

Some of the application areas which have shown high visibility and encouraging results during the IRS-UP have been enlarged to mission mode under the Remote Sensing Application Mission (RSAM) Project. These include ground water potential zone mapping, large area crop acreage, urban sprawl, landuse mapping, saline/alkaline soil mapping, flood mapping and geological mapping. The RSAM projects have helped in operationalis-



*District-level wheat inventory for Kanpur (U.P.), using IRS-1A LISS-I digitally classified data (green indicates wheat)*

ing remote sensing applications for several resource themes.

Some of the major activities and achievements made in the use of remote sensing in various application areas are given below:

#### *Wasteland Mapping*

Over 2,800 wasteland maps covering 146 districts on 1:50,000 scale have been completed and disseminated to Chief Secretaries, District Collectors, Chief Planning Officers, Divisional Forest Officers and others of the concerned districts. The NWDB has presently taken up a project to establish a Geographical Information System (GIS) for wasteland development. Six centres including SAC, NRSA, IIRS and RRSSCs are involved in carrying out case studies for this purpose.

#### *Groundwater Potential Zone Mapping*

Hydrogeomorphological maps showing probable ground water occurrence zones were prepared under Technology Mission on Drinking Water, initially for 55 districts which are designated as mini mission districts. Subsequently the study has been extended to the entire country. Priority has been given to mapping of 112 districts covered by the Drought Prone Area Programme (91) and

Desert Development Programme (21). Hydrogeomorphological mapping on 1:2,50,000 for 317 districts in the country are completed. Mapping for the remaining districts is scheduled to be completed during the first half of 1990.

#### *Geology and Mineral Resources*

Under this joint project with DOM/GSI, digital analysis in respect of 4 more areas have been completed and the data from ground follow-up is being analysed. These four areas are (i) Extensions of Wajrakarur in Andhra Pradesh (ii) Kadavur anorthosites in Tamil Nadu (iii) Sargur Schist patches of Gobichettipalayam in Tamil Nadu and (iv) molybdenum bearing granites in Ambalvayal in Kerala. A fairly comprehensive GIS package has been developed for mineral information, facilitating storage, analysis & retrieval of thematic information generated during the first phase of the project. The functionalities of different components of GIS are being tested with actual data and minor modifications/improvements are being incorporated. Preparation of mineral prognostic models based on geostatistical techniques are planned to be taken up once the data base is ready.

#### *Urban Sprawl Mapping*

Urban sprawl mapping of major cities like Bombay, Hyderabad, Madras, Ahmedabad, Nagpur and Bangalore have been completed. The maps show the growth trends of the cities and they help in planning for the expansion of cities consistent with their infrastructure and needs of greenbelt zoning, etc.

#### *Agricultural Application Projects*

The Department of Agriculture and Co-operation (DAC) and the Department of Space (DOS) have jointly launched a major project on Remote Sensing Application Mission for Agricultural Applications. It includes mainly six sub-projects dealing with large area crop acreage and production estimation, mapping of salt affected soils, drought monitoring and assessment, flood mapping, watershed prioritisation and marine fisheries.

Actions have been initiated for implementation of this joint project in collaboration with State and Central Government user agencies.

#### *1. Crop Acreage and Production Estimation*

A total of 7,03,000 sq km area, 21 percent of the area of the country, is covered by the project. The States of Punjab, Haryana and parts of Uttar Pradesh, Madhya Pradesh and Rajasthan are covered for wheat crop. The States of Orissa and Tamil Nadu form the study area for rice crop and parts of central Maharashtra and Saurashtra will be covered for study of sorghum and groundnut crops, respectively.

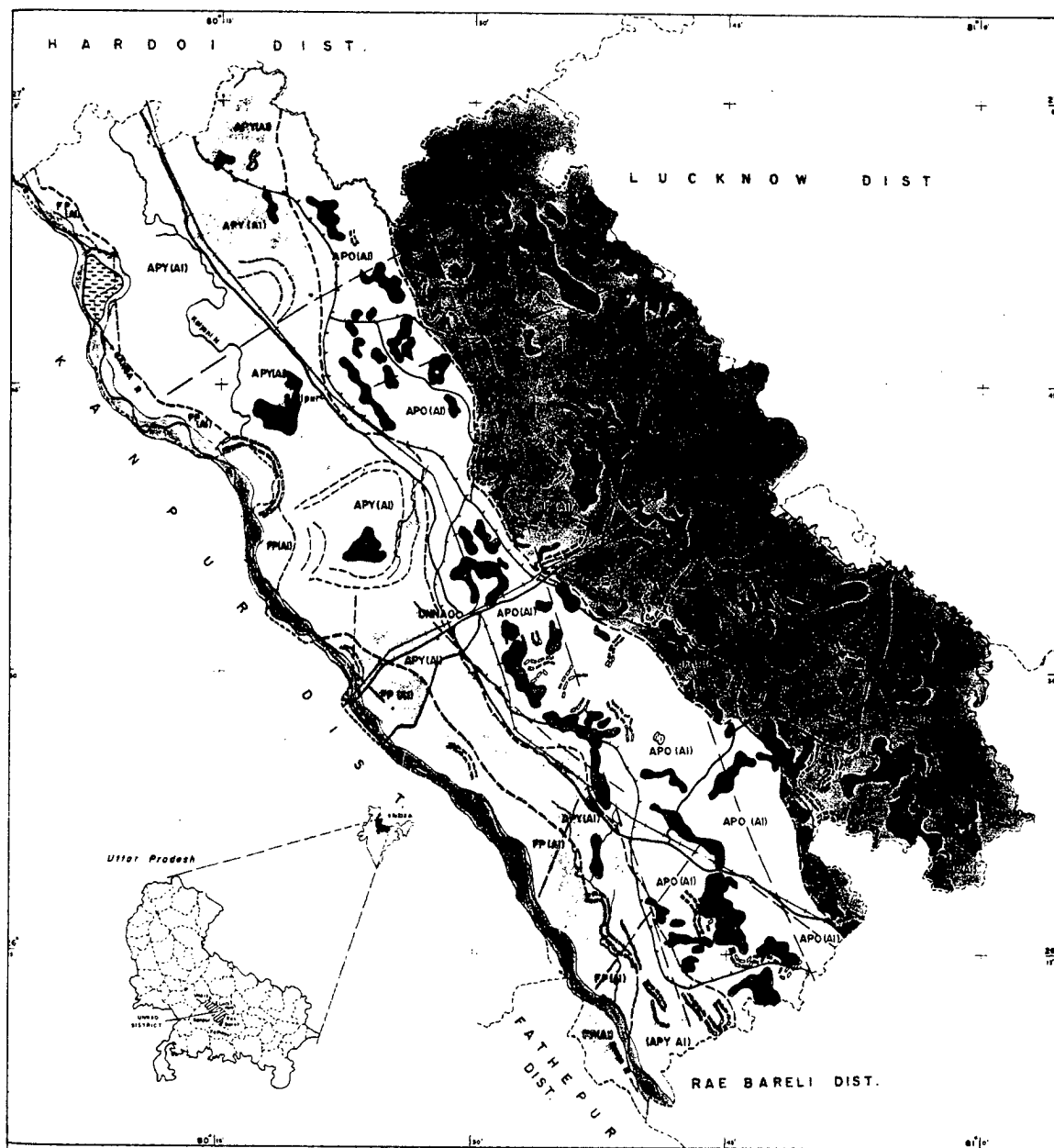
The Kharif (autumn and winter) rice acreage estimation for the 1988-89 season for Orissa was done using digital data of eighteen LISS-I scenes acquired during October 12-16, 1988. The rice acreage was estimated at  $3.92 \text{ Mha} \pm 0.22 \text{ Mha}$  with 90 percent confidence level. This compares favourably with the figure of 4.09 Mha as estimated by the State Bureau of Economics and Statistics (BES). The remote sensing based estimate (RS) was available by the end of February coinciding with the end of the harvest season. Block-level spectral yield relationships have been developed using LISS-I digital data for Cuttack and Puri districts. State level wheat acreage estimation has been done for the States of Punjab and Haryana for the rabi 1988-89, using the digital data of February 1989. The estimates were available on April 12, 1989. (April 13 is Baishakhi, beginning of the harvest season). Similarly 24 districts in western UP which is a major wheat producing region of the State have been covered.

The results are summarised below:

| State        | Wheat acreage estimates (Mha) |         |
|--------------|-------------------------------|---------|
|              | RS                            | BES     |
| Punjab       | $3.128 \pm 0.171$             | 3.126*  |
| Haryana      | $1.938 \pm 0.159$             | 1.830** |
| Western U.P. | $4.107 \pm 0.278$             | 4.175** |

\* Year 1987-88

\*\* First estimates for 1988-89



# HYDROGEOMORPHOLOGICAL MAP OF UNNAO DISTRICT, UP STATE

| MAP SYMBOL           | GEOMORPHIC UNIT                                              | GROUND WATER PROSPECTS                             |
|----------------------|--------------------------------------------------------------|----------------------------------------------------|
| BROWN - FP (A)       | - FLOOD PLAIN (FP)                                           | GOOD TO VERY GOOD NO WATER QUALITY PROBLEM         |
| LIGHT PINK - APY (A) | - YOUNGER ALLUVIAL                                           | GOOD TO EXCELLEN                                   |
| YELLOW - APO (A)     | - OLDER ALLUVIAL PLAIN                                       | DEEP AQUIFERS FREE OF SALINITY AND FLUORIDE        |
| GREEN - IF (A)       | - INTERFLUVE OF GANGA, GOMATI RIVERS                         | SAME AS ABOVE                                      |
| RED                  | - ALLUVIAL PLAIN WITH SALT ENCRUSTATIONS FILLED BACK - SWAMP | VERY GOOD, DEEPER AQUIFERS FREE OF QUALITY PROBLEM |
| DARK GREEN           |                                                              | MODERATE TO GOOD ONLY FOR VERY DEEP AQUIFERS       |
| BLUE                 | - RIVER                                                      | MODERATE TO GOOD                                   |



Vegetation and crown cover classification of Rajaji National Park, Dehra Dun District, U.P. using IRS-1A LISS-I data.

Sal: More than 80% crown cover (dark green), 60–80% (green), 40–60% (light green)

Mixed Sal: 60–80% (dark red), 40–60% (red), 20–40% (orange), 20% (yellow).

Mixed forest: 20–40% (blue), 20% (Cyan) Plantation (Pink), grass/scrub (brown), non-forest (dark brown), river bed (blue)

Methodology has been developed for acreage estimation of Sorghum using atmospherically corrected remotely sensed data and are used in Solapur and Pune districts. The estimated acreage figures are 50.3 and 30.5% of geographical area for Solapur and Pune respectively. Acreage estimation of groundnut at tehsil level of Junagadh district was experimented for Vanthali, Manavadar and Keshod taluks.

## 2. Crop Yield Modelling

Using four years (1983–84 to 1986–87) Landsat MSS digital data, yield-spectral index relation has been derived for Haryana. Using the above relation district-wise wheat yields have been estimated for Haryana during 1988–89 rabi season using IRS-1A data. This work also involved deriving regression relations between IRS measured radiance values and Landsat MSS values. An attempt to use wheat indices of sample segments used for acreage estimation, to relate to yields has been tried for Punjab. This would enable a single procedure to be adopted for acreage and yield

estimation. Generation of growth profile for wheat, necessary for normalising radiance values acquired at different dates of acquisition is being done using both IRS-1A LISS-II and NOAA-AVHRR data. Using spectral-yield relationship, district-level yields were estimated for the State of Haryana. Combining the remotely sensed data-based acreage and yield relationship gave the production estimates of  $6.21 \pm 0.4$  M tonnes for Haryana State. Similar exercise was taken up in the major wheat growing regions of Madhya Pradesh and Rajasthan also. Digital analysis work for eight districts each in Madhya Pradesh and Rajasthan has been done. Results are being evaluated.

## 3. Watershed Prioritisation

Watershed prioritisation methodology was developed and tested for Narmada Sagar catchment.

## 4. Drought Monitoring

National Agricultural Drought Assessment and Monitoring System (N-ADAMS) is based on NOAA-AVHRR data based Vegetation Index (VI). The 1986, 1987 and 1988 Kharif season VI data have been interpreted in terms of drought identification, severity level and persistence for 113 districts in the six States of Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa.

The limitations of VI as drought indicator, in the context of excess rainfall situations as in 1988 season, have also been brought out. Drought bulletins, each covering two-week periods starting from June 1989, of the six States (Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa) have been brought out and sent to District Collectors and Departments of Agriculture, Revenue and Statistics, and also to all collaborating agencies. The feed-back from user community is being used to fine-tune N-ADAMS.

## 5. Nation-wide Mapping of Saline/Alkaline Soils

The mapping legend was finalised in August 1988 for preparation of map of salt-affected soils of India

at 1:2,50,000 scale. Visual interpretation and field work for Uttar Pradesh, Punjab and Bihar have been completed for mapping at 1:2,50,000 scale. Maps for UP and Punjab are finalised and reviewed by an Expert Committee. Preliminary visual interpretation and field check for Mainpuri district have been carried out for mapping at 1:50,000 scale.

#### 6. Marine Fisheries

Techniques developed for Sea Surface Temperature (SST) mapping from NOAA-AVHRR data, using the multichannel sea surface temperature approach, is operationally used for generating global charts on SST. Location of features like thermal gradients, fronts, eddies and upwellings on SST images and probable abundance of fishery was established through a near-synchronous validation exercise during February-March 1989, involving the collaborating agencies and the maritime States. SST was derived from NOAA-AVHRR data and area co-ordinates of potential fishing grounds across temperature fronts and non-potential grounds falling in the uniform temperature zones were communicated for follow-up action. One of the most significant achievements was the reported good catches of shrimps, prawns and fishes in the areas north-west off Dwarka, west and north-west off Veraval.

#### 7. Flooded Area Mapping

The data from both IRS-1A and Landsat were monitored constantly during entire flood season. Similarly, a constant watch on the flood situation in the country has been kept since June 1989. Despite presence of clouds, in all, 9 flood maps have been prepared in real time till September 1989 from partially cloud-free satellite imageries covering flooded areas of Brahmaputra and Ganga basins.

#### 8. Bio-resources and Environment

Eleven major projects relating to environmental impact of mining, industrialisation, coastal en-

vironment, super thermal power plants, etc., are being carried out by various departments using remote sensing data and the projects are funded by Department of Environment and Forest and Wild Life. The projects include the following:

- Environmental impact of coal mines in Jharia, Raniganj belt
- Impact of iron ore mining in Goa
- Environmental impact of mining bauxite and chromite in the east coast.
- Impact of industrialisation in Madras Metropolitan area
- Monitoring of coastal environment
- Environmental impact of mining and super thermal power stations
- Land use changes due to urban and industrialisation in Ahmedabad—Vapi region
- Environmental impact around Vedaranyam
- Ocean resources and coastal environment

Evaluation of attenuation coefficients has been partially completed. Plotting of suspended sediment concentration distribution around Paradeep port has been completed. Quantitative estimate of suspended sediments has been made based on statistical algorithms. The results are to be validated with ground data. Evaluation of littoral processes for Paradeep port is in progress for bathymetry retrieval of different years data (1985 to 1987) and the products will be compared to derive the possible areas of erosion and deposition. Land form mapping (pre-field) for the Narmada area and wetland mapping (pre-field) for the Okha and Sikka area based on aerial photography were completed. Wetland maps on 1:2,50,000 and 1:50,000 scales of a part of Gulf of Kachchh and the Karnataka coast for the 1985-88 period were prepared. Various image enhancement techniques were tried with IRS-1A data for wetland mapping. Shoreline change in estuaries, deltas and gulfs was mapped on 1:2,50,000 scale (1985-88) for the Mahi and Narmada estuaries. Planimetric accuracy of maps showing shoreline change using IRS-1A LISS-II data on 1:50,000 scale was found to be within 40 metres.

### *Snow Cover Mapping*

The effect of temperature on seasonal snow melt run-off in addition to snow cover area in the Sutlej basin was examined. It has been found that the effect of temperature is not significant due to very small variations of temperature during snow melt run-off period (April to June). NRSA gave a forecast of snow melt run-off of Sutlej basin right in the beginning of April 1989. The seasonal inflow of snow melt run-off into Bhakra reservoir was forecast to be within 10% of 14.25 lakh cusec-days. This forecast was made available to the Member (Irrigation), Bhakra Beas Management Board, by April 7, 1989.

### *Nation-wide Land Use/Land Cover Mapping for Agro-climatic Zones Operational Planning*

Towards meeting the urgent requirements of Planning Commission, DOS has initiated a project to obtain up-to-date information on Land Use/Land Cover of the entire country particularly on agricultural crop land during Kharif and Rabi seasons and other land use categories along with their area estimates for agro-climatic zones planning. DOS in collaboration with 20 work centres belonging to various State/Central Government organisations is preparing the districtwise Land Use/Land Cover maps on 1:2,50,000 scale using IRS-1A satellite data. A suitable methodology has been evolved using hybrid technique of digital and visual methods of interpretation of satellite data. For this purpose Land Use/Land Cover classification system has been evolved in consultation with the Planning Commission. Out of a total 442 districts in India as identified by Planning Commission under the agro-climatic zones, 168 selected districts are being taken up for digital classification and the remaining 274 districts for visual interpretation. The digital analysis is being carried out by all the five RRSSCs, SAC, NRSA and also at Uttar Pradesh Remote Sensing Application Centre, Lucknow, and Institute of Remote Sensing, Madras, where digital analysis facilities are available. The visual interpretation is being carried out by respective State remote sensing application centres.

The preparation of Land Use/Land Cover mapping

envisages the use of IRS-1A LISS-I data collected during two seasons, i.e., Kharif and Rabi. The final maps thus prepared depict the spatial distribution of different land use categories. The important aspect of the project is to provide area under Kharif and Rabi, and double-cropped area (Kharif + Rabi) and also the different categories of forest within the notified forest area among other land use classifications. The project will be completed by the end of 1990.

### *Integrated Survey to combat Drought at District Level*

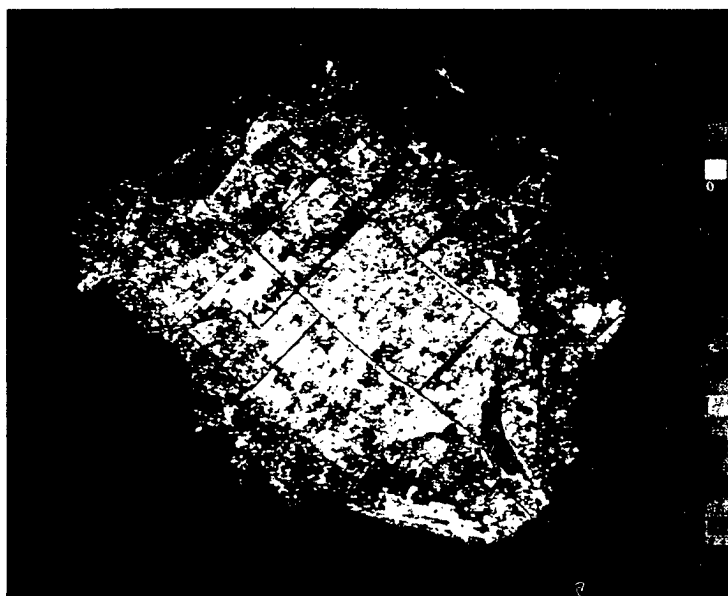
In order to integrate remote sensing with conventional data to combat drought, DOS has taken up a project on "Integrated Survey to Combat Drought at District Level", for 16 districts covered in 12 States in collaboration with respective State remote sensing application centres. The objectives are to provide packages to manage land and water resources and cropping systems at district level leading to drought alleviation/mitigation on a long term basis.

Under this project the resource information on geomorphology, ground water, surface water, land use and forest are being prepared on 1:50,000 scale by the respective work centres integrating existing information from various sources and updating the same using satellite data. The secondary data on climate, demography and socio-economic aspects are also being collected from various sources to analyse the demands and short-falls in various resources of the districts. The information on soil is being obtained from National Bureau of Soil Survey & Land Use Planning (NBSS & LUP), Nagpur. The integrated maps, thus prepared for each district using the above resources information, will specifically address the potential areas to develop and to mitigate the drought on a long term perspective.

### **Infrastructure Development**

#### *Regional Remote Sensing Service Centres*

Towards providing operational services to the users in utilising digital image processing facilities,



## URBAN ENVIRON

### SETTLEMENTS

OLD

NEW

### VEGETATION

NON-AGRIC.

HILL VEG.

RIVER CHANL.

BARREN LAND

RAILWAY

ROAD

WATERBODY

*Urban environment classification of Union Territory of Chandigarh using IRS-1A LISS-II data. Within the city, old and new constructions are separated.*

five Regional Remote Sensing Service Centres (RRSSCs) established at Bangalore, Nagpur, Kharagpur, Jodhpur and Dehra Dun have attained full fledged operational status. The digital image processing systems at RRSSCs are being effectively utilised in the fields of geology, forestry, hydrology, agriculture, etc. Under the agricultural drought monitoring project, weekly composite vegetation index maps for the year 1989 Kharif season have been generated using NOAA-AVHRR data. In addition, specific software to meet the requirements of application projects related to crops, land use, soil, water quality, surface water, etc., are developed. Apart from providing user services, several short duration training courses on digital image processing for resource scientists have been conducted. Many user departments representing Central/State Gov-

ernment organisations have benefited from these courses.

#### *1. System usage for National Projects*

A number of application mission projects, namely, "Vasundhara", National Drought Monitoring Mission, Crop Acreage and Production Estimation and Land Use/Land Cover Mapping for Agro-Climatic Zone Planning are being carried out at various RRSSCs. The software required for these projects are being developed in addition to the readily available VIPS-32 software. Nation-wide land use mapping project for 164 districts (on 1:2,50,000 scale) using digital techniques and the Integrated Watershed Development Programme (Rajasthan) form major part of the work in the RRSSCs.

## 2. Application Validation Programmes

Application validation programmes (AVP) of RRSSCs are aimed at validating the digital analysis methodologies for various applications with a view to standardise the application packages for operational use in the country's resources management. The first phase of AVPs undertaken by RRSSCs with user agencies in the fields of forestry, environment, land use and cartography has been completed. During this phase a total of 18 projects were carried out. Some of the salient results that emerged during this programme include the following:

- Evaluation of planimetric accuracy of SPOT for updating topomaps.
- Development of digital cartographic data base.
- Change detection studies around Sambhar lake area in Rajasthan and establishment of the migratory nature of desert sand feature.
- Forest cover type map of Baratang Division of Andaman islands.
- Land use/Land cover classification of Attappadi and Silent Valley.
- Identification of four new target areas for copper mineralisation, east of Malanjhand copper deposit, Balaghat district, MP, for detailed ground follow-up.
- Urban land use studies of Nagpur city for establishing industrial units and new township development.
- Integrated surveys in parts of Jodhpur district have yielded specific additional information in respect of soil, land use/land cover studies and forestry.
- Capacity studies of Bhadra reservoir in Karnataka showed a decrease in reservoir capacity by 5 to 6% in a time span of 22 years which could be attributed to siltation.
- Groundwater potential zone maps of parts of Bhandara district, Maharashtra, and Raichur district, Karnataka, have been prepared from hydrogeomorphic features derived from digital enhancements.

In addition to AVPs, many case studies are being carried out in various themes, in active collaboration with user agencies. The projects include the following:

- Retrieval of meteorological and oceanographic parameters from satellite data.
- Meteorological/oceanographic studies like delineation of mid-tropospheric ridge, mid-tropospheric circulation from polar-orbiting TIROS-N satellite, etc.
- Irrigation development monitoring
- Desert-vegetation monitoring for locust surveillance.
- Diamond exploration in Panna and Wajarkarur using IRS-1A and SPOT data.
- Compartment level stock mapping using IRS-1A LISS-II data of Melghat Reserved Forest, Maharashtra.
- Development of a methodology for environmentally sound mineral resources extraction using IRS-1A data.
- Environmental impact analysis in coal fields in Madhya Pradesh and Maharashtra using IRS-1A data.
- Environmental impact analysis of the area around Karaikal, Pondichery, using SPOT and MSS data.
- Monitoring of irrigation development in Indira Gandhi Canal Command.

## 3. Software Development

A major contribution by the RRSSCs has been made in the area of software development. A total of 35 programmes have been developed and operationalised to meet the requirements of various application projects. A major thrust is given for software development, hence a large amount of system usage is foreseen.

## 4. Training in Digital Analysis

A number of training programmes have been conducted for familiarisation with the digital analysis techniques, ranging from courses of 3 days duration for decision making personnel to courses of 15 days duration for the working-level staff. In all, about 35 such training courses have been conducted which have produced 260 trained persons in digital analysis. The trained persons belong to various departments like GSI, SOI, CAZRI, National Environmental Research Institute, De-



*Location of potential fishing grounds based on NOAA-AVHRR thermal data (March 29, 1989)*

*Low catch area: Uniform temperature zone (yellow) off Dwarka (see 1)*

*High catch area: Across temperature gradient (yellow-green-magenta) off Porbandar (see 2) and Veraval (see 3)*

fence Establishments, Karnataka State Sericulture Department, etc.

### *State Remote Sensing Application Centres*

Realising the potentials of remote sensing in resources survey and management for drawing suitable developmental plans, several State Governments have taken steps to set up remote sensing application centres in their respective States.

Presently, 19 States viz. Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu and Uttar Pradesh have established their application centres. Most of them are operationally functioning by having adequate infrastructure and carrying out many application projects including nationally co-ordinated ones. The other States are actively considering to set up such facilities. Maps/data base generated as a result of these projects have been found useful in the planning process of the States.

In addition to the State Remote Sensing Application Centres, many Central/State Government departments dealing with application areas such as geology, ground water, forestry, agriculture, soils and town and country planning have set up adequate remote sensing facilities to carry out remote sensing related studies.

### **Training and Manpower Development**

The Standing Committee on Technology and Training set up by the Planning Commission has been pursuing various actions related to training and manpower development in remote sensing. The following major actions are planned for immediate future:

1. To increase the throughput and to maximise the utilisation of the present training facilities related to remote sensing.
2. Conduct summer training courses for trainers of various universities and institutions.
3. Co-ordination with State S&T councils to promote training programmes for manpower development at State level.
4. Initiation of training programmes in remote sensing by user departments/organisations.

The training centres/institutions in the country providing remote sensing training presently are Indian Institute of Remote Sensing at Dehra Dun, National Remote Sensing Agency at Hyderabad, Space Applications Centre at Ahmedabad, Centre of Studies in Resources Engineering, IIT at Bombay, Institute of Remote Sensing, Anna University at Madras, Regional Remote Sensing Service Centres at Nagpur, Bangalore, Dehra Dun, Kharagpur and Jodhpur. Besides these, specialised training courses on remote sensing are also offered by Geological Survey of India Training Institute at Hyderabad, Forest Survey of India at Dehra Dun and National Institute of Oceanography at Goa. On-the-job training in remote sensing and photo-interpretation is imparted to departmental scientists by certain organisations such as Oil and Natural Gas Commission, Forest Research Institute, Survey of India, Central Water Commission, National Bureau of Soil Survey and Land Use Planning, etc., as a part of their regular training courses. Some of the State remote sensing centres

and universities have organised short term training courses for persons from respective States/regions. A few universities in the country impart education in remote sensing at post-graduate level. In addition, various departments such as Geology, Geography, Civil Engineering, Town and Country Planning, Architecture, Forestry, Soils, Agriculture, etc., of major academic institutions offer remote sensing as part of their curricula.

Around 250 officials are being trained every year on different remote sensing applications by various training centres in the country.

### **National (Natural) Resources Information System (NRIS)**

Optimum utilisation of existing natural resources, ensuring a balanced development of various regions and at the same time protecting the fragile environment for ensuring a cleaner earth is one of the major goals of National Natural Resources Management System (NNRMS) for which DOS is the nodal agency. It is well recognised that a comprehensive information system is essential for the decision makers to support this NNRMS concept to ensure such an environmentally benign development and for efficient and optimum utilisation of natural resources. Towards the above, evolution of a National (Natural) Resources Information System (NRIS) is one of the major elements under NNRMS.

The information system thus evolved should provide periodic and systematic information on

natural resources related to land, water, forest, minerals, soils, oceans, etc. Equally important is the need to combine this set of information with socio-economic information such as demographic data, financial allocations, developmental targets, etc. Such an integration of remotely sensed data with conventional data sources will aid systematic planning of resources utilisation. Thus the NRIS concept calls for a spatial-non spatial information system with strengths in information generation, spatial analysis and aims at integration of remotely sensed data with developmental information oriented to different levels of decision making. NRIS addresses specifically the needs of decision making at three levels—strategic level (where policies are framed), tactical level (where policies are converted into implementable programmes) and operational level (where actual implementation takes place).

Towards achieving NRIS concept and as a follow-up to the Task Force report on NRIS, Planning Commission has set up an Inter-Agency Expert Committee with DOS as the convening agency.

Towards realising NRIS in the coming decade, DOS/ISRO has already initiated pilot projects on various disciplines to develop GIS packages. The GIS package for geology under the project Vasundhara and urban land use under National Capital Region studies are in an advanced stage of development. The other themes covered are watershed management, integrated resources study to combat drought, wasteland development and forest data management. □

# Space Technology

The major technology projects of ISRO/DOS are carried out through an identified lead centre and a close co-ordination is maintained between the project core team in the lead centre and all the work centres of ISRO/DOS that are involved in the project. Highlights of development on the various technology areas during the year are given in the following sections.

## LAUNCH VEHICLE TECHNOLOGY

### Augmented Satellite Launch Vehicle (ASLV)

ASLV is an augmented version of the first Indian satellite launch vehicle SLV-3. ASLV is designed to augment the indigenous satellite launch capabilities to place 150 kg class satellites into low earth orbit.

The first two development flights had failed to achieve the missions. However, the flight experience, the failure analyses, a national level expert review after the second development flight and subsequent actions have resulted in various modifications, both hardware and software, for realising a successful ASLV-D3 by 1990-91. These modifications/actions include redesign of auto pilot, event-based ignition systems for core first stage and second stage, redesign of strap-on solid motors to reduce the dynamic pressure, enhancing the control margin, incorporation of suitable changes in the heatshield and other inter-stage structural elements and conduct of additional simulations, structural tests and tunnel tests.

### Polar Satellite Launch Vehicle (PSLV)

PSLV is being developed to achieve indigenous capability to launch remote sensing satellites into polar sun-synchronous orbits. The vehicle includes both solid and liquid propulsion stages and has the capability to place 1,000 kg class satellites in polar sun-synchronous orbit of the order of 1,000 km.



*PS-3 Sea level Static Test*

PSLV is a four stage vehicle designed to launch 1,000 kg class spacecraft into a 900 km sun-synchronous circular polar orbit. The first and third stages use solid propellants and the second and fourth stages use liquid propellants. The vehicle weighs about 275 tonne at lift-off. Its height is 44.2 m.

Substantial progress has been made in the development of PSLV. The major accomplishments to date are:

*First Stage:* A 125 tonne solid propellant booster, 2.8 m dia, 20 m long, third largest of its kind in the world, has been successfully tested. All technology problems of maraging steel development and fabrication technology as well as the development of the high energy propellant system, HTPB, have been solved.

*Second stage:* A 37.5 tonne liquid rocket engine based on the Vikas technology of Ariane launch vehicle has been indigenously realised and successfully tested at Mahendragiri. The required liquid propellants have been developed and productionised in the country.

*Third stage:* An advanced 7 tonne solid propellant upper stage motor with composite casing has been successfully ground tested twice.

*Fourth stage:* Long duration tests meeting requirements for 375 seconds of the battleship version have been successfully conducted. The performance of the gimbal control system has been satisfactory.

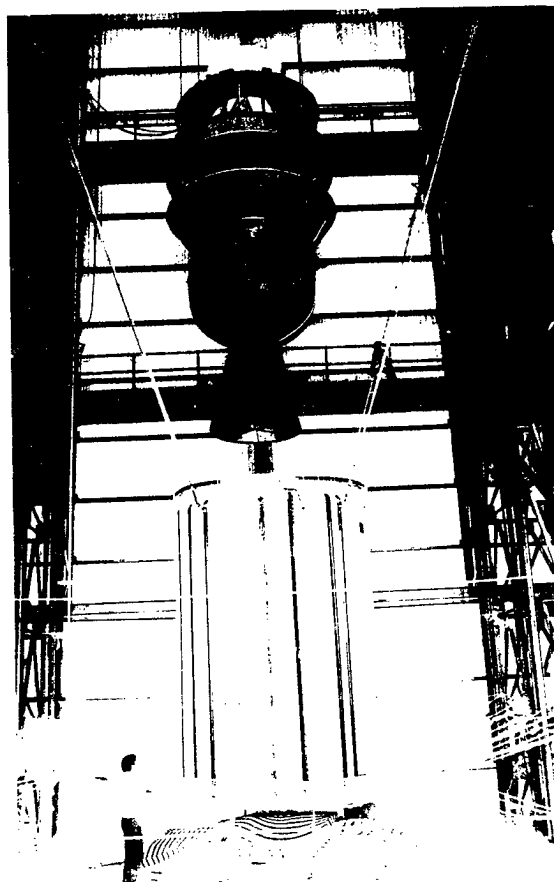
*Light Alloy Structures and Heatshield:* The first set of all interstages and heatshield was realised at HAL.

*Avionics Systems:* Electronics packages required for flight have undergone qualification tests and the fabrication of flight packages commenced. An onboard computer using a 16 bit micro processor has been developed and qualification tests have commenced. Characterisation of inertial sensors is in progress. Qualification model of Redundant Strapdown Inertial Navigation System (RESINS) is under test and evaluation. Significant progress has been made in onboard software for navigation, guidance and digital autopilot.

*Control Systems:* Secondary Injection Thrust Vector Control (SITVC) system assembly with 12 injection valves was tested in the PS-1 booster motor static test. 12 more injection valves have been fabricated. Actuators for PS-4 Engine Gimbal Control (EGC) system and PS-3 Flex Nozzle Control System were also successfully tested. Control electronics for PS-1 SITVC system was tested in PS-1 static test. PS-2 and PS-4 Gimbal Control systems were developed and PS-4 Gimbal Control was tested during PS-4 stage battleship test.

*Stage Separation Systems:* Stage separation tests for PS-1/PS-2, PS-2/PS-3 and PS-3/PS-4 were successfully completed. Three of boat-tail tests for heatshield were carried out. Full length rubber bellow for heatshield is under development. Structural and burst tests for retro-motor hardware were completed. Development tests for PS-3 destruct system using PS-3 Kevlar motor case and 3-cord configuration panel level tests for zip cord were completed. Heatshield structure incorporating acoustic blanket was subjected to acoustic testing at NAL and the performance was satisfactory.

*Launch Complex:* The 3,000 tonne, 75 m high mobile service structure of the launch complex has



*PS-2 and PS-3 separation test*

been realised. Functional tests are in progress. The associated integration and check-out facilities are expected to be ready by the end of this year. The required tracking radars are also getting ready.

*[Details of progress under launch complex are given under the chapter "Launch Support, Tracking Network and Range Facilities."]*

The first launch of PSLV is expected to take place in 1991.

### **Geo-synchronous Satellite Launch Vehicle (GSLV)**

Configuration studies on a Geo-synchronous Satellite Launch Vehicle (GSLV) capable of placing 2 tonne class payloads in geo-synchronous



*PSLV checkout control room at Valiamala*

transfer orbit are in progress. In addition to use of existing/improved solid/liquid stages, indigenous development of a cryogenic upper stage is also planned.

## **SOUNDING ROCKET PROGRAMME**

The Sounding Rocket Programme continued to be operational during the year to support rocket meteorology, atmospheric research and flight system evaluation. 71 sets of sounding rockets had been produced during the year till December 1989. The launches during the year included:

- 32 Nos. of RH-200 with 27 Nos. for chaff payload, 3 Nos. for smoke trail experiments and 2 Nos. for technology development mission.
- 30 Nos. of M-100 with meteorological payload.
- 1 No. each of RH-300 and RH-300 MK-II for ionisation experiment.

As part of the development activities, a static test on RH-300 MK-II was successfully carried out with HTPB propellant and flight hardware. RH-300 MK-I with HTPB will be launched shortly.

In addition to the payloads flight tested during the year, integration of RH-560-APC-REX (ISRO-DLR) payload was also completed. The launch of this is expected by middle of 1990.

A comprehensive global experimentation programme employing rockets, high altitude balloons, ground based observations and satellite measurements is scheduled to be undertaken dur-

ing the period, January to April 1990. Over 86 scientific groups from 21 countries are participating in this global observational programme, acronymed as 'DYANA campaign', standing for Dynamics Adopted Network for Atmosphere. India is playing a lead role with a very extensive and intensive programme and is by far the most important participant from the third world countries contributing on par with the advanced nations.

## **SATELLITE TECHNOLOGY**

The progress on the Indian Remote Sensing Satellite (IRS) and INSAT satellite programmes and related technologies are covered under 'Space Applications'.

### **SROSS Satellite**

The Stretched Rohini Satellite Series (SROSS) programme is directed towards supporting missions requiring 100-150 kg class satellites for space science, technology and application studies. The configuration of SROSS-C satellite was finalised during the year. It will carry aeronomy and celestial Gamma-ray burst detector payload. The aeronomy experiment by National Physical Laboratory is intended to investigate special features of the energetics of the low latitude ionosphere and thermosphere. Engineering model of this payload is under fabrication. The Gamma-ray burst detection experiment will study the temporal and spectral variation of celestial Gamma-ray bursts in the range of 20 keV to 3 MeV with two high resolution detectors. The detectors are under fabrication in-house. SROSS-C will be realised through the refurbishment of SROSS engineering model structure. Work on this has already commenced and fabrication of electronics packages is progressing satisfactorily.

## **TECHNOLOGY DEVELOPMENT**

The highlights of R&D activities during the year in the various areas to support the Space Programme are as follows:

## Propellants and Chemicals

Technology of making big grains through building block method was proved through the successful testing of RH-560 motor at VSSC. Simultaneous casting using pressure was successfully employed in casting igniter grains and special purpose motors. 30 different formulations were tried for Nitramine-based propellant. Two low density thermal protection system based on polyurethane and polybutadiene were developed for PSLV heatshield. Scaling up of technology on polysilastyrene and polyvinyl methyl silane was accomplished during the year. A new monomer for PMR type polyimide was prepared and the process standardised. Composites from PIM-750 types polyimides with glass and carbon were extensively characterised to use this composite as ablative material in an Agni motor. An indigenously designed and fabricated film casting unit was successfully commissioned to produce continuous polyimide film of 1" width. A process of making washable mandrels for intricately shaped composite products was transferred to HAL.

RTV silicone system was proved as an excellent potting component for joining PS-1 segments during the first static test of the motor. Foam mandrels developed earlier were extensively used for PS-1 main igniter case. Improvements on prosthetic based applications for foam systems were also brought about. Scaling up of the process of hydrolysis of cassava starch to 40 kg level was done using a CSIR process involving biochemical reactions.

Igniters were processed for special applications like fuel rich propellants, RH-200 dual thrust motors and nozzleless propulsion motors.

Release of chlorosulphonic acid for tracking smoke trail payload was quite successful.

## Materials

Nozzle throat inserts of 300 kgf were realised for ASLV. Silver-graphite brush blocks were realised for DC torque motor applications. Parametric study on the porous injector disc was completed.

In the Rapid Solidification technology, ribbons of 7075 Al. alloy modified with Ni and Ti were processed. Carbonisation experiments were continued for developing high modulus carbon fibres. 36 Mg-alloy castings were realised for ASLV, PSLV and SROSS applications. Magnesium-Lithium alloy billets were successfully prepared. Heat treatment of AA 2014 Al. alloy rings to T652 conditions was successfully completed for PSLV-PS-3 adaptor. Ti gas bottles for cryogenic project and ASLV project were realised. 9 melts of Cobalt-free, low Nickel Maraging Steel were prepared.

Evaluation of life cycle for the Ni-Cd cells assembled at VSSC was carried out. Silver-zinc batteries of various capacities were assembled and qualified to meet PSLV requirements.

Failure analysis of fasteners for PS-1 igniter, Nimonic 90 alloy thruster chamber of PS-4, etc., were carried out. A 10 tonne INSTRON was installed and interfaced with computer at VSSC for on-line test data acquisition, storage and analysis.

CFRP Yoke and C×S antenna reflector for INSAT-II TS project were realised. C×S band antenna reflector of INSAT-II TS was tested for near-field and far-field. SADA cone (SM), view-port sunshade for VHRR and solar panel substrate were the other products realised for INSAT-II TS project. A process of matte Zinc-Nickel plating was developed and qualified for black Nickel plating on stainless steel for the INSAT-II VHRR components. A process was also developed for gold plating on aluminium, stainless steel and copper alloys for the VHRR cooler components. The process for chromating INSAT-II packages made of Mg-Li alloy was qualified.

Titanium anodising of the heatshield of INSAT-II Liquid Apogee Motor was carried out on the Engineering Model.

## Structures

The activities in the structural area during the year included development of a design package for various structures subjected to buckling load and

augmentation of the FEAST package and its implementation on PC. Strain data analysis, design of interstage structures, structural integrity assessment and determination of joint rotation constants of the interface flanged joints and detailed analysis of heatshield were carried out for ASLV-D3 flight.

Analysis of PS-3 grain with unfilled loose flap gaps for internal pressure loads, analysis of PS-1 grain for internal pressure load considering ignition transient pressure variation, 3-D analysis of the PS-1 assembled grain for horizontal storage, analysis of PS-1 SITVC tank for internal pressure and tank mounting loads, etc., were carried out for PSLV. Post test analysis of PS-3 motor case strain and displacement data and design check for buckling of PS-3 motor case skirt for new flight loads were also carried out. Vibration testing and dynamic analysis of interstages and subsystems, structural testing of interstages and hydro proof testing of motor cases and gas bottles were also carried out during the year.

Design/Analysis of C × S band antenna for thermal load, lateral loads, shock moments and free vibration, analysis of SADA cone for shear, axial, transient and bending moment loads, etc., were carried out for the INSAT-II Test Spacecraft project.

## **Mechanical and Thermal Systems**

Hardware fabrication activities related to ASLV and PSLV continued during the year. The ASLV hardware realised included SITVC gas tank and injectant tank, titanium gas bottles, AS-1 nozzle divergent, AS-4/satellite separation system, RCS thrusters of 2 kgf to 250 kgf, etc. The hardware for PSLV included SITVC nose cones, SITVC tie rod and mounting assembly, igniter components such as detonator holder, detonator cap, ETA coupling, bolt cutter, satellite separation system, strap-on separation system, PS-2/PS-3 separation system, PS-3 actuation system, etc. Components for PSLV heatshield and PS-3 motor case were also produced. Fabrication works related to ABR-200 rockets, Rohini Sounding rockets and payloads were also undertaken.

A new CAD/CAM facility with mechanical design and analysis software has been commissioned. The

redesign of ASLV heatshield, PSLV-related drawings and GSLV configuration studies were carried out using this facility.

Interchangeability of segments of PS-1 motor cases has been achieved. Five middle segments, one nozzle end segment, six PS-0 motor cases and nozzles were realised during the year through external work centres.

In the spacecraft area, a clamp-band system has been designed and fabricated for the ground handling of INSAT-II TS. The temperature data from IRS-1A spacecraft were collected to study the behaviour of thermal control system and analysis completed. As a result, modifications in the thermal control system are being made for IRS-1B and IRS-1E spacecraft. Qualification tests on indigenously developed Optical Solar Reflector (OSR) were completed and the specimen tested for two years equivalent geo-synchronous orbit environment using facilities abroad. The performance of the specimen is comparable with the products manufactured elsewhere.

## **Propulsion System**

### *Solid Propulsion*

Air augmented propulsion concept using fuel rich compositions was proved through flight testing of two ABR-200 motors. One of them used Magnesium incorporated in-house propellants for both booster and sustainer.

A five-segmented sea level nozzle of 3.65 metre length and 2.5 metre diameter, and another special sea level nozzle having thermal rocasin boot for protecting the flex-seal in submerged nozzle were put to test in the static tests of PS-1 and PS-3 motors respectively. The performance was satisfactory. Flex-seal development for PS-3 nozzle was completed during the year. All ablative components for ullage motors and igniter inserts have been realised.

Flight nozzle components for AS-1, AS-2, AS-3 and AS-4 nozzles, pressure bottles and igniter cases for ASLV-D3 flight were fabricated. 15 numbers of AS-0/AS-1 igniter cases, 6 numbers of AS-2



*Assembly of nozzle in progress*

igniter, 2 numbers of AS-2 nozzles, 2 numbers of AS-4 nozzles and one AS-0 static test nozzle were also realised.

PS-3 motor case development and qualification programme for PSLV project has been completed. Production of PS-3 motor case at the rate of more than one case per month has been achieved and fifteen PS-3 cases were realised during the year. Qualification tests on igniter case for PSLV have also been successfully completed and 35 igniter cases (PS-1, PS-0 & PS-3) were realised for the PSLV project.

Predictions and analysis on all the PSLV motors before and after test, preliminary grain design studies for GSLV booster with 160 tonne propellant were the other activities during the year in the Solid Propulsion area.

#### *Liquid Propulsion Systems*

The third phase of tests on turbo pump of PSLV second stage (PS-2) was completed during the year and sixth and seventh set of turbo pumps realised. The gas generator hardware required for the entire programme were also realised.

Fabrication of dynamic mockup of PSLV PS-2 was completed. Third and fourth flight version tanks were received from France and proof pressure test completed. The second and third set of flight version structures and fifth water tank were also realised. Development tests on pressurisation system with nitrogen and helium have been completed at ATS. Two modules of command system and three numbers of gas bottles were realised. One pogo command module hardware and one pogo corrector hardware were realised. Qualification hardware of hot gas roll control module was also realised.

Two stage tests in the battleship stage configuration were conducted at Principal Test Stand.

Restart capability of PSLV PS-4 engine was demonstrated through two series of hot tests, for 8 times of 60 secs. duration each, with different hold times. Battleship test series of PS-4 has been successfully completed by testing battleship hardware for 435 secs. duration in B1 series and for a total duration of 598 secs. in B2 series.

PSLV Secondary Injection Thrust Vector Control (SITVC) Engineering Model was integrated and leak checks and flow tests conducted with six

injection valves. The SITVC system functioned normally during the PS-1 static test meeting the PSLV requirements. Integration of Roll Control System (RCS) Engineering Model Package (EMP) for PS-1 was completed with propellant tank and fluid circuits. RCS structure and titanium gas bottle for proto integration were also made ready.

Tankages required for ASLV-SITVC were also realised.

Development tests on heat-sink version sub-scale-cryogenic engine were completed using Liquid Oxygen (LOX) and Gaseous Hydrogen (GH<sub>2</sub>). A sub-scale water cooled engine was realised and tested for short duration using LOX and GH<sub>2</sub>. The indigenous development of cryogenic engine components are in progress.

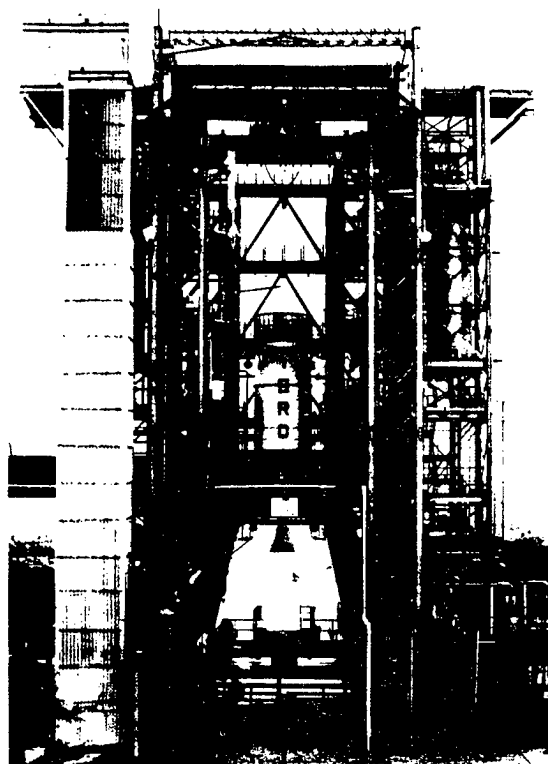
Fabrication and testing of components for IRS-1E propulsion system are in progress. RCS for IRS-1B has been realised and technique for etching process for disc filter for RCS has been developed. Development of mono propellant latch valves has been completed.

Propulsion system integration for INSAT-II TS ETM model was completed and fabrication of flight component has been started. The LAM engine for INSAT-II TS was subjected to a cumulative burn time of more than 8,000 secs. in the High Altitude Test facility and a specific impulse of more than 310 secs. was achieved. Under the qualification programme of LAM hardware a cumulative firing of 6,450 secs. in 8 spells of firings has been done so far on the Q-1 hardware. Development tests on AOCS engine, both in pulse mode and continuous mode, have been completed.

### Sensor Systems

The first unit of the star calibration system for PCMC Radar has been realised and two more units are under test.

Multi-element lens for satellite cameras similar to IRS have been fabricated and are undergoing qualification tests. The design of high resolution optics of various configurations for IRS-1C has been completed.



*PS-2 battleship stage test at Mahendragiri*

An electro-optic laboratory has been set up as part of ISAC to take up large volume fabrication and testing of various sensors and optics required for the on-going projects.

### Avionics Systems

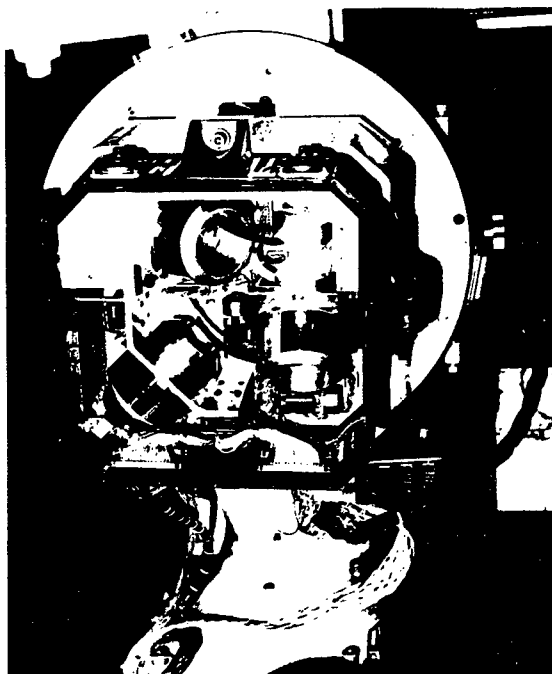
Autopilot for ASLV was redesigned with modified specifications. Modifications were incorporated in the guidance algorithm to improve its robustness and reliability. Integration of hardware subsystems for ASLV-D3 with necessary refinements is nearing completion.

Development and validation of navigation and guidance software were completed for PSLV. Autopilot design was done in digital domain for rigid body and further updated with flexible body dynamics. Load relief control was designed for high dynamic pressure region of the trajectory. Fabrication and package level tests on the qualifica-

tion model of Redundant Strapdown Inertial Navigation System (RESINS) were completed. Realisation of a test bed for performance evaluation of the integrated inertial guidance system for PSLV is in an advanced stage. Engineering model of the Stabilised Platform Inertial Navigation System (SPINS) has also been integrated and subjected to performance test as a back-up system for PSLV-D1.

Indigenous servo-accelerometer was successfully qualified for use in the navigation systems of PSLV. Qualification tests are nearing completion on Dynamically Tuned Gyroscopes (DTG). Rate integrating gyroscopes (Beryllium version) have already been qualified for ASLV/PSLV applications.

First set of Electrical Thermal Models (ETM) of reaction wheel/momentum wheel assembly, solar array drive assembly, inertial reference unit and VHRR scan mechanism were realised for INSAT-II Test Spacecraft project. Subsystems fabrication and integration of reaction wheel assembly, solar



*Engineering model of RESINS for PSLV under test on motion simulator.*

array drive assembly and redundant attitude reference system for IRS-1B is in progress.

Development efforts on ion thruster continued during the year and about 1,000 hours of operation was logged on the 10 mN Hg thruster lab model.

Augmentation of hardware-in-loop motion simulation facility is completed for use in INSAT-II TS test both in geo-stationary and transfer orbit modes.

### **Electronic Systems**

Fabrication of telemetry, tracking and telecommand (TTC) system packages for ASLV-D3 flight is in progress, both within ISRO and at external facilities.

For PSLV, qualification tests were completed on electronic system packages and one full set of qualification model was realised for equipment bay integration trials. Realisation of packages for PSLV-D1 flight is currently in progress. Engineering model of the 16 bit onboard computer (bit slice version) is being integrated with PSLV control and guidance software in PASCAL for performance tests.

All subsystems except the onboard computer have been delivered for integration of the payload for APC-REX flight. Software for onboard computer for the mission has been finalised and the flight version of the package is undergoing package-level tests.

A developmental model of coherent C-band transponder was fabricated and compatibility tests carried out with the PCMC radar to validate the system configuration.

The complete telemetry test station for INSAT-II Test Spacecraft has gone through test and evaluation. A processor-based image display system has been developed and installed at MCF, Hassan, for INSAT-II TS VHRR.

A low cost composite feed working in C and S band for direct TV reception has been developed

and tested successfully at the Doordarshan terminals at New Delhi and Bangalore. This feed eliminates the need to have independent terminals for C and S band and also covers the extended C band. Production of this feed has begun in Government Tool Room and Training Centre, Bangalore.

An omni-directional antenna operating in L-band, for use in INMARSAT Standard C type of ship terminal, has been developed for use in ship-borne terminals and small/medium size vessels.

Technology development related to monopulse comparator at C-band, QPSK modulator, Spread Spectrum Modem and S-band high power dual circularly polarised feed has also made substantial progress.

Work on the development of Ku band transponder was taken up at SAC. Several other electronic hardware development activities such as 60MB time division multiple access system, video teleconferencing, low rate voice transmission through narrow band links, etc., were continued. A Fresnel zone ring antenna for receiving TV signals from INSAT was demonstrated. An inflatable TV receiving antenna has also been demonstrated.

A microprocessor-based automated radiated susceptibility test set-up (20 v/m, 20 MHz – 18 GHz) has been developed to study the susceptibility of Electro Explosive Devices (EED) to radiated fields. An automated data compilation and test system has been developed and successfully used in INSAT-II data card matching which forms the input for electrical distribution system design. Fabrication, test and evaluation of INSAT-II TS ground checkout were completed during the year. Automated communication payload checkout system employing identical equipment set-ups for characterisation of the communication payload, both at payload level and integrated spacecraft level, was realised during the year.

### **Control Systems**

Qualification tests on the PSLV engine gimbal control system for PS-2 were completed and two packages were realised for battleship tests. Two

numbers of brushless actuators were realised for qualification of flex nozzle control system for PS-3. Qualification tests were completed on actuators and servo-electronics for LUS (PS-4) control system and four actuators were supplied for battleship tests and long duration tests at LPTF. Performance of the system was satisfactory in all the cases.

### **Flight Dynamics and Mission Planning**

Wind biased trajectories were generated for PSLV for various seasons of the year. Different approaches for matching loads on launch vehicles from force measurements and integrated pressure data were studied. Aerodynamic coefficients and load distribution for RH-200 (STT), RH-200 (chaff) and RH-300 Mark (03) were generated. Performance of different types of air intakes for ABR-200 was evaluated. Studies were undertaken on aerodynamic loads for APC-REX. Flow field in the cylindrical diffuser for High Altitude Test facility was studied using a newly developed software. Mission analysis and vehicle design studies were carried out for different configurations of GSLV. Studies were conducted on transonic flow past biconed bulbous heatshields. Transonic flow past axi-symmetric bodies at angle of attack was simulated. Thermal analysis of RESINS electronics and other electronics modules was completed during the year.

Force measurements were carried out on ASLV model to study the effect of relocation of SITVC tanks on the stability of the vehicle. Wind tunnel tests were carried out to check the effectiveness of ASLV fins for stability. Force measurements were carried out at NAL to study the contribution of protrusions like ullage, retro rockets and SITVC tanks to the aerodynamic characteristics of PSLV. Force tests were conducted on ABR-200 configuration to generate the design inputs like aerodynamic coefficients, load on fins and air intakes.

In the spacecraft area support requirement documents for IRS-1B from external stations and space segment mission requirements for IRS-1B, 1E and 1C were generated.

Detailed specifications for the telemetry interface with parallel DMA output, with multiple input data streams has been evolved for INSAT-II Test Spacecraft. Specifications for command encoder and computer interface/hand shake procedures have been finalised.

Development of operational software systems continued during the year for satellite orbit and attitude determination and prediction. A set of orbit-attitude-manoeuvre utility packages to cover a wide spectrum of user requirements were developed. Software packages to support studies and analysis in the area of astrodynamics were also developed. Development of integrated software package system for INSAT-II will be made operational by June 1990.

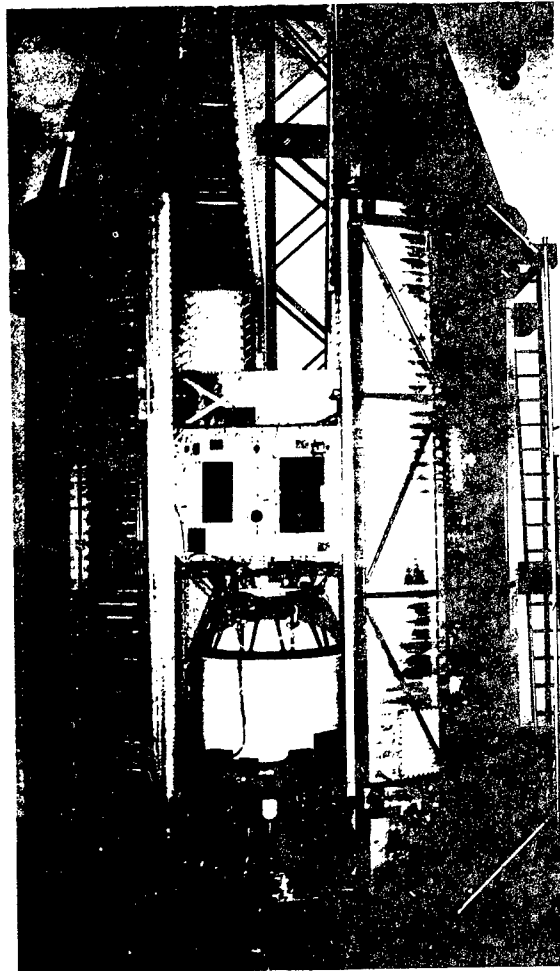
Advanced studies in star sensor attitude determination, space docking, space module re-entry, swath modelling for image processing, orbit transfer through solar sail and earth radiance profile were continued during the year and some of them have been completed.

### **Aerospace Mechanisms**

Improvements to the heatshield structure and its jettisoning system have been completed for ASLV. Modification of the strap-on system and Stage-3 separation system have also been completed.

For the PSLV Project, two more tests on PSLV heatshield rear cone were conducted during the year. Sub-scale models of heatshield hardware and acoustic blanket were fabricated and acoustic attenuation evaluation made for various thicknesses using the NAL facility. Acoustic test on full heatshield without blanket has been carried out. Data acquisition system for PSLV heatshield test facility has been commissioned. Net anchoring structure erection and retrieval system for full heatshield test has also been completed. One 5-axis CNC milling was commissioned at HAL, Bangalore, to meet the requirements of turbine rotor, stator and impellers.

Design changes on PSLV strap-on system were incorporated. Design modification on spring



*Heatshield and PS-4 in Acoustic Test Facility, NAL, Bangalore*

thruster to accommodate higher energy was also carried out. One set of retro-1 and retro-2 motors were fabricated and subjected to structural and burst pressure tests. Two full scale functional test on PS-2/PS-3 separation system were conducted successfully and structural test on satellite separation system completed.

Design and development activities were continued on the spacecraft mechanism elements such as coilable lattice booms, bi-stem boom for a PRL experiment and flexible solar array.

## PRODUCTION, ASSEMBLY, TEST AND SIMULATION FACILITIES

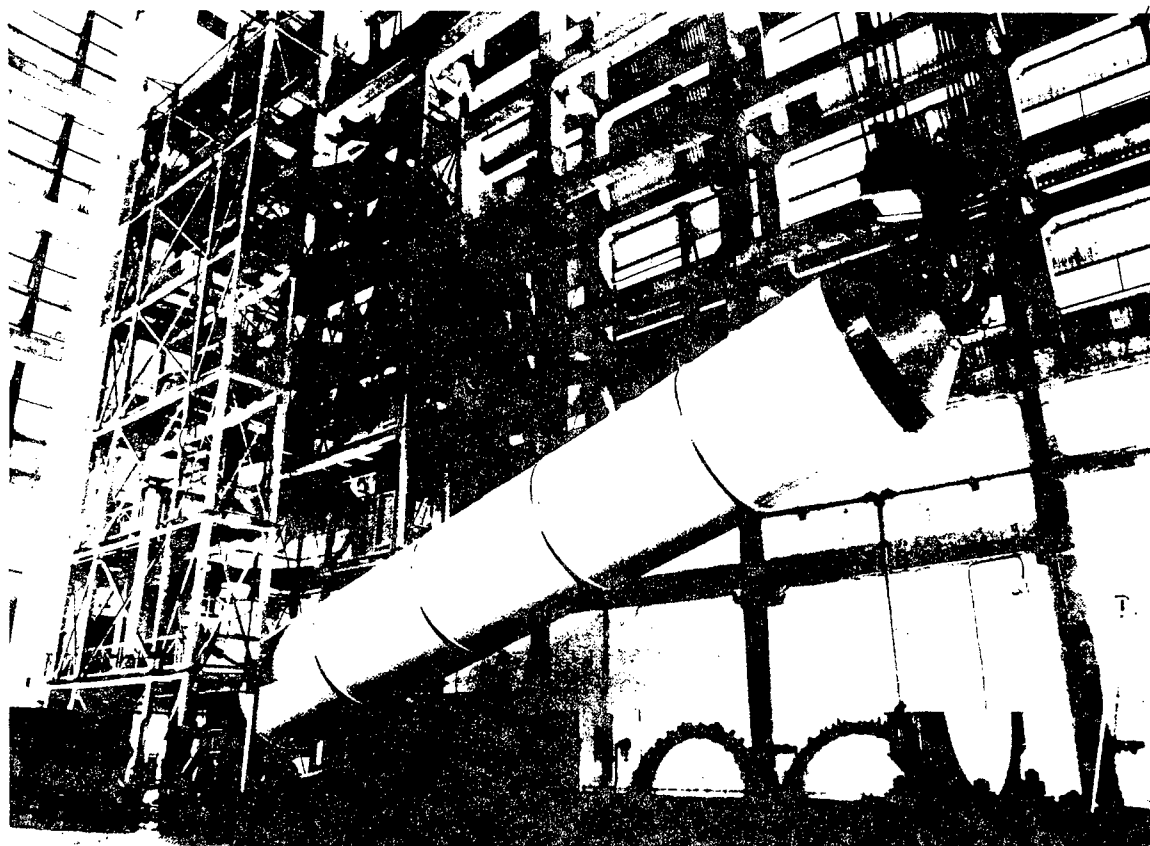
### Propellant Production

Solid Propellant Space Booster Plant (SPROB) successfully processed the PSLV PS-1 booster. During the year SPROB processed 255 tonne live solid propellant for ASLV and PSLV projects. About 80 tonne of live and 20 tonne of dummy propellant was produced at RPP, VSSC. The Ammonium Perchlorate Plant at Alwaye produced about 200 tonne of ammonium perchlorate during the year. A total of 140 motors were charged and 4,000 pyro systems were produced during the year to cater to the various programmes. A plant for producing green  $N_2O_4$  is under commissioning.

### Electronic Production

80 numbers of signal conditioners, 15 numbers of power modules and 8 numbers of multiple signal conditioners were fabricated and tested for PSLV. Fabrication of first set of flight models has also commenced. Production of inertial guidance and RF system packages for ASLV D-3 is in progress. Automated checkout systems were developed for test and evaluation of small packages and for card level tests of onboard computers. 3,300 PC boards, including 2,300 PTH, were produced. 12 types of Hybrid Micro-Circuits (HMCs) were developed and 155 numbers fabricated.

Production of precision fasteners for electronic packages and anodising and selective gold and



*Five-segmented PSLV first stage motor*

silver plating on a few packages were undertaken. Inner shell of nozzle for the development of one tonne cryogenic engine was fabricated by electro-forming of copper.

Computer Aided Design (CAD) work stations were made fully operational during the year in VSSC and they are being used for the preparation of artworks for hybrid microcircuits and multi-layer PC boards.

Engineering model electronics fabrication activities of INSAT-II TS was completed. Mother-daughter board packaging technique for INSAT-II TS has been qualified and implemented. Qualification of radiation shielding for electronic components has been qualified and implemented for INSAT-II TS electronic modules. Eight types of fabrication materials and components for spacecraft application such as solder, soldering flux, connector accessories, inter-stacking spacers and harnessing materials have been indigenised. The electronics fabrication facility at ISAC produced the total requirement of 244 numbers of PCBs for SROSS-C and 283 numbers of PCBs for IRS-1B. 381 Nos. of PCBs were realised for engineering model and flight models of INSAT-II TS.

200 HMCs were fabricated for INSAT-II TS project. About 1,000 numbers of substrates were also fabricated with thick film components for flight model applications.

### **Transducer Production**

LPSC at Bangalore produced 486 numbers of absolute pressure transducers, 13 numbers of differential pressure transducers and 106 numbers of temperature sensors during the year. Qualification tests on thin film pressure transducers, assembled with imported thin film capsules, were completed. The transducers are adequately compensated in the temperature range of  $-40$  deg C to  $+120$  deg C for use in flight (PSLV levels). The precision pressure transducers for PSLV applications have been qualified and 20 transducers are under assembly. Development of cryo temperature sensors in the range of 20 deg K and 35 deg K

has also been taken up. 4 pressure transducers were realised and tested for INSAT-II TS levels.

### **Liquid Propulsion Test Facilities**

Modifications to Principal Test Stand (PTS) to conduct battleship tests of PSLV PS-2 stage were carried out and first series of tests on the PS-2 stage (15 to 75 secs. duration) were conducted during the year. Pogo corrector development tests and PS-2 cold pressurisation tests with instrumentation were carried out at the auxiliary test stand. Modifications in the PSLV-Liquid Upper Stage (LUS) test stand were made and battleship tests with stage instrumentation of PS-4 stage were successfully demonstrated for a duration of 375 secs. each in 2 series (B1 & B2) at the LUS test stand.

The proof pressure test facility with associated fluid circuits and instrumentation has been established and proof pressure testing of PS-2 propellant tanks (4 numbers) successfully carried out.

Decontamination plant for decontaminating the PS-2 propellant tank after hot test has been commissioned.

The High Altitude Test (HAT) facility was augmented with additional air compressor. Tests on INSAT-LAM engine with instrumentation support were carried out for a cumulative duration of 15,775 secs. Tests on INSAT-AOCS engine with instrumentation were also carried out for a cumulative duration of 85,500 secs.

The EBW facility at LPSC was augmented with a high power Electron Beam Weld (EBW) gun of 150 kV, 15 kW power to meet the electron beam welding requirements of INSAT-II, PSLV and GSLV. This facility is now capable of welding to a maximum depth of penetration of 40 mm in stainless steel and 20 mm in titanium alloy.

### **Static Test and Evaluation Complex (STEX)**

STEX is located in SHAR and provides facilities for the static testing of rocket motors. Major

activities accomplished during the year include proof-pressure testing of 6 numbers of PSLV PS-1 and successful static testing of first PSLV PS-1 motor with SITVC. 310 channels to measure critical parameters like thrust, pressure, temperature, strain, etc., were provided for the PS-1 test.

Other static tests conducted during the year include PS-3 proof motor with PS-1 propellant composition, PS-3 FM with sea level nozzle, AS-4 FM with pressure cured motor and AS-2 FM with HTPB propellant.

### **Large Space Simulation Chamber (LSSC)**

LSSC being established at ISAC as part of the facilities under INSAT-II Test Spacecraft project, is intended for thermal balance and thermal performance tests of complete spacecraft. LSSC consists of a 9 m dia. and 9 m high main thermo vac chamber with removable top dish, a 7 m dia. auxiliary chamber juxtaposed with the main chamber to house the solar simulator and related optics, two liquid nitrogen storage tanks of 1 million litre capacity each, a helium plant, a motion simulator, data acquisition system and associated systems. The erection of all major systems of the facility was completed during the year and tests and trial runs are in progress. The facility will be commissioned during the beginning of 1990-91.



*One million litre liquid nitrogen storage tanks for Large Space Simulation Chamber (LSSC)*

### **RELIABILITY AND QUALITY ASSURANCE (R&QA)**

The R&QA groups at ISRO Centres/Units continued to support various programmes in respect of quality control, quality assurance, reliability analysis and test and evaluation. QA surveillance and certification activities were carried out for all the ongoing programmes. Some of the activities during the year included test and evaluation on flight and qualification models of ASLV, RSR and PSLV packages (such as digital electronic, inertial



*Quality Assurance Laboratory at ISAC*

system, RF and microwave components), digital electronics packages such as OBRM for APC-REX, CCU, RUs and telecommand decoders for PSLV. Stage clearance, in-process inspection, qualification and acceptance tests of subsystems and integrated system for the various ongoing projects were carried out. Training and certification of operators and inspectors was also continued.

A study for the indigenous manufacture of high reliability electronic parts was undertaken and a programme for the production of about 10 types of devices has been initiated at Bharat Electronics Limited.

A management information system for R&QA activities has been developed. A data base containing information on the malfunctions and failures of spacecraft and launch vehicles has been designed.

A data bank of high reliability parts used in ISRO projects with their past history and use is also being established. The microfilm library on current international standards is providing instant access to information for procurement of components by ISRO Centres.

## **SAFETY SERVICES**

While ISRO has been free from any major accidents during the year, the safety groups at ISRO Centres/Units have constantly appraised themselves of the disasters that occurred elsewhere in the world to learn from others' experiences and take preventive measures. The ISRO safety groups function synergistically with projects and divisions at ISRO Centres/Units, interacting with and advising them regarding various aspects of safety that integrate into the programmes at different stages, namely, design, construction of facilities, production, test and evaluation and launch operations. Specific activities during the year are the following:

The safety groups reviewed the handling of mechanical hardware, propellant and test during the successful static test of PSLV PS-1. All necessary safety precautions were also incorporated into the testing of liquid propellant engines from Mahendragiri. ISRO safety groups carefully reviewed the handling processes involved in the production of large propellant segments and other chemicals at its facilities at Sriharikota, Thumba and Alwaye and made specific recommendations.

The safety groups also reviewed the location of proposed works and accorded safety clearance to 30 installations. About 40 processes/operations involving hazardous, toxic and inflammable materials were also reviewed for their safety clearances.

Reviews have been conducted during the year for pyrotechnics of PSLV and other vehicles and guidelines evolved towards handling, integration and checking of these systems. Guidelines and procedures have been updated towards safety of the launch pad area, the impact zones in the sea and the air corridors. A range safety manual was brought out during the year to be followed for all launchings from Sriharikota, Thumba and Balasore.

Fire fighting and fire prevention have been given utmost importance not only with respect to constant upgradation of equipment and tools employed, but also with respect to the training of ISRO fire fighting forces at various Centres to keep them in a state of constant alert and effectiveness. The automatic fire extinguishing system of spacecraft control centre at MCF has been augmented during the year. Safety guidelines on the use of compressed gas cylinders were brought out and issued to all Centres/Units. Regular in-plant safety training programmes were also conducted.

As a part of occupational health and safety programme, the medical officers at ISRO Centres undertook screening of personnel at all levels towards general and occupational health safety. ISRO endeavoured to keep its work force in good health. An occupational health and industrial hygiene workshop was organised at VSSC with the participation of medical and safety personnel from various ISRO Centres/Units to review the adequacy of measures implemented.

Personnel safety awareness and motivation has been promoted through National Safety Day celebration, safety posters, screening of safety films and training programmes. □

# Launch Support, Tracking Network and Range Facilities

All ISRO launch missions are supported by the ISRO Range Complex (IREX) with its launch ranges at SHAR, TERLS and Balasore. The TTC network support for the spacecraft missions is provided by ISRO Telemetry, Tracking and Command Network (ISTRAC) which operates an integrated network facility comprising TTC stations at Bangalore, SHAR, Trivandrum, Lucknow, Car Nicobar and Mauritius. The Multi-mission Spacecraft Control Centre of ISTRAC is located at Bangalore.

## **ISRO RANGE COMPLEX (IREX)**

### **PSLV Launch Complex**

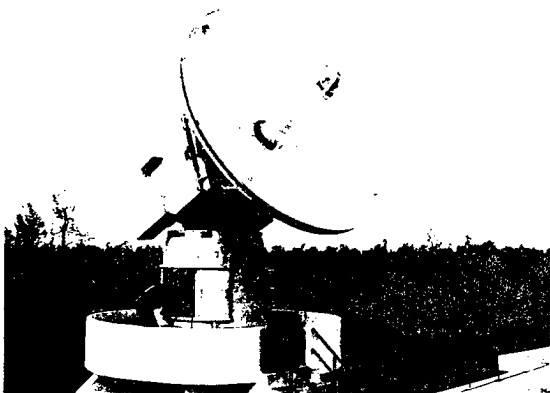
The erection of Mobile Service Structure (MST)

for PSLV was completed during the year and the facility is under commissioning phase. The works completed on MST include erection of all platforms and doors and their associated mechanisms, cladding of the tower, erection of launch pedestal and umbilical tower and commissioning of the wheel bogie system thus making the MST mobile on rails. Works in progress on MST include commissioning of 60 tonne EOT crane and 15 tonne pneumatic hoist, panelling of walls of clean room at 41 m level, erection of insulation panels and installation of air-conditioning equipment, electrical system and erection of elevator.

Installation and testing of pipelines and fluid circuits at liquid propellant storage complex and



*Mobile Service Tower, Launch Pedestal and Umbilical Tower for PSLV at SHAR*



PCMC Radar at SHAR

erection of liquid stage facilities and safety system at launch pad have also been completed. Instrumentation and control system at storage complex are under commissioning.

Testing and commissioning of optic fibre link and CCTV cable, and installation of consoles at the mission control centre have been completed.

All subsystems for the first Precision Coherent Monopulse C-band (PCMC) Radar except the transmitter have been realised. Antenna mechanical systems, servo, optical and RF systems have been erected at site. Major subsystems for the second PCMC Radar have also been realised and erection of mechanical servo unit at site has been completed.

### **Launch Support to Sounding Rockets**

Sixty-four sounding rockets were launched during the year till November 1989 from SHAR, TERLS and Balasore ranges. Two launches for other agencies were also supported by IREX. The launchings were related to smoke trail tests to derive wind profile, development of air breathing rockets, meteorological studies and to monitor stratospheric and mesospheric winds under the Indian Middle Atmosphere Programme (IMAP).

### **ISRO TELEMETRY, TRACKING AND COMMAND NETWORK (ISTRAC)**

ISTRAC continued to support the ongoing IRS-1A mission through its network of ground stations

at Bangalore, Lucknow and Mauritius and the Spacecraft Control Centre (SCC) at Bangalore. The support provided to IRS-1A includes payload operations during all the 16 repetition cycles during the year, magnetic torquer control operations to conserve fuel and in-plane orbit manoeuvre to maintain the ground track of the satellite within  $\pm 14$  km of nominal path.

An automatic signal acquisition and monitoring system has been developed and installed at Lucknow ground station. Message transfer network was implemented using PC-compatible system to transfer messages on telephone lines. Utility packages related to graphics and accounting information were developed on VAX system.

ISTRAC will support the PSLV mission with S-band TTC stations at SHAR (SHAR-I and II), Trivandrum and Mauritius. Integration of SHAR-II ground station and augmentation of Mauritius TTC station with a 10m terminal are now nearing completion. Data flow requirements and format details from different stations including display details at SHAR have been finalised.

ISTRAC will provide launch and early orbit phase support for Eutelsat-2 mission of European Space Agency (ESA), during April 1990 using the Bangalore ground station.

Orbit determination support was continued for Aryabhata, Bhaskara-II, RS D-2, NOAA-II and Landsat-5. Also, Bhaskara-I spacecraft was tracked intensively and orbit determination was carried out during its re-entry phase on February 17, 1989.

### **SHAR COMPUTER FACILITY (SCOF)**

SHAR Computer Facility provides for real-time, near-real-time and off-line computing and data processing requirements for rocket launchings and satellite tracking as well as other scientific and management functions of the Centre. The facility includes two VAX-11/785, one VAX-11/750 and two System-332 computers.

During the year, real-time system design for PSLV launch support using VAX-11/785 systems was finalised and development of software is in progress. Software design for MCC support was also finalised. □

# Space Sciences

## PHYSICAL RESEARCH LABORATORY (PRL)

### Astronomy and Astrophysics

The study of the dynamics of the hot and tenuous coronal plasma of the sun is being carried out using the three solar wind observatories set up by the PRL in Gujarat. Daily Interplanetary Scintillation (IPS) data are being recorded using digital data acquisition system. Improvements to the 1.22 m diameter infrared telescope installed at Gurushikhar are being carried out.

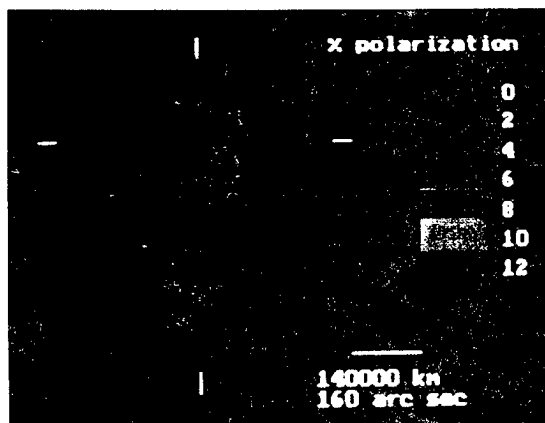
Analysis of the photopolarimetric observations has led to the detection of submicron size particles in the atmosphere of the Comet Halley. Till now it was believed that only particles above one micron existed. This finding is also supported by the Vega and Giotto spacecraft observations. Polarisation observations made on Comet Halley in the neutral ( $C_2$ ,  $C_3$  and  $CN$ ) and ionised ( $H_2O^+$  and  $CO^+$ ) molecular bands showed high degree of polarisation for all of these molecules.

### Planetary Atmospheres and Aeronomy

Total photo absorption and fluorescence cross-sections have been measured for sulphur dioxide at wavelengths ranging from 190 to 235 nm. Sulphur



A section of new 20,000 m<sup>2</sup> Thaltej Radio Telescope



Polarisation image of Comet Halley shows two regions of high polarisation (pink/red regions) which may be due to the jet activity in the nucleus. A low polarisation region near the nucleus of the Comet (intersection of four white lines) may be caused due to the multiple scattering of the sun light. (Different colours indicate percentages of polarisation)

dioxide is a pollutant in earth's atmosphere and is also present in the atmospheres of several other planets. Absolute total electron scattering cross-sections for molecular oxygen have also been measured at electron energies ranging from 0.15 to 10 eV using a photoelectron source. These measurements are important for studying the thermal budget of earth's atmosphere.

Under IMAP-Continuation programme, balloon-borne experiments have been successfully conducted for measurement of water vapour concentration profiles upto about 35 km and for comparison of ionisation parameters measured using different techniques/payloads. Also as part of the IMAP campaign to study D-region ionisation ledge, one RH-300 MK-II rocket was launched successfully and electron/ion densities measured. Based on the data available on trace gas concentrations such as  $N_2O$ ,  $CH_4$ , chlorofluorocarbons, etc., an empirical relationship to calculate

vertical distribution of these gases over any latitude has been developed.

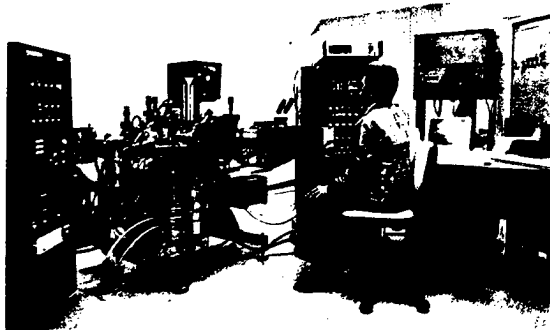
A day-glow photometer working at 630 nm has been developed and operated over equatorial region. Day-to-day variability of the emissions, short period fluctuations of the intensity and pre-sunset enhancement of airglow emissions have been detected. An all-sky camera with image intensifier has been developed to map 630 nm night airglow. Large scale structures in F-region electron density irregularities have been observed over Mount Abu.

### Earth Sciences & Solar System Studies

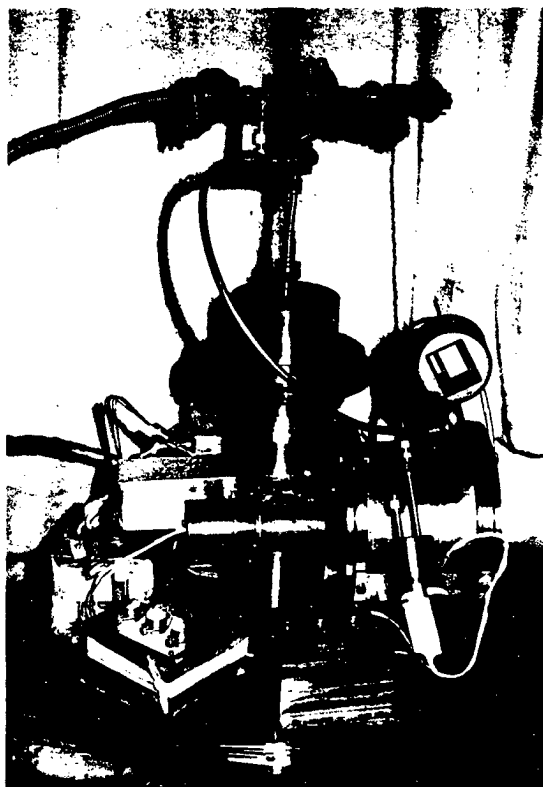
From the study of solar and galactic cosmic ray produced nuclides in meteorites three cosmogenic radioisotopes  $^{24}\text{Na}$ ,  $^{57}\text{Ni}$  and  $^{47}\text{Sc}$  have been detected for the first time in a fresh meteorite.

The installation of the ion-probe, an extremely sensitive high resolution secondary ion mass-spectrometer, has been completed and performance tests are in progress. This instrument will be useful for precision isotopic measurement in extremely small samples of meteorite and terrestrial rocks for understanding the early history of the solar system and evolution of earth over geologic time.

The ocean sediment Core SK-185 from the eastern Arabian Sea has been analysed with a high resolution. The results show that 18,000 years ago [called the Last Glacial Maximum, (LGM)] the SW monsoon was weaker and the NE monsoon was stronger than today.



*Ion-probe—a precision mass-spectrometer for isotopic studies*



*Lyman-Alpha Fluorescence Hygrometer*

A 12 m Mackeretch cover has been successfully developed and tested. Undisturbed long cores have been raised from Manasbal lake in Kashmir and preliminary results indicate that chlorophyll increases with depth.

### Theoretical and Nuclear Physics

Study of the dynamics of plasma disc around compact objects in the presence of magnetic field, relevant in understanding highly condensed neutron stars, has evolved the equilibrium configuration with physically meaningful pressure distribution consistent with magnetic field.

A new theory called boundary corrected formalism has been successfully developed giving satisfactory agreement with experimental cross-section for a wide variety of collisional system.

Physical structure behind Sdg-interacting boson model has been studied and understood for providing group theoretical description of resulting collective states in atomic nuclei.

Two important mechanisms have been developed which are capable of explaining some of the phenomena observed in space plasma, e.g., excitation of low frequency waves in the magnetosphere and the mechanism of solar bursts.

### **SPACE PHYSICS LABORATORY (SPL), VSSC**

A photon counting unit has been developed and is being integrated with the Ruby Lidar system to study the Radar returns from the higher altitudes of stratosphere. Variations of aerosol extinction with altitudes in the stratosphere has been explained in terms of heteromolecular nucleation and condensation processes.

Prominent wind shears have been detected in the boundary layer during the passage of a cold front using tristatic Doppler Radar. In-situ measurements of vector wind, temperature and humidity in the surface boundary layer have been started using high sensitivity and fast response sensors located at different heights in a tower upto about 25 m. A method has been developed to deduce night-time thermospheric meridional winds at equator from the virtual height of the F-region obtained using the ionograms recorded at SHAR and Trivandrum simultaneously.

### **TECHNICAL PHYSICS DIVISION, ISAC**

A satellite payload to monitor celestial Gamma ray bursts in the energy range of 20-3,000 keV with high temporal and spectral resolutions is under development for launch on board SROSS-C satellite.

### **UDAIPUR SOLAR OBSERVATORY**

The Doppler motion of a large number of filaments seen on full solar disk H-alpha filtergrams

have been studied. It is found that only 48% active region filaments which displayed strong Doppler motion did erupt or disappear from the solar surface. Helical twisted structures are observed in many eruptive solar prominences.

### **INDIAN MIDDLE ATMOSPHERE PROGRAMME (IMAP)**

Initiated in 1982, this multi-agency project to study the radiative, dynamic, chemical and electrodynamic characteristics of the atmosphere between the height range of 10-100 km has completed its main observational phase. A large number of campaigns involving studies of the low latitude ozone profiles, characteristic of equatorial waves, ionisation and conductivity structure have been successfully completed. During the year, measurements of water vapour, intercomparison of balloon-borne conductivities and variability of D-region ionisation have been carried out. The highlights of the results obtained so far have been published as a comprehensive IMAP/ISRO report. More detailed papers are being published in the special issue of Indian Journal of Radio and Space Physics.

As a follow-up action and to pursue the data analysis, scientific investigations and modelling work, a national committee on middle atmosphere has been constituted. The IMAP Data Centre is now being operated as one of the ISRO facilities providing the services of disseminating the data which are being submitted by IMAP scientists. The operations of six multi-wavelength radiometer/BUV-photometer established at Visakhapatnam, Mysore, Pune, Delhi, Jodhpur and Trivandrum are being continued. Meteorological rocket soundings are also being continued from Thumba and Balasore.

### **MESOSPHERE, STRATOSPHERE AND TROPOSPHERE (MST) RADAR**

The Mesosphere, Stratosphere and Troposphere Radar (MST) project envisages the establishment of MST Radar as a national facility for atmospheric research. The Radar will provide estimates of

atmospheric winds with very high temporal and spatial resolution on a continuous basis which is essential in the study of dynamical processes in the atmosphere. The project is jointly funded by Department of Space (DOS), Department of Electronics (DOE), Defence Research and Development Organisation (DRDO), Department of Science & Technology (DST), Department of Environment (DoEn) and Council of Scientific & Industrial Research (CSIR). DOS is the nodal agency for establishing this national facility. The civil and electrical works, antenna array works, transmitter building and the main building are nearing completion at Gadanki village near Tirupati.

#### **ADVISORY COMMITTEE FOR SPACE SCIENCES (ADCOS)**

Efforts were continued by ADCOS for promotion of selected space science research programmes. Action plan for promoting research in certain areas, such as origin of life, microgravity research, planetary research, etc., were initiated for possible implementation in the coming years. The total requirement of rockets and balloons for the various science programmes during the next five years has been worked out. □

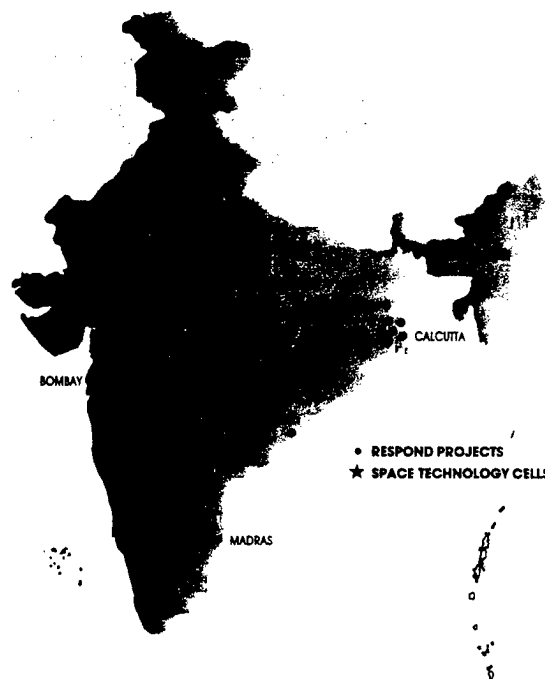
# Sponsored Research

ISRO Sponsored Research Programme (RESPOND) supports research and development projects and other scientific activities at the academic institutions in the areas relevant to the Indian Space Programme. RESPOND supports: (i) research projects in space science, applications and technology areas; (ii) the Space Technology Cells (STC) at academic institutions for carrying out research in advanced technology areas; (iii) educational activities, conferences/symposia, seminars and publication activities. Fellowships in the Indian Middle Atmosphere Programme (IMAP) were also supported under RESPOND. The prime objective of RESPOND is to strengthen the ISRO-academic institutions interaction for promoting space research in the country and establish a wide infrastructure and manpower base to support the Space Programme.

## ON-GOING RESPOND PROJECTS

|                       | No. of<br>Institutions | No. of<br>Projects |
|-----------------------|------------------------|--------------------|
| Universities/Colleges | 12                     | 20                 |
| I.I.Ts                | 2                      | 5                  |
| IISc                  | 1                      | 3                  |
| National Laboratories | 2                      | 2                  |

During the year Space Technology projects were initiated on: (a) studies of the ballistic, mechanical and degradation behaviour of propellant and fault-tolerant distributed computing system, at Indian Institute of Science, Bangalore, (b) Reactivity of Isocyanates, at University of Madras and (c) Charging behaviour and development of circuit models of geo-stationary satellites, at Jadavpur University. In the Space Applications area, the following three projects were started: (a) Study of electrical properties of materials of geo-physical interest through permittivity measurements, at J.E.S. College, Jalna, (b) Soil and land degradation studies in south coastal Andhra Pradesh using satellite data, at Col-



lege of Agriculture, Hyderabad, and (c) Study of thematic information of Visakhapatnam district using IRS-1A satellite data, at Andhra University. One Space Science project was initiated to study the transfer of radiation through interstellar molecular clouds, at University of Gorakhpur.

A number of projects initiated earlier were completed during the year and the project reports submitted to ISRO Centres. These include:

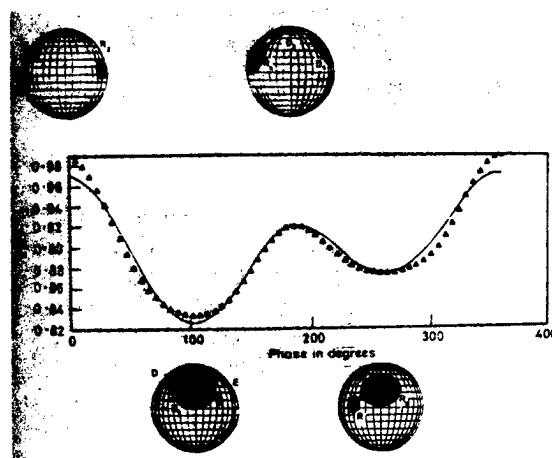
(a) Weldability evaluation and welding procedure establishment for modified ESR 15CDV6 steel by Welding Research Institute, BHEL, Tiruchinapalli (b) Development of metal-metal-oxide thin film coatings for Space Applications by Mangalore University (c) Structural weight optimisation of mobile service launch tower by Jadavpur University (d) Structure and reactivity of titanium lead dioxide anodes for perchlorate electrosynthesis by Indian Institute of Science, Bangalore

(e) Monitoring of crop production in saline and sodic soils of Gujarat with the help of remote sensing, and an experiment in imparting family-centred knowledge to the rural and urban adolescent girls and adult women through television, by MS University of Baroda (f) Study of environmental impact on autotrophs and heterotrophs of Chingleput district of Tamilnadu by University of Madras (g) Experimental study of the feasibility of preparing the topographical map by doppler shift method by Jadavpur University (h) Model for atmospheric transmittance and radiance by Indian Institute of Science, Bangalore (i) Investigations on the monsoons of South Asia by Indian Institute of Tropical Meteorology, Pune (j) Grand unified theories and the early universe by North Bengal University (k) Determination of the sizes, temperature, life times and distribution of star spots on the surface of the solar type RSCVn binaries by Osmania University.

The Space Technology Cell at Indian Institute of Science, Bangalore, has initiated technology projects related to (a) Stability and continuity analysis of computer networks with non-stationary and/or non-independent input traffic (b) Continuation study of novel baffle configurations for suppression of sloshing (c) Investigations of GaAlAs-GaAs heterojunctions used in space grade solar cells (d) Preparation and characterisation of airborne ceramics by combustion process (e) Studies in boundary layer separation and (f) Design of a VLSI chip for telemetry applications.

The Space Technology Cell at Indian Institute of Technology, Madras, has initiated study projects on (a) Interference effects in spray combustion (b) End capping of isocyanates for TDI-HTPB binder system (c) Migration of chemical ingredients in solid rocket propellant grains and (d) Effects of ultrasonic vibrations in the heat treatment of some age-hardenable alloys of aluminium and magnesium.

The projects at the Space Technology Cell, Indian Institute of Technology, Bombay, in the area of remote sensing include (a) Studies on siltation of reservoirs based on remote sensing techniques (b) Geo-modelling of a mineralised area through integration of remotely sensed geophysical data and



*The distortion waves observed (triangles) and theoretical (solid line) in the light curves of RS CVn system SV camelopardalis (period: 0.59d) indicating the presence of spot groups on the hotter component of the system (project supported at Osmania University, Hyderabad).*

geochemical data (c) Development of models for atmospheric corrections for remotely sensed data and (d) Studies on urban development and town planning based on remote sensing technology.

The educational activities supported by RESPOND include joint ISRO-IISc educational programme, joint astronomy programme, Space education cell at the Vikram Sarabhai Space Community Centre, Ahmedabad, and Space law studies, at Jawaharlal Nehru University, New Delhi. During the year, RESPOND supported 35 conferences/symposia/seminars related to Space. It also supported publication activities of Indian Academy of Sciences, National Academy of Sciences and Physics Society.

Efforts are on to increase the research projects in important areas of space technology and applications of direct relevance to the Space Programme. The research activities at Space Technology Cells are jointly carried out with ISRO scientists and these projects are generating useful results for utilisation and dissemination in ISRO's ongoing and future projects. The activities are increasing from year to year and ISRO-academic institution links are strengthened continuously through RESPOND programme. □

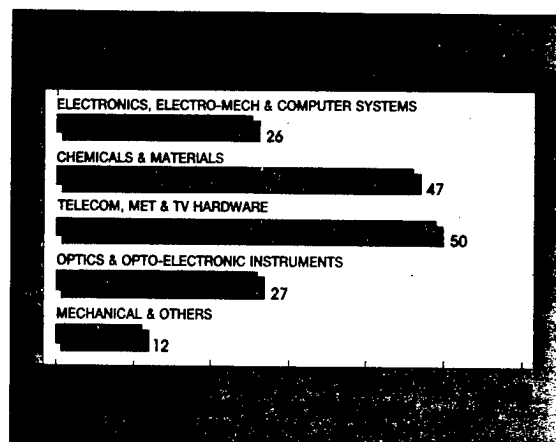
# Space-Industry Partnership

As a policy, Indian Space Programme has been seeking an active participation of Indian industries in the execution of its projects. In order to forge this linkage into a sustaining relationship for mutual benefit and growth, a two-way partnership between the Indian Space Programme and Indian industry has been evolved. This involves the transfer of advanced technologies developed in the Space Programme to industry and the provision of technological consultancy from the Space Programme to industry on the one hand, and the utilisation of industry's own technological potential and expertise for the Space Programme on the other. ISRO's technology transfer scheme promotes and supports the commercialisation of technologies developed in the Space Programme for applications in various national sectors. The three major purposes served by this scheme comprise (i) meeting the requirements of Space programmes and projects through the buy-back of products produced by industry as a result of technology transfer (ii) servicing the rapidly expanding space applications markets in India generated by the Space Programme in the areas of satellite communications, TV and radio broadcasting, meteorological observations, remote sensing for natural resources survey and management, and (iii) exploiting the full potential of the indigenous technologies developed by the Space Programme for multifarious spin-off applications.

Till the end of December 1989, 163 distinct technologies have been licensed by ISRO and NRSA. Industry is playing an increasingly important role in various tasks related to the ongoing Space projects.

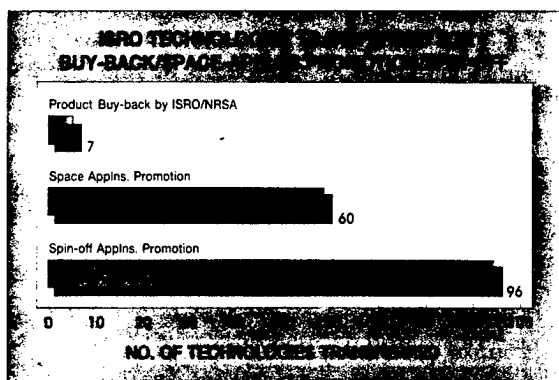
## TECHNOLOGY TRANSFER

During 1989, thirteen new product/process technologies were transferred by ISRO. Major technologies transferred include polyimide resin for glass and carbon composites, polyamic acid, vinyl ester resin (VESTOR 40), Middle end Image Pro-



cessing System (MIPS), 3 m dia road transportable/airliftable antenna, automatic microfiche camera, photowrite system, drum scanner digitiser, optics design software (Optosoft), relay parameter tester, 8 hp DC servomotor, etc. In addition, 7 more technologies have been licensed to additional entrepreneurs to meet the growing market demand. About 100 products/processes and applications software packages are in the pipeline for technology transfer.

Good progress was made during the year in the utilisation of technologies transferred by ISRO. Among the buy-back items, significant quantities of HTPB fuel binder resin, liquid phenolic resin, high silica cloth and liquid propellants like UDMH and MMH were supplied by Indian industries for the Space Programme. A production-cum-buy back agreement has been signed for carbon cloth for the launch vehicle programme of ISRO. Under the space applications and spin-off categories, an additional technology transfer agreement on Disaster Warning Receiver (DWR) developed in ISRO has been signed to meet the increased requirements for this system. The DWRs, already under use by the India Meteorological Department, have proved their usefulness during the cyclones that hit the east coast. The tradition of associating the industry with ISRO in the development of digital image analysis systems for use by the remote sensing



community, started with ISROVISION. This tradition is being continued in the development of larger capacity Middle-level Image Analysis Systems (MIAS). The markets for spin-off items have also considerably increased. There has been an overwhelming demand for additional licensing of the precipitated silica technology developed by ISRO. A number of items including upgraded ground communications equipment for use in conjunction with INSAT-II, several chemicals and instruments including flux gate magnetometer technology are under advanced stages of processing. Increasing number of requests are also being received from abroad for ISRO technologies. Steps are being taken to initiate efficient technology transfer overseas including evolution of a standardised format for international contracts.

## MARKET SURVEYS AND SYSTEM STUDIES

Market survey projects/prefeasibility reports for a number of items for which technologies had been developed in ISRO were undertaken during the year. The items include application software related to digital image processings and analysis, personnel safety tester, accelerometer calibrator, epoxydised natural rubber, polysulphide polymers, computer based MIS and monitoring systems, frame grabber, productionisation of aerospace fasteners, Very Small Aperture Terminal (VSAT), roof top terminal for business communication via satellites, etc. In addition, the socio-economic analysis on the impact of multi-

purpose hydel projects on the environment, cost benefit study of satellite-based educational television and techno-managerial assessment for use of remote sensing for deriving information on natural resources were also undertaken.

## PATENTS, COPYRIGHTS, TRADE-MARKS AND DESIGNS

During the year 1989, the patent applications for which complete specifications were filed include OLFEX dry powder for extinguishing oil fires, Satellite-based Wide-area Information Feed and Transfer (SWIFT) system and Satellite wide area radio system. Patents and Trademarks were granted for Agrophotometer (an electro-optical instrument to measure agronomical parameters) and OLFEX.

## PROMOTIONAL ACTIVITIES FOR TECHNOLOGY TRANSFER AND MARKET DEVELOPMENT

The promotional activities meant for technology transfer and industry interface include the generation of a large number of Interest Exploration Notes providing details of technologies developed by ISRO and available for transfer. These were disseminated to a wide range of industries and other high-tech institutions as well as potential users. In addition, announcements were also made in professional journals and newspapers about the availability of these technologies. Demonstrations were also arranged for various products/processes having potential for technology transfer to the industry representatives.

A two-day technical seminar-cum-exhibition on "Opportunities in Space" was organised as part of the interface between ISRO and the Confederation of Engineering Industry on December 8-9, 1989 at Bombay. This meet was intended to gear up industrial participation in the ongoing and future programmes of ISRO. In addition, several industry meets were arranged to promote industrial developments in specific product categories like communications, image analysis systems and computer applications software.

## ENTREPRENEURSHIP DEVELOPMENT AND VENTURE CAPITAL FUNDING

Policies and procedures are being evolved in order to encourage and streamline the mobility of ISRO technocrats to other organisations or to become entrepreneurs to undertake productionisation efforts based on ISRO/NRSA technologies. Two ISRO technologies were transferred during the year to a former ISRO scientist who was associated in developing the technologies. To prepare the ground for liberal venture capital funding for such technocrats and ISRO's technology licencees in the small and medium scale sectors, ISRO has been actively co-ordinating with designated developmental finance institutions in India (such as TDICI, IDBI and RCTFC).

## ISRO TECHNOLOGICAL CONSULTANCY SCHEME

Under this scheme ISRO provides expertise to Indian industries and other R&D institutions in a wide range of disciplines. Since 1982, over 83 technological consultancy projects have been undertaken by ISRO for various industrial and technological institutions. During 1989, three new assignments were undertaken. These included consultancy/guidance for development of ground-based scatterometer, evolving test and evaluation methods for high quality printed circuit boards and advanced highspeed processors for image processing.

## CONTRIBUTIONS FROM INDUSTRY

Contributions from Indian industries continued during the year towards ongoing Space projects like PSLV, IRS-1B and INSAT-II Test Spacecraft. Industry participation was actively sought and an encouraging response received in newer areas, especially for productionising sophisticated inertial navigation and guidance systems.

In realising PSLV, fabrication of eleven structures for dynamic testing has been completed by industries. HAL has concluded testing of all structures and completed flight hardware light alloy struc-



*HTPB plant at NOCIL, Bombay*

tures and assembly of the heatshield. A large number of precision manufacturing industries in the country were utilised to fabricate and supply components for light alloy structures. The maraging steel motor cases involving special fabrication techniques continue to be supplied by industries. As part of the import substitution efforts, the industry has been approached for the contour nozzles. The 240-tonne thrust bearing for the dynamic test programme was completed four months ahead of schedule, through the combined efforts of VSSC and HMT, Kalamassery. As a result of the efforts in the past for the development of production capabilities for rocket propellants in the industry, regular supplies of propellant fuels and binders like UDMH, MMH, ammonium perchlorate, HTPB and  $N_2O_4$  continued during the year.

The capabilities developed in Indian industry to supply special items like high silica cloth and liquid

phenolic resin are continuing to service the Space Programme's needs. Intensive efforts made for development of high-tech vendors for production of the specialised item of carbon cloth for future launch vehicles resulted in the establishment of a long term production-cum-supply contract this year. Contracts have also been established for productionisation of integrated liquid engines used in advanced satellite launch vehicles like PSLV and GSLV, representing a major step forward in industrial capabilities in the country. Such efforts are to continue for other products also. These efforts are expected to fructify in next couple of years in establishing industrial lines involving advanced processing techniques for servicing the future Space Programme. Indian industry provided crucial support in developing specialised systems for the launch vehicles and spacecraft in the area of precision inertial sensors/systems for navigation and guidance. To meet the increased demand for such sensors/systems in future by the Space Programme, the possibility of manufacture of the total systems in industries is being explored. An ISRO-Industry meet held in April 1989 acquainted the industry with the future requirements of ISRO for inertial systems and the facilities required for productionising the systems. The response from the industry after the meet has been encouraging. The Space Electronics Division of the Bharat Electronics Ltd. (BEL) continued to provide support to the Space Programme by production of avionics systems used in the launch vehicles/sounding rockets and ground systems used in the tracking stations for supporting various missions like IRS-1A and ASLV. Three of the PCMC Radars are in advanced stages of development at BEL. Five industries, apart from BEL, are helping in realisation of the Radars. The major developments that have served the PSLV and other projects include the development/production of maraging steel and the associated fabrication processes, specialised Al. alloy rings and a wide range of specialised forgings.

For ISRO's satellite programmes, Indian industry has contributed significantly in terms of development and supply of satellite structures and high reliability electronic circuits, apart from a wide range of ground test and handling systems. For the INSAT-II TS project, HAL, Bangalore, is sup-



*Tri-axis magnetic aspect sensor for Sounding Rockets*

plying the structural elements for the spacecraft. HAL, Hyderabad, is fabricating C-band solid state power amplifiers for the communication payloads. In addition, a number of industries are involved in the mechanical and electrical fabrication activities for INSAT-II. For the augmentation of the satellite and launch vehicle tracking network, the Indian industry played a significant role in the development and supply of servo systems, large antenna structures and instrumentation systems. ISRO had undertaken the responsibility for delivery of a 14-metre antenna system for DOT's satellite monitoring facility. The entire fabrication of various systems was undertaken in Indian industry with ISRO playing integration role. The other major systems that have made substantial progress through industrial participation pertain to the PSLV Mobile Service Tower and Large Space Simulation Chamber. The Mobile Service Tower and the associated power and environmental control systems have been completed during the year.

Beryllium Pilot Plant (BPP) at Vashi, New Bombay, which is a joint project of BARC, ISRO and DOE, continued to produce Vacuum Hot Pressed (VHP) blocks of the required grade/specifications and Beryllium Machining Facility (BMF) set up by ISRO at New Bombay continued to produce high precision beryllium components. The beryllium components for Rate Integrating Gyroscope (RIG) MK-II, are under regular supply to VSSC. Programmes for indigenous development of beryllium mirrors for spacecraft applications, critical processes like precision machining, mass relieving, electroless nickel coating, lapping and polishing have been taken up. □

# Co-operation

The complex nature of the Space Programme has led to the evolution of a variety of co-operative efforts not only with Indian industries and institutions, but also with international organisations. The Indian Space Programme has greatly benefited through such co-operative efforts in realising its objectives more expeditiously.

## CO-OPERATION WITH OTHER INDIAN AGENCIES

The interface between the Space Programme and the Indian industry has already been covered in the previous chapter.

The INSAT System is a joint venture of the Department of Space, Department of Telecommunications, the India Meteorological Department, All India Radio and Doordarshan. Indian Middle Atmosphere Programme (IMAP), referred to in the chapter on Space Sciences, is a multi-agency co-operative programme to investigate the physical and chemical phenomena and the associated processes taking place in the earth's atmosphere between 10 to 100 km altitude.

The active participation of a large number of Central and State government departments and agencies is an important feature of National Natural Resources Management System (NNRMS). The Advisory Committee for Space Sciences (ADCOS) constituted in 1980 provides a common scientific forum for space scientists in the country, especially from the universities. A number of national agencies and research institutions are participating in the various research projects under ADCOS. ISRO had initiated the concept of Space Technology Cells in 1982 at selected institutions to carry out advanced research in a few selected areas of direct interest to the Indian Space Programme. Cells at the Indian Institute of Science, Bangalore, the Indian Institute of Technology, Bombay, and the Indian Institute of Technology at Madras have since been established.

## INTERNATIONAL CO-OPERATION

### Arabsat Organisation

Arabsat Organisation has expressed interest in long-term technical co-operation with ISRO in upgrading its personnel in satellite control, satellite orbit control strategies, on-orbit tests, frequency co-ordination and general engineering support in the area of satellite communication.

### Brazil

Efforts were continued during the year to explore co-operation between INPE, Brazil, and ISRO.

### Canada

Discussions are being continued to explore the possibility of training ISRO scientists in the Canadian RADARSAT programme.

### China

ISRO and National Remote Sensing Centre of China had discussions during the year on possible co-operation in the field of remote sensing.

## COSPAS-SARSAT SYSTEM

The Indian LUT and MCC established at Bangalore during the year forms part of the international COSPAS-SARSAT network. Since this is the first LUT to be established in the Indian Ocean Region, India has been requested by COSPAS-SARSAT Organisation to serve the other countries in the neighbouring region also, namely, Bangladesh, Indonesia, Kenya, Malaysia, Maldives, Singapore, Somalia, Sri Lanka, Tanzania and Thailand.

### **European Space Agency (ESA)**

The co-operative agreement signed last year with the European Space Agency has further strengthened the collaborative activities between ISRO and ESA. ISRO's proposal to directly receive, archive and process the microwave remote sensing data from the European ERS-1 satellite is being further explored.

### **Federal Republic of Germany (FRG)**

ISRO has proposed to fly the Monocular Electro-Optical Stereo Scanner (MEOSS) payload on board IRS-1E. The payload had been earlier attempted on SROSS. The Weilheim station of GSOC continued to extend TTC support to IRS-1A mission during the year. Details of mutual TTC support for future missions, namely, IRS-1B, IRS-1C, etc., and the TTC support from ISRO stations to the German EUTELSAT mission are being worked out.

Preparations are in advanced stages for the launch of RH-560/Autonomous Payload Control Rocket Experiment (APC-REX) scheduled for second quarter of 1990 and for balloon-borne cryo-sampler experiment from Hyderabad in March-April, 1990.

A joint experiment is being prepared between SPL, VSSC, and the Max-Planck Institute for Aeronomy (MPAE) for atmospheric investigations using mobile VHF Radars. A Radar from MPAE will be brought to Trivandrum for observations along with SPL's VHF Radar.

A DLR expert team visited ISRO in January, 1990 to discuss programmes to strengthen co-operation in orbital, mission and related software development.

Exchanges took place to further collaborations in a number of already agreed fields such as MEOSS data processing, meteorite research, theoretical plasma physics, etc.

The third phase of the Indo-FRG technical co-operation programme involving joint projects in

areas of microwave remote sensing development and application, snow hydrology, oceanography, forestry and geology progressed satisfactorily.

### **France**

The French Minister for Research and Technology visited ISRO and held detailed discussions on the Indo-French collaboration in the areas of space sciences, technology and applications. Data from the French Remote Sensing Satellite, SPOT, were received, processed and distributed by NRSA to the user community in India under an MOU signed between NRSA and SPOTIMAGE company governed under the overall umbrella of the ISRO-CNES co-operation programme.

### **INMARSAT**

ISRO is planning to conduct an experiment in Aeronautical Mobile Satellite Communications with the help of INMARSAT. INMARSAT will be providing an aeronautical terminal and allow use of space-segment capacity for the experiment.

### **International Civil Aviation Organisation (ICAO).**

DOS/ISRO continued to extend the support to the Future Air Navigation System (FANS) Special Committee of ICAO.

### **Space Frequency Co-ordination Group (SFCG)**

ISRO continued its participation in the technical activities of the Inter-space agency, SFCG.

### **International Telecommunication Union**

DOS/ISRO support for the Indian participation in the space service related ITU/CCIR work continued during the year. DOS/ISRO was represented in the Indian delegation to CCIR in the final study group meeting related to Fixed Satellite Service matters.

## **Japan**

ISRO completed preparations to receive data collected by the Japanese Marine Observation Satellite, MOS-1, as part of Indian participation in the verification programme for MOS-1.

## **Mauritius**

TTC support was provided for the IRS-1A mission by the S-band ground station established by ISTRAC in Mauritius. The station is being augmented with S-band uplink with a 10 metre antenna and Precision Coherent Monopulse C-band (PCMC) Radar Systems to meet the TTC requirements for PSLV.

## **Sweden**

Within the framework of the Memorandum of Understanding between ISRO and the Swedish Board of Space Activities (SBSA), a collaborative project between NRSA and the Swedish Royal Institute of Technology on training in remote sensing image analysis has been approved in principle.

## **Syria**

Syria is exploring the feasibilities for utilising the Indian capabilities in their remote sensing programmes.

## **The Netherlands**

Post-graduate diploma courses on human settlement analysis are being conducted routinely at the Indian Institute of Remote Sensing, Dehra Dun, as part of a collaboration programme with ITC of The Netherlands.

## **Union of Soviet Socialist Republics (USSR)**

Under the umbrella of the agreement signed with GLAVCOSMOS, USSR, and the Academy of

Sciences of the USSR (Intercosmos Council) in November 1988 a number of joint efforts related to Indian participation in Soviet MIR Space Station, joint microwave remote sensing satellite, satellite-aided search and rescues, etc., are being initiated.

As part of the collaboration between ISRO and SCHENE, weekly launchings of M-100 rockets continued during the year. In addition preparations were also completed for joint participation in a major international campaign, Dynamics Adopted Network for Atmosphere (DYANA), for the study of middle atmospheric dynamics and its control over the transport of minor constituents. The DYANA campaign is being conducted world over during January 15-April 15, 1990. For India and USSR, it involves launch of a number of M-100 rockets and balloons.

Satellite observations are being continued from Kavalur Station (STARS) set up under an agreement with the Intercosmos Council of the USSR Academy of Sciences.

## **United Nations and its Subsidiary Organisations**

Active participation in the work of UN Committee on Peaceful Uses of Outer Space (COPUOS) and its subsidiary bodies continued. A few more scientists from developing countries were provided opportunities under the Indian programme, 'SHARES', on sharing of experience in Space with other developing countries.

India has been actively participating in the Regional Remote Sensing Programme (RRSP) under the auspices of the UNDP/ESCAP. Two major areas where India's participation has been beneficial are remote sensing training programmes and development of regional information system. A team from RRSP visited India during November 1989 for discussions on collaborative efforts for development of suitable regional information systems. Indian scientists at different levels had participated in the various training courses and meetings of the RRSP. Recently India has become a member of the International-Governmental Consultative Com-

mittee (ICC) under the UNDP/ESCAP which oversees the remote sensing programme of the region. India is hosting the ICC meeting in June 1991. Considered as a lead country in the Asian region in the utilisation of remote sensing for natural resources management and monitoring, India is set to play a vital role in the RRSP in the coming years.

#### **United States of America (USA)**

Tracking support was provided by ISTRAC for the current NOAA satellites. Under an Indo-US Memorandum of Understanding, NRSA has continued to receive data from Landsat and NOAA satellites at its earth station in Shadnagar near Hyderabad.

#### **General**

International Space community represented by the

national space agencies around the globe under the common forum called SAFISY (Space Agency Forum for International Space Year) and various international organisations like Committee on Space Research, International Astronautical Federation and the United Nations have endorsed the idea to designate 1992 as International Space Year (ISY) and are planning to undertake various activities involving the technology and applications of Space for common benefit of humankind. As the study and understanding of earth's environment in the context of development of human society has become the most important and challenging task before humanity and the Space technology can provide a viable and powerful tool in this endeavour at global level, a frame-work of international co-operative mission called, "Protection of Environment for Assuring Cleaner Earth," (to be known by the acronym PEACE) was proposed by Indian Space Research Organisation for consideration by the international community, in addition to the various other activities being undertaken in the context of ISY. □

# Space Centres and Units

A unique feature of all the programmes of ISRO/DOS is the synergetic interlocking of the Space Centres and Units, industries, research institutions and the user agencies. Each programme/project of the Department is co-ordinated by an identified lead Centre drawing participation from other Centres and Units. The Space Centres and Units of ISRO/DOS are briefly described in the following sections along with major activities carried out during the year.

## VIKRAM SARABHAI SPACE CENTRE (VSSC)

VSSC is located around the now famous Thumba village and the picturesque Veli hills near Trivandrum. It has extension centres at Valiamala for major facilities of the PSLV project and at Vattiyookavu for the development of composites. Its experimental ammonium perchlorate plant is located at Alwaye. VSSC employs about 5,600 persons and provides the technology base for the country's indigenous satellite launch vehicle development efforts. The Centre is also responsible for the development of a number of spacecraft subsystems. VSSC is the lead Centre for the projects such as ASLV, PSLV and GSLV. Supporting these projects are specialised R&D groups in the areas of Avionics & Mission Dynamics, Solid Propulsion, Propellants & Chemicals, Materials and Mechanical systems, Integrated Launch Vehicle Programmes, Systems Reliability, Computers & Information Systems and Programme Planning & Management. It has all the infrastructure needed to support the launch vehicle development programmes.

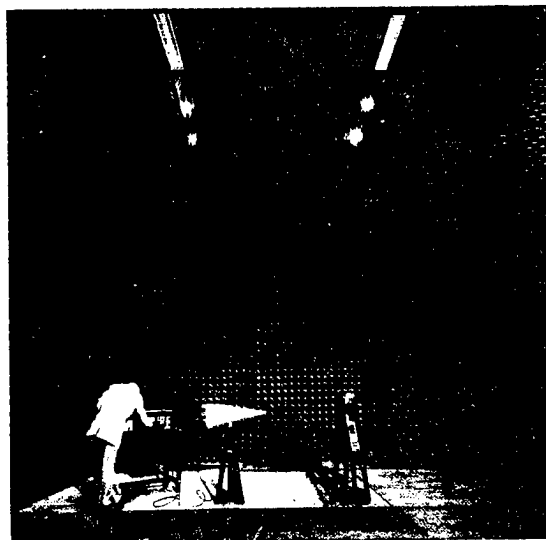
VSSC also supports the Rohini Sounding Rocket (RSR) programme, the Thumba Equatorial Rocket Launching Station (TERLS) of the ISRO Range Complex (IREX) and the Space Physics Laboratory (SPL).

Significant progress was made during the year in the development of PSLV through the testing of all

the four stages of PSLV and realisation of structural model of equipment bay. Mobile service structure for PSLV was erected at SHAR. The Failure Analysis Committee and the Expert Review Panel on ASLV have recommended certain design modification/refinements for ASLV-D3 flight and follow-up action on the recommendation has been initiated. Configuration studies on GSLV were continued during the year. Technology development in the various areas of launch vehicles also continued during the year.

## ISRO SATELLITE CENTRE (ISAC)

ISAC at Bangalore is responsible for the design, fabrication, testing and management of satellite systems for scientific, technological and application missions. With a staff strength of 2,300, ISAC is organised into five main groups, namely, Spacecraft Electronics Group, Mechanical Systems Group, Attitude & Orbit Control Systems Group, Mission Planning & Development Group and Technical Support Services Group. The Centre has built as many as 11 satellites for various missions. IRS, SROSS and INSAT-II TS are the major

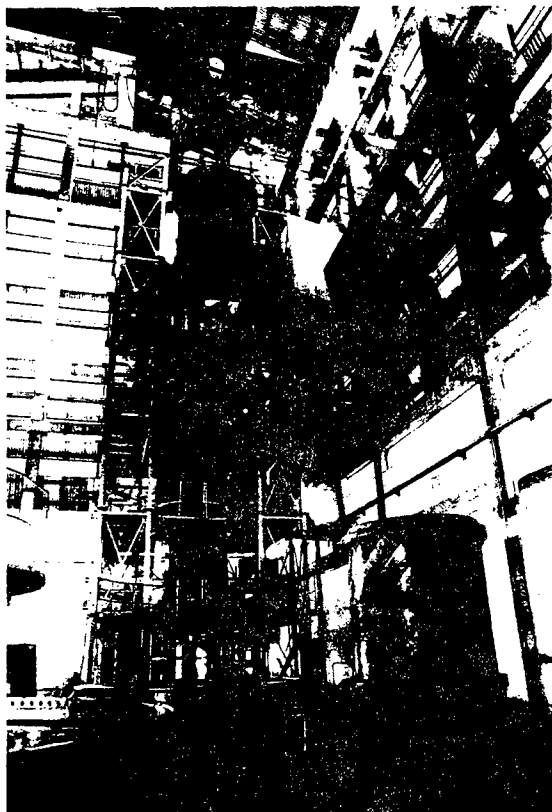


*Anechoic Chamber at ISAC, Bangalore*

ongoing projects at ISAC. Work on the IRS-1B satellite has made significant progress with the integration of various subsystems. Integration of IRS-1E, to be launched by the first developmental flight of PSLV, is also progressing satisfactorily. Work has also commenced on the second generation of remote sensing satellites, namely, IRS-1C and 1D which will have improved spatial resolutions of 10 m to 20 m and additional spectral bands.

A significant milestone in INSAT-II Test Spacecraft project was the completion of static tests on the first structure of the spacecraft and commencement of Electrical Thermal Model integration. Substantial progress was also made in the establishment of Large Space Simulation Chamber (LSSC) which is expected to be commissioned during the first half of 1990.

SROSS-C satellite configuration was finalised during the year and fabrication/refurbishment of SROSS engineering model has commenced.



*PSLV segment assembly operations*

## SHAR CENTRE

Located in the spindle-shaped Sriharikota island on the east coast of Andhra Pradesh, SHAR Centre is the main launch centre of ISRO for satellite launch vehicles and sounding rockets. The ISRO Range Complex (IREX) headquarters and Solid Propellant Space Booster Plant (SPROB), the largest of its kind in the country, are located at this Centre. The Centre also operates the Static Test and Evaluation Complex (STEX) and the computer and data processing facilities to support indigenous launch vehicle development and missions.

During the year the major activities of SHAR Centre included (a) processing, radiography and static tests of PS-1 and PS-3 motors for PSLV (b) successful realisation of PSLV Mobile Service Tower (MST) and associated systems (c) launching of 64 sounding rockets from IREX ranges at SHAR, TERLS and Balasore (d) realisation of major subsystems of PCMC Radar and (e) operationalisation of VAX-11/786 computer system.

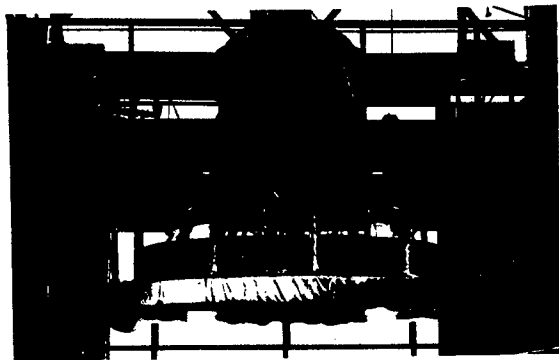
## LIQUID PROPULSION SYSTEMS CENTRE (LPSC)

LPSC, the R&D centre in the area of liquid propulsion, is responsible for the development of liquid and cryogenic propulsion stages and auxiliary propulsion systems for both launch vehicles and satellites. The activities of LPSC are carried out at Trivandrum, Bangalore and Mahendragiri. LPSC also produces precision transducers at Bangalore.

During the year 1989-90 LPSC's efforts were concentrated on the development of propulsion stages for PSLV, control systems for ASLV and PSLV, thrusters for INSAT-II Test Spacecraft and cryogenic engine technology. LPSC also has studied various options of liquid and cryogenic propulsion stages for GSLV.

## SPACE APPLICATIONS CENTRE (SAC)

SAC at Ahmedabad is ISRO's application R&D centre, with primary responsibilities to concep-



*PS-4 battleship stage test*

tualise, plan and execute projects and research programmes leading to practical applications of Space technology. The main activities include satellite-based telecommunications and TV, and remote sensing for natural resources survey and management, environment monitoring, meteorology and geodesy. The Centre is organised into Satellite Communications Area, Remote Sensing Area and Microwave Remote Sensing Programme. Support services are provided by Technical Services Group having test and fabrication facilities and Reliability and Quality Assurance Group. SAC also manages the Delhi Earth Station.

A major milestone during the year was the delivery of the Electrical Thermal Model of INSAT-II TS communication payload for integration with the spacecraft after successfully undergoing all the required tests and critical design review. The structural model of INSAT-II TS VHRR was delivered to the project after successfully undergoing the required tests. The integration of VHRR electrical equivalent model packages has been completed and detailed bench test of VHRR as a complete payload conducted. Flight model fabrication of communication payload components has already been initiated.

All the three cameras for IRS-1B have been integrated with flight packages and tested. Minor changes have been implemented to give better performance than IRS-1A. An optimum configuration for the multispectral camera for IRS-1C has been worked out. The systems design for the wide field sensor of this spacecraft has also been completed.

A project for the design and development of an airborne Synthetic Aperture Radar (SAR) has been initiated and preliminary design review completed. Updating of data products software has been continued and new software and methodologies are also being developed to meet the challenges of data products and utilisation of data from microwave sensors.

Significant progress was made in the development of various equipment for several communication projects like standard ship earth station, monitoring earth station for satellites, earth station for meteorological applications, GPS receiver, SSMA Project, etc.

## **DEVELOPMENT AND EDUCATIONAL COMMUNICATION UNIT (DECU)**

Development and Educational Communication Unit (DECU) at Ahmedabad is involved in the conception, definition, planning and socio-economic evaluation of Space applications programmes. DECU is organised along functional lines into Systems Analysis, Planning and Projects Group, Video Production Group, Social Research Group and Video Engineering Group. The major activities during 1989-90 included the following:

A number of configurations were worked out for both one-way and two-way communication of video/voice/data for education and training and, one-way video, two-way audio mode was identified as the most promising. The hardware developed by SAC for this application has been tested and a limited demonstration made.

DECU provided major inputs to the study group on the use of satellite services for education. The report of this group presents a blueprint for educational TV in the country.

Training activity at DECU during the year included a 3-week course on development communication (for Somalian officials), introductory courses on TV technology, local radio workshop, video production process, etc.



*A rural community watching TV programme*

Production of programmes has continued for broadcast for one hour on five days a week through the Pij TV transmitter located in Kheda district of Gujarat. The production of programmes for daily broadcast by the Pij TV station and the training activity are carried out in co-operation with Doordarshan, through a Memorandum of Understanding with the Ministry of Information and Broadcasting. This transmitter, with a range of about 35 km, has an important role to play as a "model" and field laboratory for local TV broadcasting, which could form an element of three-tier (local, regional and national) system of broadcasting. During the year, conscious effort was made to strengthen the field-based and participatory programmes.

Communications research continues to play a major role in the Pij operations. A large survey of

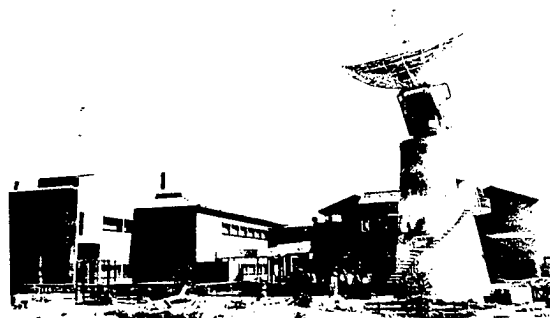
the viewership provided vital inputs for programme planning and decision making. An inter-departmental working group has been set up to examine the possibilities of replicating the Pij model.

Social research activities carried out include both communications research linked specifically to DECU's programme production activities, as well as research relevant to various facets of Space applications. Communication researchers provided formative inputs to programme production, including the preparation of "briefs" for immunisation and for income-generation activities for women. Inputs were also provided for programmes on vocational guidance, adult education and quiz series.

On-going studies include social impact of regional TV and a study in some of the villages, where a holistic study had been done during SITE (1975-76), to provide insights into the development process and the role of communication. An evaluation of the Programme for Massive Orientation of School Teachers (P-MOST) is also underway. A compilation on the studies "Communication Revolution" (the socio-cultural impact of video) carried out in various parts of the country and documentation on the "Exploitation series" broadcast by Pij have been brought out. DECU social scientists have been involved with the "Vivek Darpan" project of Department of Electronics, with the proposal for research on a major experiment in the use of radio for adult literacy and with formulating a plan for expansion of the CLASS project.

DECU's programme production facilities include two studios, outdoor recording equipment and a post-production facility. A low cost but fairly sophisticated post-production facility designed by DECU engineers was commissioned during the year.

DECU provided consultancy/assistance to a number of organisations in the areas of communication planning, system design of production facilities, selection of video/audio equipment, design of courses/syllabi for communication education/training, research, etc.



SCC & TTC station of ISTRAC at Bangalore

A Workshop on development communication was organised jointly with the German Foundation for International Development (DSE) in Ahmedabad from June 19 to 27, 1989. Participants from 8 countries attended the seminar.

### ISRO TELEMETRY, TRACKING AND COMMAND NETWORK (ISTRAC)

ISTRAC, with its headquarters at Bangalore, operates a network of ground stations to provide Tracking, Telemetry and Command (TTC) support for the launch vehicle and satellite missions of ISRO. Development and operation of interface, software packages and the network stations for the present and future missions are the responsibilities of ISTRAC. The integrated network of ISTRAC comprises TTC stations at Sriharikota, Trivandrum, Bangalore, Lucknow and Car Nicobar in addition to a multimission Spacecraft Control Centre at Bangalore. The Unit has also established an S-Band receive-only station in Mauritius to support the IRS mission. ISTRAC also operates the Satellite Tracking and Ranging Station

(STARS) at Kavalur in Tamil Nadu. The activities of ISTRAC during the year are given under the chapter Launch Support, Tracking Network and Range Facilities.

### NATIONAL REMOTE SENSING AGENCY (NRSA)

NRSA at Hyderabad is an autonomous institution supported by the Department. The agency has facilities for surveying, identifying, classifying and monitoring earth resources using aerial and satellite data. While its analysis, computation and interpretation facilities are located at Hyderabad, the satellite earth station is at Shadnagar, about 65 km from Hyderabad. This earth station has facilities to receive data from remote sensing satellites such as Landsat NOAA, SPOT and IRS. NRSA also operates the Indian Institute of Remote Sensing (IIRS) at Dehra Dun, a premier remote sensing and aerial photo-interpretation training centre in the country.

### PHYSICAL RESEARCH LABORATORY (PRL)

PRL at Ahmedabad is the premier national centre for research in Space and allied sciences. It is an autonomous institution supported mainly by the Department of Space. PRL is also entrusted with the management of the Udaipur Solar Observatory.

The research programmes of PRL are carried out through four main divisions, namely, Astronomy and Astrophysics, Planetary Atmosphere and Aeronomy, Earth Sciences and Solar System and Theoretical Physics. □

### DISTRIBUTION OF FUNDS TO CENTRES/SCHEMES

(Rs. in lakhs)

| Centre/Unit            | VSSC     | SHAR    | ISTRAC  | SAC     | DECU   | ISAC     | LPSC    | CENTRAL<br>MANAGEMENT<br>RESPOND<br>AND OTHERS | INSAT-I | PRL    | NRSA    | TOTAL    |
|------------------------|----------|---------|---------|---------|--------|----------|---------|------------------------------------------------|---------|--------|---------|----------|
| Actuals<br>1988-89     | 11579.74 | 2301.37 | 822.98  | 2451.34 | 250.95 | 13874.27 | 1339.50 | 1446.95                                        | 6224.29 | 608.00 | 1334.78 | 42234.17 |
| Re Esti<br>1989-90     | 9424.00  | 2185.00 | 1215.00 | 2880.00 | 302.00 | 13863.00 | 2337.00 | 2370.00                                        | 5243.00 | 602.00 | 1100.00 | 41521.00 |
| Budget Esti<br>1990-91 | 11269.00 | 2431.00 | 1195.00 | 3121.00 | 370.00 | 13855.00 | 4787.00 | 2870.00                                        | 1569.00 | 679.00 | 1340.00 | 43486.00 |

# Technical Appendix

## I TECHNICAL REPORTS

1. ISRO-CED-TR-80-89  
Dampness, Seepage and leakage in buildings
2. ISRO-NNRMS-TR-81-89  
Study of groundwater potential zones of Pava-gada Taluk using two different scales of Landsat TM imagery and borewell data
3. ISRO-CED-TR-82-89  
Acoustics of buildings—ISAC Auditorium
4. ISRO-CED-TR-83-89  
Test and evaluation procedure for civil works
5. ISRO-SHAR-TR-84-80  
The Kalman Filter—a brief survey
6. ISRO-SHAR-TR-85-89  
Base flow analysis of a simulated high altitude test facility

## II SCIENTIFIC REPORTS

1. ISRO-HQ-SR-33-88  
Report of the ADCOS study-cum-task team for instrumentation for atmospheric sciences and meteorology (ASTIASM)
2. ISRO-PRL-SR-34-89  
Revaluation of the total ozone measurements with the Dobson Spectro-photometer at Mt. Abu/Ahmedabad during 1951-85

## III TECHNICAL NOTES

1. ISRO-SHAR-TN-41-82  
Six components test system for large solid rocket motors
2. ISRO-SHAR-TN-42-83  
S-Band servo system capabilities

3. ISRO-SHAR-TN-43-87  
Tail-off thrust computation
4. ISRO-SHAR-TN-44-88  
Heavy rain over Sriharikota
5. ISRO-SHAR-TN-45-89  
Surface radio refractivity over SHAR
6. ISRO-SHAR-TN-46-82  
Inter-station time transfer over data links
7. ISRO-SHAR-TN-47-81  
Estimation of error in the upper winds derived by copper chaff tracking
8. ISRO-SHAR-TN-48-83  
Preliminary report on data processor

## IV PRODUCT ASSURANCE SPECIFICATION

1. ISRO-PAX-304 (issue-1)  
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## **VIII NEWSLETTERS/PERIODICALS**

1. SPACE INDIA (in English & in Hindi)—January-March 1989 and April-December 1989
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3. Safety Awareness Service—July 1989
4. NNRMS Bulletin—September 1989
5. Space-Industry Newsletter—September 1989 and February 1990
6. Interest Exploration Notes on Advanced Technologies from ISRO/DOS
7. IRS-1A Imageries—Printed in A4 size for distribution at Seminars/Meetings. □

# Acronyms

|                                                                                           |                                                                      |
|-------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| <b>ABR:</b> Air Breathing Rocket                                                          | <b>CSIR:</b> Council of Scientific & Industrial Research             |
| <b>ADCOS:</b> Advisory Committee for Space Sciences, constituted by ISRO                  | <b>CWC:</b> Central Water Commission                                 |
| <b>AES:</b> Ahmedabad Earth Station                                                       | <b>DAE:</b> Department of Atomic Energy                              |
| <b>AOCS:</b> Attitude & Orbit Control System                                              | <b>DCP:</b> Data Collection Platform                                 |
| <b>APC-REX:</b> Autonomous Payload Control Rocket Experiment, a Joint ISRO-DLR experiment | <b>DECU:</b> Development & Educational Communication Unit, Ahmedabad |
| <b>ARABSAT:</b> Satellite owned by Arab Satellite Communication Organisation              | <b>DEMUX:</b> Demultiplexer                                          |
| <b>ASLV:</b> Augmented Satellite Launch Vehicle                                           | <b>DES:</b> Delhi Earth Station                                      |
| <b>BARC:</b> Bhabha Atomic Research Centre, Bombay                                        | <b>DLR:</b> German Aerospace Research Establishment                  |
| <b>BOL:</b> Beginning of Life                                                             | <b>DGCA:</b> Directorate General of Civil Aviation                   |
| <b>BSS:</b> Broadcast Satellite Service                                                   | <b>DOE:</b> Department of Electronics                                |
| <b>CAD:</b> Computer Aided Design                                                         | <b>DOEn:</b> Department of Environment                               |
| <b>CCD:</b> Charge Coupled Device                                                         | <b>DOS:</b> Department of Space                                      |
| <b>CCIR:</b> International Radio Consultative Committee                                   | <b>DOT:</b> Department of Telecommunications                         |
| <b>CCT:</b> Computer Compatible Tape                                                      | <b>DRS:</b> Direct Reception System (TV)                             |
| <b>CDR:</b> Critical Design Review                                                        | <b>DRT:</b> Data Relay Transponder                                   |
| <b>CFRP:</b> Carbon Fibre Reinforced Plastic                                              | <b>DST:</b> Department of Science & Technology                       |
| <b>CNC:</b> Computer-aided Numerically Controlled machine                                 | <b>DTG:</b> Dry Tuned Gyro                                           |
| <b>CNES:</b> French National Space Research Agency                                        | <b>DWS:</b> Disaster Warning System                                  |
| <b>COSPAS-SARSAT:</b> International Search & Rescue Satellite System                      | <b>DYANA:</b> Dynamics Adopted Network for Atmosphere                |
|                                                                                           | <b>ECT:</b> Emergency Communications Terminal                        |
|                                                                                           | <b>EIRP:</b> Effective Isotropic Radiated Power                      |
|                                                                                           | <b>EMI:</b> Electromagnetic Interference                             |

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|----------------------------------------------------------------|--------------------------------------------------------------------------|
| <b>EOL:</b> End Of Life                                        | <b>INS:</b> Inertial Navigation Sensors                                  |
| <b>ERS-1:</b> European Remote Sensing Satellite-1              | <b>INSAT:</b> Indian National Satellite                                  |
| <b>ESA:</b> European Space Agency                              | <b>INTELSAT:</b> International Telecommunications Satellite Organisation |
| <b>ETM:</b> Electrical Thermal Model                           | <b>IR:</b> Infrared                                                      |
| <b>ETV:</b> Educational Television                             | <b>IRS:</b> Indian Remote Sensing Satellite                              |
| <b>FAC:</b> Failure Analysis Committee                         | <b>IRU:</b> Inertial Reference Unit                                      |
| <b>FM:</b> Frequency Modulation                                | <b>ISAC:</b> ISRO Satellite Centre, Bangalore                            |
| <b>FRP:</b> Fibre Reinforced Plastics                          | <b>ISRO:</b> Indian Space Research Organisation                          |
| <b>FRR:</b> Flight Readiness Review                            | <b>ISTRAC:</b> ISRO Telemetry, Tracking and Command Network              |
| <b>FSS:</b> Fixed Satellite Services                           | <b>ITU:</b> International Telecommunications Union                       |
| <b>GCP:</b> Ground Control Point                               | <b>IUP:</b> IRS Utilisation Programme                                    |
| <b>GMT:</b> Greenwich Mean Time                                | <b>KCP:</b> Kheda Communications Project                                 |
| <b>GPS:</b> Global Positioning System                          | <b>LAM:</b> Liquid Apogee Motor                                          |
| <b>GSFC:</b> Goddard Space Flight Centre, U.S.A.               | <b>LANDSAT:</b> Remote Sensing Satellite of U.S.A.                       |
| <b>GTO:</b> Geo-synchronous Transfer Orbit                     | <b>LCT:</b> Low Cost Terminal                                            |
| <b>GTS:</b> Global Telecommunications System                   | <b>LISS:</b> Linear Imaging Self Scanner                                 |
| <b>HAT:</b> High Altitude Test                                 | <b>LNA:</b> Low Noise Amplifier                                          |
| <b>HDDTR:</b> High Density Digital Tape Recorder               | <b>LOX:</b> Liquid Oxygen                                                |
| <b>HMC:</b> Hybrid Micro Circuits                              | <b>LPSC:</b> Liquid Propulsion Systems Centre                            |
| <b>HTPB:</b> Hydroxyl Terminated Polybutadiene                 | <b>LSI:</b> Large Scale Integrated circuit                               |
| <b>ICC:</b> INSAT Co-ordination Committee                      | <b>LSSC:</b> Large Space Simulation Chamber                              |
| <b>IIRS:</b> Indian Institute of Remote Sensing, Dehra Dun     | <b>LUS:</b> Liquid Upper Stage                                           |
| <b>IMAP:</b> Indian Middle Atmosphere Programme                | <b>LUT:</b> Local User Terminal                                          |
| <b>IMD:</b> India Meteorological Department                    | <b>MBPS:</b> Mega Bits Per Second                                        |
| <b>INMARSAT:</b> International Maritime Satellite Organisation | <b>MCC:</b> Mission Control Centre                                       |

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|------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| <b>MCF:</b> Master Control Facility, Hassan, Karnataka                 | <b>NPL:</b> National Physical Laboratory, New Delhi                         |
| <b>MDDS:</b> Meteorological Data Dissemination Service                 | <b>NRIS:</b> Natural Resources Information System                           |
| <b>MDUC:</b> Meteorological Data Utilisation Centre, New Delhi         | <b>NRSA:</b> National Remote Sensing Agency, Hyderabad                      |
| <b>MEOSS:</b> Monocular Electro-Optical Stereo Scanner                 | <b>OSR:</b> Optical Solar Reflector                                         |
| <b>MI &amp; B:</b> Ministry of Information and Broadcasting            | <b>PBAN:</b> Polybutadiene Acrylic Acid Acrylo Nitrile, a rocket propellant |
| <b>MIC:</b> Microwave Integrated Circuits                              | <b>PCB:</b> Printed Circuit Board                                           |
| <b>MIS:</b> Management Information System                              | <b>PCMC:</b> Precision Coherent Monopulse C-band Radar                      |
| <b>MLB:</b> Multi Layer printed circuit Board                          | <b>PDR:</b> Preliminary Design Review                                       |
| <b>MMH:</b> Mono-Methyl Hydrazine, a liquid propellant                 | <b>PRL:</b> Physical Research Laboratory, Ahmedabad                         |
| <b>MSS:</b> Multi-Spectral Scanner                                     | <b>PSLV:</b> Polar Satellite Launch Vehicle                                 |
| <b>MST:</b> Mobile Service Tower                                       | <b>PTI:</b> Press Trust of India                                            |
| <b>MST Radar:</b> Mesosphere, Stratosphere and Troposphere Radar       | <b>QA:</b> Quality Assurance                                                |
| <b>MUX:</b> Multiplexer                                                | <b>RCC:</b> Rescue Co-ordination Centre                                     |
| <b>NAA:</b> National Airports Authority                                | <b>RCS:</b> Reaction Control System                                         |
| <b>NAL:</b> National Aeronautical Laboratory, Bangalore                | <b>RDSS:</b> Radio Determination Satellite Service                          |
| <b>NASA:</b> National Aeronautics & Space Administration, USA          | <b>RESINS:</b> Redundant Strap-down Inertial Navigation System              |
| <b>NASDA:</b> National Aeronautics & Space Development Agency of Japan | <b>RESPOND:</b> Research Sponsored by ISRO                                  |
| <b>NICNET:</b> National Informatics Centre Network                     | <b>RN:</b> Radio Networking                                                 |
| <b>NNRMS:</b> National Natural Resources Management System             | <b>R &amp; QA:</b> Reliability & Quality Assurance                          |
| <b>NOAA:</b> National Oceanographic & Atmospheric Administration, USA  | <b>RRSSC:</b> Regional Remote Sensing Service Centre                        |
|                                                                        | <b>RSR:</b> Rohini Sounding Rocket                                          |
|                                                                        | <b>SAC:</b> Space Applications Centre, Ahmedabad                            |
|                                                                        | <b>SADA:</b> Solar Array Drive Assembly                                     |
|                                                                        | <b>SAR:</b> Synthetic Aperture Radar                                        |

**SAS&R:** Satellite-Aided Search & Rescue

**SBRTN:** Satellite-based Rural Telegraph Network

**SCC:** Spacecraft Control Centre

**SDUC:** Secondary Data Utilisation Centre

**SHAR:** ISRO's Launch Centre, Sriharikota, Andhra Pradesh

**SHARES:** An ISRO Programme for Sharing of Experience in Space

**SITVC:** Secondary Injection Thrust Vector Control system

**SLAR:** Side-Looking Airborne Radar

**SM:** Structural Model

**SPINS:** Stabilised Platform Inertial Navigation System for launch vehicle guidance

**SPOT:** The French Remote Sensing Satellite

**SROSS:** Stretched Rohini Satellite Series

**SSMA:** Spread Spectrum Multiple Access

**SSPA:** Solid State Power Amplifier

**STARS:** Satellite Tracking & Ranging Station, Kavalur, Tamil Nadu

**STFSDS:** Standard Time & Frequency Signal Dissemination Service

**STS:** Space Transportation System of NASA

**TDMA:** Time Division Multiple Access

**T&E:** Test and Evaluation

**TERLS:** Thumba Equatorial Rocket Launching Station, Thumba, Trivandrum

**TIFR:** Tata Institute of Fundamental Research, Bombay

**TT&C:** Telemetry, Tracking & Command

**TVC:** Thrust Vector Control system

**TVRO:** Television Receive Only

**TWTA:** Travelling Wave Tube Amplifier

**UDMH:** Unsymmetrical Dimethyl Hydrazine, a liquid fuel for rockets

**UGC:** University Grants Commission

**VHRR:** Very High Resolution Radiometer

**VLPRT:** Very Low Power Radio Transmitter

**VLSI:** Very Large-Scale Integrated circuit

**VSNL:** Videsh Sanchar Nigam Limited

**VSSC:** Vikram Sarabhai Space Centre, Trivandrum

**WARC:** World Administrative Radio Conference

**WMO:** World Meteorological Organisation

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