Remote Sensing Satellites and Sensors

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1. Introduction

Remote sensing is a multi-disciplinary activity which deals with the inventory, monitoring and assessment of natural resources through the analysis of data obtained by observations from a remote platform. It is the science/technology of making inferences about material objects from measurements made at a distance without coming into physical contact with the object under study. When viewed in this context, remote sensing covers various disciplines from astronomy to laboratory testing of materials. However, remote sensing is currently used more commonly to denote identification of earth features by detecting the characteristic electromagnetic radiation that is reflected, emitted or scattered by the earth surface. Electromagnetic radiation extending from the ultraviolet to the far infra-red and microwave regions provides the greatest potential in the context of earth resources survey. For collection of remotely sensed data the first requirements are a platform and a sensor.

2. Platforms in remote sensing

There are three main categories of platforms namely ground borne, air borne and space borne. Cherry arm configuration of remote sensing van and tripod are the two commonly used ground borne devices. These have the capability to view the object from different angles. Air borne platforms can further be classified into balloon based and aircraft based ones. Aircrafts are commonly used as remote sensing platforms for obtaining photographs. In India, four types of aircrafts are currently used for remote sensing operations:

Dakota: The service ceiling height is 5.6 km to 6.2 km, minimum speed is 240 km/hr.

Avro: Ceiling height is 7.8 km, minimum speed is 240 km/hr.

Cessna: Ceiling height is 9 km, minimum speed is 350 km/hr.

Canberra: Ceiling height is 14 km, minimum speed is 560 km/hr.

Special aircrafts used abroad for remote sensing are:

U-2: Ceiling height is 21 km (for strategic photography), minimum speed is 798 km/hr. Rockwel x-15 (Research craft): Ceiling height is 108 km, speed is 6620 km/hr.

Platforms in space are not affected by atmosphere and hence the orbits can be defined. Entire earth or any part of earth can be covered at specific intervals. The mode can be geostationary permitting continuous sensing of a portion of the earth or sun synchronous with polar orbit covering the entire earth at the same equator crossing the local time. The ceiling heights of the space borne platforms of different series of satellites vary between 220 km in case of shuttle to 36,000 km for geostationary.

3. Techniques in remote sensing

Remote sensing techniques have been effectively utilized by various thematic specialists and planners to obtain real time data and information concerning the areas, prevailing conditions etc. In the past, such work has been done largely upon aerial photographs. With the advent of space technology the potential for obtaining needed information on various themes and other resources throughout the world has substantially increased. No doubt that the remote sensing data is gaining wider acceptance and appreciation in various resources management surveys in India due to the inherent advantages offered by the technology. In a vast country like India, "time" is a major element to survey, explore or make a status report for natural resources. The advent of remote sensing techniques at this juncture tenders more usage in view of cost effectiveness, time limit and inaccessible area since conventional methods sacrifice the above factors. However, the last decade has seen the emergence of a second generation of remote sensing satellites such as ERS -1 European Resource Satellite, devoted mostly to oceanography, and the Japanese Marine Observation Satellite (MOS) programme for Earth and Oceanography monitoring, and Indian Remote Sensing

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IRS-I series of satellites with a multipurpose mission. But in terms of remote sensing data, American LANDSAT and the French SPOT vehicles deserve to be mentioned.

On July 23, 1972, the first Earth Resources Technology Satellite, now called as LANDSAT, was launched. The satellite's prime remote sensing devices were the TV type cameras operating in three separate visible wavelength bands and an optical multispectral scanning system providing four wavelength bands of information in the visible and near infrared portion of the spectrum. The satellite operates in a polar orbit about 912 kilometers above the earth and circles the earth every 103 minutes completing 14 orbits a day with repetitive coverage of 18 days. LANDSAT 4/5 fly on their nominal orbital altitude of 705 km and both equatorial crossing time and cycle repetitive coverage are maintained at 9.45 hour and 16 days respectively. LANDSAT-MSS was carried by all the five LANDSAT satellites and it has a cross track scanning system . LANDSAT TM which is also a cross track scanner is similar to MSS with a bi-directional oscillating scan mirrors and arrays of detectors. Some of the improvements of LANDSAT-TM over LANDSAT-MSS are seven spectral bands and extended spectral range in the visible and reflected IR region, improved detector sensitivity and radiometric resolution and also presence of thermal IR band with 120 m resolution.

The French satellite SPOT is an advanced satellite technology having push broom of scanners and off nadir viewing capabilities. SPOT employs High Resolution Visible (HRV) imaging system with 20 m MSS mode and 10 m panchromatic mode of spatial resolution. The multispectral mode records green, red and reflected infrared images. The ground swath is 60 km wide. SPOT employs two HRV systems with a total width of 117 km including 3 km sidelap. SPOT satellite is capable of imaging the same area from several orbits during its repetitive coverage of 26 days and it is generally 7 times at the equator and 11 times at latitude 45 degrees. This is possible due to tilting of the mirror upto 27 degrees on either side in 45 steps each of 0.6 degrees to obtain image strips at distances upto 475 km away from the nadir.

The advantages of satellite remote sensing have so far been harnessed for survey and mapping and it is now being explored for monitoring natural resources on real-time basis. The unique capability of remote sensing technology is mainly due to a wide range of information available from electromagnetic spectrum, synoptic view, frequent repitivity, multispectral mode of data coupled with real-time data acquisition and dissemination. In view of these added advantages, the technology becomes an inevitable tool in the sustainable development and utilization of our natural resources.

4. The Indian Scenario

The Remote Sensing programme was initiated in India in the year 1970 when aerial surveys were conducted using a Hasselblad camera to obtain infra-red imagery to study coconut wilt disease in Kerala. Indian space scientists took advantage of LANDSAT system which was made available by the US, and developed ground stations and analysis facilities to make full use of data from these satellites. Before venturing on our own operational remote sensing satellite system, like Indian Remote Sensing satellite (IRS), ISRO embarked on two experimental remote sensing missions, viz. Aryabhatta and Bhaskara.

Aryabhatta was the first experimental satellite that was successfully launched in April 1975 in an approximate 600 km orbit above the earth, with the help of Soviet intercosmos rocket. The orbit was inclined at about 50 degree to the polar axis. It provided the opportunity to set-up ground based receiving, transmitting and tracking systems. This satellite functioned for six years providing confidence in indigenous design and fabrication of space worthy satellites, and also to evolve the methodology of conducting a series of complex operations.

Bhaskara-I satellite was launched with Soviet help on June 7, 1979, mainly as an earth observation experiment to collect, process, analyse and disseminate data on Hydrology, Forestry, Geology using two television cameras. Its life was for one year.

Bhaskara -II was launched on November 20, 1981 with Soviet assistance. It was a non-sunsynchronous satellite. The data over a particular region was not acquired at the same local time in repeated orbits, thus resulting in a wide variation in the solar illumination angle. This introduced radiometric variations which posed difficulties in the analysis and utilization of multitemporal data. At the end of two years this satellite had completed 11,000 orbits around the earth.

The Bhaskara -III TV payload system consisted of two TV cameras with one operating in the 0.54 to 0.66 micrometer band. Each picture frame covered an area of 340 km X 340 km with a ground resolution of 1 km and a typical overlap of 10 percent between successive picture frames. Though the Bhaskara TV payload capabilities were very coarse compared to the remote sensing satellites available at that time, Bhaskara programme gave tremendous experience in organizing space based remote sensing system.

Remote Sensing Satellite IRS-IA was launched on March 17, 1988 from Baikanur cosmodrome in then USSR. This 975 kg satellite circles the globe at an altitude of 904 km in a polar sun-synchronous orbit, crosses the equator at 10:25 hrs local time and returns to its original orbital trace every 22 days enabling repetitive collection of data over the same area at the same local time. Whenever it passes over India, the satellite images about 148 km wide strip of the country in the so called push broom mode. As the orbit period of IRS-IA is 103 minutes, the satellite completes 14 orbits in a day. The satellite path over India shifts 1.17 degrees of longitude to the west everyday for the satellite to cover the entire Indian subcontinent. After conducting a series of application projects, the best spectral bands to discriminate different classes were found as similar to the first four spectral bands of Thematic Mapper. Various combinations of the bands mentioned below (which were adopted in LISS-I and LISS-II cameras of IRS) provide information for specific themes.

Band I - (0.45 -0.52 micrometer): A strong relationship exists between spectral reflectance in this region and plant pigment. Comparatively higher penetration in water is found. This band is useful for mapping suspended sediments/water quality and various studies related to coastal region.

Band 2 - (0.52 - 0.59 micrometer): It is useful for vegetable discrimination and allows study of senescence rate of leaves. It is also sensitive to iron oxides.

Band 3 - (0.62 - 0.68 micrometer): It is centered around the chlorophyll absorption band of vegetation and useful for identification of plant species.

Band 4 - (0.77 - 0.86 micrometer): Shows high reflectance for healthy vegetation and is useful for green biomass estimation, crop vigor studies etc. Water absorption in this region clearly demarcates land and water boundary.

The second-generation remote sensing satellites are IRS-IC and IRS-ID. IRS-IC was successfully launched on December 7, 1995 and put into polar sun-synchronous orbit at an altitude of 817 km. The most important improvements are that it can have a revisit capability of five days, a high resolution panchromatic camera system giving resolution of around 5.8 m. Apart from improving the spatial and temporal resolution, off-nadir viewing helps a revisit frequency of 5 days which can provide stereo images. A payload steering mechanism supports and rotates the pan camera to a predetermined angle in the pitch-yaw plane with the maximum scan range being $\pm$ 26. This corresponds to an off nadir coverage of $\pm$ 398 km on the ground.

The Wide Field Sensor (WIFS), with a ground swath of 770 km and resolution of 188m, enables the dynamic monitoring of natural resources and observes the same region once in every five days. It has red bands, which are useful in generating vegetation indices.

IRS-1C has an onboard recorder so that data from any part of the world can be acquired, recorded and played back/ downloaded to earth receiving station. In view of its capabilities, an agreement by ISRO and counterpart in the US for receiving Indian Satellite data was made for the coming decade, which is going to economically benefit India in billions of dollars.

With the successful launch of PSLV-D3 on March 21, 1996 from Sriharikota range (SHAR)~ AP, ISR-P2, a 922 kg remote sensing satellite was put in to a 817 km polar sun-synchronous orbit with equatorial crossing at 10:30 hrs. This satellite has similar LISS-II cameras as that of IRS-IA & IB, orbits at 817 km with a revisit capability of once in 24 days.

IRS-P2 has two remote sensing payloads and a payload for X-ray astronomy. The WIFS payload is similar to that of IRS-IC but with an additional SWIR (short wave infrared) band. This band is sensitive to moisture content in vegetation, provides data for crop condition assessment and has applications like snow and cloud cover differentiation, snow-melt run off studies, flood damage assessment and geology.

The IRS-P3 remote sensing payload is a Modular Opto-electronic Scanner (MOS) of the German space agency DLR. MOS has eighteen spectral bands. Data from this is primarily used in ocean related studies, chlorophyll mapping for biomass estimation, coastal water discrimination, sediment transport and ocean dynamics.

5. The expectations ahead

Thus, Remote Sensing has now become a very important subject for the Indian scientists, especially for the ISRO personnel. The Department of Space, being the nodal agency under the National Natural Resource Management System (NNRMS) programme, has set up a chain of Regional Remote Sensing Centres all over the country to provide the facilities to the user organizations for digital analysis of remotely sensed data for various application missions and projects. These centers assist in survey, management and planning of natural resources using techniques of digital processing of remotely sensed data. They can also provide assistance in processing satellite data for extracting information on crop growth, availability of surface and ground water, detection and monitoring of floods, draughts, forest fires, crop diseases and mapping and preparing inventory of diverse natural resources such as forest, agriculture, soil geology, marine resources etc.

Fruits of Remote Sensing Application are to reach the mass at large. Steps must be taken in this direction. Obviously the 'Integrated Mission for Sustainable Development (IMSD)' stands as a pioneer in this goal. Development of Natural Resources Information System (NRIS) is a pre-requisite towards achieving the objective. The database requires to be updated regularly at suitable intervals. With the launch of a series of Indian Remote Sensing satellites, the cost of development and sustenance of NRIS is expected to be within the means. The outputs of the mission projects like Country-wide Forest Mapping, Wasteland Mapping, Drinking Water Mission, Nation-wide Land Use/ Land Cover Mapping, Crop Acreage and Production Estimation, IMSD and scores of other users' projects are to serve as data base for NRIS. This must lead to optimum utilization of natural resources of the country.

Data source: ISRO, Department of Space, Govt. of India.

Education is an ornament in prosperity
and a refuge in diversity.

— Aristotle