IRS Satellites: History, Characteristics and Applications

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ABSTRACT *Indian Earth Observation Satellite programme, since its commencement is focused on societal benefits and its ultimate objective is sustainable development. To address this goal it is applications driven and within a limited time period the applications have significantly diversified. The Department of Space (DOS) to achieve its primary objective of promoting development and application of space science and technology to assist in all-round development of the nation started the two major satellite series - INSAT and IRS. The information derived from remotely sensed data is an essential component of the National Natural Resources Management System (NNRMS). The Indian Remote Sensing (IRS) satellite program is to support national and sub national economies in the areas of agriculture, soils, water resources (surface and ground), forestry and ecology, geology and mineral resources, cartography, rural and urban development, marine fisheries, watershed management and coastal management. The objectives of the present paper are – (i) to discuss the evolution of IRS satellites; (ii) to describe characteristics of IRS satellites sensors and (ii) to highlight the applications of remotely sensed data acquired by IRS series of satellites.*

Keywords: *IRS, Resources, Applications, Satellite, Sensor*

1. History of IRS Satellites:

Since inception, The Department of Space (DOS) has the vision to harness space technology for national development, while pursuing space science research and planetary exploration. To actualize this vision the DOS has evolved and focused on four distinct fields – (i) to develop indigenous capability for launching vehicles and the development and operationalisation of Polar Satellite Launch Vehicle (PSLV) and development of Geo-synchronous Satellite Launch Vehicle (GSLV) are significant achievements in this field; (ii) the multi-purpose Indian National Satellite (INSAT) programme for the telecommunication, broadcasting, development of education and meteorology etc; (iii) the Indian Remote Sensing Satellite (IRS) programme for observation of earth surface features for various developmental purposes, and (iv) Research, Training and advancement in Space Sciences and Technologies for better acquisition and processing of remotely sensed digital data and to convert it into information for the socio-economic benefit of the country.

India's first indigenously designed and developed experimental satellite the Aryabhata (named after the famous ancient astronomer and mathematician) was successfully launched by a Soviet Kosmos-3M rocket on April 19, 1975 from Kapustin Yar. Starting from Bhaskara-I, the First Experimental Earth Observation Remote Sensing Satellite built in India and launched from Vostok, Russia (former USSR), in 1979 to the latest Cartosat 2 Series satellite launched (by indigenous launch vehicle PSLV) in 2018 a variety of sensors are operating in visible, infrared, thermal and microwave spectral regions, including hyper-spectral sensors to acquire digital data at spatial resolutions ranging from 1 km to a meter have been built and launched indigenously along with satellites of developed nations. Indian Space Research Organisation (ISRO) on 15 February 2017 in a single launch successfully fixed 104 satellites in orbits; out of these 3 satellites were Indian and rest were of the developed countries mainly the USA. Within a limited time period indigenous PSLV and GSLV have established huge number of IRS and INSAT series satellites in orbits. The facilities to receive and process the remotely sensed data have been established in different parts of India along with various international ground stations. The focus of the present article is the Indian Remote Sensing Satellite (IRS) series along with sensor characteristics and applications.

In the early experimental phase, Bhaskara-1(June 7, 1979) and Bhaskara-2 (November 20, 1981) provided data for land applications on the basis of two types of sensor systems – (i) television camera with spatial resolution of 1 km operated in visible and near infrared bands and (ii) Satellite Microwave Radiometer (SAMIR) for oceanic and atmospheric applications. Following the success of this experimental phase, India initiated an indigenous Indian Remote Sensing Satellite (IRS) programme to support national and sub national economies in the areas of agriculture, soils, water resources (surface and ground), forestry and ecology, geology and mineral resources, cartography, rural and urban development, marine fisheries, watershed and coastal management.

The IRS-1A was launched as first indigenous trendsetting operational remote sensing satellite on March 17, 1988 into a Sun-synchronous Polar Orbit (SSPO) by Vostok launch vehicle from Baikonur, former USSR. It was followed by the IRS-1B, an identical satellite, launched by same vehicle and from the same place on August 29, 1991. The IRS-1A/1B satellite sensors Linear Imaging Self-Scanning (LISS-I and LISS-II) operated in visible and near-infrared (NIR) bands with spatial resolutions of 72.5 m and 36.25 m respectively. IRS-P2 satellite was launched (after the failure of IRS-P1 mission on September 20, 1993) by indigenous launch vehicle PSLV-D2 (P series is named after PSLV) on October 15, 1994 with only LISS-II sensor. LISS-I and LISS-II sensors provided useful data for applications in the fields of land use land cover mapping, agriculture, forestry, hydrology, pedology, oceanography, geology, natural resource management, disaster monitoring, and cartography. To further improve the quality of data IRS-1C and 1D, identical satellites, were launched with three sensors – LISS-III, PAN (panchromatic) camera and a Wide Field Sensor (WiFS) with spatial resolutions of 23.5 m, 5.8 m and 188 m, respectively. In addition to fulfilling the general requirements, theme based IRS missions, for applications like natural resource management (RESOURCESAT series and RISAT series), ocean and atmospheric studies (OCEANSAT series, Megha-Tropiques and SARAL) and large scale mapping i.e. detailed mapping applications (CARTOSAT series) have been introduced and well established (Table 1).

Table 1. History of Indian Remote Sensing (IRS) Satellites and Major Applications

Sl. No.	Name	Launch Date	Status	Applications
1	IRS-1A	17 March 1988	Mission Completed in 1992	Land Use Land Cover Mapping, Agriculture, Forestry, Hydrology, Soil Classification, Coastal Wetland Mapping, Natural Resources (especially identification of potential groundwater locations), Disaster Monitoring, Cartography, etc.
2	IRS-1B	29 August 1991	Mission Completed in 2001	
3	IRS-P1 (also IE)	20 September 1993	Crashed, due to launch failure of PSLV	Mission Failed
4	IRS-P2	15 October 1994	Mission Completed in 1997	Land, Oceanographic and Atmospheric applications
5	IRS-P3	21 March 1996	Mission Completed in 2004	Technology Evaluation and Scientific Methodology Studies
6	IRS-1C	28 December 1995	Mission Completed in 2007	Land and water resources management. Applications in forestry, agriculture, environment, soil characteristics, wasteland identification, flood and drought monitoring, ocean resource development, mineral exploration, land use and monitoring of underground and surface water resources.
7	IRS 1D	29 September 1997	Mission Completed in 2010	
8	IRS-P4 (Oceansat-1)	27 May 1999	Mission Completed in 2010	Ocean- and atmosphere-related applications
9	Technology Experiment Satellite (TES)	22 October 2001	Mission Completed	Experimental satellite to demonstrate and validate the technologies
10	IRS P6 (Resourcesat-1)	17 October 2003	In Service	Integrated land and water resources management
11	IRS P5 (Cartosat 1)	5 May 2005	In Service	First Indian Satellite (IRS P5) designed with capability to have stereo images;

12	IRS P7 (Cartosat 2)	10 January 2007	In Service	Digital Elevation Model (DEM); Geo-engineering (mapping) applications
13	Cartosat 2A	28 April 2008	In Service	
14	IMS 1	28 April 2008	In Service	To provide remotely sensed data to students and scientists in developing counties, previously it was referred as TWsat (Third World satellite)
15	Oceansat-2	23 September 2009	In Service	Ocean- and atmosphere-related applications
16	Cartosat-2B	12 July 2010	In Service	Geo-engineering (mapping) applications
17	Resourcesat -2	20 April 2011	In Service	Integrated land and water resources management
18	Megha-Tropiques	12 October 2011	In Service	To understand the tropical weather and climate and associated energy and moisture budget of the atmosphere in tropical regions.
19	RISAT-1	26 April 2012	In Service	In agriculture, especially paddy monitoring in kharif season (sensor has cloud penetration and day-night image capability) and management of natural disasters like flood and cyclone.
20	SARAL	25 Feb 2013	In Service	Marine meteorology and sea state forecasting; Seasonal forecasting; Climate monitoring and research; Continental ice studies; Protection of biodiversity; Management and protection of marine ecosystem
21	Resourcesat -2A	07 Dec 2016	In Service	Integrated land and water resources management
22	Cartosat-2D	15 Feb 2017	In Service	Cartographic applications, urban and rural applications, coastal land use and regulation, utility management like road network monitoring, water distribution and creation of land use maps. Change detection to bring out geographical and manmade features and various other Land Information System (LIS) as well as Geographical Information System (GIS) applications.
23	Cartosat-2E	23 June 2017	In Service	
24	Cartosat-2 F	Jan 12, 2018	In service	

Source: Data compiled by Author from Indian Space Research Organisation, Department of Space.

2. Characteristics of IRS Satellites:

The quality of data acquired by earth surface observation satellites depends on the sensors used in the satellites. The four major characteristic features of sensors are spatial resolution, spectral resolution, radiometric resolution and temporal resolution. Resolution is defined as the ability of the sensor system to render the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of electromagnetic spectrum (spectral), radiation quantity (radiometric) and revisit frequency (temporal). In the identical satellites IRS-1A and 1B the Linear Imaging Self-Scanning Sensor (LISS-I and LISS-IIA/B) of two multispectral cameras were used. Each LISS camera consists of the collecting optics, imaging detectors, in-flight calibration system, the processing electronics and data formatting electronics. LISS uses linear array detectors (CCD – charged-couple-devices). These sensors operated in the visible and near-infrared (NIR) bands. In IRS-P2 satellite LISS-IIM (Linear Imaging Self-Scanning System-II Modified) sensor was used. It operated in push broom scanning mode as linear CCD line detector in four spectral bands in VNIR (Visible and near-infrared) bands.

IRS-1C/ID, the identical twin satellites, used LISS-III, PAN (Panchromatic camera) and WiFS (Wide Field Sensor) camera sensors operating in pushbroom scanning mode using solid state charge-coupled-device detectors. PAN (Panchromatic camera) is a push broom imager with a very high spatial resolution of 5.8 m. LISS-III sensor operates in VNIR and SWIR bands with a spatial resolution of 23.5 m and 70.5 m, respectively. WiFS camera provides two spectral bands in the VNIR range with spatial resolution of 188 m and temporal resolution of 5 days.

The experimental earth observation satellite IRS-P3 used WiFS and MOS (Multispectral Optoelectronic Scanner) and IXAE (Indian X-ray Astronomy Experiment) experimental sensors. The payload in IRS-P4 or Oceansat-1 includes OCM (Ocean Color Monitor) and MSMR (Multi-frequency Scanning Microwave Radiometer). OCM is a solid-state radiometer with high radiometric sensitivity (12 bit quantization level), which provides multi-spectral imagery with narrow spectral widths in eight bands in VNIR range. MSMR is a dual-polarized four-frequency radiometer measuring microwave brightness temperature.

Cartosat-1 or IRS-P5 has PAN-F (Panchromatic Forward-pointing camera) and PAN-A (Panchromatic After-pointing camera) cameras to obtain two-line stereo configuration for terrain modeling. Each camera operates in spectral band of 0.5 to 0.85 μm, a spatial or geometric resolution of 2.5 m, a swath width of 30 km for stereo imagery, and data quantization or radiometric resolution of 10 bits. The Cartosat-1 data products are to two types – standard product which is radiometrically corrected and georeferenced and precision product which is ortho rectified product.

ResourceSat-1 or IRS-P6 carries three sensors – LISS-III, LISS-IV and AWiFS (Advanced Wide Field Sensor) and all are push broom scanners using linear arrays of CCDs. LISS-III camera is identical to the one used in IRS-1C/1D. The LISS-IV is multispectral high-resolution three band push broom camera in VNIR bands with a spatial resolution of 5.8 m. It can be operated in multispectral mode i.e. data collected in 3 bands and mono mode i.e. data collected in single selected band corresponding to a swath of 70 km. AWiFS is a wide-angle medium resolution (56 m nadir and 70 m at swath edge) camera. The wide swath 804 km of this WiFS heritage sensor provides temporal resolution or revisit frequency of five-day.

Table 2. Characteristics of IRS Satellites

Satellite	Sensor	Spectral Resolution (μm)	Spatial Resolution (m)	Swath width (km)	Temporal Resolution (days)	Orbit Characteristics and Radiometric Resolution or Quantization Level
IRS-1A/1B	LISS-I, and LISS-II A/B (3 sensors)	0.45-0.52 0.52-0.59 0.62-0.68 0.77-0.86	72.5 m LISS-I 36 m LISS-II	148 74 x 2	22	Orbit – Sun-synchronous; Altitude – 904 km; Inclination – 99.5^0; Equatorial crossing – 10.26 a.m.; Orbit Period – 103.2 minutes. Radiometric Resolution – 7 bit;
IRS-1C/1D	LISS-III	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	23.5 23.5 23.5 70	142 142 142 148	24	Orbit – Sun-synchronous, Altitude – 904 km; Inclination – 98.69^0 Equatorial crossing – 10.30 a.m. Orbit Period = 101.23 min. Radiometric Resolution – 7 bit, Pan-6 bit
	PAN	0.50-0.75	5.8	70	24 (5)	
	WiFS	0.62-0.68 0.77-0.86	188	804	5	
IRS-P3	WiFS	0.62-0.68 0.77-0.86 1.55-1.70	188	804	5	Orbit: Sun-synchronous; Equatorial crossing at 10:30 AM Altitude = 817 km; Inclination = 98.7°; Orbit Period = 101.35 min; Radiometric Resolution – 7 bit
	MOS-A MOS-B MOS-C	0.75-0.77 0.41-1.01 1.595-1.605	1500 520 550	195 200 192	24	
IRS-P4 (Oceansat-1)	OCM MSMR	0.4-0.9 6.6, 10.65,	360 x 236 105x68,	1420 1360	2 2	Orbit: Sun-synchronous; Altitude = 720 km;

		18, 21 GHz (freq.)	66x43, 40x26, 34x22			Inclination = 98.28º; Orbit Period = 99.31 min; Equator crossing at 12:00; Spatial Resolution in km for frequency sequence; Radiometric Resolution – 12 bit.
IRS-P6 ResourceSat-1	LISS-IV	0.52-0.59 0.62-0.68 0.77-0.86	5.8 5.8 5.8	70	24 (5)	Orbit - Sun-synchronous Altitude = 817 km, Inclination = 98.69º, Orbit Period = 101.35 min; Equator crossing at 10:30 a.m. Radiometric Resolution – 10 bit
	LISS-III*	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	23.5 23.5 23.5 23.5	140	24	
	AWiFS	0.62-0.68 0.77-0.86 1.55-1.70	56-70 56-70 56-70	740	5	
IRS-P5 CartoSat-1	PAN-F PAN-A	0.50-0.75 0.50-0.75	2.5 2.5	30 30		Orbit - Sun-synchronous ; Altitude = 618 km; Inclination =97.87º; Orbit Period of 97 min; Equatorial crossing - 10:30 a.m. Radiometric Resolution – 10 bit

Source: Compiled by Author from ISRO.

3. Applications of IRS satellites:

In 1982 the Planning Commission of India had recognized necessity and significance of establishing a National Natural Resource Management System (NNRMS) to efficiently manage the natural resources by applying remote sensing techniques in conjunction with traditional techniques. Planning Committee of NNRMS (PC-NNRMS) sets guidelines for earth observation based systematic inventory of the country's natural resources and oversees the progress of remote sensing applications for natural resources management in the country. PC-NNRMS in 1984 constituted six Standing Committees on – (i) Agriculture and Soil; (ii) Bio-resources and Environment; (iii) Geology and Mineral Resources; (iv) Ocean Resources; (v) Remote Sensing Technology and Training and (vi) Water Resources; and in 1997 three more were constituted on (vii) Rural Development; (viii) Urban and (ix) Cartography. The themes of these Standing Committees themselves represent the major fields of applications of information acquired from earth observation satellite IRS series. The main applications of IRS series satellites are listed in brief in the following section.

Applications in Agriculture and Soil

The agricultural applications of IRS satellite series are following: - (i) Cropping pattern mapping; (ii) Pre-harvest crop area, production and yield estimation; (iii) Condition assessment; (iii) Monitoring command areas; (iv) Compliance monitoring (farming practices) e.g. crop stubble burning; (v) Identification of suitable sites for different agricultural practices; (vi) Mapping of soil characteristics; (vii) Mapping of soil management practices; (viii) Mapping of saline soils and monitoring of land reclamation; (ix) Inventorying and categorization of wastelands; and (x) Identification of fishery prospects.

Applications in Bio-resources and Environment

The applications of IRS satellite series in forestry, biodiversity and ecosystem sustainability are following: - (i) Mapping of forest cover, types, density and species inventory; (ii) Measurement of biophysical conditions of forest strands; (iii) Social forestry and agroforestry mapping; (iv) Biomass estimation; (v) Afforestation and deforestation assessment; (vi) Forest fire surveillance; (vii) Forest health and vigor monitoring; (viii) Detailed survey and inventory of the existing bio-resources; (ix) Environmental impact assessment including pollution (land, water and air); (x) Mapping and monitoring of tiger reserves, elephant corridors, biosphere reserves, mangroves and coral reefs; (xi) Assessment of fuel wood and timber resources; and (xii) Environmental hazard related studies like zonation and damage assessment (floods, drought, cyclone, landslide, volcano, earthquake etc.).

Applications in Geology and Mineral Resources

Geological applications of IRS series satellites include the following: - (i) mapping of surfacial deposits and bedrock; (ii) Lithological and structural mapping; (iii) Mineral prospecting and exploration; and (iv) Geo-hazard mapping, monitoring and zonation.

Applications in Oceanography

The applications of IRS series satellites, especially Oceansat-1 and Oceansat-2, include the following: - (i) Identification of potential fishery zones; (ii) Phytoplankton abundance and habitat assessment; (iii) Observation of marine pollution and sedimentation and its impact; and (iv) Assessment of sediment dynamics, tidal fluctuations, sea level changes and coastal circulations.

Applications in Water Resources

The applications of IRS series satellite data products in water resource include the following: - (i) Mapping of surface water bodies; (ii) Identification of potential ground water resources; (iii) Wetland mapping and monitoring; (iv) Snow pack and glacial monitoring; (v) Ice thickness measurements; (vi) Rivers, watersheds and ice lake monitoring and modelling; (vii) Flood mapping and monitoring; (viii) Monitoring reservoir extends over seasons and irrigation scheduling and flood management; and (ix) Snowmelt runoff forecasting.

Applications in Urban Sector

The applications of IRS satellites data products in urban sector are following: - (i) Mapping and Land Use Land Cover classification; (ii) Urban sprawl analysis; (iii) Identification of illegal encroachment, and constructions; (iv) Property tax assessment and estimations; (v) Transport and urban planning; (vi) Mapping of utilities and services; (vii) Population estimation; (viii) Slum detection and monitoring; and (ix) Site suitability analysis

Applications in Cartography

Mapping constitutes an integral component of the process of resource management and mapped information is the common product of analysis of remotely sensed data from IRS series satellites. The Cartosat series is especially oriented towards geo-engineering mapping and DTM (Digital Terrain Modelling) or DEM (Digital Elevation Modelling). Natural as well as manmade features such as transportation networks, settlements and administrative boundaries are represented spatially with respect to geo-referenced data and integrated with attribute information or non-spatial in GIS (Geographical Information System). Baseline, thematic and 2D and 3D topographical maps are essential for planning, evaluation and monitoring, for civilian and military reconnaissance and land use planning.

Conclusion: Since inception the IRS satellite series is oriented towards societal benefits and its ultimate objective is sustainable development of India. To address this goal it is applications driven and has greatly diversified in applications, that too in a limited time period. The information derived from remotely sensed data is an essential component of the National Natural Resources Management System (NNRMS). The Indian Remote Sensing (IRS) satellite program is to support national and sub national economies in the areas of agriculture, soils, water resources (surface and ground), forestry and ecology, geology and mineral resources, cartography, rural and urban development, marine fisheries, watersheds, coastal and disaster management.

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