ACTIVITIES AT INDIAN SPACE RESEARCH ORGANISATION (ISRO) ON DEVELOPMENT OF SPACE BORNE REMOTE SENSING SENSORS.

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ABSTRACT

Space based remote sensing for natural resources management is a major programme goal of Indian Space Research Organisation (ISRO). Expertise and experience in the field of remote sensing has been built up since 1970 through a number of experiments involving aerial flights, sensor development, setting up data processing system and evolving interpretation techniques using aerial and satellite imageries. Before embarking on an operational satellite based earth resources survey programme it was decided first to have an experimental system to gain experience in the design, development and management of a satellite based remote sensing system. This goal has been achieved through BHASKARA-I & II satellites launched in June 1979 and November 1981.

Bhaskara satellites carried two remote sensing payloads, namely a two band TV camera system and a multifrequency passive microwave radiometer. Of the two TV cameras one operates in the wavelength range of 0.54 to 0.66 micron and the other in the wavelength of 0.75 to 0.85 microns. Each picture frame covers an area of about 340 km x 340 km on ground with a spatial resolution of about 1 km. The microwave radiometer system consisted of three independent channels operating in the 19.1, 19.6 and 22.35 GHz in Bhaskara I. In case of Bhaskara-II, one of the 19 GHz channels has been replaced by 31.5 GHz and the spatial resolution is about 125 km. The Bhaskara programme provided valuable experience on various aspects of implementing and utilising satellite based remote sensing system such as definition of sensor system and its development, design and development of space based platforms and associated ground based data reception system, data product generation and utilisation.

Rohini Satellite launched by ISRO's launch vehicle SLV-3 carried a two band solid state camera operating in the visible and near IR wavelength region, capable of providing a spatial resolution of about 1 km.

Consolidating the experience gained in the various aspects of remote sensing, ISRO has taken the next step of going in for a National Operational Satellite based remote sensing system. One of the important programme element to achieve this is the Indian Remote Sensing Satellite

(IRS) series. The first of the series IRS-1A, will carry cameras using Linear Imaging Self Scanned Sensors (LISS) made of CCD, operating in the push broom scan mode. Of the two cameras one has a spatial resolution of ~73 meters (LISS-I) and the other ~36 meters (LISS-II). LISS-I has a swath of ~148 km, where as the same width is realised by the combined swath of two LISS-II cameras. Both the cameras have four spectral bands in the 0.45-0.86 micron wavelength region.

The paper gives the details of the various remote sensing data acquisition systems of ISRO, their present status and future plans.

1. INTRODUCTION

One of the major programme goals of the Indian Space Research Organisation (ISRO) in the area of space applications, is to realise operational capabilities in remote sensing using space platforms for monitoring of earth resources and environment, so as to have a remote sensing based resource management information system. For more than a decade ISRO is involved in the development of the various technologies and application programmes to achieve the above goal. These include development of a variety of remote sensors, conducting aerial flights, setting up ground based data processing and interpretation hardwares and carrying out specific end to end application experiments using aerial and satellite imageries in close co-ordination with a number of user agencies.

Over the past decade ISRO has successfully developed and utilised a variety of sensors operating in the visible, infrared and microwave regions of the electromagnetic spectrum. Starting with a single channel aircraft thermal scanner operating in the 10.5 to 12.5 micron band in 1970, today a six channel multispectral scanner (MSS) has been developed and made operational for the collection of multispectral data from aircraft. An improved version of the aircraft MSS with seven spectral bands similar to thematic mapper is under development. Significant progress has also been made in the development of both active and passive microwave Remote Sensors for aircraft platform. Development of spaceborne remote sensors was initiated first for the experimental earth observation satellite BHASKARA-I. The present paper describes various space borne remote sensors developed and being developed by ISRO, their present status and future plans.

2. BHASKARA-I AND BHASKARA-II SYSTEMS

The Bhaskara-I project, originally known as the Satellite for Earth Observation (SEO) was conceived as one of the key intermediate steps towards going for a fullfledged operational remote sensing satellite system for India. The primary objectives of Bhaskara-I mission were

- to conduct earth observation experiments at visible, near IR and microwave frequencies for a variety of earth resources and meteorology applications.

- to evolve the methodology of retrieval and processing of such data using appropriate ground systems.

- to generate user oriented data products for dissimination of such information

- to demonstrate the specific applications of such data products in earth resources and meteorology

In an ideal case an earth observation satellite system should be three axis stabilised so that the sensors can point towards the earth continuously. However to gain time we used the satellite configuration of the 1st Indian satellite ARYABHATTA, which was a spinning satellite. 'BHASKARA-I' was launched on June 7, 1979 from a Soviet Cosmodrome in a near circular orbit of mean altitude 534 kms and inclination 50.7°. The 444 Kg satellite carried two major remote sensing payloads namely a two band TV camera system and a two frequency microwave radiometer. The satellite was spin stabilised with its spin axis maintained at right angles to the orbital plane. Such configuration enables both the payloads to 'look' along the local vertical once during every spin. 'Bhaskara-I' was launched on November 20, 1981. It is an improved version of 'Bhaskara-I' having a three frequency radiometer to enable differentiation between water vapour and liquid water in the atmosphere.

2.1 Multispectral TV Camera

Bhaskara TV payload system consists of two TV cameras, one operating in the 0.54 to 0.66 micro band and the other in the 0.75 to 0.85 micron band[1]. Each picture frame covers an area of 340 km x 340 km with a ground resolution of about 1 km and a typical overlap of 10% between successive picture frames. The built in reseau marks and inflight radiometric calibration help in producing geometrically and radiometrically corrected picture on the ground. The camera is mounted on the spacecraft with its optical axis at the right angles to the spin axis. The cameras are exposed at the instant when the optical axis of the camera points to the local vertical. Read out takes place at a slower rate commensurate with the telemetry capability of the spacecraft. The basic sensor of the TV camera payload is a Super Vidicon Camera Tube consisting of an image intensifier with a gating facility coupled to a storage type vidicon tube. A specially designed multi-element lens is used for each camera. The focal length of the lens and the active face plate area together decide the field of view of the camera. A summary of the camera specifications is given in Table 1.

Table 1

TV camera payload specifications

Sensor Type	:	Slow scan vidicon coupled to an image intensifier
Imaging lens	:	F/no.1.9 Focal length 18.46 mm Field of view 49.37 degrees
Spectral channels	:	Camera-1 0.54 - 0.66 microns Camera-2 0.75 - 0.85 microns
Picture Frame	:	340 x 340 Km^2 for a 525 Km altitude
Ground Resolution	:	About 1 Km
Exposure Control	:	1, 1.5, 2 ms selectable by ground command
Power	:	22.5 W average
Weight	:	44 Kg

The system can be put in 'calibration mode' by ground command. The mechanical shutters do not operate during the calibration mode and the tube face plate is illuminated by flashing an LED source. In one calibration cycle, the cameras are exposed to four different intensity levels one of which is zero illumination and other three are spread out, over the dynamic range. This calibration cycle then repeats itself during the calibration mode. The exposure duration can be changed by ground command to get additional calibration levels.

The initial 'switch on' of BHASKARA-I TV camera payload was not successful. Extensive ground simulation studies indicated that the anamolous behaviour during the switch on of the TV camera was due to a corona discharge in the high voltage section of the payload. Poor adhesion of the potting compound with the high voltage stand off, coupled with trapped air, caused the corona. With time, the trapped air leaked out and camera-1 was switched on successfully on May 16, 1980.

BHASKARA-II payload was suitably modified to take care of the problems observed in BHASKARA-I and the camera performance was satisfactory in BHASKARA-II. The imagery received from both bands was comparable in quality to any other imagery of similar resolution. Multiband imagery from the TV payload has been received over the complete Indian sub-continent. Figure 1 shows the typical imageries received from the BHASKARA-II TV cameras. The multiband imagery received from BHASKARA-II has been used to demonstrate various applications in the field of geology, hydrology and forestry.

2.2 Satellite Microwave Radiometer (SAMIR)

The SAMIR system of BHASKARA-I consisted of three independent channels operating at 19.1, 19.6 and 22.235 GHz frequency bands. Each channel contains a scalar horn antenna, dicke switch, mixer/preamplifier, square law detector, suitable d.c. amplifiers and telemetry interface circuits[2]. In the case of BHASKARA-II one of 19 GHz channels has been replaced by a channel at 31.4 GHz.

In BHASKARA-I the spatial resolution of the 19 GHz radiometer was 150 km and the spatial resolution of the 22 GHz radiometer was 230 km respectively. In BHASKARA-II all the three radiometers had same spatial resolution of 125 km. Broad specifications of the radiometers are given in Table-2.

Table 2

Specifications of SAMIR

	BHASKARA-I		BHASKARA-II	
Frequency (GHz)	19.1 19.6 22.235	(R1) (R2) (R3)	31.4 19.35 22.235	(R1) (R2) (R3)
System Noise Figure (dB)	6.5 6.5 7.5	(R1) (R2) (R3)	8.5 6.5 7.5	(R1) (R2) (R3)
Predetection Bandwidth (MHz)	100		100	
Integration Time Constant (m.sec)	350 470	(R1 & R2) (R3)	300 (All channels)	
Spatial Resolution (km)	150 230	(R1 & R2) (R3)	125 (All channels)	
Brightness Temperature Range (°K)	4 - 320		4 - 320	
Temperature sensitivity (°K)	1		1	

The SAMIR system can be operated in two possible modes, depending upon the spin-axis orientation. In the 'Normal Mode' the spin axis of the satellite is normal to the orbital plane and hence the antenna would scan along the satellite track. In the 'Alternate Mode' the spin axis of the satellite would lie in the orbital plane, tangential to the orbit at a certain latitude, thus converting the radiometers effectively into a scanning system. In the 'Alternate Mode' data will be sampled at fourteen different angular positions and the effective coverage during each orbit will be around 1000 km with a 125 km ground resolution at nadir.

Analogue data from all the channels is sampled at various angular positions around nadir, depending upon the mode of operation. As the data acquisition and telemetry transfer rate are not synchronous, data is held in various sample and hold circuits, till it is transferred to the satellite data stream.

Various tests conducted during the initial phase operations and operational phase have confirmed the consistant performance of SAMIR Radiometers onboard BHASKARA-I & II. SAMIR data was used for a number of meteorological applications. These include estimation of water vapour and liquid water content, rain fall estimation over ocean area, estimation of wind speed over ocean, study of floods etc.

3. SMART SENSOR ONBOARD ROHINI SATELLITE

Rohini series of satellites are launched by the Indian launch vehicle SLV-3. A two band solid state camera was designed for Rohini Satellite. A 256 element photo diode array is used as the basic detector. The satellite is spin stabilised with spin axis normal to the orbital plane. During each spin the camera scans the earth approximately ±4.5° to the local vertical producing 80 scan lines thereby generating a picture frame of 250 km x 80 km. The image resolution is about 1 km from 500 km orbit[3].

One of the unique features of the camera is that it is capable of carrying out limited feature identification onboard. This is realised by taking the ratio of the 2 band output and having a decision circuitary to discriminate between the different classes based on ratioing. The feature identification code and video information from any one of the cameras is transmitted. The camera specifications are given in Table-3.

Table 3

Rohini Smart Sensor Specifications

Resolution	-	1 km (nominal)
Spectral bands		
Channel 1	-	0.65 ± 0.05 microns
Channel 2	-	0.85 ± 0.05 microns
Swath	-	25 km
Overlap	-	30%
Optics size	-	Focal length 25 mm, f/1.4 system
Memory	-	140 K bits
Power	-	4 watts
Weight	-	3 kg.

The Rohini satellite carrying the payload was launched on April 17, 1983 from the Indian launch station at Sriharikota. The camera functioned normally as planned and it was possible to establish the possibility of limited feature identification onboard. Water bodies, biomass, bare land and clouds can be easily identified with onboard processing.

4. SENSOR SYSTEM FOR THE FIRST INDIAN REMOTE SENSING SATELLITE (IRS)

Valuable experience and insight gained in various aspects of remote sensing, like data collection, processing and dissimination, implementation of space and ground segments, data interpretation, end to end application programme and issues relating to integrating the remotely sensed data with conventional data system for resource management, lead ISRO to take the next logical step of going in for a national operational satellite based remote sensing system. To achieve this, ISRO has initiated IRS programme which envisages the launch of a series of satellites. The first of the IRS series (IRS-1A) will be semi-operational and will carry remote sensing payloads operating in the visible and near IR. Future satellites are expected to cover other regions of electromagnetic spectrum including microwaves. Fig. 2 gives IRS series concept[4]. IRS-1A will be a three axis stabilised satellite in a near polar sunsynchronous orbit at an altitude of 904 km.

4.1 IRS payload parameter choice

The IRS payload parameters are choosen, keeping in view the requirements of the Indian users and technological constrains to realize a system by 1985/1986. IRS camera is based on the concept of 'Push Broom Scanning' using Linear Imaging Self Scanning Sensors (LISS).

The spatial resolution needs for agricultural application in the country have been found to be in the range of 40-70 meters. For other applications, like geology, hydrology, forestry etc. a spatial resolution of above range is quite adequate. Keeping this in view two different cameras are planned for IRS-1A, namely one with 73 meters resolution (LISS-I) and the other with 36 meters (LISS-II). The 73 meters payload in addition to meeting a number of user requirements, enables continuity of data service to users accustomed to LANDSAT class of imageries. Resolution of 36 meter is comparable to thematic mapper onboard LANDSAT-4.

Four spectral bands in the range 0.45 to 0.86 micron has been selected for the cameras. The actual band and bandwidth has been chosen on the basis of extensive experiments carried out at various test sites to get maximum discriminability. Since the cameras use CCD as basic detector elements, middle and thermal IR can not be covered. However the chosen bands are expected to provide adequate information for various themes we are interested in studying.

Number of quantisation level is another important parameter, which has to be optimised so as to have adequate radiometric accuracy. LANDSAT MSS had 6 bit quantisation, whereas Thematic mapper and SPOT provide 8 bit quantisation. Analysis by Tucker[5] shows that improvement of classification accuracy is very marginal for with quantisation higher than 7 bits. The study conducted by ISRO also supports this and it has been decided to have the data digitised to 7 bits.

The saturation radiance of the camera is chosen to cover a broad range of reflectivity from water to snow and also takes into account possible seasonal changes.

LISS-I has a swath of 148 km and two LISS-II camera gives a combined swath of 145 km. The swath is found adequate to provide a minimum side lap between passes on successive days and will have repetitivity of coverage for a particular scene of 22 days from an orbit of 904 km.

4.2 Payload configuration

As mentioned earlier the design of IRS camera is based on the concept of 'push-broom' scanning, using linear imaging self scanned sensors. The linear detector array is used to image the scene in the cross track direction to the satellite motion. The width of the scene in the cross track direction (swath) depends on the effective array length and the optics used. Each time the array advances to a distance equal one resolution element a new scan line is generated. Each detector array provides data in a single spectral band and additional spectral bands are generated by using additional arrays with appropriate spectral band selection techniques.

One of the major tasks of the design of the camera is to choose the optimum optical system to meet the camera specifications. The possible configurations could be broadly classified in two categories (1) to have a single collecting optics for all 4 bands and use appropriate spectral separation system for band selection (2) to use separate collecting optics for each band. In the later case each band will have its own lens filter assembly and a CCD at the focal plane. Considering the simplicity in optical design, fabrication, and good image quality with less polarisation effect IRS camera uses separate lens filter assembly for each band. Another advantage is that a failure or misalignment in one optical system will not geoparadise all bands. However this calls for tight tolerances on the allowable focal length variation between lenses so as to have proper registration between the bands. The detector selecteed is a 2048 element CCD. The photo element size is 13 microns x 13 microns.

The cameras will have facility for onboard calibration. The onboard calibration enables response degradation studies to augment extensive ground data generated for radiometric correction. In order to achieve maximum reliability it is proposed not to use any moving mechanism in the path of the camera. Hence it is planned to conduct the calibration during night when the radiance from the earth in the wavelength region is negligibly small. Two LEDs directly illuminating each CCD will be used as a standard calibration source.

The electronic design of the camera ensures that a single point failure does not geoparadise the total camera function. Each band has four gain settings which can be selected on ground command. The LISS-I data is transmitted via S band at 2.5 GHz and the LISS-II data is transmitted via X band at 8.3 GHz. The specifications of the camera are given in Table-4.

Table 4

IRS-1A CAMERA SPECIFICATIONS

		(LISS-I)	(LISS-II)
1.	Geometric Resolution (meters)	72.5	36.25
2.	Swath (km)	148	74 (145 combined swath)
3.	No.of calibration levels	6	6
4.	Weight (kg)	35	75 + 75
5.	Power (Watts)		
	Picture taking mode	32	32 + 32
	Calibration mode	40	40 + 40
6.	Envelope (meters)		
	EO module	0.335 x0.4 x 0.27	0.42 x 0.515 x 0.48 (each)
	Electronics Package	0.2 x 0.2 x 0.235	0.2 x 0.2 x 0.235(each)

CAMERA SYSTEM PERFORMANCE PARAMETERS
(APPLICABLE TO LISS-I & LISS-II)

1. Spectral bands (μm)

Band-1	0.45 - 0.52
Band-2	0.52 - 0.59
Band-3	0.62 - 0.68
Band-4	0.77 - 0.86

2. Nominal Saturation exposure ($\mu w/cm^2/sr/\mu$)

	Gain 1	Gain 2	Gain 3	Gain 4
Band-1	33	27	17	11
Band-2	33	27	17	11
Band-3	30	23	17	10
Band-4	20	16	14	10

3. SNR (at max. saturation radiance >128

4. Signal quantisation levels (bits) 7

5. Sensor MTF (square wave response 100% contrast)

Band-1	0.40
Band-2	0.40
Band-3	0.30
Band-4	0.20

6. Band to band registration (pixel) $< 1/4$

The bread board version of the payload has already been fabricated and the design concept has been verified. The engineering model fabrication is in progress. The launch of IRS is planned in early 1986. The future plans of IRS series include to have a high resolution camera with a spatial resolution of 15-20 meters (IRS-1B), and to extend the imaging capability to middle IR and thermal (IRS-2). Development of space born microwave payload system is also being considered for future missions.

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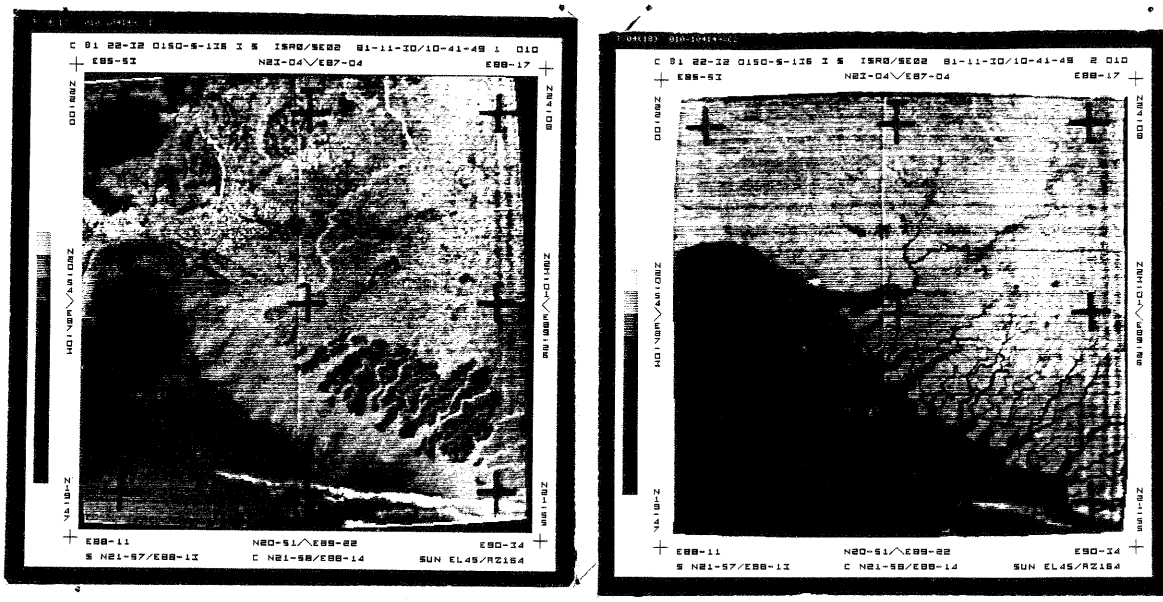

CAMERA-1
0·54 – 0·66 μ

CAMERA-2
0·75 – 0·85 μ

FIG-1 TYPICAL IMAGERIES RECEIVED FROM BHASKARA-II TV PAYLOAD

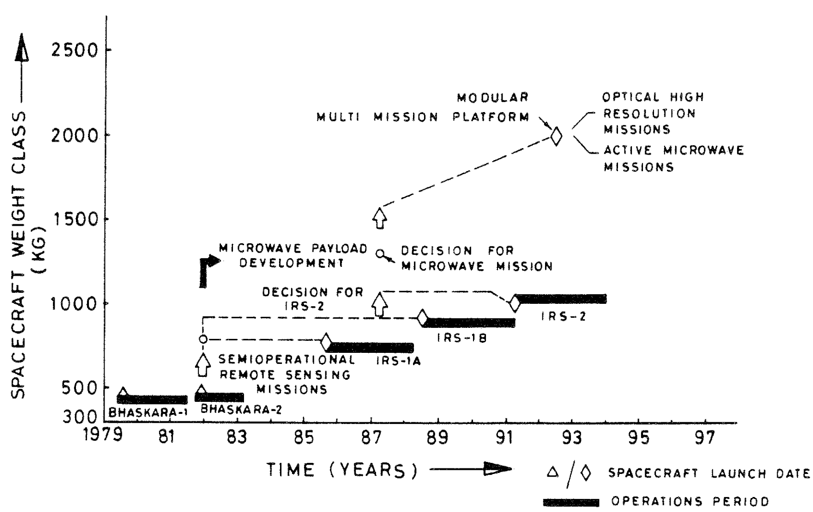

FIG-2 IRS SERIES CONCEPT