July-Sept. '96

SPACE india

INDIAN SPACE RESEARCH ORGANISATION

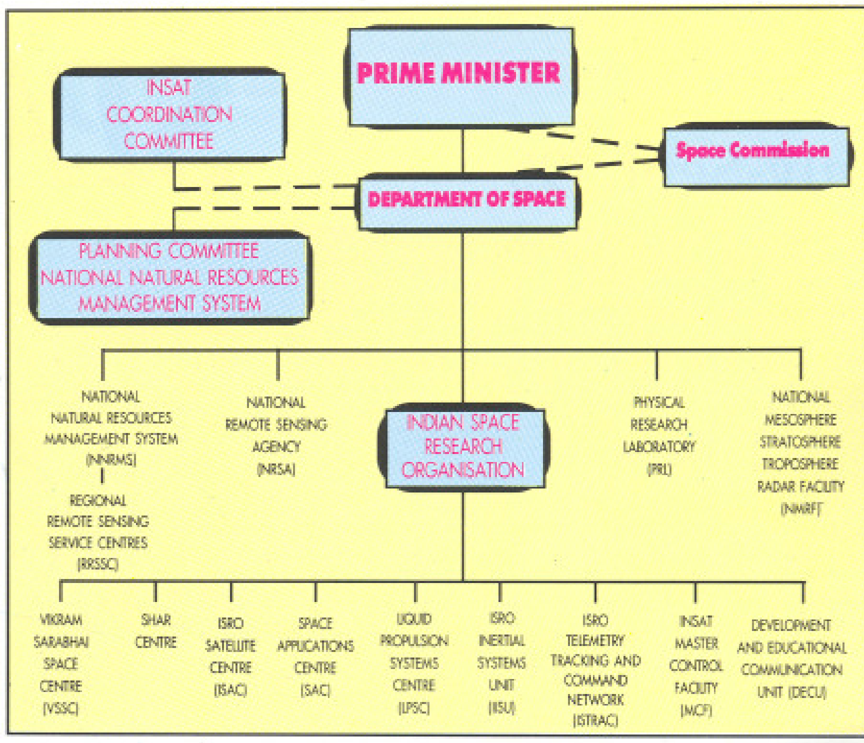
The Indian Space Programme

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

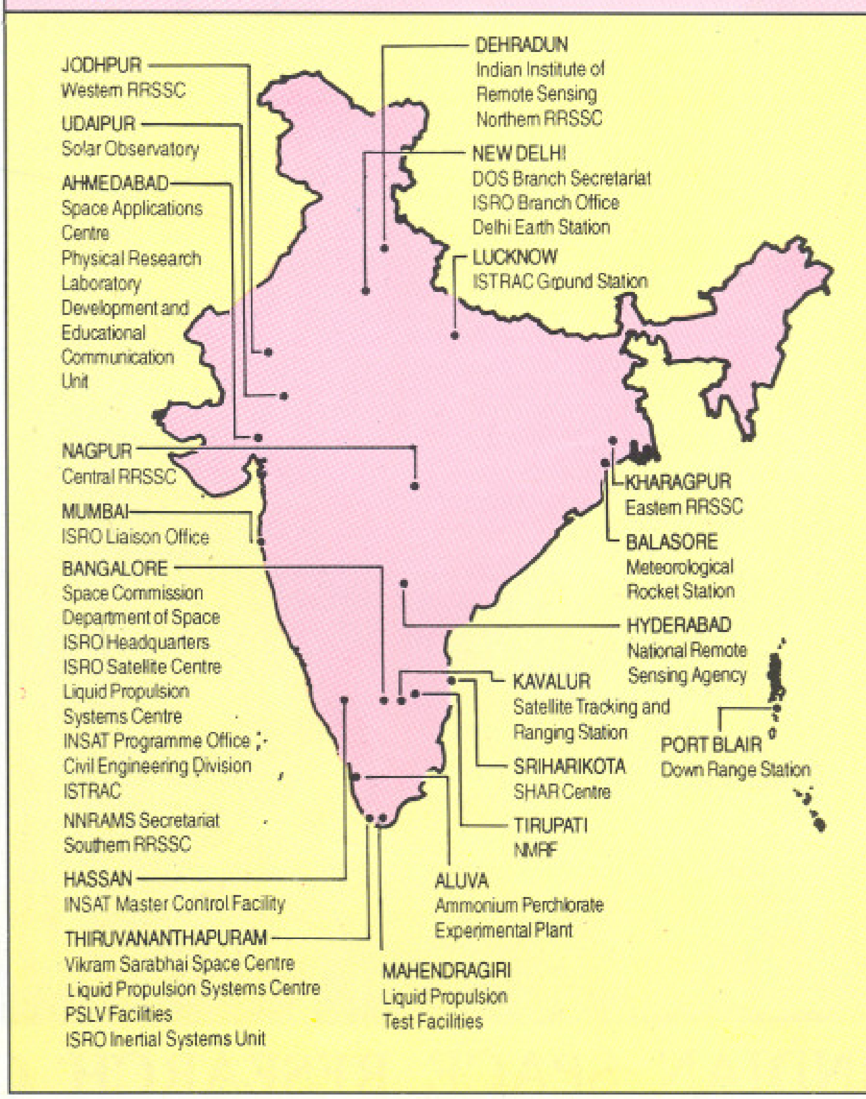
The Indian Space Programme is directed towards the goal of self-reliant use of space technology for national development, its main thrusts being: (a) satellite communications for various applications, (b) satellite remote sensing for resources survey and management, environmental monitoring and meteorological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

The Indian Space Research Organisation (ISRO) is the research and development wing of DOS and is responsible for the execution of the national space programme. ISRO also provides support to universities and other academic institutions in the country for research and development projects relevant to the country's space programme.

Both the DOS and ISRO Headquarters are located at Bangalore. The development activities are carried out at the Centres and Units spread over the country.



Space Centres and Units in India



FRONT COVER

Parts of Iran as seen by IRS-1C Panchromatic camera

EDITORS

S. Krishnamurthy
Manoranjan Rao

PRODUCTION ASSISTANCE

B. Chandrasekhar
B.C. Suryaprakash

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CONTENTS

Indian Space Programme - How Others See?

Since the launch of a small sounding rocket in November 1963, India has come a long way in its space programme. India's capability in the development and application of space technology for national development as well as to provide space services and hardware, is increasingly being noticed by the international community. How does the world community perceive the Indian space programme? Space India reproduces in this issue three articles which appeared recently in magazines published from three different regions of the world — Aviation Week & Space Technology, USA, Interavia, Business & Technology, Switzerland and CSIRO Space Industry News, Australia.

Aviation Week & Space Technology/August 12, 1996

COVER STORY

Space India is grateful to the publishers of Aviation Week & Space Technology for the permission granted to reproduce the article.

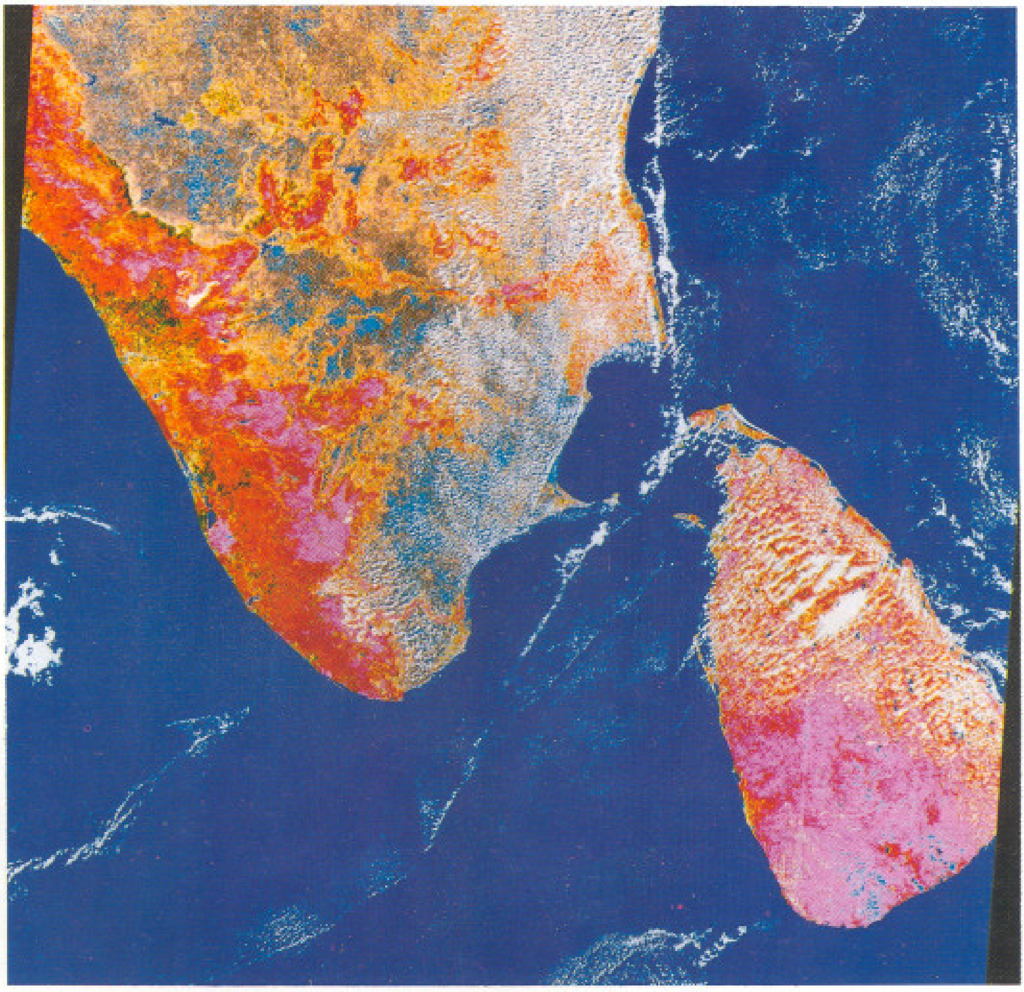
India Builds A 'Crown Jewel'

Michael Mecham/Bangalore

With modest funding, India has developed an independent satellite industry. Will launchers be next?

Heading into the 21st century, India's national space program is remaining true to the form of its first three decades. It continues to adapt the technology of others while employing its own unique ideas on how spacecraft can serve a nation of more than 900 million people who are trying to overcome rural poverty and illiteracy.

The budget for the nation's main space agency, the Indian Space Research Organisation (ISRO), is modest by most national standards, about $ 300-350 million a year for development and operations.



This Wide Field Sensor image of southern India and Sri Lanka was taken shortly after the launch of IRS-1 in December. WiFS' strengths include vegetation stress analysis.

Despite that, the Indians have achieved notable success in the design and development of their own Earth-resources and communications satellites. Next on their agenda is a commercial launch industry.

The Indian Resources Satellites (IRS)* series is a "jewel in the crown," says Tina Cary, director of applications and training for Eosat, the U.S. - based satellite imagery marketing firm. Eosat looks on the IRS series as a crucial addition to its Landsat imagery.

Similarly, India's indigenously produced satellites are to be tapped by Intelsat for supplemental transponder capacity. Insat, a government-owned and managed commercial satcom

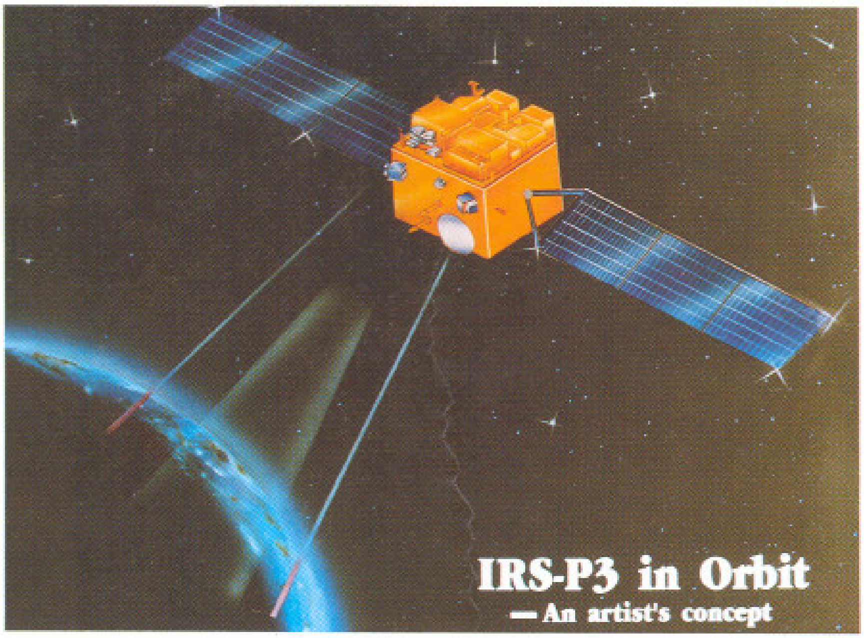
**IRS is Indian Remote Sensing Satellite – Space India* company, has tailored the Insat-2E's C-band footprint to stretch from central Asia across China and down to Australia specifically for Intelsat's use.

Success for Insat-2E will be two-fold. The spacecraft also is intended to inaugurate India's commercial launch program using its new GSLV booster*.

India's first communications satellites were built for it by the former Ford Aerospace and combined meteorology, voice and data transmissions, and a direct broadcast capability. The Ford Insat-1 series had a checkered career (two of four failed in orbit), but the last of the series (Insat-1D) remains operational. It has been joined by the first three of the spacecraft built by ISRO, Insat-2A/2B/2C. Insat-2C, launched last December, introduced K_u-band technology to India.

Together, the four spacecraft give the Indian National Satellite System 70 transponders in space, all fully booked. Insat-2D, nominally scheduled for launch in October or November, is to be the last launched by foreign boosters. When the $50-million Insat-2E is launched about 2000, India will have one of the largest domestic satcom system in the world.

The Insat-2C/2D series' communications systems include 12 C-band and



The IRS-P3 launched in March carried imaging instruments for Germany, a WiFS (wide-field sensor and an X-ray astronomy package

three K_u-band transponders, ranging in power from 4-50 watts. It also offers a mobile satellite service channel. Transponder capacity of the 2E series is still being defined.

The 70 transponders in the current Insat series cover a network of 30 million subscribers—only the start of what is needed, according to Krishnaswamy Kasturirangan, chairman of India's Space Commission and head of the ISRO, its operational arm.

Launch of the Insat-2D/2E series will boost the transponder level to about 100. The introduction of the Insat-3 series after the turn of the century will increase the total to 150, taking into account replacement capacity for the present INSAT-1D and 2A/2B spacecraft.

In all, eight or nine spacecraft are to be involved, plus two or three satellites for direct-to-home services. The total investment is about $ 1-1.5 billion.

THE TYPICAL INDIAN SATELLITE dish is still in the 15-33-ft.-dia. range, but some 300 8-ft. dishes are now being licensed for multichannel reception. By 2000, Insat Programme Manager K Narayanan expects 6-ft. dishes to begin proliferating. That still does not match the 18-in. dish potential of North American or European very small satellite dish (VSAT) technology but it will help push that technology on line.

For ISRO Chairman Kasturirangan television will provide the Indian space programme with much of its future. But not just for commercial programming.

"Television is slowly developing as an educational tool," Kasturirangan says. Its development has prompted ISRO to join forces with other cabinet agencies (such as education and rural development) to launch some of the most ambitious plans for satellite technology. Between them, educational and business services provided through VSAT technology are expected to fuel India's most explosive satellite growth potential.

Despite its huge population, India is not yet an urban society; about 60% of its people live in rural villages. The country has 18 officially recognized languages, so universal communication, even with English as a second language, is not possible. Satellite-based interactive television is seen as an educational tool to help hurdle this problem.

The interactive TV program being watched the most is a $3-million, two-year pilot project that started this summer. Sponsored by ISRO and local governments in the central Indian state of Madhya Pradesh, the program involves installing an interactive television system in village centers where illiteracy is high. Discussions are in local dialects on the most basic of education needs, such as hygiene and family planning.

ISRO sees the Madhya Pradesh experiment as a step toward its proposed Gramsat program, which would extend direct broadcast services throughout rural India ("gram" is the Hindu word for village). Narayanan anticipates that Gramsat will involve a second-generation mobile satellite system that is capable of transmitting to hand-held receivers, possibly using Ku-band.

It cannot be successful if it is not affordable. "It's going to be a fairly ambitious system," Kasturirangan says. "I would not venture to say that we have all the answers or know how to do it on a nation basis."

From the start, ISRO has expected its communications satellites to do double duty as meteorological spacecraft. They are linked to battery-operated receivers and a siren alert system that warns villagers of cyclones. Since its first use on the Insat-1 series, the program has been expanded to include the collection of hydrological data from 100 Earth stations. ISRO is being asked by the cabinet to develop a network reporting system to monitor water usage.

Similarly, ISRO is studying a proposal to use satellites as monitors of the national power grid, which has switching stations in many remote locations. Besides collecting and distributing management data, the proposal envisions using satellites to interrogate sensors for autonomous maintenance checks to help avoid outages.

ISRO also is marching toward its goal of launcher self-sufficiency. Its Polar Satellite Launch Vehicle (PSLV) system is now operational and capable of lifting 2,200-lb. spacecraft into 400-550-mi. orbit.

Designed to meet India's launch schedule for Earth-imaging and mapping satellites - eight launches over the next decade - the PSLV also is intended to make India competitive in bids for replacement of swarm satellites in low-Earth orbits like Iridium.

A bigger brother to the PSLV that is capable of lifting 4,000-5,500-lb. payloads into a geostationary transfer orbit is expected to be operational by the end of the decade. Called the Geostationary Satellite Launch Vehicle (GSLV), it is an Ariane 4-class booster aimed at meeting national needs first. But it will enter the commercial market once launch experience is gained, Kasturirangan said.

THE INDIANS HOPE TO CAPITALIZE on their launch facility's excellent geographical position at 13 deg N. Lat., which is second only to Arianespace's launch center at Kourou, French Guiana, in its proximity to the equator.

Named the SHAR Center, the launch facility is located on Sriharikota Island about 50 mi. north of Madras on the Bay of Bengal. It has a clean splashdown area for nearly all launches, although vehicles headed for Sun-synchronous/polar orbits do have to make a dog-leg during their second-stage burns to avoid flying over Sri Lanka.

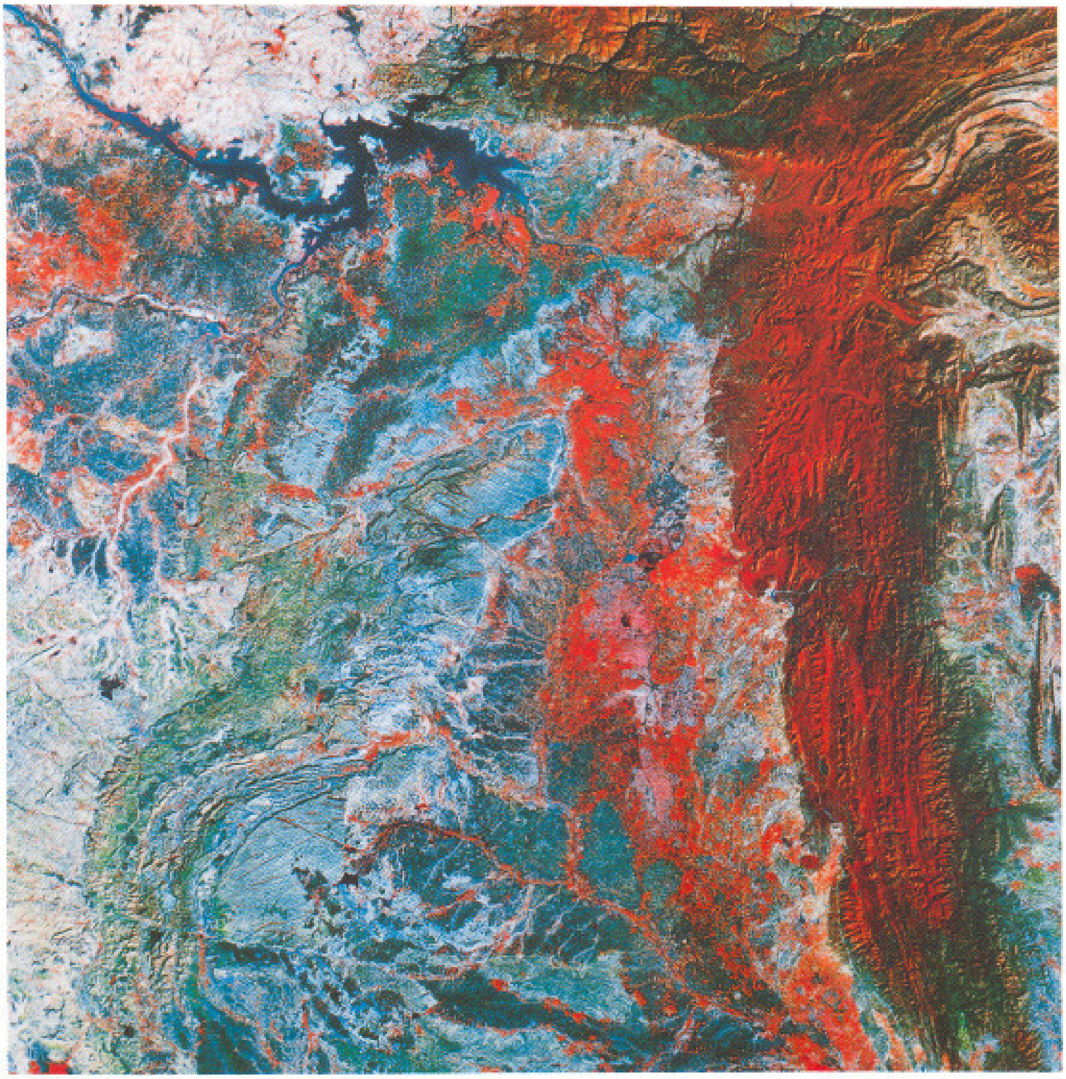
**Space India would like to correct that while GSLV is intended for launching INSAT class of satellites after its developmental launches are completed. INSAT-2E will be launched by the European Ariane Vehicle in 1997/98.*

COVER STORY

Cost-Conscious Indians Find Profits in Imaging Satellites

Michael Mecham/Bangalore

India's Earth imaging program was born 20 years ago when Hasselblad cameras loaded with infrared film were flown on aircraft to study coconut wilt disease. Today, with five Earth-imaging satellites in operation and plans for at least twice that many, India has become a major supplier of multispectral imaging data throughout the world.



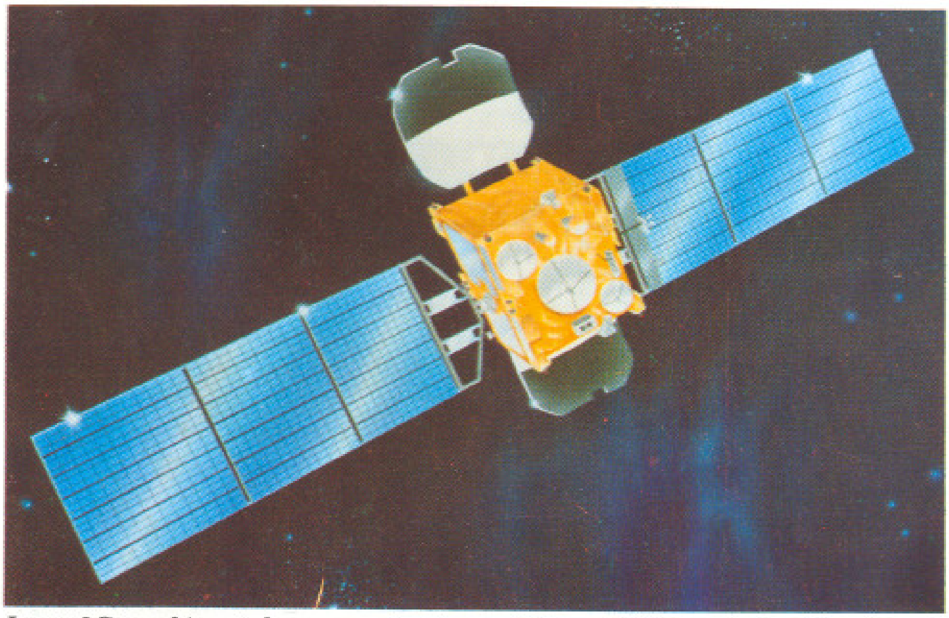
The cumulative effect of India's spacecraft gives the nation a powerful Earth-imaging inventory. Shown is a PAN/LISS-3 image from IRS-1C of Andhra Pradesh

This progress reflects the use of satellite imagery by India's agricultural, economic and social planners as a basic tool for improving its economy and relieving population pressures.

"The relevance of remote sensing is for the development of the country," says Earth Observation System Deputy Director V Jayaraman. "The market is right here. "The market is overseas as well, with India's imagery becoming a basic resource for U S and European customers.

In Earth imaging, the Indian Space Research Organisation (ISRO) is trying to balance costs by developing a P-series of its Indian Remote-Sensing (IRS) satellites as quick turnaround vehicles that will cost about $15 million each. A basic IRS costs about $50 million and carries a heavier instrument load that produces data useful to more disciplines. Both IRS and the P-series will weigh 2,200-2,700 lb. and are to be launched by the PSLV series. Launch costs are about $ 25-30 million.

ISRO's Earth Observation office is still working out



Insat-2C combines telecommunications with very high resolution black and white and IR imaging for a cyclone warning network.

the timing for its P-4 and IRS-1D launches for next year on the PSLV booster, Jayaraman says. The order of launch will depend on the continued health of spacecraft now in orbit.

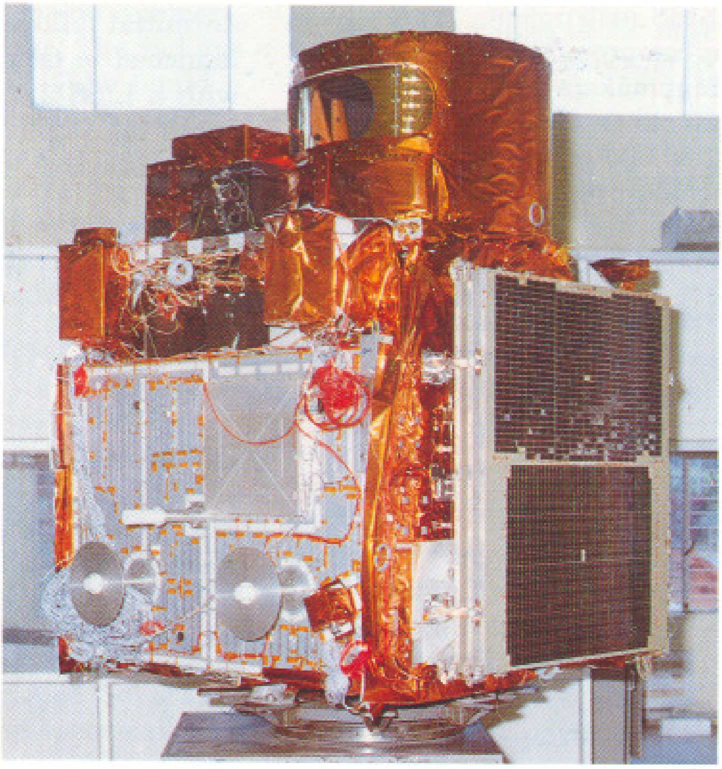
ISRO also is debating how to set priorities for funding and development of eight other missions it has identified through 2005. The initial priority will probably fall on two or three satellite development programs under India's ninth Five-Year Plan, which begins in fiscal 1997.

Eosat, the US distributor of Landsat imagery, is watching all of this closely because it regards the Earth-imaging programs run by India's National Remote Sensing Agency in Hyderabad as the centerpiece for its worldwide marketing efforts for the coming decade.

The Lanham, Md.-based company has acquired world distribution rights for India's remote-sensing system (other than data used inside India). Besides receiving the Indian data at its Norman, Okla., processing center, Eosat has contracted with GAF of Germany to process the IRS data for the European and North African markets. GAF will use the Neustrelitz ground station owned by the German Aerospace Research Establishment (DLR).

Hyderabad's National Remote Sensing Center led development of the country's original spin-stabilized Bhaskara spacecraft 20 years ago. Launched by Russian boosters, the spacecraft offered 1 km. (.62-mi.) resolution and set the stage for today's IRS series.

The first-generation IRS-1A/1B series launched in 1988 and 1991, respectively, introduced India's Linear Imaging Self-scanning Sensor, which operated in four spectral bands covering the visible and near infrared, like Landsat 4/5. LISS-1 provides 72-meter (45-ft.) resolution and LISS-2, 36-meter (22-ft.) resolution. The first-generation IRS program also established a long working relationship, with France's Thomson-CSF, which supplied ISRO with charge-coupled devices (CCDs) for the LISS scanners.



IRS-1C, seen during dynamic balancing test, introduced better resolution in its Linear Imaging Self-scanning Sensors and a high-resolution steerable panchromatic camera

The second-generation IRS series was launched last December and introduced the highest resolution mapping capability commercially available. The 2,750-lb., three-axis body-stabilized IRS-1C carries a panchromatic camera that provides 5.8-meter (19-ft.) resolution with 6-bit imaging from an operational altitude of 435 mi. By comparison, France's Spot offers 10-meter resolution in panchromatic and 20 meters in multispectral.

IRS-1C's LISS-3 sensors operate in three visible and near-infrared bands providing 23.5 meter (77-ft.) resolution and a fourth in shortwave IR with 71-meter (233-ft) resolution. Once again, CCDs from Thomson-CSF are used in the LISS-3.

The panchromatic and LISS instruments represent a compromise for users. Mapmakers want at least 20-meter resolution to draw 1:50,000 scale maps. They would prefer 1-meter resolution for 1:10:000 scale maps, but that is too fine a scale for the thematic mapping community.

The new IRS series (IRS-1D is a duplicate) also introduces ISRO's Wide Field Sensor (WiFS), which has an image area of 810 km. (500 mi.) but a resolution of 189 meters (620 ft.). The WiFS swath allows it to map India in five days.

ISRO is now defining the characteristics of its LISS-4 series, but Jayaraman says it will have better than 10-meter resolution and steering capability. It has also identified a LISS-3 Prime instrument package that would offer the same four-band widths but with improved resolution.

India's 2,200-lb., low-cost P-series is now operational after two successful developmental launches. After an initial failure, P-2 was launched in October, 1994, with a LISS-2 scanner on board to compliment IRS-1B coverage.

Last March, P-3 carried three modular optical electronic scanners (with 500-meter resolution) for the DLR, a WiFS and an X-ray telescope. Inclusion of the telescope follows India's tradition of making multi-discipline spacecraft. Scientific payload opportunities have been announced for at least two more of the P-series.

ISRO candidate payloads under discussion include:

- Development of P-6 mission as Cartographic Satellite-1 in about 1999 using stereoscopic panchromatic mappers with 2.5 meter (8.ft.) resolution. CartoSat-2 would follow in about 2002.

- Launch of Oceansat as the P-7 mission about 1999 including a Ku-band altimeter, scanning microwave radiometer and thermal IR capability.

- Development of the third-generation IRS series (IRS-2A) for launch about 2000 to include high-resolution LISS instrumentation and WiFS with 125 meter resolution.

■

Aviation Week & Space Technology/August 12, 1996

COVER STORY

India Sees Commercial Future for New Booster

Michael Mecham/Bangalore

India plans to begin offering commercial launches by the end of the decade from a new Ariane-class booster now in development.

Called the Geostationary Satellite Launch Vehicle (GSLV), the launcher is largely a derivative of the Indian Space Research Organization's (ISRO) Polar SLV, which completed its development testing last March and has now entered service with three launches scheduled over the next three years.

A new US Transportation Dept. assessment forecasts a continued strong launch market for such small-and medium-weight payloads to transfer orbit (Aw&ST Aug.5, p.18). GSLV's promised 5,500 lb. payload capacity at a $ 70-million launch cost should make it a major alternative to the established US European, Russian and Chinese systems.

GSLV'S DEVELOPMENT was predicated on the acquisition of Russian cryogenic technology for its third stage, but U S objections have prompted Russia to drop plans to transfer the cryo technology, though not the upper stages, themselves. India is to receive its first cryogenic motor later this year for use on GSLV's first developmental flight in 1998. But as for developing cryogenic technology, ISRO will be on its own, Launch Program Director D Narayana Moorthi said.

The US alleged that India is in violation of the Missile Technology Control Regime. India has refused to endorse the MTCR because it regards the agreement as a way for developed space powers to prevent it from competing in the commercial industry. The Indians point out that the liquid hydrogen/liquid oxygen upper stage planned for the GSLV requires too much launch pad preparation time to be practical for a ballistic missile program.

The GSLV will use the PSLV's first-stage solid motor, a 275,000-lb. booster with a 9.2-ft. diameter that produces 1 million lb. of thrust. "We have the third largest solid booster flying after the Titan and the space shuttle," Moorthi said.

India developed a maraging steel casing specifically for the first stage that is cast in five segments. Fuel is hydroxyl terminated polybutadiene.

India's PSLV launcher uses six solid strap-ons. The next-generation GSLV introduces a cryogenic third stage and adapts the PSLV's second-stage liquid engine technology for its strap-ons.

Instead of the PSLV's six solid rocket booster motors, the Indians have substituted four liquid boosters derived from the PSLV's second stage. The PSLV's SRBs are 3.2-ft. in diameter and produce 145,200 lb. of thrust each.

But the GSLV's liquid-fueled (unsymmetrical dimethyl hydrazine and nitrogen tetroxide) Vikas motors will provide sufficient lift to allow the GSLV to lift payloads up to 5,500 lb. into a geosynchronous transfer orbit. Without the strap-ons, the GSLV matches the PSLV's performance (with strap-ons) and could put a 3,300-5,500-lb. payload into a polar Sunsynchronous orbit.

The PSLV's second stage, which produces 158,400lb. of thrust, acts as the GSLV's second stage as well.

Because of the improved efficiency of cryogenic upper stages, India's Space Commission began funding a series of pre-GSLV demonstration projects a decade ago. The work was carried out at the ISRO's Liquid Propulsion System Center in Trivandrum in southern India.

But the commission was concerned that it had taken nations such as the U.S. 15 years to develop their own cryogenic technology, so it asked Russia to collaborate by transferring their cryogenic technology as well as two upper stages for the initial GSLV launches.

An agreement was signed with Glavkosmos in 1991 to that effect, but U.S. opposition forced the Russians to back away. Three years later, the Glavkosmos contract was modified to allow the export of four completed upper stages and two ground models, but not the cryogenic technology itself.

The imported cryo stages will allow the ISRO to proceed with its first GSLV developmental launch in 1998 and to stay on track for its first launch with a commercial satellite - its own Insat-2E - two years later. India expects the Ariane launch of Insat-2D to be the last it will have to buy for the Insat series.*

Government funding has been approved for the Trivandrum center to continue developing cryogenic upper-stage technology, Space Commission Chairman Krishnaswamy Kasturirangan said.

The 36 ft. upper stage is to carry 26,400 lb. of LH/LOX and have 16,500 lb. of thrust.

"Going commercial is the goal," Moorthi said. ISRO expects commercial launches to be priced at about $80 million.

India's launch programs started in the early 1960s. "Space applications were seen as the way to go for a developing country like India," he said. The early emphasis was on sounding rockets, in part because the Trivandrum region is home to an equatorial electromagnetic phenomena that has attracted worldwide scientific interest.

TWO PROGRAMS GREW out of India's first major launcher effort, the four-stage SLV-3 series. First was an "augmented" program called ASLV to act as a low-cost intermediate vehicle. The second was the larger PSLV series. The ASLV series, which ended with a successful test flight in 1994, was a technology validator for PSLV even though the two were developed in parallel.

The initial PSLV launch in September, 1993, suffered from a software error in the guidance system, but the second attempt in October, 1994, successfully launched the 1,770 lb. IRS-P2 imaging satellite into a 500 mi. polar orbit. The final developmental launch of IRS-P3 last March ended the developmental program. One measure of the program's success was that placing the IRS-P3 in orbit required less fuel on the PSLV than the Russian Molniya.

The next goal is to increase payloads to the 2,600 lb. level, which would qualify the vehicle for Iridium low-Earth orbit communications satellite replacement missions, Moorthi said.

Improved booster performance will be needed to carry the extra 660 lb. of payload. The extra boost is expected from a switch in the SRB firing order. The program took a conservative approach of firing four on the ground and two in the air during the developmental program. Now the launch teams will switch to a 2-4 firing sequence, he said. ■

**INSAT-2E is planned for launch by Ariane Vehicle – Space India*

India's IRS family comes of age

by **Hormuz P Mama**

Bombay: A new marketing agreement with EOSAT of the USA consolidates India's position as a leading player on the remote sensing market.

"Few countries use their remote sensing satellites as extensively for socio-economic development as India does", emphasises Dr K Kasturirangan, Chairman of the Indian Space Research Organisation and of the Space Commission. The benefits of remote sensing programmes — which cover fields like agriculture, forestry, oceanography, bioresources, geology, water resources, land use planning, mining, literacy and many more — far exceed the investments made, but are not easily quantifiable.

On the other hand, these satellites increasingly offer hard-currency returns for their investors and user agencies. EOSAT of the USA has agreed on exclusive global commercial distribution of Indian Remote Sensing (IRS)-series satellite data. The Department of Space (DOS) plans to launch 10 IRS satellites in 10 years, including today's IRS-1B and IRS-P2. Dr Arturo Silvestrini, EOSAT President, says the EOSAT agreement brings together "the world's largest commercially-oriented earth monitoring programme and the world's most extensive commercial data distribution network". The data could generate over $1 billion in revenue over a decade.

ISRO's marketing arm, the Antrix Corporation, will get 50 percent of the access fee for each ground station, and 10 percent of the royalty on data sales, explains Dr Kasturirangan. Overall revenue for India could thus be about $100 million in 10 years. Earnings from value-added services like processing maps from such data, could be worth four times more than that data alone. In the long term, IRS may have 30 percent of the global market, he adds. IRS is the only programme with assured long-term continuity and rapid development. The latest IRS-1C has a resolution of 6m, compared to 10m for SPOT. "It is the highest resolution for a commercial satellite", says Dr Kasturirangan, "and future IRSs will be even better". Once again, high reliability is a factor in India's success. The 7.5 year-old IRS-1A, with no redundancy, still works perfectly.

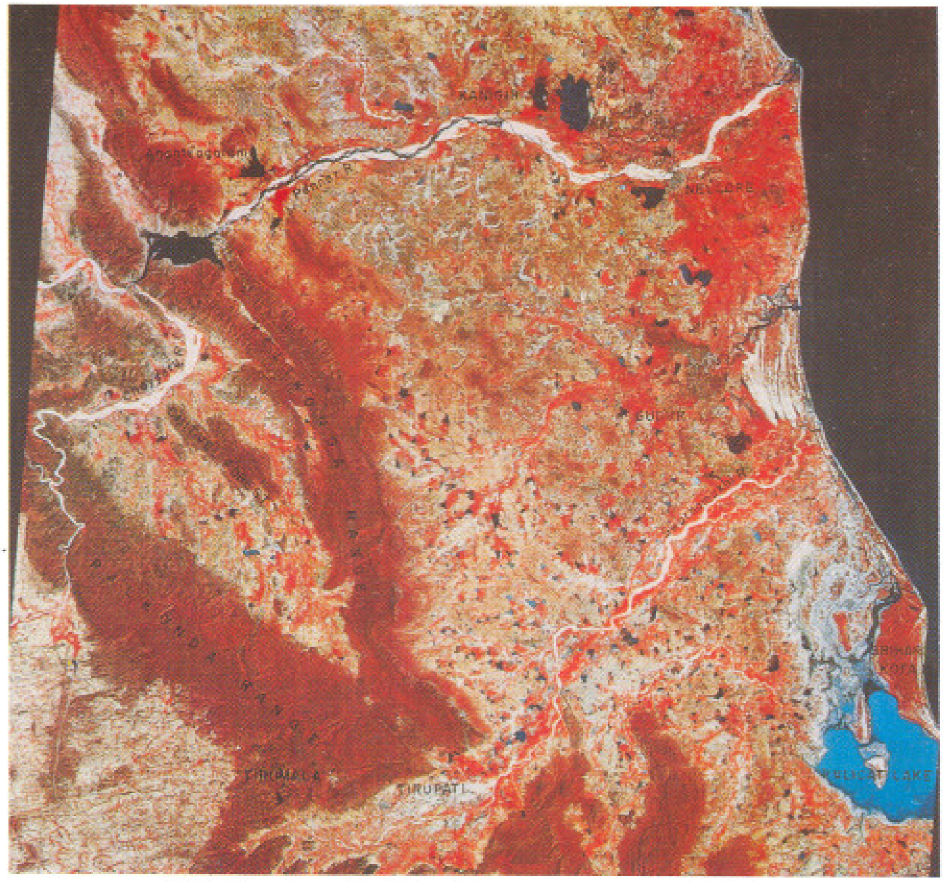
Business as usual

EOSAT moved quickly to reassure customers following reports that the Indian ministry of defence had decided to block civil use of IRS-1C images inside India's footprint in

IRS Satellite Characteristics

Satellite	*Launched*	*Instruments*	*Resolution*
IRS-1A	1988	LISS-1 (multispectral)	72m
IRS-1B	1991	LISS-2 (multispectral)	36m
IRS-1C	1995	PAN (panchromatic)	5m
IRS-1D	1997	LISS-3 (multispectral)	25m
		WiFS (broad swath)	180m
IRS-P2	1994	LISS-2 (multispectral)	36m
IRS-P3	1996	WiFS(broad swath)	180m
		MOS	1-2km
IRS-P4	1997	LISS-3 (multispectral)	25m
IRS-P5	1998	LISS-4 (multispectral)	10m
		WiFS upgrade (broad swath)	125m
IRS-P6	1999	PAN (panchromatic)	2.5m

order to monitor military activities in areas around India's borders. EOSAT's director of worldwide sales and marketing, Shawana P Johnson, explains that the move will not affect the US firm, whose agreement with Antrix only gives EOSAT rights to data outside India's footprint: "The decision ...has no impact on the commercial value of our arrangement with Antrix." Johnson goes on to say that she expects no negative repercussions in terms of customer perception of the IRS service: "Our customers are business people and environmentalists who ... are typically not involved with or troubled by these types of decisions."



IRS-1A view of Sriharikota region, near Madras

By end-1995 five of the 15 global EOSAT stations were able to receive IRS data directly. This number will increase to 10 by the end of 1996. A wide range of future developments is contemplated. By 2002, a resolution of better than 1m will be offered for cartography payloads. By 2004-5, the 2-tonne IRS-2 will have advanced payloads, including a multi-frequency, multi-polarisation synthetic aperture radar.

The "P" series features low-cost, applications-specific payloads, "IRS-P2 was designed, developed and tested in just one a half years", points out Dr Kasturirangan. The P3 will be mainly for oceanography and for atmospheric chemistry, while P4 will have an ocean colour monitor, he adds. Very-high resolution (10m) multi-spectral cameras will be on P5 to P7 by the year 2000.

Dr Kasturirangan also expects a good market for satellite hardware. For a start, ISRO is trying for subcontracts from the industry majors. ISRO can offer all products and services across the board, which the majors do not. ISRO has already supplied C-/Ku-band feed horns to Hughes and held training programmes for Malaysian and Korean personnel. Four satellite demodulation and desynchronisation units for IRS-1 data processing are being sold to EOSAT.

"If an advanced-technology product needs high manpower input, then we can produce it at 60 to 70 percent of the global price," Dr Kasturirangan notes. Talks are on with Hughes, Matra-Marconi, Loral and others, for supply of hardware.

For satellite launch services, India's PSLV can place a one-tonne payload into polar-polar orbit, while the GSLV will take 2.5 tonnes to GTO. Talks are on with Arianespace to market the PSLV for the lower end of its requirements. IRS-1C and IRS-P3 were launched as scheduled earlier this year by PSLV-D3, and both are reported to be functioning normally.

■

Feature Article

India's Space Program: for the people

Space India is thankful to Commonwealth Scientific & Industrial Research Organisation (CSIRO), Australia for the permission granted to reproduce this article from CSIRO Space Industry News.

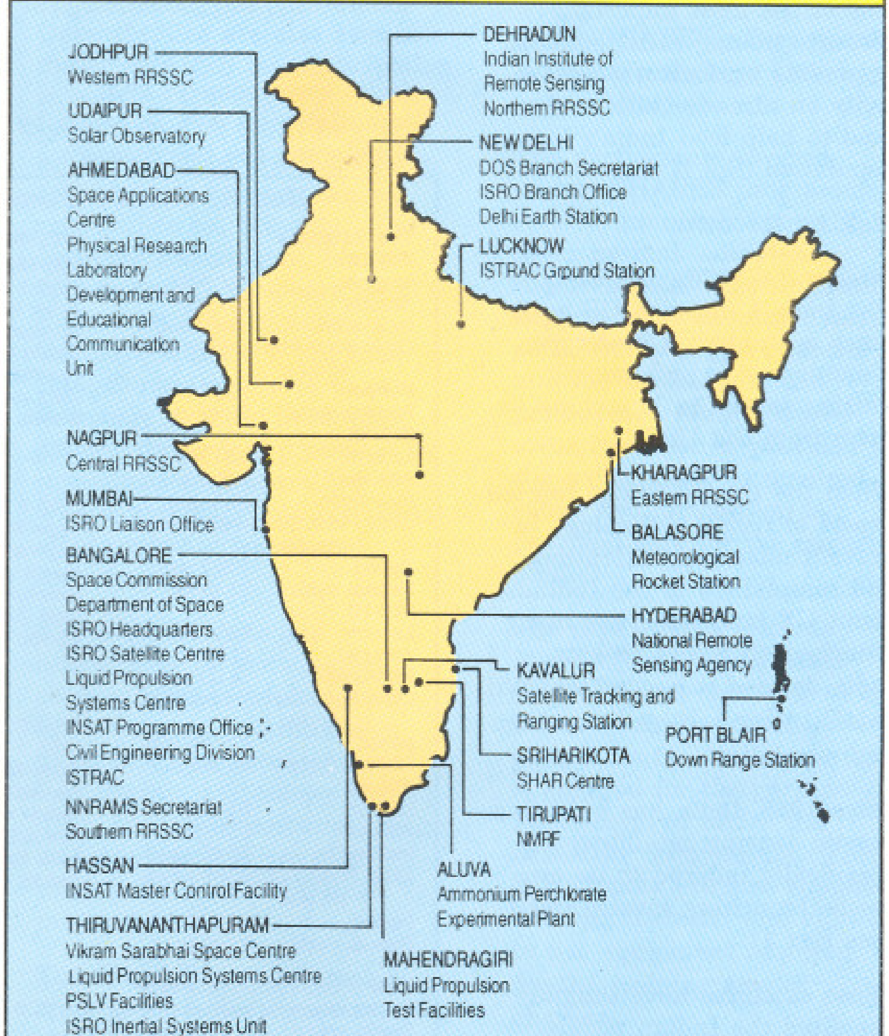
- **Wayne Deeker**

India's space program has achieved great success, comparable to wealthier space-technology nations, since inception in the 1960s. India can reliably and inexpensively launch its own remote sensing satellites, among the world's most sophisticated, at about one third the cost of US European counterparts. India also has considerable expertise in receiving, processing and analysing remotely sensed data; international and domestic users value the high quality data products.

India's achievements stem largely from its application-based approach. Space program leaders always maintained space technology had potential to improve the lives of many Indians, and that it should be used to do so (Spl N 67). But in the 1960s and 70-s it was difficult for a country that cannot provide safe drinking water to justify rising expenses, now around $300 million per year, on space research. Now, the Indian people believe the expense has been worth it.

India's earliest space project, SITE, the Satellite Instruction Television Experiment, delivered educational programs about health and family planning to about 2000 rural villages. The recipients made their appreciation known to their elected representatives, and thereafter the Indian government has given social space-applications extremely high importance, and a prominent position in govern-

ESTABLISHMENTS OF THE DEPARTMENT OF SPACE



ment. Priority applications include: communications: weather prediction: and resource management.

With a largely rural economy and population, India needs current information about the use and misuse of its natural resources. Remote sensing allows coverage of the whole country in days, which can be repeated every few weeks. Such rapid assessment, for example, permits prevention of vegetation losses: without satellites, the denudation would continue being noticed too late.

One of the most important resource management goals is improving agricultural productivity on already cultivated land to help feed India's huge population (Spl N 67).

Making its own

During the 1970s and early 80s, India built with US assistance a number of prototype communication and remote sensing satellites, launching them from the USSR.

When the United States limited export of rocket technology to prevent missile proliferation, and complained to the Indians about US built satellites being launched on Soviet rockets. India decided it needed its own satellite launch and construction capability.

Since 1988, India has built five remote sensing satellites, specifically tailored to its own needs, launching several itself (See Box 1).

Those satellites have tangibly benefited the Indian people. Examples include:

* Water location. Using satellite pictures, researchers found 180 wells in Rajasthan, with a 92% success rate, compared to the 40% success rate of conventional methods.
* Forest and land-use mapping. A whole-country forest map took seven years, whereas a ground based inventory would have taken fifty.
* Drought measuring and relief.
* Mineral exploration.
* Harvest and yield estimates.

ISRO identifies its future remote sensing needs as: high resolution mapping: improved spectral resolutions for crop and vegetation applications, especially to discriminate vegetation types; oceanic applications, including weather prediction and fisheries: atmospheric applications, specifically global change monitoring and meteorological uses.

India saves money, and stimulates its own economy by developing the technology itself, and can offer other developing countries low cost data products.

After two decades of hard work, culminating in the most recent launches of IRS-IC in December 1995, and IRS-P3 in March 1996, India is a leader in remote sensing technology and data products. The next decade holds even more promise, as India plans to launch another eleven satellites.

The Indian people are proud of their space achievements. Even though India's space program has proven itself, it can only continue by adhering to the original goals of improving life for ordinary people.

Box 1. India's Remote-sensing Satellite

The Satellites

IRS-1A
Launch: 03/1988
Altitude: 904 Km
Inclination 99.49 deg
Orbit: Polar, Sun synchronous, circular
Period: 103.2 min
Repeat cycle: 22 days.

IRS-1B
Launch: 08/1991
Altitude: 904 km
Inclination: 99.5 deg.
Orbit: Polar, Sun synchronous, circular
Period 103.2 min.
Repeat cycle: 22 days.

IRS-1C
Launch: 12/1995
Altitude: 817 Km
Inclination: 98.69 deg.
Orbit: Polar, Sun synchronous, circular
period: 101.35 min
Repeat cycle: 24 days

IRS-P3
Launch: 03/1996
Altitutde: 817 Km
Inclination: 98.69 deg.
Orbit: Polar, Sun synchronous, circular
Period: 101.35 min
Repeat cycle: 24 days

Sensors:

IRS-1A, IRS-1B
LISS-1 (Linear Imaging self-scanning sensor)
Type: Multispectral pushbroom imager with CCD detector arrays
Applications: Land use, Agriculture, Forestry, Hydrology
Swath width: 148 Km
Resolution: 36.5 m
Data rate: 5.2 Mbit/s S-Band
Bands: Band 1 - 0.46-0.52 microns VIS
Band 2 - 0.52-0.59 microns VIS
Band 3 - 0.62-0.68 microns VIS
Band 4 - 0.77-0.86 microns NIR

LISS-2 (Linear Imaging self-scanning sensor)
Type: Multispectral pushbroom imager with CCD detector arrays.
Applications: Land Use, Agriculture, Forestry, Hydrology
Swath width: 145 Km
Resolution: 72m
Data Rate: 2 x 10.4 Mbit/s X-Band
Bands: Band 1 - 0.46-0.52 microns VIS
Band 2 - 0.52-0.59 microns VIS
Band 3 - 0.62-0.68 microns VIS
Band 4 - 0.77-0.86 microns NIR

IRS-1C, IRS-1D, IRS-P3
LISS 3 (Linear Imaging Self-Scanning Sensor)
Type: Multispectral pushbroom imager with CCD detector arrays
Applications: Land and water resources management
Swath width: 142 Km
Resolution: spatial 23.5 m radiometric 128 grey levels
Data Rates: 42.45 Mbit/s
Bands: Band 1 - 0.52-0.59 micron VIS
Band 2 - 0.62-0.68 microns VIS
Band 3 - 0.77-0.86 microns NIR
Band 4 - 1.55-1.75 microns SWIR

PAN (Panchromatic Camera)
Type:multispectral pushbroom imager with CCD detector arrays
Swath width: 70.5 km
Resolution: spatial 6 m radiometric 64 grey levels
Data Rate: 84.9 Mbit s
Bands: 0.5-0.9 microns

WiFS (Wide Field Sensor Camera)
Type: Multispectral Pushbroom imager with CCD detector arrays
Objects: Vegetation index mapping
Swath width: 770 km
Resolution: spatial 188 m radiometric 128 grey levels
Data Rate: 2 Mbit/s
Bands: 0.62-0.68 microns VIS
0.77-0.86 microns NIR

IRS-P3 also carries X-ray astronomy instruments.

Source: http\p:/pid.do.op.dlr.de/ISIS/info-board/texts/space/platforms/operationaVIRS-text, courtesy DLR, Germany.

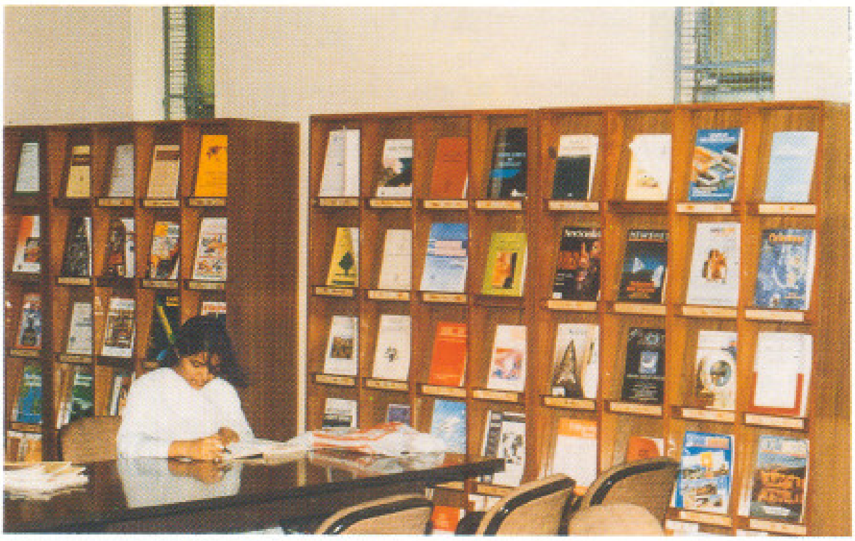
India SHARES Experience

The application of space technology in providing better quality of life has been convincingly demonstrated by a number of countries. However, expertise in this area is not readily available to most of the developing countries. India, while building up its space programme, was fortunate to have received help from a number of countries. To reciprocate this help, India made an offer during the second United Nations Conference on Peaceful Uses of Outer Space (UNISPACE-82) to share its experience in space technology and its application with other developing countries through the programme called SHARES - Sharing of Experience in Space".

The main thrust of SHARES programme is training of personnel in space applications, primarily, remote sensing and communications. The opportunities available under SHARES include:

- regular courses, laboratory work and on-the-job training.
- participation in selected projects and programmes.
- joint experiments on Indian rockets, satellites and balloons
- opportunities to make astronomical observations
- assistance in system studies and consultancy in specific areas
- assistance in project implementation
- digital analysis of satellite remote sensing data
- development of remote sensing equipment and technology transfer.

Under the SHARES programme, training in remote sensing is given in one of the institutions of Department of Space, namely, Indian Institute of Remote Sensing (IIRS) Dehra Dun, National Remote Sensing Agency (NRSA), Hyderabad and Space Applications Centre (SAC), Ahmedabad.



Library at Indian Institute of Remote Sensing

Opportunities are also available under SHARES for participation in some of the ongoing programmes of ISRO in space sciences. Observation times on astronomy telescopes can be provided to participants. The National Mesosphere, Stratosphere and Troposphere (MST) Radar established near Tirupati, about 200 km from Bangalore is available to continuously monitor the atmospheric dynamical processes for investigation of prevailing winds, planetary and equatorial waves, gravity waves and turbulence, etc.

Exchange of visits and consultancy on some aspects such as equipment design, fabrication and maintenance, application projects, joint system studies, technology development as well as software design and development are also considered under SHARES programme.

The SHARES programmes is open to participants sponsored by the governments of developing countries. The emphasis is to develop a nucleus of expertise in those countries for promoting developmental applications of space. Developing countries are encouraged to identify a small group of persons in their selected area of application for sponsorship under SHARES. Participants must have working knowledge of English.

The participants covered under SHARES programme receive financial support to cover normal subsistence requirements. The financial support however may not be sufficient to support spouse and the members of the participants family. Hostel accommodation is provided to the participants at nominal rates. Accommodation is provided only for the participants.

The expenditure towards international travel under SHARES programme is to be borne by the sponsoring governments. No course fee is charged for the participants covered under the SHARES programme. The participants are also supplied training material and allowed to use equipment required for the training free of charges.

All enquiries related to SHARES programme may be addressed to:
Scientific Secretary,
Indian Space Research Organisation, Antariksh Bhavan,
New BEL Road
BANGALORE 560 094, INDIA,
Tel: 3415474, 3416356, 3415357
Telex: 0845-2499, FAX: 080-3415298
Grams: ISRO.

Institutions where Training is given under SHARES Programme

The Indian Institute of Remote Sensing (IIRS), Dehra Dun, was set up in 1965 in collaboration with The Netherlands, on the pattern of the International Institute of Aerial Survey and Earth Sciences (ITC), Enschede, The Netherlands. The institute is first of its kind in South East Asia and is run by National Remote Sensing Agency (NRSA). It conducts regular training courses in remote sensing at post-graduate level for scientists, engineers and technicians in the fields of forestry, ecology, geology, geomorphology, hydrogeology, engineering geology, soil survey, soil conservation, agriculture, urban and regional planning, water resources, coastal processes and marine resources. In addition, the institute conducts research in photo interpretation and thematic mapping of earth and ocean resources and provides consultancy to a number of users.

IIRS offers both short and long term courses covering different aspects on the use of aerial photographs and remote sensing technique for survey of natural resources. The long term courses are structured in three modules. The first two modules covering basics of remote sensing, photogrammetry and specific areas of applications are common to all courses. The third module includes project work on use of remote sensing techniques in areas of specific interest.

IIRS is equipped with a wide range of equipment for image interpretation, photogrammetry and cartography, digit analysis, ground truth measurements and photo processing.

National Remote Sensing Agency (NRSA), Hyderabad, is engaged in satellite data acquisition, analysis and interpretation of remote sensing data for resources survey and management. NRSA offers training to scientists and technicians in different applications areas. There are two types of courses - an eleven week course on remote sensing for scientists and engineers involved in remote sensing projects and a two-week appraisal course on remote sensing for senior level scientists, engineers and decision makers at supervisory level. The eleven week training course in remote sensing applications is designed for resources scientists (in Agriculture, Forestry, Geology, Geomorphology, Landuse, Water Resources, Environment, etc.) to make them conversant with modern aspects of remote sensing and encourage them to use remote sensing in their routine resources survey and monitoring. The course is structured in two modules. The first module of eight weeks duration covers basic of remote sensing, sensors, platforms, interpretation techniques, digital analysis, GIS and exposure to applications of remote sensing in agriculture, geology, geomorphology, groundwater, hydrology and landuse. The second module of three weeks duration, is devoted to hands-on experience by undertaking simple remote sensing application projects.

The two week course is designed to appraise senior scientists, engineers and decision makers on the principles of remote sensing and its application for natural resources management.

Space Applications Centre (SAC), Ahmedabad is engaged in conceptualising, planning and executing space application projects in the fields of communication and remote sensing, and utilisation of Indian Remote Sensing Satellite data. SAC offers training courses of 12 weeks duration. The participants should have a degree/postgraduate degree in any branch of science with 4 to 5 years of experience.

The courses in Remote Sensing cover fundamental aspects of remote sensing, data acquisition, processing, analysis and interpretation and information extraction for resources management. The emphasis is on a broad spectrum of application areas such as land and water resources, marine environment and geology. During the latter half of the courses, participants will be attached to one of the IRS utilisation projects like crop production forecasting, forest mapping and damage detection, water quality monitoring, watershed characterisation, monitoring of coastal environment, marine fisheries, crop stress detection and crop yield meddling.

SAC has facilities for data processing and data analysis - both visual and digital, digital image processing and ground truth.

In satellite communications, the courses conducted include satellite communications, satellite broadcasting and allied applications. Ahmedabad Earth Station (AES) is available to the trainees for hands-on experience in various aspects of satellite communications and satellite broadcasting.

Development and Educational Communications Unit (DECU) also located in the SAC campus has facilities including a TV studio, video equipment for outdoor programme production and a group of multi-disciplinary professionals both in the field of hardware and software for TV programme production. Advanced as well as basic courses on production skills, communication research and video engineering are offered.

Post Graduate Course in Satellite Communications

The Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations, has announced that a 9-month Post Graduate Course in Satellite Communications will be conducted at ISRO's Space Applications Centre at Ahmedabad from January 1, 1997. The course is directed towards university educators and researchers, telecommunications professionals and specialists and system managers, engineers and planners. The programme is designed to enable the participants to serve as hubs for furthering the skills and knowledge of other professionals in their countries, so that they could make meaningful contribution towards planning, development and management of their own satellite based communications systems.

The CSSTE-AP, established in November 1995, is colocated with Indian Institute of Remote Sensing at Dehra Dun. The Centre develops skills and knowledge of university educators and scientists through theory, research, applications, field exercises and pilot-projects in space science and technology. The programme is aimed at developing indigenous capability of participating countries in designing and implementing space-based research and applications programmes. The details of the educational modules have been finalised based on the curriculum developed under the auspices of the UN. Cur-

Remote Sensing & GIS Course in progress rently the first 9-month course on Remote Sensing and Geographic Information Systems (GIS) which started in April 1996 at Dehra Dun is in progress.

The topics covered under the Satellite Communications include:

* Orientation course
* Communications Systems - An overview
* Satellite Communications Systems
* Earth Station systems
* Broadcasting using communications satellite
* Specialised applications and future trends of Satellite Communications
* Operational Communications Satellite Systems
* Network planning, management and operational issues of communications systems
* Development, education and training applications

Further, the participants will carry out an approved project in his/her home country for a period of one year, formulated jointly by the scholar and their advisor at the Centre during one year course.

The participants should have degree in electronics, telecommunications, electrical engineering or post graduate degree in science (physics, electronics) or equivalent with at least five years experience in teaching/research or professional experience in the field of communications engineering.

Space Applications Centre (SAC) of Indian Space Research Organisation (ISRO), where the course is being conducted, is an R&D centre for Satellite Communications and Remote Sensing. SAC interfaces with the actual users of satellite systems. The Centre was engaged in the design, development and commissioning of a number of satellite earth stations for experiments conducted by ISRO using ATS-6 of US, Franco-German Symphonie satellite, India's APPLE, etc. The centre has also designed and built earth station equipment and payloads of Indian satellites like APPLE and INSAT.

Further details on the Satellite Communication Course can be had from:

Mr George Joseph
Director
Space Applications Centre (SAC)
Indian Space Research Organisation (ISRO)
Dept. of Space, Govt. of India
Ahmedabad 380 053
Fax: 0091-079-6568073
Tel: 0091-079-6423956 (Off.)
0091-0279-31302 (Res)
E-mail : george@sac.ernet.in

CSSTE-AP - Malaysia Signs Agreement

Malaysia signed on August 23, 1996, the Agreement for the CSSTE-AP (affiliated to the United Nations) which has been established in India. The Agreement for the Centre was opened for signature by member countries of the region on November 1, 1995. The Acting High Commissioner of Malaysia, Mr Kamilan Maksom, signed the Agreement on behalf of the Government of Malaysia in New Delhi in the presence of senior officials of the Department of Space and Ministry of External Affairs.

It may be recalled that the Agreement has already been signed by India, Indonesia, Kazakhstan, Kyrghyzstan, Mongolia, Nepal, Nauru, Republic of Korea, Sri Lanka and Uzbekistan and Democratic Republic of Korea.

Vikram Sarabhai Award for Prof U R Rao

Prof U R Rao, Member, Space Commission and former Chairman of ISRO, has been awarded the biennial international Vikram Sarabhai Award for 1996. The award, instituted by the Indian Space Research Organisation (ISRO) and the Committee on Space Research (COSPAR) of the International Council of Scientific Unions, consists of a gold medal and a citation.

Presenting the award at a special ceremony on July 15, 1996 held to coincide with the 31st COSPAR Scientific Assembly at Birmingham, UK, Dr K Kasturirangan, Chairman, ISRO, recalled the contributions of Prof Rao towards understanding of the solar as well as galactic cosmic ray variations, electromagnetic state of interplanetary space and characteristics of solar wind. He highlighted Prof Rao's contribution to the development of space technology in India which brought about a revolution in communication and natural resources management through INSAT and IRS systems. Prof Rao was responsible for initiation of Integrated Mission for Sustainable Development in India. Also, he was responsible for the successful programme of India's satellite launch vehicle development. As Vice President of International Astronautical Federation and as Chairman of the Committee for Liaison with International Organisations and Developing Nations, Prof Rao played a crucial role in fostering space programmes in developing countries.

Accepting the award, Prof Rao said 'I am honoured to receive the prestigious 1996 Vikram Sarabhai Award, especially because of my very intimate association with Vikram for over two decades, first as his student and later as his colleague at the Physical Research Laboratory, Ahmedabad, during which period, I had the unique privilege of sharing with his ideas, plans and dreams of utilising space technology for the rapid development of India". He said that his involvement in the Indian space programme since 1970, gave him a unique opportunity of seeing many of these dreams come true. He said that the phenomenal progress achieved by India in communications, tackling the problem of rural education, implementing effective disaster management system, utilising space remote sensing and in building self-reliance in satellite as well as launcher technology would not have been possible but for the dedicated efforts of his colleagues in ISRO.

"We are on the threshold of change — a change which has recognised the global inter-connectivity of both natural and anthropogenic phenomena through weather, climate, geosphere and biosphere environment, inextricably linking the fate of all country on this planet. Yet, wide spread illiteracy, large scale starvation, exponentially growing population, pollution, poverty and environmental degradation continue to haunt and divide the world into haves and have-nots. I firmly believe that —— providing food, economic and health security to every citizen on this planet has to be viewed as a collective responsibility of the entire humankind. ——— I urge all of you, my dear fellow space scientists, to work towards making the dream of the global village come true", Prof Rao said.

Concluding his speech, Prof Rao said that he was deeply moved by the gesture of the COSPAR in honouring him with Dr Vikram Sarabhai Award for his humble contribution to space research in developing countries.

The Vikram Sarabhai Award was instituted in 1990 to recognise outstanding contributions made by individual scientists to space research in developing countries. Prof Rao is the first Indian to receive this award. The earlier recipients are Academician Kotelnikov of Russia (1990), Prof C Y-Tu of China (1992) and Prof Blamont of France (1994). ■

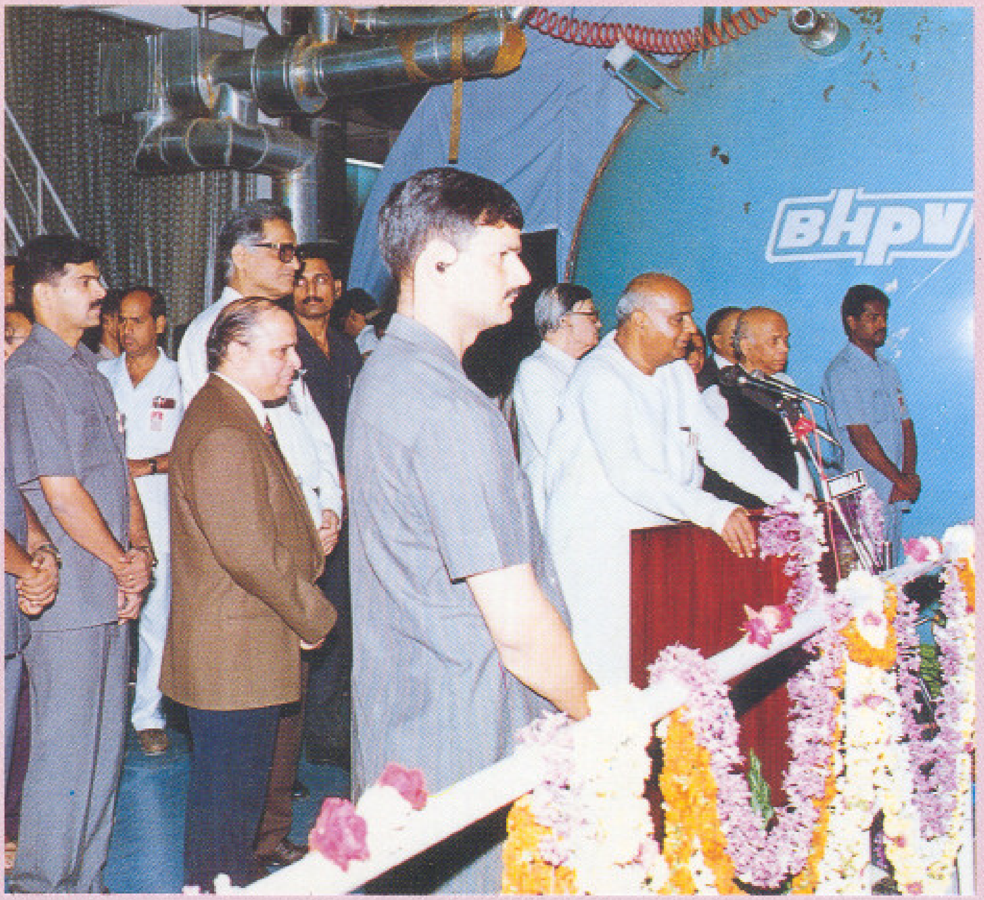
Prime Minister Visits ISRO Satellite Centre

Prime Minister, Mr H D Deve Gowda, accompanied by Governor of Karnataka Mr Khursheed Alam Khan and Karnataka Chief Minister Mr J H Patel, visited ISRO Satellite Centre (ISAC), Bangalore on September 7, 1996. ISRO Chairman, Dr K Kasturirangan took the Prime Minister around the various facilities and laboratories, including INSAT-2D and IRS-1D system which are under integration.

At the end of the visit, addressing ISRO personnel at ISRO Satellite Centre as well as at other ISRO Centres (who were linked via INSAT), the Prime Minister announced that he is very much convinced of the contributions made by scientists and technologists towards the growth of industry and agriculture as well as alround development of the nation. "The Indian scientists and technologists, while earning international recognition have brought dignity to the nation" he added.

The Prime Minister expressed his happiness for having got personally acquainted with the technological progress made by ISRO and complimented the scientists, technicians and other personnel. Recalling the excellent services provided by the space programme to the development of the nation, he assured government's complete support in enhancing the programme during the coming 9th Five Year Plan. The Prime Minister reiterated that, in spite of the existing financial constraints, he would ensure that sufficient resources will be made available to high technology programmes of the nation. □

Dr. K. Kasturirangan (left) explaining about a satellite to the Prime Minister in the ISAC exhibition. In the centre is Mr. R. Aravamudhan, Director, ISAC.



Prime Minister Mr. H.D.Deve Gowda addressing ISRO Community from the Large Space Simulation Chamger area. On his left is Mr. J.H. Patel, Chief Minister of Karnataka and behind him is Mr. Kursheed Alam Khan, Governor of Karnataka.

A view of the audience

View of Indian Institute of Remote Sensing, Dehra Dun