CHAPTER VI
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SATELLITE APPLICATIONS

Space communication technology has become an outstanding example for peaceful uses of outer space. For the past 45 years, tremendous progress has been made in this field, and commercial communication on a global scale has come within the reach of most nations – both developed and developing. India has been in the forefront of applying modern science and technology for national development since independence. Harnessing the technologies of atomic energy and outer space has been pursued by India since the inception of these technologies by the advanced nations. Through dedicated effort an infrastructure has been created in India for space research and its application.

Indian space programme is primarily application driven. Two major space systems have been established under DoS: (i) Indian National Satellite (INSAT) system providing services for telecommunications, television broadcasting and meteorology including disaster warning, and (ii) Indian Remote Sensing (IRS) satellite system for resources survey and management. This chapter will analyse INSAT programme and remote sensing applications for communication and other applications.
THE INSAT SYSTEM

INSAT systems are a joint venture of the Department of Space, Department of Telecommunications (DoT), Indian Meteorological Department (IMD), All India Radio (AIR), and Doordarshan. The overall coordination and management of INSAT systems rests with secretary-level INSAT Coordination Committee (ICC).¹ Chapter 4 discussed the origin, evolution, configuration, and the failure and success of INSAT satellites. This chapter concentrates on how INSAT programme – comprising one of the largest domestic communication satellite systems in the Asia Pacific region – benefited communication and other applications.

Precursors of INSAT Programme

In a vast country like India, mass communication plays a vital role in creating among people awareness about national policies and programmes by providing information and education, besides healthy entertainment. It helps people to be active partners in the nation-building endeavour.

Doordarshan, the country's national television network, is one of the largest terrestrial networks in the world. The flagship of Doordarshan, DD-1, operates through a massive network of 1042 terrestrial transmitters of varying powers reaching over 87 percent of the population to provide extended coverage. There are sixty-five

additional transmitters giving terrestrial support to other channels. Doordashan has established programme production facilities in forty-nine cities across the country. The first telecast originated from a makeshift studio in the Akashvani Bhavan, New Delhi, on 15 September 1959. A 500W transmitter carried the signals within a radius of 25 kilometre around Delhi. The next city to enjoy television broadcasting was Bombay, in 1972. By 1975, Calcutta, Madras, Srinagar, Amristar, and Lucknow also had hosted television station.

In 1975, the Department of Atomic Energy (DAE) of the Government of India entered into an agreement with NASA to jointly conduct the first experiment with satellite technology in India, popularly known as SITE (Satellite Instructional Television Experiment) with a view of providing informal education to the rural masses of India through an intimate medium of communication. Accordingly, ATS-6, the first-ever educational satellite in the world, launched by USA, was used for this purpose. The SITE was in operation for one full year from August 1975 to July 1976 and covered six states. The SITE programme covered 2400 villages in twenty districts of Rajasthan, Bihar, Orissa, Madhya Pradesh, Andhra Pradesh and Karnataka.

This joint venture of NASA, ISRO and AIR had the objectives of (a) exploring the potential of satellite for nation-wide communication through the

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television medium and (b) broadcasting instructional programmes in the field of agriculture, family planning, education etc. The programmes under SITE were classified into two broad categories: (1) educational television (ETV) meant for school children in the age group of 5–12 years and (2) instructional television (ITV) for adult audience, primarily designed for neo-literates and illiterates. ETV programme focused on making education more interesting, creative, purposeful, and stimulating and also on creating awareness in the changing society. The telecasts for adult viewers were to cover incidents of national importance, improved practices in agriculture, hygiene, family planning, nutrition, etc., along with some recreational programmes. The programmes were telecasted for duration of four hours each day in two transmissions.4

In the mean time Satellite Telecommunications Experiment Project (STEP) was undertaken in 1975. While SITE was primarily an experiment in direct television broadcasting, an experiment to gain experience in domestic telecommunications using satellites was initiated. Accordingly, STEP was undertaken using the Franco-German Satellite Symphonies for a two-year period, 1977–1979.5 Under STEP several experiments in digital satellite communication, single channel per carrier (SCPC) systems, radio-networking and television transmissions with several audio channels were carried out. Capabilities to integrate satellite communication channels

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4 Evaluation Report on satellite Instructional Television Experiment (SITE), Programme Evaluation Organization (PEO), Study No. 119, 1981.
with the conventional terrestrial network were acquired. A road-transportable and an air-liftable terminal were built, and experiments with these terminals effectively demonstrated the use of satellites for remote area and emergency communications. Experiments in the field of computer networking via satellites were initiated. Indigenous equipments were field-tested during STEP. The most important outcome of STEP was the insight it provided to communications-system planners on how to go about planning the communications network of the country. With the completion of SITE and STEP a firm technological base was established in India for applications of satellite communications.\(^6\)

After the success of SITE and STEP, it was APPLE that played a vital role in satellite communications. APPLE was the first-ever Indian satellite launched into the geotransfer orbit (GTO) in 1981, for communication purpose. It conducted a wide range of experiments and involved advanced telecommunication techniques and use of small earth stations. Television links between different cities and regions became possible. For the first time, national events could be telecasted live to various parts of the country. The satellite link was found to be useful in expediting cyclone relief. The space link was tried to make inter-bank transitions between Mumbai and Ahmedabad. A leading newspaper *The Hindu* printed its remote edition using the satellite.\(^7\)


Computer interlinks and data transmission between Ahmedabad, Mumbai and Sriharikota were also successfully accomplished. A video course on satellite communications to post-graduate students at several centres was conducted in a teleconference mode. A video course in robotics (Sophisticated Technology relating to robots) was telecasted to about five hundred scientists and engineers at Bangalore, Ahmedabad, Chennai, New Delhi and Hyderabad. APPLE ended its effective lifetime on 19 September 1983, a day after ISAT-IB was placed in its space home.

INSAT System for Communications

The INSAT system has been a major catalyst for the rapid expansion of television coverage in India. Satellite television presently covers over 65 percent of Indian land mass and over 90 percent of the population. At present forty Doordarshan channels, including news uplinks, are operating through various transponders. Presently INSAT has 175 transponders for all applications purposes including TV relay.

At present, 1406 transmitters of Doordarshan are working in INSAT system out of which 1138 transmitters [117 high power transmitters (HPT), 744 low power transmitters (LPT), 259 very low power transmitters (VLPT) and 18 transposers] are operating in the DD-1 network and 153 TV transmitters (68 HPTs, 80 LPTs and 5

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VLPTs) are working in the DD-2 network.\textsuperscript{11} Besides, 111 regional service transmitters (6 HPTs, 9 LPTs and 96 VLPTs) and 4 HPTs for digital transmissions are also operational in the Doordarshan. Network Forty-seven Private TV channels are operational through four private TV teleports. The following Doordarshan Satellite Television Services are benefited through INSATs: National networking service (DD-1), DD-News (DD2), DD-Bharathi and Digital Satellite News Gathering (DSNG) service and regional services for the states Andhra Pradesh, Assam, Bihar, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand and Chhattisgarh.\textsuperscript{12} Karnataka, Kerala, Madhya Pradesh, Maharashtra, Nagaland, Nagpur, North-East Orissa, Port Blair, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand, and West Bengal. Besides these, INSAT 4B, the most recent satellite launched into the orbit, boosts the Direct To Home (DTH) service covering all the national channels of the Indian Government and some of the private channels and more than thirty radio channels.

INSAT System for Educational Programme

Apart from entertaining people, the INSAT system helped to launch other useful programmes too. In the 1990s Educational TV (ETV) services were started. INSAT is being used to provide ETV service for primary-school children in Tamil,

Marathi, Oriya, Telugu and Hindi. A general enrichment programme on higher education (college sector) is telecasted on the national network. These are produced by the University Grants Commission (UGC) and are a part of its countrywide classroom programme. *Gyandarshan* is an exclusive Educational TV channel of India started in January 2000 by Indira Gandhi National Open University (IGNOU). Ministry of Human Resources Development and Prasar Bharathi requested the UGC, NCERT, Central Institute for Educational Technology, State Institute of Research and Training, and IGNOU to produce round-the-clock programmes. *Gyandarshan III* channel dedicated to technical education was started on 26 January 2006, for the benefit of the students of the prestigious Indian Institute of Technologies (IITs) pursuing studies in technology and engineering.

ISRO realised the necessity of modernising the education services. Hence, it decided to launch an exclusive educational satellite as part of ongoing INSAT series, and in 2004 EDUSAT was launched from SHAR. Primarily, EDUSAT programme has three phases. The first phase of the programme was a pilot project associated with Karnataka higher education. This programme was inaugurated before the launching of EDUSAT. The main beneficiary of the programme was Visveswaraiah Technological University, with hundred nodes in the network covering all its

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engineering colleges. In addition, EDUSAT pilot projects were taken up in Y B Chawan Open University in Maharashtra and Rajiv Gandhi Technical University in Madhya Pradesh. Under the second phase, a programme for Karnataka primary education sector under 'Sarva Shiksha Abhiyan' covering 885 primary schools has been made operational using the southern regional beam of EDUSAT. Networks for IGNOU, CEC/UGC, CIT/NCERT, AICTE and Department of Science and Technology have been set up using the national beam. Interactive networks for Kerala and Tamil Nadu are operational and extensively used for teacher training and other training programmes using regional beam. The operations of third phase is under way.

Radio Networking

Radio Networking (RN) through INSAT provides reliable high-fidelity programme channels for national as well as regional networking. At present 213 (AIR) stations have been equipped with S-band receive terminals and around 100 AIR stations upgraded with C-band terminals. A total of seventy-six RN channels are being up-linked at present. There are thirty-two RN channels operating in S-band and seven in C-band. Single channel captive uplink earth stations at thirteen major programme-producing centres (Srinager, Ahmadabad, Bhopal, Cattack, Patna, Guwahati, Shillong, Thiruvananthapuram, Hyderabad, Bangalore, Jaipur, Shimla and

\[16\] Space India, January- March, 2004, p.4.
\[17\] Countdown,
The captive earth station at Broadcasting House (BH), Mumbai, provides uplink of two Vividh Bharati channels. The earth station at BH, Delhi, has been augmented to provide uplink for seven RN carriers in CXS band. Twenty-three RN carriers are operating in INSAT-2C and nine RN carriers operating in INSAT-2B S-1 and S-2. Seven RN channels are uplinked from BH, Delhi, to operate with CXC transponder of INSAT-2B. These programmes are being received by sixteen major AIR stations (Mumbai, Guwahati, Hyderabad, Rajkot, Chennai, Bangalore SPT, Bangalore, Aligarh, Gorakhpur, Dharwad, Alleppey, Cuttack, Chinsurah, Nagpur, Ahmedabad, and Bhopal). Four transportable uplink terminals have been acquired by AIR for the coverage of events taking place at remote locations and for programmes fed live from the spot via INSAT. AIR has also acquired a DSNG RN terminal, which is capable of uplinking CD quality music channel from any remote location to a central place, such as Delhi. Recently AIR has launched twelve radio channels on DTH terminals in KU-band at Todapur, New Delhi. Efforts are under way to augment this to thirty channels.20

Telecommunications

Telecommunications is one of the first applications of space technology. Beginning with a passive relay of voice and video signals by a satellite, active repeaters in synchronous orbit offered 24-hours service in telecommunications from 1965.

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Rapid advances in microelectronics, satellite altitude control and deployable solar panels paved the way for transition from international to national or domestic application of the technology. As satellites became more and more sophisticated, simpler ground stations were found to be adequate to handle the signals. In addition to underground cable and terrestrial microwave systems, satellites offered a third medium of telecommunications with its advantages of diversity in a national network. The cost of connecting any place became independent of distance in a satellite system. Service over difficult terrain or water became possible and the time involved in laying ground links could be saved. The system was not affected by weather and maintenance hardly a problem. Above all, transportable earth stations became a reality.

In the field of telecommunications, space links offer definite advantages: flexibility in routing circuits, negligible sensitivity to terrain and natural disasters, cost-effective long-distance links, diversity of transmission media and enhanced reliability. The quality of long-distance subscriber dialling and after trunk, both within and outside the country, has considerably improved with the satellite medium.\(^{21}\) The remote areas are connected through the telecommunications network.

A total of 624 telecommunication terminals of various sizes and capabilities (excluding NICNET, RABMN and VSAT microterminals) are operating in INSAT

telecommunication network providing 10,070 two-way speech circuits, which is equivalent to over 492 routes. These include 89 for BSNL, 125 for government users and 27 for closed user group (CUG)/Very Small Aperture Terminal (VSAT) operators earth stations and 354 BSNL VSATs (239 multi channel per carrier (MCPC) VSATs, 53 High Speed VSAT Network (HVNET) terminals and 62 VSATs operating under the remote Area Business Management Network. A total of 25,000 CUG VSATs are operating through INSAT. Captive satellite-based networks for National Thermal Power Corporation (NTPC), Gas Authority of India Ltd (GAIL), Nuclear Power Corporation (NPC), Indian Telephone Industries (ITI), Oil and Natural Gas Commission (ONGC), National Fertilizers Limited (NFL) and Coal India Limited (CIL) are operational. A number of captive government networks are also working with INSAT. More organisations are in the process of implementing their own captive network using INSAT.

Mobile Communication

With the launch of INSAT-2C in December 1995 and INSAT-2D in June 1997, mobile satellite service (MSS) started in the Indian landmass and the adjoining maritime area. Space-based mobile links are different from radio telephones provided within limited areas (such as cities) for use by taxi operators, sales persons and others on the move. Again, radiopaging service is restricted to only alerting

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holders of receivers to brief incoming messages without two-way conversation. In contrast, satellite links will be operated from transportable terminals kept in vehicles or ships. Initially, this was a regional operation, which was later extended to international level.

The following three classes of services are provided. Class A consists of voice, data, and fax, including direct dial telephone links between mobile terminals and Public Switched Telephone Network (PSTN) subscribers and between one mobile terminal and another. Data and fax services are provided between mobile and PSTN subscribers. Group call service is also possible to a selected group of mobile terminals. Class B Service is a messaging service, wherein the hub-station stores and forwards messages between mobile terminals and the end-user, including another mobile terminal. Class C Service is called reporting — a one-way service from a mobile operator to an end-user. The hub-station acts as a store and forward unit. A B-band MSS was added to INSAT system with the launch of INSAT-3C in 2002 and GSAT-2 in 2003.24

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Telemedicine

Telemedicine is one of the unique applications of space technology for societal benefit. DoS Telemedicine Programme, which was started in 2001,\textsuperscript{25} is aimed at linking via INSAT remote/rural district hospitals in areas like Jammu and Kashmir, Ladakh, Andaman and Lakshdweep Islands, North Eastern States and some of the remote and tribal districts in the states of Kerala,\textsuperscript{26} Karnataka, Tamil Nadu, Chhatisgarh, Punjab, West Bengal, and Orissa with super-speciality hospitals in major cities.\textsuperscript{27} While DoS provides telemedicine systems—software, hardware and communication equipments as well as satellite bandwidth, the state governments and the speciality hospitals have to allocate funds for their part of infrastructure, workforce and maintenance. Technology development, standards and cost-effective systems have been evolved in association with various state governments, NGOs, speciality hospitals and industry. DoS interacts with state government and speciality hospitals for bringing an understanding between the parties through an MoU.\textsuperscript{28}

During 2005–2006, the telemedicine network has been further expanded to cover 152 hospitals – 120 remote/rural/district hospitals/health centres connected to 32 speciality hospitals located in major cities. A mobile health service vehicle

\begin{itemize}
  \item \textsuperscript{26} \textit{Countdown}, No.284, December, 2003, pp.2–3.
  \item \textsuperscript{28} A. K. Sangal, “Telemedicine”, \textit{SAC Courier}, vol.28, No.1, January, 2003, pp.6-7.
\end{itemize}
“DISHA” operated by private entrepreneur in the Madurai district of Tamil Nadu has also been provided telemedicine connectivity. An International Telemedicine Conference (INTEL – EMEDINDIA – 2005) was sponsored by DoS and others at Bangalore (presently Bengaluru) during March 2005. An outcome of this conference was the constitution of a National Task Force by the Ministry of Health and Family Welfare. The taskforce will work out various aspects of implementing telemedicine in the country. In September 2006 this project was expanded to four other hospitals, viz., Manipal Hospital, Bengaluru, Sir Ganga Ram Hospital, New Delhi, Madras Diabetic Research Foundation, Chennai, and Ambajogai (Maharashtra).

Meteorological Applications

Meteorology is the science of weather changes. It studies the changes in earth’s atmosphere: the change in wind, rainfall, pressure, humidity, etc. Under the British rule first meteorological observatory was established in Madras (presently Chennai) in 1972. Following this, meteorological observatories were founded in other parts of the country. In 1875 India Meteorological Department (IMD) was established in Calcutta. The headquarters of IMD was later shifted to Simla, then to Poona, and finally to New Delhi. In the initial period, ballons were used for various studies. However, in 1960, when Indian space programme was established, sounding rockets were used instead. The first sounding rocket Nike- Apache and the other

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30 Space India, April–September 2006. p.4.
31 Available at www.imd.ernet.in.
sounding rockets that were used to study the upper atmosphere. In the mean time, India received the first cloud picture by a ground station, in Mumbai from Television Infrared Observations Satellite VIII (TIROS VIII), a US satellite launched in 1963.\textsuperscript{32} The indigenous development of Rohini enabled the country to carry the meteorological payloads. Slightly bigger RH-200 were later used regularly to launch payloads up to 6 kg to a height of 60–90 kilometre to study the changes in temperature, humidity, and wind velocity at different heights of the atmosphere. In 1970 a programme to launch Russian sounding rockets on a regular basis was started to study the upper air circulation from the Arctic to the Antarctic known as M-100, the rockets went up to 90 kilometre, and during the descent of the payload (which was delayed by a parachute that opened at 65 kilometre) data were collected on the outside temperature, the state of the sea, and other parameters. The first-generation weather satellites operated by the United States used television cameras to take cloud pictures. Simple ground equipment installed in several countries including India was able to get the pictures in real-time during the satellites pass over them. It took about 30 minutes to record one picture. Later-generation satellites were able to store and relay data. Then came the use of sensors, which recorded data in infrared channels. It was possible to measure from satellites the temperature at different attitudes.\textsuperscript{33}


With the introduction of TIROS-N series in polar orbit in 1978, it was possible to get images at different visible and infrared wavelengths and data on the vertical distribution of temperature and humidity as a function of altitude. Once temperature and humidity are measured, the pressure at different levels could be inferred.³⁴

Low-orbiting, near-polar satellites do not, however, provide comprehensive data, as they cover the area once or twice a day. Short-term forecasts need more frequent observations. Even for long-term studies, the data are not enough. Another limitation related to the measurement of air movements, which are important for tropical areas. Knowledge of the pressure is not adequate to infer wind movements, because the relationship between the two is not strong near the equator. Some other means are therefore called for to study the air movements.³⁵

Geostationary satellites have constant field of vision and can therefore track the motion of clouds and indicate wind movements. Four of five geostationary satellites needed to cover all longitudes were provided under an international programme of the World Meteorological Organization.

³⁵ Mohan Sundara rajan, India in Orbit, p.149.
Indian weather experts became familiar with the use of cloud pictures received from American satellites and the weather data collected by Russian meteorological satellites both transmitted to Delhi. Tracking of cyclones became possible.

Although satellites provided data on some parameters of the weather, they could not measure the amount of rainfall or atmospheric pressure at the surface. A weather satellite can act as a data link receiving data from a variety of places and transmitting them to a ground station. Such facility has for the first time made data collection from remote and difficult areas cost-effective and technically feasible. The need for supplementing satellite data with ground-based information collected from a wide range of places including the oceans emphasised the need for a domestic satellite system.

Indian scientists gained valuable experience in designing and operating a microwave radiometer aboard the country's first experimental earth observation satellite, Bhaskara. It proved useful in deriving weather data such as atmospheric water content, horizontal moisture gradients, ocean surface winds and precipitation rates over oceans.36

When INSAT was designed, considerable importance was given to weather study. The system was designed to provide round-the-clock half-hourly synoptic

36 Ibid., pp.149–150.
images of the weather conditions including cyclones, sea-surface and cloud-top temperatures, water bodies and snow over the entire country and the adjoining sea areas. In addition, it was designed to collect and transmit meteorological, hydrological, and oceanographic data from unattended remote platforms. The system would provide timely warnings of cyclones, floods, and storms.

The very high resolution radiometer (VHRR) on the INSAT series provides weather information. It had a spatial resolution of 2.75 kilometre in the visible band and 11 kilometre in the infrared band. The radiometer in INSAT-2 gives a better performance: 2 kilometre in the visible and 8 kilometre in the infrared channels. The meteorological data of INSAT system is processed and disseminated by the INSAT meteorological data processing system (IMDPS) of IMD. Upper winds, sea surface temperature, and precipitation index data are regularly gathered. The products derived from the image data include: cloud motion vectors, sea surface temperature, outgoing long-wave radiation, and quantitative precipitation index. The products are used for weather forecasting: both synoptic and numerical weather prediction.\footnote{Government of India, Department of Space, Annual Report 2005-2006, (Bangalore: ISRO, 1998), p.22.}

INSAT-VHRR imageries are used by Doordarshan and newspapers for weather reporting as part of the news content. At present, repetitive and synoptic weather system observations over Indian Ocean from geostationary orbit are available only from INSAT system. INSAT-VHRR data are available in near real-time
at 90 Meteorological Data Dissemination Centres (MDDC) in various parts of the country. With the commissioning of direct satellite service for processed VHRR data, MDDC type of data can be provided at any location in the country. For quick dissemination of warnings against impending disaster from approaching cyclones, specially designed receivers have been installed at the vulnerable coastal areas in Andhra Pradesh, Tamil Nadu, Orissa, West Bengal, and Gujarat for direct transmission of warnings to the officials and public in general using broadcast capability of INSAT. IMD's Area Cyclone Warning Centres generate special warning bulletins and transmit them every hour in local languages to the affected areas. IMD has installed 350 such receiver stations. Out of these 100 are digital CWDS (DCWDS) based on advanced technology. The DCWDS has been deployed with acknowledgement transmitters to get conformation at transmitting station.38

Later renamed as KALPANA-1, METSAT was the first exclusive meteorological satellite, launched in 2002, in order to focus more on meteorology. As we know, the earlier meteorological programme was just one of the activities of INSAT. METSAT not only give adequate data related with meteorology but also paved the way for the launch of further meteorological satellites. It carries a VHRR capable of imaging the earth in the visible, thermal infrared and water vapour bands. It also carries data from unattended meteorological platforms.39

Satellite-Based Training and Developmental Communication Channel

Satellite-Based Training and Developmental Communication Channel using INSAT, which is operational since 1995, provides a unique one-way video and two-way audio system of interactive education where the teaching-end includes a simple studio and uplink terminal for transmitting live or pre-recorded lectures. A total of eight extended C-band channels – six on INSAT-3B and two on EDUSAT – are being used for the programme. The participants at the classrooms located nationwide receive lectures through dish antennas and have a facility to interact with during lectures using telephone lines. The teaching-ends are now available at Gujarat, Madhya Pradesh, Orissa, Karnataka, and Ahmedabad as well as at Goa University and Anna University. The direct receive system network consists of more than 4000 classrooms, spread across the country. Several state governments are using TDCC system extensively for distance education, rural development, women and children development, Panchayat Raj and industrial training.

Satellite News Gathering and Dissemination

Satellite newsgathering using INSAT system enables on-the-spot real-time news coverage. Prasar Bharati has twelve digital outdoor-broadcast DSNG terminals operating through INSAT network in C-band. Important events in different locations

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are transmitted to a central station at Delhi for rebroadcast over DD channels. Two Ku-bands DSNG terminals have been added by DD in INSAT network.42

Press Trust of India (PTI) is implementing a system to provide its news and information services at higher speed and increased volume and variety directly to a wider range of media and other users by utilising the broadcast facilities of INSAT-3C. The project utilise a RN type of channel on one of the broadcast (CXS) transponders of the satellite. PTI satellite news and facsimile dissemination project is working with fifteen terminals (fourteen from PTI and one shared with AIR).43

Satellite-Aided Search and Rescue (SAS&R)

India is a member of the international COSPAR-SARSAT programme to provide distress alert and position location service through Low-Earth Orbit Search and Rescue (LEOSAR) satellite system.44 Under this programme, India has established two Local User Terminals (LUTS), one at Lucknow and the other at Bengaluru. The Indian Mission Control Centre (INMCC) is located at ISTRAC, Bengaluru. In the beginning, INSAT-2A and INSAT-2B were equipped with 406 MHz Search and Rescue payload, and at present similar payload has been carried by INSAT-3A.45 It picks up and relays alert signals originating from the distress beacons

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of maritime, aviation, and land users. Indian LUTS provide coverage to a large part of Indian Ocean region rendering distress alert services. The search-and-rescue activities are carried out by the Coast Guard, Navy, and Air Force. INMCC is linked to the ROCs and other International Mission Control Centre (IMCCs) through automatic telex and aeronautical fixed telex communication network. The Indian LUTs and MCC provide service round the clock and maintain the database of all 406 MHz registered beacons equipped on Indian ships and aircraft.

The distress events supported by INMCC during the past years are as follows:

1. On 21 July 1998, INMCC picked up 406 MHz distress signal from Belize registered vessel MV Osool, which sank in Arabian Sea because of bad weather. INMCC transmitted message to RCC and Coast Guard of Mumbai, which coordinated the rescue operations and twenty crewmembers were rescued from nearby the ship MV Pratibha Godauni.46

2. On 19 January 2005, a private helicopter belonging to Hindustan Ink crashed at Vapi (Daman). Both the crewmembers were rescued.

3. On 18 May 2005, a Hong Kong vessel was drifting and later abandoned by the crew. The first alert was made through INMARSAT-C followed by COSPAS-SARSAT EPIRB activation. Twenty-one crewmembers were rescued. INSAT system detected the alert first with 98 minutes' time advantage compared to LEO system.47

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The management of India’s varied natural resources calls for a delicate balance between competing demands and protection of the fragile environment. In the present day context, this entails the maximum utilisation of existing natural resources to reduce regional imbalances, promote sustainable development and at the same time ensure the protection of the environment. This is the goal of the National Natural Resources Management System (NNRMS)—an integrated resources management system aimed at optimal utilisation of country’s natural resources by a proper and systematic inventory of the resource availability using remote sensing data in conjunction with conventional techniques. National Natural Resources Management System (NNRMS), under the aegis of DoS, is aimed at optimum utilisation of the country’s natural resources by systematic inventory using earth observation data in conjunction with conventional techniques. The selected themes of applications include: agriculture and soils, forestry and ecology, geology, land use/land cover, urban land use planning and development, ocean studies, water resources grassland mapping, and archaeology. Remote sensing data is used for several resources-survey and management applications. Application projects of national relevance are carried out with the involvement of user agencies both at central and state levels.
The remote sensing application projects at national, regional, and local levels are carried out through NRSA (Hyderabad), SAC (Ahmedabad), five RRSSCs located at Bengaluru, Dehradun, Jodhpur, Kharagpur, and Nagpur, and NE-SAC at Shillong. State and central government departments, state remote sensing centres and others are associated in these projects.

Agriculture and soils

India is predominantly an agriculture country, with about 80 percent of its people depending on agriculture. Hence remote sensing data are extremely useful for the country. In this connection pre-harvest Crop Acreage and Production Estimation (CAPE) is implemented for major crops using remote sensing data. CAPE, a scheme started during the seventh five-year plan, is a countrywide project funded by the Ministry of Agriculture and Cooperation and executed by DoS along with various State Remote Sensing Applications Centres, State Departments of Agriculture and Agricultural Universities. Achievements of CAPE include the evaluation of multi-date remote sensing data for crop identification, creation of a geo-referenced

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cadastral database for accurate evaluation, development of yield models using trend and weather data.49

Forecasting agricultural output using Space, Agro-meteorology and Land (FASAL) observation was initiated as a pilot programme in Orissa during Kharif 1998–99 for rice with the participation of Orissa Remote Sensing Applications Centre (ORSAC) and other concerned departments and Orissa University of Agriculture and Technology. Capitalising the experience of CAPE, efforts are on to institutionalise FASAL, which envisages phased implementation in collaboration with State Agricultural Statistical Agencies.50

Forestry and Ecology

The remote sensing applications for effective forest management on a more scientific basis is commensurate with the priorities set at state, district, and micro level studies. The shift in priority of forest management towards ecologically sustainable forest resources management calls for reliable spatial database with a provision to update and retrieve for management decisions at various levels. The spectral response of forests was studied in two different bio-geographical sites, one with heterogeneous and the other with homogeneous forest types. The former is in the middle Andaman Islands and the latter in the Central Tarai Forest Division in

Uttar Pradesh. The Middle Andaman forests include many types such as evergreen, moist deciduous and mangrove, while the Tarai includes eucalyptus and teak. Spectral values from LANDSAT TM, IRS LISS II and airborne radar (SAR-X band) data were studied. The results indicated that the spatial forest data can be used to estimate the density, area, volume, and leaf area index that are related to biomass and productivity.\(^{51}\)

At the behest of Department of Biotechnology, a project to prioritise biologically rich areas in North-Eastern region, Western ghats and Western Himalayas has been taken up. The project envisages characterising biodiversity at landscape level using remote sensing data and geographic information system on various ecological parameters like forest fragmentation, priority, patchiness, juxtaposition, interspersion, and so on. Prospecting of these regions will be based on the sum of all these parameters. In phase-I of the project, vegetation mapping in digital form was prepared on 1:250,000 scale using IRS data. The methodology has been developed based on pilot studies in Meghalaya and Madhya Pradesh. Besides these, remote sensing data are helpful in forest volume estimation and generation of volume tables, stock fables preparation and yield calculation as well as ecological consideration and zonation of forests, remote sensing and biodiversity studies, forestry conversion studies, forest fire damage and GIS applications in forestry.\(^{52}\)

\(^{51}\) Mohan Sundara rajan, *India in Orbit*, p.164.
Waste Land Mapping

India, with a land spread of 328 MHa, is the seventh largest country in the world.\textsuperscript{53} It is also the second most populous country, accounting for more than a billion people, with a decadal growth rate of 21.56 percent. It is tropical in climate and monsoon dependent for its agricultural water requirements. It has gross cropped area of about 195 MHa with an average net sown area of 145 MHa.\textsuperscript{54} India’s ever growing population is exerting enormous pressure on the per capita arable land availability. There is an increasing demand for land for both agricultural and non-agricultural use. This results in the creation of sizeable stretches of land that are not suitable for further agricultural use or offer uneconomical agricultural returns. It also reduces per capita cultivable land, besides causing ecological imbalances. These wastelands suffer on account of land degradation, soil salinity, water logging, desertification, soil erosion and so on.

The need to have a dependable base line information about wastelands has been long felt. Accurate statistical information and consolidated maps on any scale, showing geographical location and spatial distribution pattern of wastelands are not available. Such information could empower the planners and decision-makers in preparing various programs for reclamation, management, and development of all

\textsuperscript{53} India 2002: A Reference Annual, p.1.  
\textsuperscript{54} Updates@nrsa, October, 2005, Vol.2, Issue.4, p.6.
such lands, mainly for afforestation, pasture development and to meet fuel and fodder demands.

Initially, mapping the wastelands of the country was conceived as an in-house study of NRSA in order to demonstrate the capabilities of remote sensing for mapping and monitoring of wastelands within the shortest possible time. A standard classification was evolved and state-wise maps were prepared on 1:1m scale for the entire country in 1985. This study had enabled prioritisation of 182 critically affected districts (wastelands exceed more than 15 percent of total district area). A 13-Category Wastelands Classification was adopted to represent the areas under different wastelands. Based on this classification, the whole country was mapped on 1:50,000 scale under different phases (phase I to V, during 1986–2000). The study was sponsored by the Department of Land Resources, Ministry of Rural Development (MRD). About 63.87 MHa, equivalent to 20.17 percent of total geographical area of India, was estimated as wastelands in this exercise. Subsequently, the MRD requested NRSA to update these maps by using one-time data sets, preferably for the year 2002–03. NRSA continues to concentrate on wasteland mapping covering 192 districts of India. All the maps prepared are available in digital format with visual interpretation of IRS LISS-III data.55

In the present mapping, wasteland datasets have been organised into different geospatial layers namely base, village, wasteland, and watershed. The present wasteland map provides necessary impetus for wasteland reclamation by user-communities like district-level administrators, planners, decision-makers, rural development agency officials, line department officials, NGO and so on.56

Ocean Studies

Remote sensing has been used for marine applications under the Marine Remote Sensing Information Services (MARSIS) programme of Department of Ocean Development (DOD). The study of oceans was gaining importance, as this was particularly useful for the study of monsoons as well as ocean biology. US NOAA satellite data are used for the retrieval of Sea Surface Temperatures (SSTs).57 Subsequently, ISRO launched IRS-P4 popularly known as Oceansat – 1 in 1999, specifically created to physical and biological oceanographic studies.58 The satellite has two main sensors on board – the ocean colour monitor (OCM) and the multi-frequency scanning microwave radiometer (MSMR), the former with a higher resolution and receptivity of two days.59

56 Updates@nrsa, Loc. cit.
The main applications are to monitor and indicate potential fishing zones in castle waters and to explore deep-sea fishery resources. In the initial days potential fishing zones were sea surface temperature data. Further it provides information on sediment dynamics, shoreline change, marine pollution, oil slicks and coral reefs. The MSMR sensor also provides information on monsoons and help in understanding meteorological conditions. This data usage is coordinated with the National Institute of Oceanography in Goa.

Drinking Water

In India, rivers and ground water are the main sources of drinking water. Though India is networked with a good number of rivers, over-exploitation of the existing reserves of water and unplanned usage has led to the problem of water shortage. About thirty percent of the inhabitants of India living without access to drinking water. In this scenario, finding ground water sources for planning sustainable drinking water schemes assumes great significance. The presence and movement of ground water is controlled by the lithology, structure, geomorphology, and recharge conditions of the area. Satellite remote sensing presents an efficient and cost-effective solution for studying these features.


\[\text{61 Space Flight, Loc.cit.}\]
Funds are being provided for provisions of drinking water facility in the state budgets right from the first five-year-plan period. The Accelerated Rural Water Supply Programme (ARWSP) was introduced in 1972–73 by the Government of India, to assist the states and union territories to accelerate the pace of the coverage of drinking water supply. The Technology Mission, also called the National Drinking Water Mission (NDWM), on drinking water and related water management was launched in 1986. The NDWM was renamed Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1991. NRSA took up RGNDWM in January 1999. Supported by the Department of Drinking Water Supply of the Ministry of Rural Development, the Mission was proposed with two major objectives. Preparation of ground water prospects maps would be done to locate ground water zones for prioritising sites for planning recharge structures. A database would be created which would facilitate easy updating, editing, archival, data integration, analysis, and generation of derivative maps. This would also serve as an excellent data bank for all ground water studies and related application.

The ground water maps contain information on different rock types that occur in the area and various landforms that represent the terrain and also hydrological details like stream courses, canals, water bodies, tank, and canal irrigated areas and ground water irrigated areas. The maps provide comprehensive information

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63 Available at www.rajivgandhidrinkingwatermission/htm.
on ground water prospects indicating depth to water level, nature of aquifer, type of wells, suitable depth, range of wells, suggested and expected yield range, success rate of wells, quality of water, type of recharge structures suitable and priority for recharge etc. Tentative locations for planning different types of recharge structures are also indicated. This mission is being operated under different phases throughout the country.

Snow and Glacier Investigations

Glaciers are normally described as a mass of ice crystal, water, and rock debris. Out of this, ice is the essential part of the glacier. In the Himalayas, the glaciers cover approximately 33,000 sq. kilometre area, and this is one of the largest concentrations of glacier-stored water outside the polar regions. Glaciers are emerging as first measurable indicators of global warming. Study of snow and glaciers is facilitated by data from IRS satellites. In addition, during northern hemispherical winter, snow covers large area in the Himalayas. Melted water from the seasonal snow and glaciers formed an important source in the North Indian rivers during critical summer months. Since Himalayas have very rugged terrain, conventional methods are difficult to use. Remote sensing is useful to collect information on various aspects of snow and glacial studies such as glacier inventory, glacial mass balance, advance and retreat of glaciers, mapping and modelling of crevasses, marine dammed glacier lakes.

64 updates@nrsa, April 2004, Vol.1, Issue-2, p.7.
mapping of seasonal snow cover, snow pack characteristics, potential sites for avalanches and snow-glacier run-off modelling.66

IRS-WIFS data has been extensively used for assessing accumulation and ablation of seasonal snow in parts of Jammu and Kashmir. Weekly snow cover monitoring from 1996–97 has established changing snow accumulation and ablation pattern in the region. The study has shown that accumulation of snow in early winter is substantially lower in 1998–99 (18 percent) as compared to normal years (60 percent). In 1998, by December end, the region up to 3800 metre was completely devoid of snow and snowmelt was observed up to 5000 metre altitude.67

Remote sensing technique has been extensively used to map various glacial features as glacier boundary, accumulation area, ablation area, equilibrium line and marine-dammed lakes. A glacier inventory of Indian Himalayas was carried out on 1:250,000 scale using satellite images. During the investigation, 1702 glaciers covering an area of 2330 sq. kilometre were mapped. Glacier inventory of 1:50,000 scales were carried out in the Sutlej and Beas basins. The study indicated the presence of 334 glaciers and 1987 permanent snowfields in the Sutlej basin covering an area of 2697 sq. kilometre.68

67 Mohan Sundara rajan, India in Orbit, p.165.
Archaeological Applications

Satellite archaeology is based on the study of geometric patterns of soil and vegetation marks, palaeo-channels, palaeo-mudflats, and trendlines. Analysis of IRS LISS-III and IV data in conjunction with collateral information has indicated an unexplored archaeological site. With the help of available satellite data, field study has indicated presence of pottery, bones, stonewall, and trench. In the mid-1990s several field studies were conducted at Junagadh in Gujarat and on the banks of mythical River Saraswati. In the recent past archaeological survey was undertaken at Kutch district and North Gujarat. In this exploration, ancient pottery, copper coins, millstones, skull, etc. were unearthed. Similarly, the same satellite data were extremely useful for this work, which held across the country.

National Geographic Information System

National Geographic Information System (NGIS) is a major initiative of organising the image and spatial data assets and make them accessible to users – for both viewing and physical access. National-level spatial layers on various themes such as land use, land cover, soils, drainage, water bodies, wasteland and vegetation type, besides administrative boundaries at different levels, settlements, transport network, etc., have been organised. NGIS has been formally released in April, 2005.

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RESOURCESAT-I AWIFS-based image base has been used in this effort. Planning Commission is intending to use this database for natural resources management.71

Natural Disaster Management

India is a large country and prone to a number of natural calamities. Among all the natural disasters that the country faces, river floods are the most frequent and often devastating. The shortfalls in the rainfall cause droughts or drought-like situation in various parts of the country. The country has faced some severe earthquakes causing widespread damage to the life and property. India has a coastline of about 8000 kilometre, which is prone to very severe cyclonic formations in the Arabian Sea and Bay of Bengal. Another major problem faced by the country is in the form of landslides and avalanches. With an increase in the perception towards spreading a culture of prevention in the disaster management scenario, considerable emphasis is now being placed on research and development activities in the area of information technology for disaster preparedness and prevention. This has brought in a significant positive change even though the multitude and frequency of disasters in the country has increased; remote sensing, on the other hand, as a tool can very effectively contribute towards the identification of hazardous areas, monitor the

Remote sensing makes observation of any object from a distance and without coming into actual contact. Remote sensing can gather data much faster than ground-based observation and can cover large area at one time to give a synoptic view. Remote sensing comprises aerial remote sensing, which is the process of recording information such as photographs and images using sensors on aircrafts, and satellite remote sensing, which consists of several satellite remote sensing systems which can be used to integrate natural hazard assessments into development planning studies.

Disaster Management Support

The Disaster Management Support (DMS) programme of DoS addresses information requirements of the user community by utilising space-based data. With a synergistic use of remote sensing and communication capabilities of the Indian satellites, several support services are being provided in the event of disasters. DMS programme includes (i) creation of digital database for facilitating hazard zonation and damage assessment, (ii) monitoring major natural disaster using satellite and aerial data and development of appropriate techniques and tools, (iii) acquisition of close contour data for hazard-prone areas using air-borne Laser Terrain Mapper, (iv)

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strengthening the communication backbone for timely dissemination of information and emergency support, (v) development of Air-borne Synthetic Aperture Radar (ASAR) towards all-weather monitoring capability,\textsuperscript{73} (vi) establishment of a Decision Support Centre (DSC) at NRSA as a single-window service provider and (vii) supporting the International Charter on Space and Major Disasters, as a signatory to the charter.\textsuperscript{74}

This chapter concludes with some of the applications of geographic information system and remote sensing in various disasters.

1. \textit{Drought}: GIS and remote sensing can be used in drought relief management such as early warnings of drought conditions to help plan out strategies to organise relief work. Satellite data may be used to target potential ground water sites for taking up well-digging programmes. Satellite data provides valuable tools for evaluation areas subject to desertification. Film transparencies, photographs, and digital data can be used for the purpose of locating, assessing, and monitoring deterioration of natural conditions in a given area.\textsuperscript{75}

2. \textit{Earthquake}: GIS and remote sensing can be used in preparing seismic hazards maps in order to assess the exact nature of risks.

\textsuperscript{73} Updates@nrsa, Vol.1, Issue.1, January 2004, p.4.
3. **Floods**: Satellite data can be effectively used for mapping and monitoring flood in undated areas, flood damage assessment, flood hazard zoning and post-flood survey of river configuration and protection.76

4. **Landslides**: Landslide zonation map comprises a map demarcating the stretches or area of varying degree of anticipated slope stability or instability. The map has an in-built element of forecasting and hence is of probabilistic nature. Depending upon the methodology adopted and the comprehensiveness of the input data used, a landslide hazard zonation map can provide help about the location, extent of the slope area likely to be affected, and rate of mass movement of the slope mass.

76 Updates@nrsa, *Loc.cit.*